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Biology and Management of Peanut Burrower Bug (Hemiptera: Cydnidae) in Southeast U.S. Peanut

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Abstract

Peanut burrower bug, *Pangaeus bilineatus* (Say), is a piercing-sucking pest of peanut, *Arachis hypogaea* (L.), that is native to Central and North America. The insect spends most of its life below the soil surface and is not easily detected in the field. Although injury to peanut is sporadic in the Southern USA, the bug has become a serious economic pest for farmers in the region in recent years. During and after peanut seed formation, adult and immature bugs feed directly on seeds through the hull, reducing the quality and value of the crop. The value of peanut is reduced by approximately $209/MT when feeding injury is present on ≥3.5% of kernels by weight. Deep tillage prior to planting and application of granular chlorpyrifos during the growing season are the only tactics currently available for managing *P. bilineatus* in peanut in the United States. Relatively little research attention has been focused on *P. bilineatus*, and improved knowledge of the insect's biology and ecology is needed to develop an integrated pest management (IPM) strategy that significantly reduces financial losses caused by this insect. The purpose of this article is to provide a review of the taxonomic history, biology, pest status, and management of *P. bilineatus* primarily as it relates to peanut production systems in the Southeast USA.

Key words: Cydnidae, IPM, field & forage crop, host plant resistance, sampling

Taxonomic Treatment

The peanut burrower bug, *Pangaeus bilineatus* (Say), is a subterranean agricultural pest native to Central and North America. It was first described by Say in 1824 as *Cydnus bilineatus* but was moved to the genus *Pangaeus* by Stål in 1862 and placed in the subgenus *Homaloporous* by Uhler in 1877 (Froeschner 1960). The family Cydnidae (burrower or burrowing bugs) is comprised of six subfamilies: Amaurocorinae, Amnestinae, Cephalocteinae, Cydninae, Garsauriinae, and Sehirinae (Schwertner and Nardi 2015). *Pangaeus bilineatus* resides in the Cydninae within the tribe Geotimini. The insect has a confusing taxonomic history as subtle variations observed between species types resulted in the publication of 26 synonyms for *P. bilineatus* (Froeschner 1960). Synonyms include: *Pangaeus uhleri*, *P. fortis*, *P. vicinus*, *P. douglasi*, *P. scotti*, and *P. spangbergi* (Sailer 1954, Froeschner 1960).

Distinguishing Peanut Burrower Bug from Other Burrower Bugs

Proper pest identification is the first step in developing a management strategy. The primary diagnostic feature of peanut burrower bug is the deep, sharply impressed line that parallels the anterior margin of the pronotum from side to side (Fig. 1). Burrower bugs found in Southeast USA peanut, *Arachis hypogaea* (L.), fields include *P. bilineatus*, *Dallasiellus lugubris* (Stål), *Cyrtomenus ciliatus* (Palisot), and *Sehirus cinctus* (Palisot); however, *P. bilineatus* is the only species of economic concern (Froeschner 1960, Chapin and Thomas 2003). *Dallasiellus lugubris* is smaller (3.9–5.5 mm length) than *P. bilineatus* (5.3–7.8 mm length) and lacks the deep impressed line parallel to the anterior margin of the pronotum (Froeschner 1960). *Cyrtomenus ciliatus* can be distinguished by its large body size (approx. 8.9 mm length) and bulbous shape (Froeschner 1960). *Sehirus cinctus*, or white-margined burrower bug (4.6–5.2 mm length), is easily distinguished from other groups by the white line that extends around the lateral margins of the pronotum, corium, and abdomen (Froeschner 1960).

Life Cycle and Description

Pangeaus bilineatus is a paurometabolous insect, like other cydnids (Sites and McPherson 1982, Riis et al. 2005, Schwertner and Nardi 2015). According to Cole (1988) in Texas in 1971–72, the majority of adults overwintered in the soil at depths of 6–8 in.

Fig. 1. The sharp, deeply impressed line that runs parallel to the anterior and lateral edges of the pronotum serves as the primary diagnostic feature of *Pangaeus bilineatus* (Froeschner 1960).

(15–20 cm), terminated diapause in late February and early March, and progressively moved toward the soil surface as temperatures increased. Active nymphs have been observed during winter months (December–February) in Georgia, USA, within fields previously planted to peanut, suggesting that at least a portion of the population may not enter diapause in this region (personal observations). Evidence suggests at least three *P. bilineatus* generations/year occur in South Georgia, and a single generation can be completed in approximately one month under favorable conditions in the lab (Abney and Aigner 2018, Aigner and Abney 2020).

