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Amrasca biguttula (Ishida) (Hemiptera: Cicadellidae): a new invasive pest of agricultural crops and ornamental plants in the United States

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The Florida Department of Agriculture and Consumer Services reported the first detection of *Amrasca biguttula* (ESA common name: two-spot cotton leafhopper) on cotton in 2024, marking the arrival of yet another invasive hemipteran pest in the US. Starting in July 2025, the pest caused extensive economic damage in cotton that required insecticide applications throughout South Georgia with additional detections in Alabama and South Carolina. While efforts to tackle other invasive hemipteran pest such as the Asian citrus psyllid, *Diaphorina citri* (Kuwayama) and the spotted lanternfly, *Lycorma delicatula* (White), are still underway, *A. biguttula* is a new pest that is likely to impact industries ranging from row crop agriculture to specialty and vegetable crop productions as well as nursery and ornamental plant trade. This review synthesizes the existing literature on *A. biguttula* in both its native range in Asia and established invasive ranges in Asia and West Africa, while also highlighting its emerging pest status and tentative management recommendations for this pest in the US.

KEYWORDS
biological control, chemical insecticides, cotton jassid, hopperburn, host plants, integrated pest management, invasive pest, United States

1 Introduction

The continuous spread of invasive species poses a significant threat to natural and semi-natural ecosystems, agricultural productivity, livelihoods, and global economies (Bradshaw et al., 2016; Seebens et al., 2018). Recently, an invasive exotic insect pest identified as the two-spot cotton leafhopper or cotton jassid, *Amrasca biguttula* (Ishida) (Hemiptera: Cicadellidae), formerly classified as *Empoasca devastans* distant, was detected in the

southeastern United States (US) (Esquivel et al., 2025). The insect is referred to as the two-spot cotton leafhopper because of the prominent and distinct black spots located on the hind margins of its forewings (elytra) (Esquivel et al., 2025). Native to Asia, *A. biguttula* is a multivoltine, sap-sucking polyphagous pest that attacks numerous economically important crops and horticultural plants across its native range, which extends from western Asia to Japan and Micronesia. *Amrasca biguttula* feeding results in substantial economic losses in crops such as cotton (*Gossypium* species (Malvaceae)), okra (*Abelmoschus esculentus* (L.) Moench (Malvaceae)), and eggplant (*Solanum melongena* L. (Solanaceae)) (Ahmed, 1982; Ahmad et al., 1986; Saeed et al., 2015; Chauhan et al., 2016; Manivannan et al., 2021; CABI, 2025). This pest is also known for its ability to survive and reproduce on a range of related plant species (Saeed et al., 2015; see Table 1).

Amrasca biguttula has recently undergone a dramatic range expansion, progressively spreading its geographical distribution across major oceanic barriers. This includes establishment in West Africa (PR-PICA, 2022; Jacques et al., 2024; Kouadio et al., 2024) and rapidly invading the Caribbean (Puerto Rico, and Barbados) and the US with confirmed detections in the southeastern US including Alabama, Florida, Georgia, Louisianna, Mississippi, North Carolina, South Carolina, Tennessee and Texas (Cabrera-Asencio et al., 2023; Esquivel et al., 2025). Rapid transcontinental spread underscores its significant invasive potential and the immediate threat presented to agricultural systems. *Amrasca biguttula* is notable for its pest status in Asia and West Africa, and recent invasive status in North America, where it is a potential threat to cotton, okra, eggplant, and some ornamental plants (Cabrera-Asencio et al., 2023; Jacques et al., 2024; Kouadio et al., 2024; Esquivel et al., 2025; Azrag et al., 2025). Most research on *A. biguttula* remains regionally fragmented, concentrated largely within its native Asian range (India, Pakistan, etc.), or is newly emerging from its West African and Caribbean invasion sites. Given *A. biguttula's* demonstrated capacity for rapid spread and ability to cause significant damage across cotton and vegetable production systems, particularly in the southeastern US, it is critical to synthesize the available literature and adapt this knowledge for US growers, extension agents, and researchers. Here, we review the existing but scattered literature on: (1) The origin, distribution, and occurrence of *A. biguttula* in the US (2) the host range of, and damage caused by *A. biguttula* in both its native and invasive ranges, (3) the role of predators, parasitoids, and entomopathogens in the management of *A. biguttula* and (4) the integrated management of *A. biguttula* including insecticide applications, cultural practices, biological control, and host plant resistance to limit crop damage. Finally, we highlight future directions for refining *A. biguttula* management within an integrated and sustainable pest management framework.

2 Origin and global distribution

The native geographical distribution of *A. biguttula* is significantly more expansive than its common association with the Indian subcontinent suggests. The species' range extends longitudinally from Iran to Japan, and encompasses regions from South Asia to Indonesia, with confirmed records from Afghanistan, Vietnam, China, Taiwan, the Pacific Islands (e.g. Guam), India, Sri Lanka, Bangladesh, Iraq, and Pakistan, among other neighboring countries where it feeds on cotton, okra, eggplant, and various alternative host plants (Jayasimha et al., 2012; Saeed et al., 2015; Al-Hamdany and Al-Karboli, 2017; Abbas et al., 2018; CABI, 2025).

The geographical range of *A. biguttula* has recently and significantly expanded, a pattern indicative of high invasive potential, with the species successfully colonizing and establishing populations in new areas, including countries within West Africa and Central Africa. The first detection of *A. biguttula* in Africa was recorded on okra in Ghana in 2021 (EPPO, 2024). Subsequently, between 2022 and 2024, the pest rapidly achieved widespread establishment, leading to significant damage on cotton crops across several countries, including Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Mali, Niger, Senegal, and Togo (PR-PICA, 2022; Badiane, 2023; Jacques et al., 2024; Kouadio et al., 2024; Akonde et al., 2024). Attacks were also observed on other plants: okra, eggplant, kenaf, roselle, pepper, cashew, mango, soybean, cowpea, among others (PR-PICA, 2022; Jacques et al., 2024; Kouadio et al., 2024). The pest was recently found on okra in western Nigeria (R.A. Adebayo, pers. comm.).

Amrasca biguttula is a serious invasive pest that has recently expanded its range beyond Asia, with documented invasions in Africa and the Americas. The first record of *A. biguttula* in the Americas was in April and May 2023, with populations detected on different lines of cotton and eggplant in Juana Díaz, Rio Cañas Abajo, Santa Isabel, Boca Velázquez, Puerto Rico (Cabrera-Asencio et al., 2023), resulting in significant damage to cotton and okra foliage. As of 2024, it was found in Barbados (IPPC, 2024), Antigua, Anguilla, St. Kitts and Nevis, and the Virgin Islands (Liburd et al., 2024). Recently, it was recorded on cotton in Martinique (Caribbean Island) (Dumbardon-Martial and Pierre, 2025) and on okra in Honduras (Michel and Orozco, 2025). The Florida Department of Agriculture and Consumer Services Cooperative Agricultural Pest Surveys monitoring network recorded the detection of this pest in Florida in 2024, establishing a new US record (FDACS, 2024). By 2025, confirmed reports indicated the spread and establishment of *A. biguttula* throughout the southeastern US, primarily infesting cotton and okra crops (Figure 1; EDDMapS, 2026).

3 Occurrence and spread in the United States

Following its detection in Puerto Rico in April 2023 (Cabrera-Asencio et al., 2023), *A. biguttula* was officially detected and confirmed in the continental United States in Miami-Dade County, southern Florida in late 2024, as a result of the monitoring efforts by the Florida Department of Agriculture and Consumer Services "Cooperative Agricultural Pest Surveys" monitoring network (FDACS, 2024). The initial detections of *A. biguttula* occurred

TABLE 1 Reported host-plants range and regions for *Amrasca biguttula* and their distribution in the US and beyond.