Adults

Pangaeus bilineatus adults are oval-shaped, 5.3–7.8 mm in length, and light brown to shiny black in color, depending on their age. Freshly molted adults are white and remain below ground while their exoskeletons harden and gradually darken in color (Fig. 2a). The bug's tibiae are modified with spines that wrap around 360° and project 45° posteriorly (Fig. 2b). When disturbed, a pungent odor is emitted from metathoracic glands as a probable defense mechanism. Roth (1961) described the fungistatic and repellent properties of metathoracic gland secretions from another cydnid, *Scaptocoris divergens* (Froeschner). The odor is similar to that released by other species in the pentatomoid superfamily, and is likened by many to the smell of coriander or cilantro. The meso- and meta-pleural evaporatoria on the ventral thoracic plates (Fig. 2c and d) facilitate diffusion of these odorous compounds. The terminal segment of the male is a capsule that contains the genital clasper, while the terminal segment of the female consists of two genital plates that control access to the reproductive organs (Fig. 2e and f). Sailer (1954) provides detailed illustrations of *P. bilineatus* males' genital claspers.

Eggs

Eggs are approximately 1 mm in length, oval-shaped, and opaque-white in color (Fig. 3a). Oviposition begins less than 8 d after mating and nymphs have been observed within 14 d of mating (Aigner and Abney 2020). Red eyespots appear on the developing embryo after a few days, and the egg retains a pearly white to cream coloration until the nymph emerges (Fig. 3b).

Nymphs

Pangaeus bilineatus develops through 5 nymphal instars (Fig. 4). Immatures spend most of their development below ground. First instar nymphs (Fig. 5a) have an average pronotum width of 0.66 mm (Table 1) and are beige in color. Second instar nymphs (Fig. 5b) have an average pronotum width of 0.9 mm and are light brown in color. Third instar nymphs (Fig. 5c) have an average pronotum width of 1.27 mm with dark brown (almost black) sclerotized parts (e.g., head, legs, tergal plates) and lighter colored membranous tissue between. Third and fourth instar nymphs are similar in color, but the latter (Fig. 5d) is slightly larger with an average pronotum width of 1.8 mm. Fifth instar nymphs (Fig. 5e) are slightly larger than fourth instars (2.6 mm average pronotum width) but possess distinctly visible wing pads. In a growth chamber at 29°C, 40% RH, and a 14:10 light–dark cycle, the insect can complete development from egg to adult in approximately 30 d (Aigner and Abney 2020).

Geographic Distribution and Host Range

The distribution of *P. bilineatus* ranges from Guatemala, northward throughout Mexico, and includes much of the southern and eastern U.S. (Fig. 6) (Sailer 1954, Froeschner 1960). The species also occurs in eastern Canada, Puerto Rico, Bermuda, and Hawaii (Russell 1934, Sailer 1954, Froeschner 1960, Lis et al. 2000, Paiero et al. 2003, Garcia 2011).

Though its full host range is unknown, *P. bilineatus* is quite polyphagous, and has been reported to feed on a variety of tissue in several crops including peanut seeds, cotton seedlings (*Gossipium hirsutum* L.), newly sprouted wheat (*Triticum aestivum* L.), pepper seeds (*Capsicum* spp. L.), spinach seedlings (*Spinacia oleracea* L.), and strawberry fruit (*Fragaria ananassa* Duchesne) (Swenk 1913, Gould 1931, Russell 1934, Cassidy 1939, Tissot 1939, Watson and Tissot 1942, Sailer 1954, Smith and Pitts 1974, Cole 1988). In a laboratory colony, adults and nymphs have been observed feeding on seeds, stems, and roots of peanut, tubers of yellow nutsedge (*Cyperus esculentus* L.), florets of river oats (*Chasmanthium latifolium* (Michx.) Yates), stems of chickweed (*Stellaria media* (L.) Villars), and stems and roots of white clover (*Trifolium repens* L.) (personal observations). Cydnids are primarily seed and root feeders, and although *P. bilineatus* has been observed feeding on a variety of plant tissue, its host preferences are unknown (Froeschner 1960, Smith and Pitts 1974, Lis et al. 2000, Schwertner and Nardi 2015).