Family	Species	Common name	Plant group (crop-host)	US distribution	Stage (if applicable)	Reported from
Malvaceae	*Hibiscus cannabinus*	Kenaf	Fiber crop	No	Eggs/adults/nymphs	India, China, and Pakistan
	Gossypium spp.	Cotton		Yes		US (FL, AL, SC, GA, TX, NC, MS, TN), Thailand, Sri Lanka, Vietnam, Bangladesh, India, Puerto Rico, Virgin Islands, Ghana, Cameroon, Burkina Faso, Mali, Nigeria, Côte d'Ivoire, Pakistan, Japan, China, and Togo
	Abelmoschus esculentus	Okra	Vegetable crop			India, Thailand, Nepal, Sri Lanka, Vietnam, US (GA, FL, SC, NC, TX), Puerto Rico, Barbados, Niger, Japan, Burkina Faso, Benin, Mali, Cameroon, Niger, Côte d'Ivoire, Bangladesh, and Pakistan
	Sida acuta	Common wireweed	Weed			India, Pakistan, Burkina Faso, and US (GA, FL)
	Abutilon indicum	Indian mallow	Ornamental/weed plant	No; but potential host		Pakistan, Bangladesh, Ghana, Nigeria, Côte d'Ivoire, and India
	Alcea rosea	Hollyhock		Yes		Pakistan, India, and US (FL, GA, TX)
	Hibiscus rosa-sinensis	Tropical/Chinese hibiscus				India, China, Sri Lanka, Thailand, Vietnam, Bardados, Puerto Rico, Philippines, US (FL, GA, LO, TX), and Japan
	Hibiscus sadbariffa	Guinea sorrel and roselle	Vegetable/legume grain/pulse oilseed crop	No		India, Côte d'Ivoire, Benin, Mali, and Niger
Fabaceae	*Pisum sativum*	Garden pea				India
	Vigna unguiculata	Cowpea and black-eyed pea				Nigeria, Benin, and India
	Glycine max	Soybean				China, Australia, and India
	Vigna radiata	Mung bean				Pakistan, India, and Bangladesh
	Phaseolus vulgaris	Common bean/snap bean				China, Pakistan, Australia, US (GA, FL), and India
	Cajanus cajan	Pigeon pea				India, Nigeria, and Ghana
	Pisum sativum	Garden pea				India
	Arachis hypogaea	Peanut				India, and Pakistan
Solanaceae	*Solanum nigrum*	Black nightshade	Weed	Yes		US (FL), Burkina Faso, and India
	Solanum melongena	Eggplant and brinjal	Vegetable/tuber crop			Philippines, Puerto Rico, US (FL, GA), Barbados, Mali, Thailand, Ghana, Sri Lanka, China, Bangladesh, Pakistan, Burkina Faso, and India
	Solanum lycopersicum	Tomato		Yes		India, Barbados, US (FL, GA, MS), and Pakistan
	Solanum tuberosum	Potato		No; but potential host		India, China, and Pakistan
Tiliaceae	*Grewia asiatica*	Phalsa	Fruit/cereal/forage plants			India
Poaceae	*Zea mays*	Corn				Burkina Faso, and India
	Cynodon dactylon	Bermuda grass				

(Continued)

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TABLE 1 Continued

Family	Species	Common name	Plant group (crop-host)	US distribution	Stage (if applicable)	Reported from
Vitaceae	*Vitis vinifera*	Grape vine				India, China, Highlighted as a risk host in US, and Australia
Pedaliaceae	*Sesamum indicum*	Sesame	Oilseed			India, Burkina Faso, and Pakistan
Asteraceae	*Helianthus annuus*	Sunflower	Ornamental/Oilseed crop	No	Adults/nymphs	Australia, Pakistan, Ghana, Egypt, Sudan, and India
Amaranthaceae	*Amaranthus* spp.	Amaranth	Weed/vegetable			
	Chenopodium murale	Nettlelead goosefoot	Weed			
Chenopodiaceae	*Beta vulgaris* var. *saccharifera*	Sugar beet	Industrial root crop			
Euphorbiaceae	*Ricinus communis*	Castor	Weed/perennial crop			Mali, Ghana, Burkina Faso, Nigeria, Bangladesh, India, and Pakistan

Yes, confirmed crop-host attacked by *Amrasca biguttula* in the US; No, crop-host occurs in the US but not confirmed *A. biguttula* infestation; GA, Georgia; FL, Florida; AL, Alabama; SC, South Carolina; NC, North Carolina; MS, Mississippi; TN, Tennessee; TX, Texas; LO, Louisiana.

*The information compiled in Table 1 was derived from consultative discussions with research counterparts across Asia, Africa, and the Americas.

on cotton, eggplant, wireweed (*Sida acuta* Burm. f. (Malvaceae)), black nightshade (*Solanum nigrum* L. (Solanaceae)), hollyhock (*Alcea* species (Malvaceae)), and *Hibiscus* species (Malvaceae) (Danner, 2025), suggesting that this polyphagous sap-sucking pest can utilize a plethora of host plants, ranging from both economically important crops and horticultural plants as well as weeds. Over time, however, repeated detections during monitoring surveys raised concerns about the species' ability to survive, reproduce, and potentially expand into open-field agricultural crops thus becoming a major pest of cotton. In response to this emerging threat, a coordinated regional monitoring effort was established and implemented across the southeastern states (Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia) during the 2025 cotton growing season to monitor the distribution and activities of *A. biguttula* (Esquivel et al., 2025).

Amrasca biguttula was first detected in commercial cotton in July 2025 in several counties, including Gilchrist, Jacson, and Calhoun Counties in Florida (Conover et al., 2025). The first field detection of *A. biguttula* in South Carolina was documented on July 7 in Barnwell County (Esquivel et al., 2025). In Georgia, the initial detection occurred on okra in Seminole County before the pest was found infesting cotton on July 9. In Alabama, the earliest known specimen was collected via a sweep net on June 19 (Esquivel et al., 2025). The first confirmed establishment of *A. biguttula* in North Carolina occurred in September 2025, when both adult and nymph life stages were detected infesting cotton and okra crops within Robeson and Scotland Counties (Walgenbach, 2025). In September 2025, the presence of *A. biguttula* was confirmed in the same month and year in Louisiana on hibiscus plants at multiple retail locations (Villegas and Kerns, 2025); although these findings indicate a high risk for local introduction and highlight a key pathway of invasion into Louisiana, no detections had been confirmed in cotton or other cultivated field crops within the state at that time. *Amrasca biguttula* was confirmed to be actively infesting cotton fields in Raymond, Mississippi, on September 9, 2025 (Towles et al., 2025). As of September 2025, the Texas detection sites for *A. biguttula* were widespread, encompassing numerous commercial plant nurseries in cities including Bellmead, McAllen, Weslaco, Harlingen, Victoria, Rosenberg, San Antonio, Cedar Park, College Station, Waco, Longview, Corpus Christi, and El Paso (Vyavhare et al., 2025). Although a probable detection of this pest in cotton was noted in Fort Bend County, Texas, this finding had not yet been fully confirmed (Vyavhare et al., 2025).

The 2025 growing season marked an explosive and unprecedented range expansion as *A. biguttula* established itself in commercial row crops. This pest has since been confirmed across the core cotton-growing states in US, demonstrating high invasive potential and rapid colonization. As of October 2025, *A. biguttula* has been reported in over 150 US counties. The rapid, trans-regional spread across the Southeast cotton belt highlights *A. biguttula* adaptability and ability to sustain damaging populations on key agricultural hosts, particularly cotton and okra, positioning it as a major new threat to US crop production. The invasion dynamics of *A. biguttula* show a clear distinction between its establishment in cultivated fields and its detection via commercial pathways. Cotton and okra represent the two primary agricultural

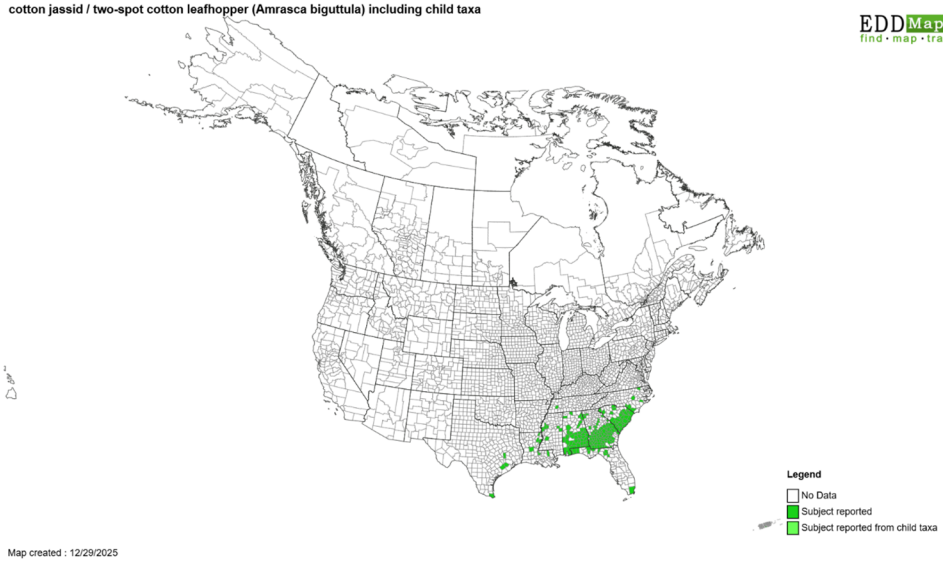


FIGURE 1
Map of the US showing *A. biguttula* infestation (Source, EDDMapS, 2026 https://www.eddmaps.org/distribution/uscounty.cfm?sub=9266&map=density).

crops on which large, damaging populations have been confirmed across the Southeast. In contrast, hibiscus and other ornamentals frequently served as initial detection sites, particularly within nursery and retail environments. The confirmed occurrence of infested hibiscus plants at major retail outlets in Florida, Louisiana, and Texas highlights the significant risk of spread through commercial plant movement and the need for rigorous nursery inspections.