Injury to Peanut and Economic Impact

Pangaeus bilineatus has piercing-sucking mouthparts that inject digestive enzymes into plant tissue and ingest dissolved nutrients in a process known as non-reflux extraoral digestion (Cantón and Bonning 2020). Adults and nymphs feed directly on peanut seed through the hull which can cause commercial grade reductions and facilitate aflatoxin contamination leading to a loss in crop value of more than 50% (Smith and Pitts 1974, Chapin et al. 2006, Mbata and Shapiro-Ilan 2013). Feeding injury can be seen as yellow to dark brown spots or pits on mature seed once the testa is removed. (Fig. 7) (Smith and Pitts 1974).

The potential for *P. bilineatus* to become a serious economic pest of peanut in the United States was first mentioned by Smith and Pitts (1974). Injury to peanut was first reported in Georgia in 1959, and significant economic injury was documented in Alabama in 1966 and in the southern peanut growing region of Texas in 1968 (Smith and Pitts 1974). Although *P. bilineatus* injury to peanut is sporadic spatially and temporally, the insect is considered a serious threat to peanut in Georgia, where approximately 50% of United States peanut production occurs annually. (USDA–NASS 2020).

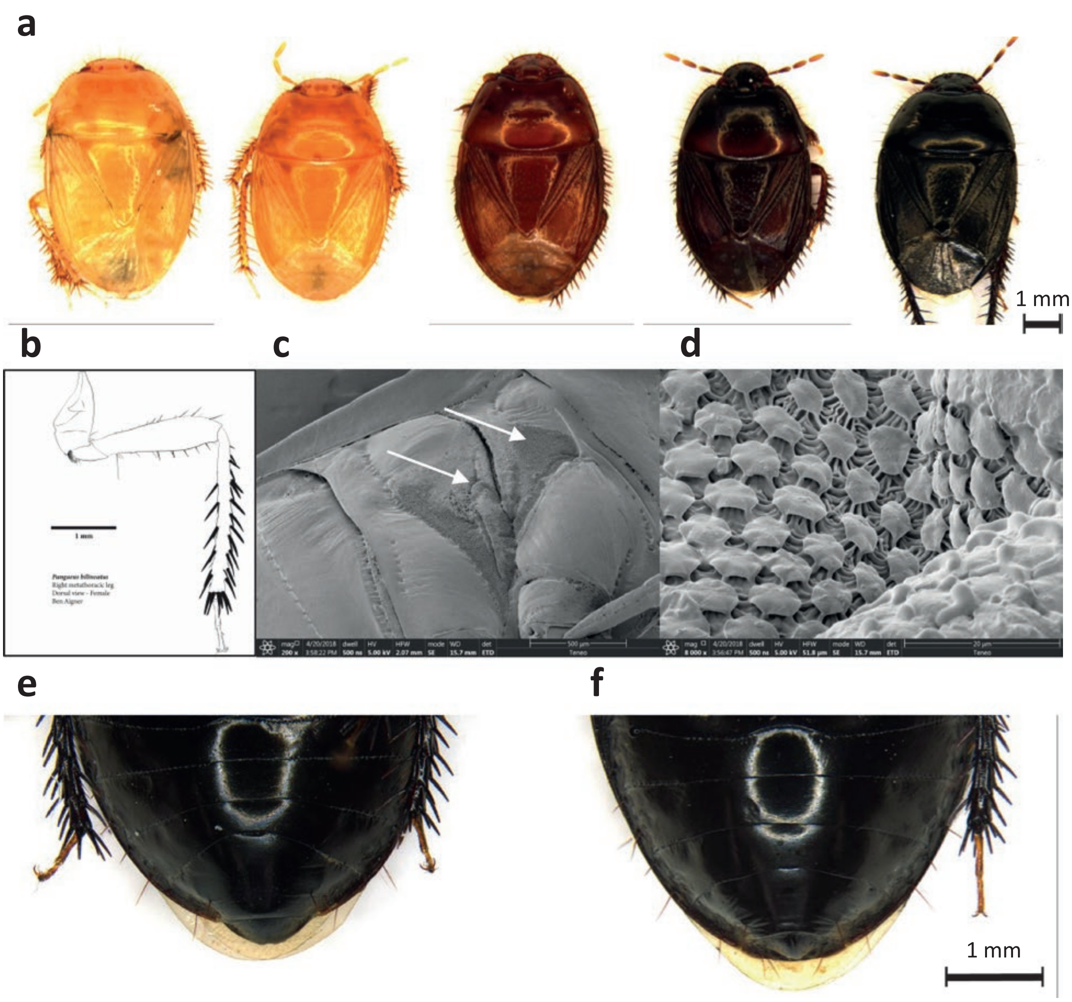


Fig. 2. a–f. a) Adult *Pangaeus bilineatus*' gradual sclerotization post imaginal ecdysis at approximately 4 h (far left), 7 h (near left), 14 h (center), 22 h (near right), and >30 h (far right). b) Drawing of the dorsal view of the right metathoracic leg of a female *P. bilineatus* (Drawing by B. L. Aigner, 2018). c) Scanning