While global trade and transportation of agricultural materials or products might have inadvertently facilitated the spread of *A. biguttula*, the success of this pest can be attributed to its multivoltine nature and broad host range (see Table 1), apparent capacity for dispersal, and its potential to occupy a wide range of climatic conditions and ecosystems. These factors most likely played a part in the establishment and rapid spread of *A. biguttula* from Puerto Rico into the continental US. The widespread and near-simultaneous appearance of *A. biguttula*, across multiple states in the Southeastern US in 2025 suggest that Hurricane Helene, which brought strong cyclonic winds from the Florida panhandle across several southeastern states may have played a key role in facilitating its rapid dispersal. Extreme wind events are well-recognized drivers of long-distance insect dispersal, particularly for small, flight-capable Hemipterans (like leafhoppers and aphids), rapidly overcoming geographical barriers and accelerating the establishment of invasive pests (Harris and Todd, 1980; Sparks, 1986; Drake and Farrow, 1988; Westbrook and Isard, 1999; Wen et al., 2019). As with many leafhoppers, *A. biguttula* is a small, lightweight insect (2–3 mm in length) that is inherently susceptible to wind currents. We reasoned that Hurricane Helene, which made landfall in September 2024 as a major storm in the big bend region of Florida and then moved across southern Alabama and Georgia followed by South Carolina, North Carolina, Virginia, and Tennessee, created ideal conditions for this type of rapid, mass dispersal. Our hypothesis is based on three prongs: (1) timing of *A. biguttula* detection in Florida in late 2024 (Esquivel et al., 2025) and its earlier detection in Puerto Rico in April 2023 (Cabrera-Asencio et al., 2023). Hurricane Helene's timing in September 2024 coincided with the reproductive phase of *A. biguttula*, when the Florida population may have been establishing and producing a late-season generation of mobile adults. (2) The hurricane's sustained, counterclockwise wind patterns may have effectively lifted adult *A. biguttula* from newly established populations in Florida or the Caribbean and deposited them directly into the cotton and okra-producing areas of Georgia, South Carolina, Alabama, and North Carolina, thereby serving as a wind vector. (3) By rapidly moving the pest from the initial Florida foothold to new, distant host environments (like Barnwell County, SC, or Robeson County, NC), before the main 2025 growing season began, the storm essentially "seeded" the entire region. This may have provided a significant head start for the multi-state infestation that was fully realized in the summer of 2025. In sum, we hypothesize that, while it is difficult to isolate Hurricane Helene as sole driver of the spread of *A. biguttula*, the storm and/or its passage provided a plausible, highly effective, and efficient dispersal mechanism that likely accelerated the slow, incremental spread of a newly invasive pest into the widespread, rapid, and simultaneous establishment observed across the southeastern states.

Despite the above hypothesis, it is important to note that successful long-distance transport of insects by hurricane winds does not necessarily result in successful establishment. Following dispersal, population persistence depends on several factors, including host plant availability, climatic suitability, local environmental conditions, and stochastic mortality. Consequently, even if *A. biguttula* individuals were transported to multiple states by Hurricane Helene, establishment success would likely have varied considerably among locations. At present, *A. biguttula* populations in Tennessee appear to be low. Although Tennessee was significantly affected by Hurricane Helene, *A. biguttula* is primarily a tropical and subtropical pest with limited tolerance to low

temperatures. The colder winter conditions characteristic of Tennessee likely present a substantial overwintering constraint compared with the milder climates of Florida and the coastal plain regions of the southeastern US. We therefore hypothesize that while the hurricane may have facilitated the transport of *A. biguttula* into more northern locations, including Tennessee, the apparent lack of sustained populations may be attributable to reduced overwintering survival and/or limited availability of suitable host plants following dispersal. As a result, successful establishment may have occurred preferentially in regions where climatic conditions and host resources were more favorable for population persistence and growth. Hurricane Helene should be regarded as one of several plausible factors that may have contributed to the rapid regional dispersal of *A. biguttula*, rather than as the primary or sole driver of its observed spread across the southeastern US.

4 Host range

Amrasca biguttula feeds on a variety of host plants, including fiber and vegetable crops, ornamental and fruit plants as well as several weed species (Table 1). Cotton, eggplant, okra, potato (*Solanum tuberosum* L. (Solanaceae)), and sunflower (*Helianthus annuus* L. (Asteraceae)) are among >50 'true' and 'incidental' plant species attacked by this pest in both its invasive and native ranges (see Table 1). Saeed et al. (2015) established a clear distinction in hosts categorization based on life stage duration: defining 'true' host plants as those that support both the nymphal and adult life stages of *A. biguttula*. Conversely, plant species that sustained only a minimal presence of adults or nymphs for short periods were classified as 'incidental' hosts. The polyphagous nature of *A. biguttula* is demonstrated by its reliance on both wild and cultivated plant species to support viable nymphal and adult populations. This broad host range includes a minimum of eight commercially significant plant families (Malvaceae, Solanaceae, Asteraceae, Fabaceae, Poaceae, Euphobiaceae, Amaranthaceae, and Vitaceae), among others in Asia, West Africa and the Americas (see Table 1; Saeed et al., 2015, 2018; Rajendran et al., 2018; Ghosh and Karmakar, 2021; Akonde et al., 2024). The main hosts of *A. biguttula* are within the Malvaceae family (e.g., cotton, okra, and hibiscus), which provide substantial food for survival, growth, and reproduction in subtropical and tropical zones (Ghosh and Karmakar, 2021; Kouadio et al., 2024). Due to its polyphagous and multivoltine nature, *A. biguttula* appears to be highly adaptable and resilient to heterogeneous cropping systems, seasonal crop rotation and agro-climatic variations in tropical and subtropical regions. The effects of season shifts have been a common phenomenon in *A. biguttula* migration among various host plants (from primary crops, secondary vegetables, weeds, and ornamental plants). Moreover, the movement of this pest occurs in response to the availability of host and phenological shifts in plants, enabling *A. biguttula* to remain active during off-season periods. These behaviors may have significant impact on population resilience and survival under diverse agro-ecological conditions.

The host range of *A. biguttula* in the US, as indicated by early detection and establishment records from 2024 and 2025, includes high-value agricultural crops such as cotton (see Tables 1, 2). Alongside the primary crops, initial surveys identified many weed species and additional crops capable of temporarily sustaining the pest, including black nightshade, common wireweed, snap bean (*Phaseolus vulgaris* L. (Fabaceae)), and eggplant. The current list of known hosts in the US not only demonstrates the pest's polyphagous nature but also its preference for species within the Malvaceae and Solanaceae families, which aligns with its behavior in its native range. The strong preference for cotton and okra establishes them as the key surveillance targets for US growers, while the role of hibiscus highlights the risk posed by the ornamental trade in facilitating the pest's long-distance dispersal throughout the US.

5 Biology and life cycle

The descriptive biology and life cycle of *A. biguttula* have been extensively documented across its native and invaded ranges (Nagrare et al., 2012; Jayasimha et al., 2012; Ghosh and Karmakar, 2021; Cabrera-Asencio et al., 2023; Esquivel et al., 2025; Michel and Orozco, 2025). Key characteristics of the pest's descriptive biology and life cycle can be summarized as follows (Nagrare et al., 2012; Jayasimha et al., 2012; Cabrera-Asencio et al., 2023; Esquivel et al., 2025; Michel and Orozco, 2025): *A. biguttula* is a small leafhopper, exhibiting light green, pale green or yellowish-green coloration, with adults ranging between 2.0 and 3.5 mm in length. This species is distinguished from most native congeners by its characteristic external markings: specifically, two distinct black dots situated on the apex of each forewing (Figure 2). Their distinctive markings constitute the basis for its common name, the "two-spot cotton leafhopper". They are highly mobile, jumping and/or flying quickly when disturbed. Both nymphs and adults target and feed on the underside (abaxial) of the leaf surfaces, using their piercing-sucking mouthparts to pierce the mesophyll tissues, subsequently injecting phytotoxic saliva. These feeding habits are crucial as they contribute to the initial development of hopperburn (Figure 3) in plants and decreasing the ability of photosynthesis and impacting overall plant health leading to the complete desiccation of the plants.

The adult female leafhopper inserts individual yellowish-white, curved eggs into the parenchymatous tissues of young, actively growing leaves, often along the midribs and/or veins on the underside of the leaves. This protected location makes *A. biguttula* difficult to detect and target with topical insecticides. Egg hatching typically takes 4 to 11 days, depending on temperature and host plant quality. Upon hatching, nymphs exhibit a pale green pigmentation, dorsoventrally flattened bodies, and display high levels of activity, often dispersing rapidly when disturbed. The nymphal stage consists of five (5) instars, each characterized by increasing size, wing pad development, and feeding intensity. Nymphal development is significantly influenced by temperature and the quality of host plants, generally lasting 7 to 21 days, with faster

TABLE 2 Mechanisms and effectiveness of key natural enemies and biocontrol strategies of *Ambrasca biguttula*.

Taxonomical name			Locations	Host plants: preferred stage of feeding	Mechanism	Efficacy	References
Order	Family	Species					
Predators							
Araneae	Araneidae	*Neoscona theisi*	Pakistan, India, Cameroon, Ivory coast	Cotton, okra: Adults, nymphs	Sit and wait web hunting via vibration and visual cues to assess prey	Field report shown strong contribution to suppression	Mari et al. (2007); Saeed et al. (2015); Jacques et al. (2024); Kouadio et al. (2024); Nagrare et al. (2025)
	Lycosidae (*Wolf spiders*)	Multiple spp.	Pakistan	Okra: Nymphs, adults	Active ground hunting		Mari et al. (2007)
Coleoptera	Lady beetles (Coccinellidae)	*Cheilomenes sexmaculata; Hippodamia convergens; Cycloneda sanguinea; Coccinella septempunctata; C. undecimpunctata; Hyperaspis maindroni; Scymnus nubilus; Menochilus sexmaculatus; Brumus suturalis*	India, Pakistan, Puerto Rico	Cotton, okra: Nymphs, potentially adults	Visual cues, and direct predation	Observed moderate predation, prey location on leaves and flowers	Vennila (1998); Cabrera-Asencio et al. (2023); Esquivel et al. (2025)
Araneas	Thomisidae (Crab spiders)	Thomisidae spp.	Pakistan	Okra: Nymphs, adults	Ambush predation on flowers		Mari et al. (2007);
Hemiptera	Reduviidae	*Zelus longipes* (*L.*)	Pakistan, Puerto Rico	Cotton, okra, eggplant: Nymphs and eggs	Hunting (ambush predator) actively on undersides of the leaf via piercing-sucking	Observed moderate predation	Cabrera-Asencio et al. (2023)
	Geocoridae	*Geocoridae* spp.					
	Minute pirate bugs (Anthocoridae)	*Orius* spp. and *Orius insidiosus*			Contact and movement predation (piercing and sucking) in response to plant volatiles		
Neuroptera	Green lacewings (Chrysopidae)	*Chrysoperla carnea*	Pakistan	Cotton, okra, castor: eggs, nymphs, and adults	Chemosensory prey (biting and nocturnal feeding) location on leaves	High predation. Positive impact in the reduction of jassids populations in lab bioassay and open-field	Abbas et al. (2018); Sattar et al. (2011); Nadeem et al. (2022)
Parasitoids							
Hymenoptera	Trichogrammatidae	*Trichogramma chilonis Ishii, Pseudoligosita nephotetticum*	India, Japan	Cotton and okra: Eggs	Oviposits into the leafhopper eggs, larval develop and prey on host embryo	High parasitism.	Saeed et al. (2015); Bhatt and Karnatak (2018); Ghosh and Karmakar (2021); Adachi-Hagimori et al. (2023)
	Eulophidae	*Aprostocetus purpureus*	Pakistan	Okra: Eggs	Endoparasitism	Moderate	Saeed et al. (2015)
	Aphelinidae/Encyrtidae	*Anagyrus dactylopii*	Nigeria	Okra, Sorrel: Nymphs	Suppresses early nymphs	Moderate	Akonde et al. (2024)
	Mymaridae/*fairyflies*	*Arescon enocki*	Japan, Pakistan			High egg parasitism	

(Continued)

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TABLE 2 Continued

Taxonomical name			Locations	Host plants: preferred stage of feeding	Mechanism	Efficacy	References
Order	Family	Species					
Parasitoids							
				Cotton, okra, castor, cucurbits: Eggs	Contact oviposition into eggs on leaf veins surface		Rao et al. (1968); Sahito et al. (2018); Adachi-Hagimori et al. (2020); Saeed et al. (2015); Adachi-Hagimori et al. (2023)
		Anagrus japonicus, Anagrus empoascae; Anagrus atomus (fairyfly), *Stethynium empoascae*	Japan, India, Pakistan	Okra: Eggs			
Diptera	Tachinidae	*Chrysoexorista javensis*	India	Eggplant: Nymphs and adults	Oviposition	Low rate of effectiveness	Rajendran et al. (2018)
Entomopathogens							
Fungi	Clavicipitaceae	*Beauveria bassiana*	India, among other regions	Cotton, eggplant (aubergine), okra: Nymphs and adults	Spore penetrates via the cuticle (adhesion to cuticle, germinate, penetrate, leading to systemic mycosis), sensitive to UV and high RH. Work best under moderate temperature	High mortality rate (60-75%) in both open-field and lab: effective in humid season (~28 °C)	Islam et al. (2023); Ghosh and Karmakar (2021)
		Metarhizium anisopliae (CKM-048)	Thailand, Pakistan, India				Maketon et al. (2008); McGuire and Northfield (2020); CABI (2025)
	Cordycipitaceae	*Isaria fumosorosea (Cordyceps)*	Bangladesh, India	Okra: Nymphs and adults	Spore germination and colonization	Moderate in lab and greenhouse	Lafta et al. (2025); Halder and Seni (2021)
		Verticillium/Lecanicillium lecanii	India, among other regions		Cuticle infection and active conidial contact leading to subsequent mycosis. Work best under favorable humidity	High mortality rate, 70 to 89% reduction *in vitro* bioassay and open field studies	Manivannan et al. (2018)
	Ophiocordycipitaceae	*Purpureocillium lilacinum PL1*	Vietnam, India, among other regions	Okra: Nymphs			Nguyen Thi et al. (2023)
Bacteria	Enterobacteriaceae	*Serratia marcescens*			Via ingestion and direct phyllosphere contact with the formula		Rajendran et al. (2018)
	Bacillaceae	*Bacillus thuringiensis (Bt)*	India, among other regions	Okra, cotton: Nymphs		Moderate effective	CABI (2025)
		Bacillus pumilus					Sivakumar et al. (2017)
	Pseudomonadaceae	*Pseudomonas fluorescens*				High mortality rate (71-92%)	Manjula et al. (2017)

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growth observed on nutritionally enriched hosts like cotton and okra. Upon emergence, adults begin feeding and mating. Adults may live and survive for 12 to 45 days, with females generally living longer (compared to males), and capable of laying 100 to 200 eggs during their lifetime, enabling rapid population buildup under favorable environmental conditions. The duration of *A. biguttula* life cycle is contingent upon environmental parameters, such as temperature, relative humidity, and the quality of host plant, resulting in a reported development time ranging from 8 to 46 days.

6 The importance of molecular identification of *Amrasca biguttula*

Identification of *A. biguttula* has traditionally relied on morphological characteristics, particularly in adult specimens. Adults are readily recognized by their pale-green coloration and the presence of two characteristic black spots on the forewings (Cabrera-Asencio et al., 2023). Additional diagnostic traits, including wing venation patterns and male genitalia morphology, have been used to distinguish *A. biguttula* from other members of the tribe Empoascini (Sagarbarria et al., 2020; Dung et al., 2021). However, morphological identification can be challenging because the characteristic wing spots are absent or inconsistently expressed in nymphs, which are the developmental stage most commonly encountered during field scouting. Furthermore, cotton and other host plants may harbor mixed infestations of morphologically similar leafhopper species, such as the potato leafhopper, *Empoasca fabae*, making species-level diagnosis based solely on morphology unreliable. The recent US detection study emphasized that morphological identification of nymphs is particularly problematic and may lead to misidentification in newly invaded regions (Zhao and Balkcom, 2026).

Consequently, molecular diagnostics have become an important complement to traditional taxonomy. DNA barcoding based on the mitochondrial cytochrome c oxidase subunit I (COI) gene has been widely used to confirm the identity of *A. biguttula* and investigate genetic relationships among populations (Hebert et al., 2003; Sagarbarria et al., 2020; Sharma et al., 2025). In the first molecular confirmation of *A. biguttula* in the US, specimens collected from Alabama were analyzed using COI sequencing and Bayesian phylogenetic methods (Zhao and Balkcom, 2026). The resulting phylogeny placed the US specimens firmly within the *A. biguttula* clade with 100% posterior probability support, clearly distinguishing them from other *Amrasca* species and related Empoascini taxa (Zhao and Balkcom, 2026). This study provided the first molecularly validated record of *A. biguttula* in the US and established a reference sequence for future surveillance efforts. The authors concluded that molecular diagnostics provide a dependable tool for species discrimination, particularly when dealing with immature stages, damaged specimens, or mixed infestations, and should be used alongside morphological methods to improve detection accuracy and support pest management programs.