electron microscope (SEM) image of the evaporative structures on the right meso- and meta-pleura of an adult *P. bilineatus* female. Pictured areas of *P. bilineatus*' ventral thoracic plates are referred to by Froeschner (1960) as the mesopleural evaporatorium and the osteolar peritreme. d) Close-up SEM image of the metapleural evaporatorium near the opening of the metathoracic gland (Images by J. Shields, Georgia Electron Microscopy, UGA, 2018). e) Terminal segment of a male *P. bilineatus* showing the capsule that encloses the male genital clasper. f) Terminal segment of a female *P. bilineatus* showing the genital plates that enclose the female genitalia.

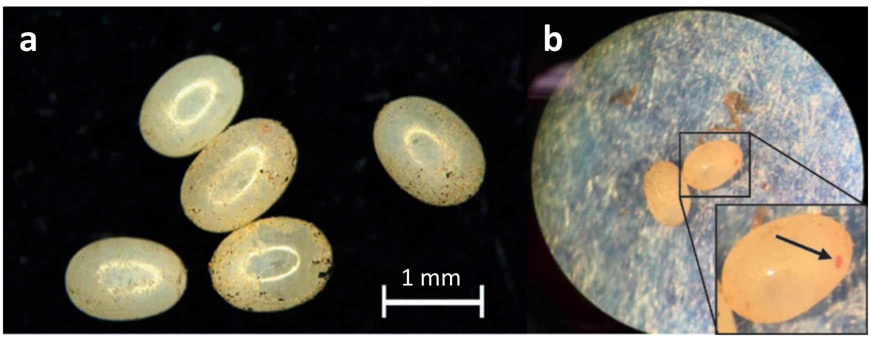


Fig. 3. a–b. Eggs of *Pangaeus bilineatus* a) < 3 d old, and b) > 3 d old (arrow pointing to red eyespot).

Significant economic losses have been reported throughout Georgia since 2010 (Mbata and Shapiro-Ilan 2013, Abney 2014, Abney 2015, Abney 2016, Abney 2017). Because the insect and the injury occur below ground, injury is usually not detected until peanuts reach a buying point, where grading occurs. Injury greater than 3.49% by weight results in loss of grade from 'segregation I' to 'segregation II' and a loss in value of approximately $209/MT (USDA 2019). Losses due to *P. bilineatus* injury in Georgia were estimated to be approximately $15 million in 2014, and losses were disproportionately endured by relatively few producers (Abney 2014). Though Sailer (1954) raised concerns that the species might transmit viral diseases through plant roots, no cases of virus transmission have been documented.

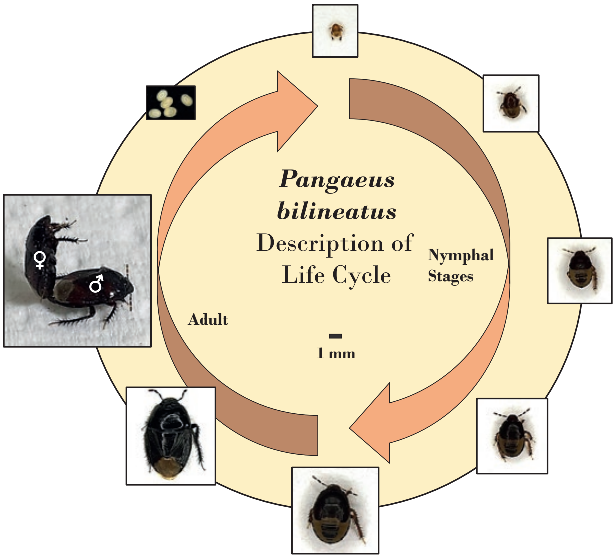
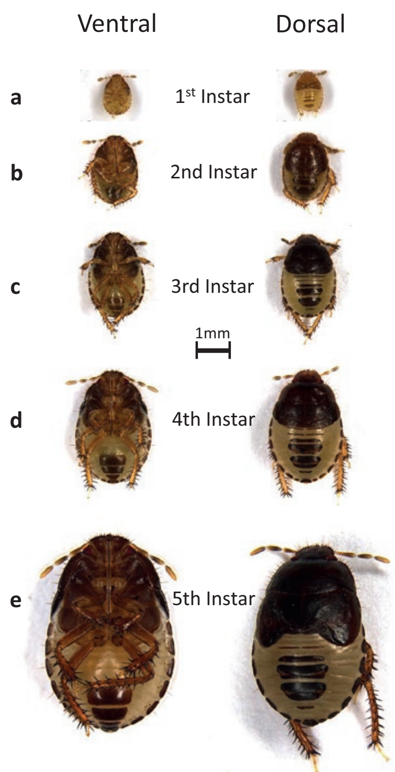


Fig. 4. Life cycle of *Pangaeus bilineatus*. After hatching, the bug develops through 5 nymphal instars before eclosion to adulthood. The image at 270° portrays mating adults.



Figs. 5. a–e. Ventral and dorsal view of immature *Pangaeus bilineatus* captured in a) first instar, b) second instar, c) third instar, d) fourth instar, and e) fifth instar stadia.

Natural Enemies

Very little is known about the natural enemies of *P. bilineatus*, and biological control at a management scale has never been reported in the field. Johnson (1973) described *P. bilineatus* as a host of the strepsipteran parasite, *Triozocera mexicana* (Pierce), in the family Mengeidae. However, Cook (2015) suggested that *T. mexicana* likely does not occur in the United States, and Johnson (1973) may have misidentified either *Triozocera vernalis* (Kifune and Brailovsky) or *Triozocera texana* (Pierce). Southern fire ant, *Solenopsis xyloni* (McCook) (Hymenoptera: Formicidae), workers were seen foraging on eggs and small nymphs of *P. bilineatus* in Texas, but this behavior was rarely observed (Smith and Pitts 1974). An ascomycotic fungal entomopathogen of the family Ophiocordycipitaceae and genus *Hirsutella* was identified from field-collected specimens in Emanuel County, Georgia, but it has not yet been identified to species (L. Castrillo, USDA, personal communication).

Table 1. Average pronotum width of *P. bilineatus* nymphs and adults by life stage and ratio of growth between life stages

Life stage	Avg pronotum width (µm)	Std dev	MSE	Growth ratio
1st Instar	656.868[a]	24.170	7.64	
2nd Instar	904.824[a]	47.382	14.98	1.377
3rd Instar	1266.695[a]	48.211	15.25	1.400
4th Instar	1799.552[a]	101.101	31.97	1.421
5th Instar	2591.334[a]	80.987	25.61	1.440
Adult	3582.144[b]	128.396	31.14	1.382

[a]n = 10.
[b]n = 17.

Management

Sampling and Monitoring

There are no established economic thresholds or sampling protocols for *P. bilineatus* in any crop. The insect spends most of its life cycle below ground where it is difficult to detect, and peanut injury may go entirely unnoticed until pods and seed are inspected after harvest. In the summer, adults actively fly at dusk (Highland and Lummus 1986, Abney and Aigner 2018). Published field sampling techniques for *P. bilineatus* include light trapping and pitfall trapping (Smith and Pitts 1974, Highland and Lummus 1986, Chapin and Thomas 2003, Mbata and Shapiro-Ilan 2013, Abney and Aigner 2018). Light traps have been used to study the insect's distribution and population dynamics in Texas and Georgia (Highland and Lummus 1986, Abney and Aigner 2018), and pitfall traps have been effectively used to measure the seasonal abundance of *P. bilineatus* in South Carolina and relate trap catch to peanut injury ratings (Chapin and Thomas 2003). While Highland and Lummus (1986) did not find any biotic or abiotic predictors of peak *P. bilineatus* light trap captures in peanut, they did find a close correlation between light trap captures and field infestations. The presence and abundance of *P. bilineatus* in light traps and pitfall traps are dependent on abiotic factors as well as the insect's behavior, but could be useful indicators of field infestation. To date, trap capture data have not been used to inform decision making in peanut pest management programs. In addition, trapping observations could help elucidate farm-scale spatiotemporal distribution patterns of *P. bilineatus* and help identify risk factors (e.g., elevation, soil texture, soil moisture) associated with economic injury (Chapin and Thomas 2003, Holland et al. 2005, Mbata and Shapiro-Ilan 2013). Direct assessment (Hutchins 1994) of *P. bilineatus* population density has been achieved by collecting a known volume of soil and determining the number of bugs present. Although the method of soil extraction was not described, soil samples were used by Smith and Pitts (1974) to measure *P. bilineatus* abundance during insecticide efficacy field