7 Feeding habits, damage and economic importance

Both the nymphal and adult stages of *A. biguttula* damage plants and feed by inserting their piercing and sucking mouthparts (stylet) into the phloem tissue on the undersides of leaves to suck plant sap, resulting in upward curling along the edges. During feeding, *A. biguttula* injects toxic saliva that contains cell wall-degrading enzymes, which subsequently compromise the cellular integrity of the mesophyll tissue and obstruct the plant's nutrient and water translocation pathways, thereby causing "hopperburn" symptoms such as chlorosis, necrosis, and leaf margin rolling (Rajendran et al., 2018; Thapa et al., 2019). In severe infestations, the characteristic hopperburn damage is visually identifiable by a sequence of progressive symptoms: it begins with a yellowish discoloration (chlorosis) near the leaf tips surrounding the feeding sites, which subsequently develops into browning (necrosis) and leaf curling. This deterioration ultimately culminates in the complete scorching and dropping of the leaves, buds, flowers, and fruitlets, which leads to plant stunting and significant reductions in crop yield and harvest quality (Devi et al., 2018; Thapa et al., 2019; Jacques et al., 2024).

Severe infestations of *A. biguttula*, observed in both its native and invasive ranges, cause significant damage to economically important crops and ornamental plants (Tables 1, 2). This damage includes plant stunting, widespread defoliation, and the premature shedding of buds, flowers, and developing fruit, which collectively compromise final yield potential and quality (Thapa et al., 2019). The economic damage inflicted by *A. biguttula* in its native range is significant across multiple crops infesting all stages of crop development: reported yield reductions frequently exceed 60% in cotton (Ahmed, 1982; Ahmad et al., 1986), reach up to 50% in okra (Devi et al., 2018), and may equal or exceed 37% in eggplant as pest density escalates (Ahmed, 1982). *Amrasca biguttula* is reported to cause significant economic impact on cotton and okra production across its invasive range in West Africa (Jacques et al., 2024; Akonde et al., 2024). Since 2022, the invasion of *A. biguttula* into West African countries, such as Cameroon, Côte d'Ivoire, Mali, Burkina Faso, Niger, Senegal, and Togo, has resulted in significant yield losses, ranging between 10% and 50% in both cotton and okra (PR-PICA, 2022; Jacques et al., 2024; Akonde et al., 2024). In Côte d'Ivoire, the highly invasive *A. biguttula* has nearly completely displaced the previously dominant major cotton pest, *Jacobiasca lybica* (Bergevin and Zanon) (Hemiptera: Cicadellidae) (Kouadio et al., 2024; EPPO, 2024) in that country. Although the economic impacts of *A. biguttula* in its native range have not been comprehensively quantified, a major outbreak in West African during the 2022/2023 season provided distinct data on its cost to cotton production: Côte d'Ivoire sustained an estimated loss of XOF 34 billion (USD 59 million), whereas Burkina Faso reported a loss of XOF 65 billion (USD 105 million) (Kouadio et al., 2024).

In 2025, populations of *A. biguttula* were observed feeding on economically important crops like cotton in the southeastern US; however, the full extent of its economic impact remains uncertain

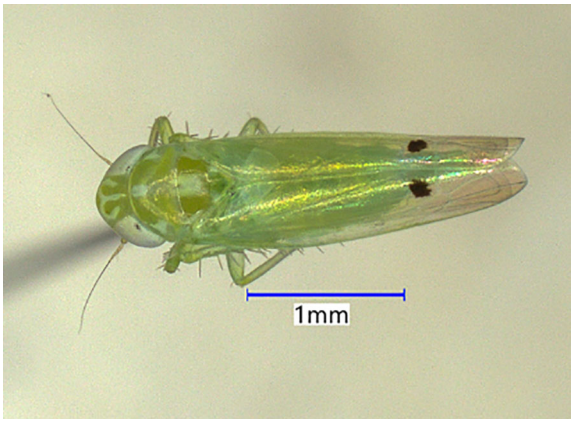


FIGURE 2
Adult *Amrasca biguttula*; note prominent black spots on the wings. Image courtesy of Dr. Isaac Esquivel, North Florida Research and Education Center.



FIGURE 3
The hopperburn syndrome caused by *Amrasca biguttula* results in "yellowing, reddening, then browning of leaves, which lead to wilting and curling of the leaves". Photo by Cabrera-Asencio.

due to the late summer detection of the infestations. Cotton production, essential to the US economy and local farmers, has an annual estimated value exceeding $7 billion (USDA, 2025). The progression of *A. biguttula* damage in cotton in the US is notably rapid; within less than two weeks, infested plants can transition from mild leaf discoloration to pronounced hopperburn symptoms, and in severe infestations, complete defoliation may occur. This multivoltine pest has also been detected causing damage to vegetable crops including okra and eggplant, as well as ornamental plants like hibiscus in several Southeastern states (Table 1) (Esquivel et al., 2025). Its ability to utilize a multiplicity of host plants, including both vegetables and non-crop hosts, may enable *A. biguttula* to remain active throughout the year, thereby becoming a significant pest of cotton, several vegetable crops, and ornamental plants especially in the Southeastern states, a region shown by Azrag et al. (2025) to possess the necessary climatic and ecological conditions for *A. biguttula* establishment. The crops that are most at risk from *A. biguttula* invasion in US and beyond are listed in Table 1.

8 Interactions with other pests and pathogens

The interactions among *A. biguttula* and its natural enemies, host plant, and microbes are an important factor that affects where they can survive and reproduce, and how effectively they are controlled. Although sap-feeding induced hopperburn is the most obvious symptom, continuous feeding impairs host plants and exposes the crops to secondary diseases and physiological stress, which may additionally contribute to decreased fruit and fiber quality and yield (Saeed et al., 2015; Rajendran et al., 2018). In addition to reducing photosynthesis, prolonged feeding by *A. biguttula* nymphs damages mesophyll and vascular tissues, causing chlorosis and tissue deterioration. Such injury may facilitate the establishment of opportunistic fungal and bacterial pathogens by creating favorable infection sites and altering nutrient availability within the plant (Fatima and Senthil-Kumar, 2015). In a diversified agroecological setting, *A. biguttula* often coexists with other sap-feeding pests, particularly *Bemisia tabaci* (whiteflies), *Aphis gossypii* (aphids), and *Thrips tabaci* (thrips); these pests share overlapping feeding niches. Due to this, they vie for the same resources and collectively inducing heightened plant stress and yield losses (Akonde et al., 2024; Esquivel et al., 2025). Such pest interactions may complicate their control, because most biopesticides target one specific species. *Amrasca biguttula* infestations will likely increase the use of synthetic insecticides, which may have negative impact on pest ecology; also, this can inadvertently alter the predatory and parasitoid community and induce secondary breakouts of other pests that are detrimental and non-resistant to the plant. For example, wide-spectrum insecticides applied to suppress *B. tabaci* will kill jassid predators (such as *Chrysoperla* spp. (lacewings), and *Orius* spp. (minute pirate bugs)), which may lead to an increase in the abundance of *A. biguttula* among other harmful plant pests (Saeed et al., 2015). These tropic chain reactions illustrate the significance and need to use selective insecticides and ecological integration in IPM strategies.

Availability of suitable plants may naturally help *A. biguttula* thrive at the landscape level. Saeed et al. (2015) explored 48 non-cotton plant species. Of those, 24 were original breeding hosts for nymphs and adults, demonstrating how intercrops, weeds, and border plants can affect insect populations in different ways. According to Esquivel et al. (2025) weeds, such as *Abutilon indicum* and *Sida acuta* serve as bridge habitat hosts that support and nourish *A. biguttula* populations, which eventually re-infest vegetable and horticultural crops (Table 1).

Although the relationship between *A. biguttula* pathogens and vectors remain poorly understood, members of the Cicadelllidae possesses the physiological potential to distribute phytopathogens according to Qin et al. (2025). In particular, plant viruses and phytoplasmas are transmitted specifically via insect piercing and sucking mouthparts. Under the optimal agroecological conditions,

A. biguttula can harbor and/or physically transmit plant diseases and infect open field agricultural plants, as shown by leafhopper vectors (Xu et al., 2021). Moreover, the ecological adaptability of *A. biguttula* highlights the need for comprehensive and multitrophic solutions that incorporate selective insecticide application, biopesticides, the use of natural enemies (like predatory and parasitoid), cultural practices, mixture cropping systems, and habitat management within an IPM framework. Maintaining parasitoid and predator populations within cotton-vegetable landscapes could significantly reduce insect outbreaks, while minimizing the need for overuse of synthetic insecticides (Saeed et al., 2015; Adachi-Hagimori et al., 2020; USDA-APHIS, 2025).

8.1 Natural enemies and biocontrol of *Amrasca biguttula*

Biocontrol agents are crucial for regulating *A. biguttula* populations in West Africa and Asia, where this pest has become well established. A diverse community of generalist predators, egg-parasitoid wasps, and entomopathogenic microbes (e.g. fungi, bacteria, virus, and nematode), have been used to naturally suppress *A. biguttula* among other pests, as detailed in Table 2. Moreover, as this pest continues to spread in the Western Hemisphere, one of the most important questions for US entomologists is which natural enemies are most effective in the management of this polyphagous pest of cotton, vegetable, and horticultural plants.