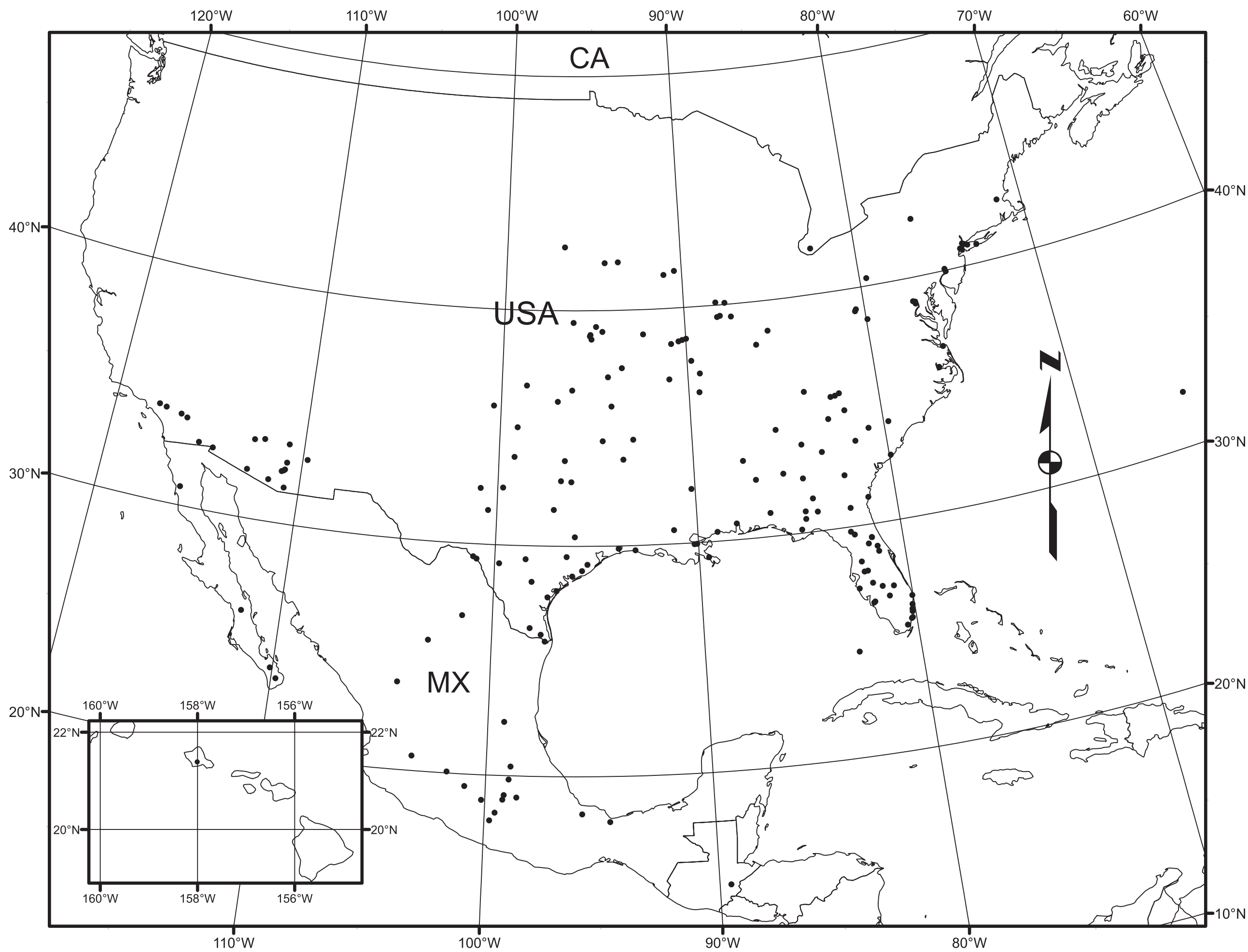


Fig. 6. Map of historical occurrence of *Pangaeus bilineatus* as documented in Froeschner's: Cydnids of the Western Hemisphere (1960) (Map drawn by B.L. Aigner and M.S. Crossley). Additional locations not listed by Froeschner (1960) include Ontario, CA (Paiero et al. 2003) and Oahu, Hawaii (Garcia 2011).

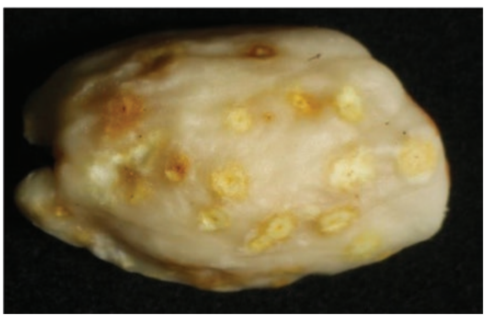


Fig. 7. Peanut seed with testa removed showing severe *Pangaeus bilineatus* feeding injury.

trials. Though time consuming and labor-intensive absolute soil sampling of this type avoids the behavioral bias potentially associated with active and passive trapping.

Cultural Management

Host plant resistance is an important element of IPM that can directly counter insect herbivory via physical (e.g., spines, trichomes) and chemical (e.g., herbivore-induced plant volatiles, plant secondary metabolites) plant defenses (Fürstenberg-Hägg et al. 2013, Trapero et al. 2016, Van Emden 2017). Peanut breeding programs have prioritized the development of cultivars with traits conferring resistance to viruses like *Tomato spotted wilt orthotospovirus* (TSWV) and causative agents of leaf spots (*Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. & M.A. Curtis) Deighton), and stem rot (*Sclerotium rolfsii* Sacc.) due to the prevalence and economic impact of these pathogens (Chamberlin 2019). For the past 4 decades, three runner-type cultivars have dominated planted acreage in the Southeast USA: 'Florunner' (1980s and 90s), 'Georgia Green' (1990s and 2000s), and 'Georgia-06G' (2000s to present) (Branch and Culbreath 2015). The increased occurrence of *P. bilineatus* injury following the release and widespread adoption of cultivar 'Georgia-06G' in 2007 (Branch 2007) might indicate a higher relative susceptibility of this cultivar to *P. bilineatus* injury compared to previously grown cultivars. An effort to identify and incorporate host plant resistance traits against *P. bilineatus* into new commercially viable cultivars is needed and would provide benefit for future IPM programs.

Crop rotation and tillage can have significant impact on soil dwelling arthropods (House and Del Rosario Alzugaray 1989, Poggi et al. 2021), but information regarding the effects of specific practices on *P. bilineatus* is lacking. In the early 2000s, adoption of conservation tillage practices (i.e., no-till, strip-till, and mulch-till) steadily increased in cotton, corn, and soybean agroecosystems in the Southeast USA to >60% of planted acres in 2015 (Claassen et al. 2018). Cotton, corn, and bahiagrass are common rotational crops with peanut in the Southeast USA, but actual rotation patterns vary by state and area within a state (Chapin and Thomas 2003, Puppala et al. 2018, Wright et al. 2020, Anco and Thomas 2021, Jordan 2021, Strayer-Scherer 2021). Studies evaluating the effect of tillage practices and rotational crops suggest that conventional moldboard plowing prior to peanut planting can significantly reduce the risk of peanut burrower bug injury compared to strip-till planting into wheat or corn residue (Chapin et al. 2001, Chapin and Thomas 2003). Subsequent studies found significantly less *P. bilineatus* injury to peanut grown in conventional versus conservation tillage (Abney et al. 2017). However, conventional tillage does not guarantee peanut to be free from *P. bilineatus* injury, and the cost of converting from conservation to conventional tillage can be high in economic and environmental terms. Given these facts and the sporadic nature of *P. bilineatus* injury, many growers are reluctant to alter tillage regimes solely for the purpose of managing burrower bug.