Saeed et al. (2015) demonstrate that several vegetable crops and weed plants utilized by *A. biguttula*, also attract and harbor a significant number of predators like green lacewings, coccinellieds, spiders, minute pirate bugs, and big-eyed bugs (Table 2). These insect predators may exert significant top-down pressure on *A. biguttula* populations, a process referred to as the "green-bridge effect", wherein natural enemies shift between non-crop vegetable and crop to reduce pest communities at the beginning of the season (Rao et al., 1965, 1968; Cotte and Cruz, 1989; Mari et al., 2007; Adachi-Hagimori et al., 2020; Cabrera-Asencio et al., 2023). Additionally, lacewings are broadly effective in suppressing pests, even with minimal insecticide spray (Saeed et al., 2015). Interestingly, the augmentative introduction of *Chrysoperla* spp. decreased populations and damage caused by *A. biguttula* in a cotton farm field (Saeed et al., 2015). Importantly, several of these predators, such as spiders, *Orius*, *Geocoris*, *Chrysoperla*, and lacewings, are natively abundant and widely available as well as distributed across the Western Hemisphere and the US agroecosystems. Hence, their conservation should be prioritized due to their ability to suppress these invasive pests. Egg parasitoids in the family *Mymaridae* (fairyflies), e.g., *Arescon enocki*, *Anagrus japonicus* and *Stethynium empoascae* have been shown to strongly attack and actively parasitize *A. biguttula* eggs on vegetable and ornamental plants (Adachi-Hagimori et al., 2020, 2023). These results are especially applicable to the Southeastern US, where Hibiscus and okra are often cultivated in gardens, and commercial farms. The existence of these parasitoids (Table 2) may facilitate reduction of this pest and also minimize the widespread application of synthetic insecticides.

Entomopathogenic fungi (EPF) serve as a major biocontrol agent for *A. biguttula*, specifically in humid and warm climatic environment, which fosters the growth of spores and fungi-pest-infection (Maketon et al., 2008; CABI, 2021). For example, Maketon et al. (2008) conducted an open-field trial in Thailand for *Metarhizium anisopliae* (CKM-048 strain), which effectively reduces the population of *A. biguttula* on eggplant compared to synthetic insecticide (e.g., pyrethroid lambda-cyhalothrin in a rates of $1.25 * 10^{13}$). Similarly, a study carried out in Pakistan and India show significant mortality of *A. biguttula* (adult and nymphal stages) upon application of *Lecanicillium* spp. and *Beauveria bassiana*, thereby demonstrating their effective potential as alternatives to synthetic insecticides in IPM strategies (CABI, 2025). Such EPF can be utilized in rotation techniques and/or microclimatic conditions with optimal relative humidity and moderate temperatures for optimal spore viability. Similar agroclimatic environments are often observed in the southeastern US between early summer and late spring, suggesting that this time period is suitable for evaluating EPF-based control alongside other biocontrol methods against *A. biguttula* (Table 2).

9 Management

9.1 Sampling and scouting

Phillip Roberts and colleagues with Georgia Cooperative Extension developed sampling and scouting methods for cotton in the southeastern US. The first indication of an *A. biguttula* infestation always started as "hopperburn" on the edges of fields, but infestations often moved across the field within only a week or two. Under severe pressure, cotton defoliation occurred in as little as two weeks from the onset of plant injury. Immature insect populations were found primarily in the upper mainstem leaves and sampling was focused on abaxial leaf surface located at the fourth mainstem node from the terminal. Immatures were observed on third to fifth nodes from the terminal, but the fourth node was used for sampling. The optimal treatment threshold was determined to be an average of 1 to 2 nymphs per leaf across the field, or hopperburn evident on inner portions of the field with *A. biguttula* present.

9.2 Chemical control

Chemical insecticides remain the primary management strategy for *A. biguttula* in cotton and vegetable production systems, particularly in South Asia where the pest is endemic; across multiple agroecological zones, synthetic insecticides provide rapid knockdown and reliable suppression once economic thresholds are exceeded (Thapa et al., 2019; Patel et al., 2017; Rajasekar and Mallapur, 2017) (Table 3). Neonicotinoids constitute the dominant chemical class used against *A. biguttula*. Neonicotinoid insecticides such as imidacloprid, thiamethoxam, and acetamiprid are extensively used for *A. biguttula* management in cotton and okra production systems in India, Pakistan, and Nepal (Saeed et al., 2017; Kumari et al., 2022; Kharjule et al., 2023;

Shah et al., 2025). These compounds act on nicotinic acetylcholine receptors, producing rapid paralysis and mortality while also providing systemic protection through plant tissues. Foliar applications of imidacloprid 17.8% SL significantly reduced jassid densities in okra and cotton and frequently produced the highest benefit-cost ratios among evaluated treatments (Thapa et al., 2019; Patel et al., 2017; Hemadri et al., 2018). Similar efficacy has been reported for acetamiprid and dinotefuran, with studies demonstrating substantial reductions in nymphal and adult populations (Maitlo et al., 2020; Sagar and Balikai, 2015; Kumari et al., 2022). The development of newer neonicotinoids and related chemistries has expanded available control options. Nitenpyram and dinotefuran have shown strong performance in field trials, often outperforming older chemistries such as acephate and chlorfenapyr (Sahito et al., 2017; Hafeez et al., 2020; Shah et al., 2025). Flupyradifurone, a butenolide insecticide within IRAC Group 4, has also demonstrated efficacy against *A. biguttula* and *Be. tabaci*, offering an additional systemic option with improved selectivity (Singh et al., 2020). These advances highlight the continued refinement of systemic insecticides targeting sap-feeding Hemiptera.

Beyond foliar applications, alternative delivery methods have been investigated to improve sustainability and early-season protection. Seed treatments with imidacloprid provide effective suppression during early crop establishment, reducing the need for immediate foliar sprays and potentially preserving natural enemy communities (Hasnain et al., 2013; Kranthi and Kranthi, 2025). Comparative seed treatment studies have also identified acephate and other compounds as effective early-season protectants (Satyan et al., 2015), although efficacy varies among active ingredients. Formulation innovations further enhance chemical control performance. Controlled-release formulations, such as carboxymethyl cellulose–based imidacloprid, have demonstrated prolonged bioavailability and reduced environmental leaching while maintaining strong suppression of leafhopper populations (Kumar et al., 2011). Such technologies address key limitations of conventional sprays, including rapid degradation and environmental concerns.

Despite the increasing emphasis on newer chemistries, traditional organophosphates and pyrethroids continue to play an important role in *A. biguttula* management by demonstrating varying degrees of efficacy across cotton, okra, and ornamental systems, often providing valuable alternatives where neonicotinoid performance has declined (Rajasekar and Mallapur, 2017; Badiane, 2023; Shah et al., 2025). For example, field trials conducted in Senegal demonstrated that fluxametamide significantly reduced *A. biguttula* infested cotton plants compared with untreated controls and resulted in increased cotton seed yield (Badiane, 2023). Furthermore, research on cotton has demonstrated that strategic combinations of insecticides of different chemistries, can provide enhanced efficacy by substantially suppressing *A. biguttula* populations; mixtures of chlorpyrifos 50% EC and cypermethrin 5% EC have consistently produced strong short-term suppression across cotton and okra systems (Dahal et al., 2020; Shah et al., 2025). Similarly, *A. biguttula* suppression were observed when spinetoram, acetamiprid, thiamethoxam, and profenofos were combined with carbendazim (Table 3).

Recent efficacy trials in the southeastern US indicated that multiple classes of insecticides provided satisfactory control of populations in cotton. While mortality was evident at three days post-treatment with most insecticides, damage symptoms continued to develop even after application as a result of the toxins that were injected at the time of feeding. Pyrethroid insecticides (IRAC class 3A) consistently did not provide population suppression; however, inexpensive broad-spectrum organophosphates such as dicrotophos and acephate provided excellent control. In addition, most neonicotinoids provide satisfactory efficacy as did materials that are commonly applied for whitefly and aphid control such as spinosad, buprofezin and flonicamid. In the first publicly available chemical trial addressing invasive US populations on ornamental hibiscus, Yadav et al. (2026) evaluated several chemistries at Clemson University. Afidopyropen (Ventigra, IRAC Group 9D) showed potential, though its performance varied across treatments. In contrast, while cyantraniliprole (IRAC Group 28) offered rapid knockdown of both adults and nymphs, its limited residual activity led to a population rebound within 14 days. Similarly, bifenthrin-based products provided immediate suppression but demonstrated inconsistent control over the nymphal stage. Research conducted in Nepal and India suggests that the botanical derived insecticides, particularly azadirachtin, as well as other biopesticides, are effective against *A. biguttula* in cotton and okra production systems (Patel and Patel, 1996, 2017; Kumar et al., 2020; Bhandari et al., 2022; Kharjule et al., 2023; Shah et al., 2025). In the aggregate, these products represent at least six modes of action that could be rotated to mitigate or slow development of insecticide resistance.

9.2.1 Insecticide resistance in *Amrasca biguttula*

The prolonged and intensive reliance on chemical insecticides for managing *A. biguttula* has led to widespread resistance across multiple insecticide classes, posing a significant threat to sustainable control. Resistance has been most pronounced against neonicotinoids and pyrethroids, but documented cases also include organophosphates and several newer chemistries, reflecting sustained and often indiscriminate selection pressure in cotton-based production systems (Akmal et al., 2020; Saeed et al., 2017; Kranthi and Kranthi, 2025). Continuous exposure to insecticides through practices such as the widespread use of imidacloprid-treated *Bt* cotton seed has been identified as a key driver of resistance evolution by maintaining early-season selection pressure on field populations (Kshirsagar et al., 2012a, b). Geographically, resistance has been widely reported across India and Pakistan. Early reports from Pakistan documented resistance to pyrethroids including cypermethrin and fenpropathrin, while subsequent studies confirmed reduced susceptibility to neonicotinoids such as imidacloprid and thiamethoxam (Saeed et al., 2017). In India, resistance has been detected to a broad range of compounds, including methyl demeton, endosulfan, monocrotophos, and cypermethrin (Santhini and Uthamasamy, 1997; Chalam and Subbaratnam, 1999; Praveen, 2003), as well as to newer neonicotinoids such as acetamiprid, thiacloprid, and clothianidin (Karar et al., 2013; Halappa and Patil, 2016).

Quantitative resistance ratios illustrate the severity of the problem. Saeed et al. (2017) reported resistance levels ranging from 2.3–29.3-fold for acetamiprid, 4.8–95.0-fold for imidacloprid,

TABLE 3 Chemical insecticides and botanical control approach used globally: mechanisms and role on *A. biguttula*.

Active product class	IRAC mode of action (Moa)	Crop: locations	Status of resistance	Mechanism	Efficacy	References
Chemical control						
Neonicotinoid: Nitenpyram	4A	Okra: Nepal, and Pakistan	Resistance signal	Quick knockdown and rotate with non-4A MoAs	Above 80% reduction within 2 days trial.	Thapa et al. (2019); Saeed et al. (2017)
		Cotton: Pakistan	No resistance		Above 80% reduction under field conditions	Shah et al. (2025)
Neonicotinoid: Thiamethoxan		Cotton, okra: India, Pakistan	–		Above 60-80% reduction in field	Malanno et al. (2025)
Neonicotinoid: Thiamethoxam		Bt cotton: India	No resistance reported	Nicotinic acetylcholine receptor agonist; systemic	1.00 leafhopper/3 leaves	Kharjule et al. (2023)
Neonicotinoid: Dinotefuran		Cotton: India	–	Useful for rapid suppression, also rotate with non-4A MoAs		Halappa and Patil (2016); Sreenivas et al. (2015)
Neonicotinoid: Dinotefuran		Cotton: India	No resistance reported	Nicotinic acetylcholine receptor agonist; rapid paralysis and mortality	64.7% reduction; 2.39 jassids/3 leaves	Kumari et al. (2022)
Neonicotinoid: Imidacloprid		Cotton, okra: Pakistan	Low-high resistance signal	Fast knockdown in plant, but very slow when treated with seeds	Suppress cotton jassid	Saeed et al. (2017)
Neonicotinoid: Imidacloprid 17.8% SL	4A	Okra: India	–	Fast knockdown in plant, systemic	1.04 leafhoppers/3 leaves; B:C ratio 1:9.54	Patel et al. (2017)
Neonicotinoid: Imidacloprid	4A	Cowpea: India	No resistance reported	Nicotinic acetylcholine receptor agonist; systemic protection	0.09-0.11 leafhoppers/3 leaves; yield 1.40 Mg/ha	Singh et al. (2022)
Neonicotinoid: Imidacloprid	4A	Okra: West Bengal, India	No resistance reported	Nicotinic acetylcholine receptor agonist; systemic protection	Higher yield (12.72 t/ha vs control 7.70 t/ha)	Subba et al. (2022)
Neonicotinoid: Imidacloprid	4A	Cotton: Punjab, India	No resistance reported	Nicotinic acetylcholine receptor agonist; systemic protection	53.8% reduction; 3.13 jassids/3 leaves	Kumari et al. (2022)
Neonicotinoid: Flonicamid	29	*Bt* cotton: India	No resistance reported	Chordotonal organ modulator; feeding cessation	Most effective: 0.92 leafhopper/3 leaves	Kharjule et al. (2023)
Neonicotinoid: Acetamiprid 20% SP	4A	Okra: India	–	Fast knockdown, systemic	1.69 leafhoppers/3 leaves; B:C ratio 1:7.70	Patel et al. (2017)
		Cotton: India, US	–		3.96 hoppers/3 leaves; 64.54% reduction >70% control in 3 days	Rajasekar and Mallapur (2017); Roberts et al. unpubl. data
Chloropyriphos 50% EC + Cypermethrin 5% EC: Organophosphate and Synthetic Pyrethroid.	Group 1B and Group 3A	Okra: Nepal	Resistant	Provides rapid suppression of the pest population	Most effective treatment overall. It maintained the lowest pest counts	Bhandari et al. (2022)
Phenylpyrazole: Fipronil 5% SC	2B	Okra: India	–	GABA-gated chloride channel blocker	1.89 leafhoppers/3 leaves; B:C ratio 1:7.31; 89.34% suppression claimed but actual ~81%	Patel et al. (2017)
Phenylpyrazole: Fipronil	2B	Six districts, Karnataka, India	Low-moderate resistance (1.10-1.67 fold)	GABA-gated chloride channel blocker	LC_{50}: 14.57-27.25 ppm across districts	Sagar and Balikai (2014)

(Continued)

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TABLE 3 Continued

Active product class	IRAC mode of action (Moa)	Crop: locations	Status of resistance	Mechanism	Efficacy	References
Chemical control						
Spinosynys: Spinosad	5	Cotton: India	No *A. biguttula* specific resistance trend reported	High efficacy against nymphs and adults in field trials	Often softer on many natural enemies than OPs/pyrethroids.	Kranthi & Kranthi (2025); Shah et al. (2025)
Spinosyn: Spinetoram 12 SC	5	Cotton: India	–	Nicotinic acetylcholine receptor allosteric activator	3.59 hoppers/3 leaves; 67.81% reduction	Rajasekar and Mallapur (2017)
Organosphosphate: Acetaphate	1B (Acetylcholinesterase inhibitors)	Cotton: Pakistan	Susceptible	Foliar suppression; rotate with non-1B MoAs	Above 60% population reduction under field conditions	Shah et al. (2025)
Organophosphate: Acephate	1B	Cotton: Pakistan	No resistance reported	Acetylcholinesterase inhibitor; blocks nerve transmission	83-90% mortality at 24h post-spray	Karar et al. (2013)
Organophosphate: Acephate	1B	Okra: Côte d'Ivoire, West Africa	No resistance reported	Acetylcholinesterase inhibitor; contact and ingestion action	41 ± 7.2 A. biguttula/plot (comparable to botanicals)	Able et al. (2025)
Organophosphate: Chloropyriphos 50% EC + Pyrethroid: Cypermethrin 5% EC	1B and 3A	Okra: Nepal	–	Combined AChE inhibition and sodium channel modulation	14.11 jassids/5 leaves (~8.47/3 leaves); 45-62% reduction; yield 20.11 t/ha	Dahal et al. (2020)
Organophosphate: Dimethoate 40EC	1B	Cotton: Pakistan	–	Acetylcholinesterase inhibitor	Recommended at 400ml/acre; max 2 applications	Hasnain et al. (2013)
Organophosphate: Dimethoate	1B	Cotton: Pakistan	Resistance documented	Acetylcholinesterase inhibitor	77-85% mortality at 24h; drops to 28-34% by 72h	Karar et al. (2013)
Pyropenes: Afidopyropen	9D	Cotton: Pakistan	No resistance	Activation of TRP channels; potent feeding inhibition and hormetic	High toxicity, complete feeding inhibition	Tariq et al. (2025)
Thiourea: Diafenthiuron 50 WP	12B	Cotton: India	–	Inhibits mitochondrial ATP synthase	2.99 hoppers/3 leaves alone; 73.21% reduction. With carbendazim: 2.87/3 leaves, 74.30% reduction	Rajasekar and Mallapur (2017)
Botanicals						
Neem; azadirachtin	–	Okra: Nepal	No resistance	–	Slower suppression action than chemical synthetic, good fit for natural enemy compatibility. IGR effects.	Thapa et al. (2019)
Neem oil extract	UN	Cotton: Pakistan	No resistance	Act as a repellent, antifeedant, and toxin; useful for rapid suppression	Above 65% population reduction under field condition	Shah et al. (2025)
		Okra: Nepal	No resistance	Inhibit growth and feeding; useful for rapid suppression		Saud et al. (2025)
Azadirachtin 5% EC	UN (Ecdysone agonist)	Okra: India	–	Blocks molting hormone synthesis; antifeedant and repellent	2.84 leafhoppers/3 leaves; B:C ratio 1:5.81	Patel et al. (2017)
Neem oil 1% EC	UN (Ecdysone agonist)	Okra: Nepal	–	Blocks molting hormone synthesis; antifeedant and repellent	17.96 jassids/5 leaves (~10.78/3 leaves); 22-39% reduction; yield 17.74 t/ha	Dahal et al. (2020)