Irrigation represents another potential cultural management tool for *P. bilineatus*. Although the cause is unknown, *P. bilineatus* injury tends to occur at a higher rate in non-irrigated than irrigated peanut fields (Highland and Lummus 1986, Riis et al. 2005, Aigner et al. 2019). Current availability of irrigated land and the need to maintain crop rotations for agronomic reasons limit the amount of peanut that can be irrigated in Georgia to approximately 50% of the total crop each year.

The effects of cover crop (Chapin and Thomas 2001, Chapin et al. 2003), planting and harvest date, and weed seed bank on peanut burrower bug populations and peanut injury are largely unknown, but the insect's broad host range suggests that investigation in these areas is necessary. Adjustment of planting and/or harvest dates could have an impact on incidence of injury. In warm climates, later harvest dates expose the crop to risk of feeding injury through October and into November, enabling further damage to the crop. According to Hart (2020), early burn down of cover crops and winter weeds that may be suitable hosts for insect pests can reduce the 'green bridge' – where polyphagous pests in warm climates move from cover crop to cash crop (Alyokhin et al. 2020) – between successive plantings. Additionally, weed seed bank could provide food resources to facilitate the survival of populations within fields during fallow periods.

Chemical Management

The only insecticide labeled for use against *P. bilineatus* in peanuts in the United States is the granular formulation of the organophosphate chlorpyrifos (Chapin et al. 2001, Chapin and Thomas 2003, Abney 2021). Granular chlorpyrifos applied at pegging (R2 growth stage) was shown by Chapin et al. (2001) to significantly reduce peanut burrower bug feeding injury in peanut even in high-risk fields planted following a rotation of wheat or corn. The recommended application rate is 2 lbs. AI per acre, which can be delivered by a 10–18″ banded application (Abney 2021). Specialized equipment is required to apply granular chlorpyrifos, and rainfall or irrigation is needed within 10–14 d to activate the insecticide and to optimize residual efficacy (Pike and Getzin 1981). Broad-spectrum insecticides like chlorpyrifos can have negative impacts on beneficial arthropod communities leading to secondary pest outbreaks (Ruberson et al. 1998, Lu et al. 2012, Hill et al. 2017), but there is currently no chemical alternative for *P. bilineatus* management. Lambda cyhalothrin, bifenthrin, and imidacloprid have been examined for efficacy but none have consistently reduced injury (Chapin and Thomas 2003, Abney et al. 2017). Mbata and Shapiro-Ilan (2013) concluded that a combination of the entomopathogenic nematode, *Heterorhabditis bacteriophora* (Poinar), and chlorpyrifos results in a synergistic effect under laboratory conditions. The nematode apparently did not cause *P. bilineatus* mortality in the absence of insecticide, and field efficacy of the nematode and insecticide combination has not been tested. The regulatory fate of chlorpyrifos is uncertain, and there is a need for continued research to find safe and effective chemical alternatives (Eaton et al. 2008, Grandjean and Landrigan 2014, Mie et al. 2018, Foong et al. 2020).

Closing Remarks

Though not fully described, the host range of *P. bilineatus* is certainly large and contains a wide variety of wild and cultivated plants (Sailer 1954, Highland and Lummus 1986, Lis et al. 2000). The insect is a severe economic threat, especially to peanut (Smith and Pitts 1974, Lis et al. 2000). The mechanism(s) responsible for the upward trend in peanut burrower bug injury witnessed since 2010 in the Southeast USA is a mystery. Several factors may be at play, including increasing adoption of reduced-till farming techniques throughout the early 2000s, a transition to greater use of the peanut cultivar 'Georgia-06G', and an increasingly warm climate.

Effective management of *P. bilineatus* in peanuts will require improved knowledge of the insect's biology, more effective monitoring and management tools, and a greater understanding of the factors that place peanut at risk of economic injury. For instance, treating light traps with sex pheromone could increase trap efficacy and improve the correlation between trap counts and pest densities in peanut fields. There are currently no economic thresholds or economic injury levels for *P. bilineatus* in any crop. These are the foundations of IPM programs and would provide growers with more precise information regarding the appropriate use of management tools, including insecticides, to prevent economic loss. Furthermore, a better understanding of *P. bilineatus*' interactions with crop and non-crop habitats could reveal critical places where targeted sampling and management efforts could enhance pest control. Given the limitations of current monitoring and management tools, continuation of efforts to elucidate the biology and ecology of the cryptic, native, peanut burrower bug will be critical to develop safe, effective, and sustainable pest management practices in peanut agroecosystems.

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