(Continued)

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TABLE 3 Continued

Active product class	IRAC mode of action (Moa)	Crop: locations	Status of resistance	Mechanism	Efficacy	References
Botanicals						
Boiled neem leaves extract	–	Cotton: Pakistan	No resistance	Handmade botanical repellent and growth repressor	55% population reduction under field condition	Shah et al. (2025)
Botanical: *H. suaveolens* hydroethanol extract	UN (Ecdysone agonist)	Okra: Côte d'Ivoire	No resistance reported	β-caryophyllene (42.3%), bergamotene, terpinolene; repellent and insecticidal	43.3 ± 15.4 for P. decolorata; effective on multiple pests	Able et al. (2025)
Botanical: Azadirachtin (Neem)	UN (Ecdysone agonist)	Six districts, Karnataka, India	Low resistance (1.00-1.41 fold)	Growth regulator; feeding deterrent; multiple modes	LC_{50}: 399.09-563.45 ppm; Mysore (1.00) to Dharwad (1.41) resistance ratios	Sagar and Balikai (2014)
Botanical: Agniastra (neem+garlic+chili +tobacco+cow urine)	UN-E	Okra: India	No resistance reported	Multiple bioactive compounds; contact and feeding deterrent	61.97-71.79% reduction; yield 12.21 t/ha (approaching imidacloprid 12.72 t/ha)	Subba et al. (2022)
Botanical: NCGC (neem+chili+garlic+cow urine)	UN-E	Cowpea: India	No resistance reported	Synergistic action of azadirachtin, capsaicinoids, organosulfur compounds	Best botanical: 0.03-0.04 leafhoppers/3 leaves; highest yield 1.54 Mg/ha; superior to imidacloprid	Singh et al. (2022)
Botanical: A. indica + S. lycopersicum hydroethanol extract	UN-E	Okra: Côte d'Ivoire	No resistance reported	Azadirachtin + glycoalkaloids (dehydrotomatine, α-tomatine); growth regulation	Most effective botanical: 39.7 ± 3.2 A. biguttula/ plot (comparable to acephate 41 ± 7.2)	Able et al. (2025)
Botanical: H. suaveolens hydroethanol extract	UN-E	Okra: Côte d'Ivoire	No resistance reported	β-caryophyllene (42.3%), bergamotene, terpinolene; repellent and insecticidal	43.3 ± 15.4 for P. decolorata; effective on multiple pests	Able et al. (2025)
Botanical: A. indica + S. lycopersicum hydroethanol extract	UN-E	Okra: Côte d'Ivoire	No resistance reported	Azadirachtin + glycoalkaloids (dehydrotomatine, α-tomatine); growth regulation	Most effective botanical: 39.7 ± 3.2 A. biguttula/ plot (comparable to acephate 41 ± 7.2)	Able et al. (2025)

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and up to 1197.9-fold for thiamethoxam in Punjab, Pakistan. More recent surveys documented sustained and, in some cases, intensified resistance to imidacloprid, profenofos, chlorpyrifos, and bifenthrin, along with moderate to high resistance to deltamethrin, fipronil, clothianidin, chlorfenapyr, and carbosulfan (Hussain et al., 2025). Abbas et al. (2018) similarly reported elevated resistance to deltamethrin, bifenthrin, chlorpyrifos, and additional compounds, underscoring the cumulative impact of long-term exposure across multiple modes of action.

Notably, even newer chemistries introduced to counter resistance are showing early signs of reduced susceptibility. Abbas et al. (2018) reported substantial resistance to nitenpyram, spirotetramat, and chlorfenapyr, although comparatively low resistance levels were observed for sulfoxaflor and flonicamid, suggesting these compounds may retain greater efficacy within rotation programs. These findings reinforce the need for discontinuation of heavily compromised insecticides and implementation of strategic rotation schemes.

Mechanistically, resistance in *A. biguttula* appears to be largely metabolic and enzyme-mediated. Elevated activities of mixed-function oxidases, glutathione-S-transferases (GSTs), esterases, and other detoxification enzymes have been implicated in conferring cross-resistance across multiple insecticide classes (Sagar and Balikai, 2014; Halappa and Patil, 2016; Hussain et al., 2025). Enhanced oxidative metabolism and conjugation pathways contribute to detoxification of neonicotinoids and other compounds, indicating that resistance is multifactorial rather than solely target-site based (Sagar et al., 2013). Additionally, sublethal exposure effects may exacerbate resistance risks. Tariq et al. (2025) demonstrated that while afidopyropen suppressed feeding in parental generations, F_1 offspring exhibited enhanced feeding, longevity, and fecundity, suggesting hormetic-like responses that could facilitate pest resurgence. Overall, the resistance profile of *A. biguttula* reflects intense and sustained chemical selection pressure, with broad-spectrum erosion of insecticide efficacy across regions. These patterns underscore the urgent need to integrate chemical control with non-chemical strategies (Jalloh et al., 2026), enforce resistance monitoring programs, and implement mode-of-action rotation within an IPM framework to preserve remaining effective chemistries and mitigate further resistance development.

10 Future directions and research needs

Due to the broad habitat diversity of *A. biguttula*, documented economic impact on cotton, and its capacity to spread rapidly across both agricultural and non-agricultural settings, the US and future invasion regions require geographically focused surveillance and biological management options. Cotton production in the US is primarily located in the southeastern region where year-round vegetable and nursery production is juxtaposed across the landscape. These horticultural and ornamental crops likely serve as alternate hosts and reservoirs. Fortunately, this region also harbor a wide range of generalist predators such as lady beetles, *Geocoris punctipes*, *Orius insidiosus*, and *Chrysoperla rufilabris*, as well as several spider communities. The above species have functional similarities to predators reported in Africa and Asia; they likely offer significant pest suppression when preserved via decreased early-season use of broad-spectrum insecticides (organophosphates, neonicotinoids and pyrethroids) combined with and habitat enrichment such as planting flowering border crops to support natural enemies' survival. Additionally, more research is necessary to identify existing native parasitoids (such as *Anagrus atomus* and *A. epos*) that might parasitize *A. biguttula* eggs, since they are closely associated with leafhoppers. Several entomopathogenic fungi (i.e. *Metarhizium anisopliae*, *Beauveria bassiana*, and *Lecanicillium lecanii*) exhibit potential in the control of *A. biguttula*.

Extension and outreach programs will need to focus on science-based IPM approaches to provide education on *A. biguttula* monitoring and control. As agricultural growers and scouts in the Americas have little experience with this pest, teaching proper scouting methods and economic thresholds are necessary to prevent overzealous application of insecticides that could lead to rapid development of resistance and secondary pest outbreaks. Comprehensive extension initiatives must consider resistance management, crop rotations, host plant resistance, minimizing broad spectrum insecticide application, and rotating IRAC groups (Table 3), with a goal of preserving natural enemies. Equally important is the dissemination of knowledge to specialty crop producers and the ornamental nursery industry through targeted outreach programs. Novel technological tools like remote sensing, canopy stress detection, pheromone attractants, and sticky traps may be integrated into an early warning detection program for *A. biguttula*. Proactive, collaborative research and extension efforts will be essential for slowing the spread of this invasive pest and minimizing its potential impact on agriculture.

11 Conclusion

In conclusion, *A. biguttula* is a very serious invasive insect pest of food, fibre and ornamental crops across tropical and subtropical regions with its distribution extending from South and Southeast Asia to the Middle East, Africa, and, more recently, parts of Central America and the US. This species can spread extremely rapidly and reproduce at an alarming rate. In newly invaded areas, plant damage can be severe and occurs rapidly. While synthetic insecticides provide short term control, the insect is known to develop resistance quickly and early season insecticide applications will inevitably eliminate natural enemies and favor secondary pest outbreaks. More work is needed to identify genes that provide host plant resistance as well as identification of optimal natural enemies and pathogens that provide pest suppression. Given recent invasions of the pest in North America and Africa, there is a need for coordinated research to better understand ecology and sustainable management strategies.

Author contributions

OU: Visualization, Writing – review & editing, Conceptualization, Writing – original draft, Validation, Data curation, Methodology. AJ: Conceptualization, Writing – review & editing, Methodology, Data curation, Writing – original draft, Visualization, Validation. AE: Writing – original draft, Data curation, Visualization, Writing – review & editing, Validation, Methodology. SB: Writing – review & editing, Visualization, Validation. JM: Writing – review & editing, Visualization, Validation. PR: Writing – review & editing. MT: Supervision, Writing – review & editing, Project administration, Writing – original draft, Visualization, Resources, Validation, Funding acquisition.

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