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Bagrada hilaris (Hemiptera: Pentatomidae), An Invasive Stink Bug Attacking Cole Crops in the Southwestern United States

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ABSTRACT. An invasive stink bug, *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae), was discovered in the Western Hemisphere in 2008 near Los Angeles, CA, presumably introduced on container shipments arriving at the Port of Long Beach. In the subsequent 4 years, it has spread throughout southern California, southern areas of Arizona, Nevada, and Utah, southern and west–central New Mexico, and extreme western Texas. We initiated studies on the seasonality and host range of this invasive insect as it adapts to this non-native habitat. We have learned that the bagrada bug has a single population peak between July and October in urban areas dominated by native and introduced weeds, and two population peaks (March–May and September–November) timed with the production of cole crops in agricultural areas. In greenhouse tests, we found 14 plants on which bagrada bug fed heavily, out of 38 agricultural crops and weed plants evaluated. The opportunistic use of host plants other than crucifers, the use of soil oviposition sites, and tolerance of warm climates may contribute to its invasive potential.

Key Words: bagrada bug, *Bagrada hilaris*, brassicaceous plant, invasive species, Pentatomidae

Bagrada hilaris (Burmeister, 1835) (Hemiptera: Pentatomidae) is a recent introduction to the United States. First identified in coastal southern California in 2008, the geographic distribution of this bug has expanded eastward, and by 2012, it was found across southern regions of California, Arizona, Nevada, and Utah, as well as in western and southern New Mexico and western Texas. It also has been detected in the agricultural central valley and central coastal regions of California. In the past few years, the bagrada bug has been particularly damaging to conventional and organically grown cole crops in the Coachella and Imperial valleys of California and the Yuma Valley of Arizona. Given that this pest is new to the Western Hemisphere, integrated pest management (IPM) strategies consistent with modern cropping systems need to be developed. This article provides information on *B. hilaris* biology and host range in the United States that will facilitate the development of IPM strategies.

Pest Status

B. hilaris, formerly *Bagrada cruciferarum* Kirkaldy or *Bagrada picta* (F.) (Hemiptera: Pentatomidae), is native to Africa, India, and Asia (Howard 1906), where it is known by various names, including bagrada bug, painted bug, or harlequin bug (not to be confused with the harlequin bug *Murgantia histrionica* (Hahn), which is native to Mexico and Central America; McPherson and McPherson 2000). Since the early 1900s, *B. hilaris* has been reported as an important pest of cruciferous crops (Brassicaceae), particularly in India and Pakistan (Vekarta and Patel 1999, Sahito et al. 2010, Malik et al. 2012). Before its arrival in the United States, the most recent problems have occurred in Africa (http://www.infonet-biovision.org/default/ct/103/pests) while India also has suffered occasional outbreaks (Lal and Singh 1993). Its presence has also been reported in southern Europe (specifically the island of Pantellaria in Italy), Australia, the Middle East, and Southeast Asia (Guarino et al. 2008).

Until June 2008, when it first was reported in Los Angeles County, CA (Arakelian 2008), bagrada bug had not been observed in the Western Hemisphere. Within 2 years, its known geographic range had expanded to include southern California, southern Arizona, and extreme southern New Mexico (Bundy et al. 2012) wherever brassicaceous plants (wild mustards and cultivated cole crops) were found. In 2011, it was found in southern areas of Nevada and Utah and west–central New Mexico. Most recently the bagrada bug was discovered damaging cole crops in the central coastal areas of California (Dara 2012), and it has been reported in cotton and residential gardens in west Texas (Vitanza 2012). At particular risk is >90% of the nation's commercial crops of broccoli, cauliflower, cabbage, Brussels sprouts, and other cole crops grown in California and Arizona on ≈170,500 acres (U.S. Department of Agriculture–National Agricultural Statistics Survey [USDA–NASS] 2011). In 2012, California production of broccoli, cauliflower, and cabbage was valued at US$606 million, US$210.6 million, and US$67.5 million, respectively (California Agricultural Statistics Review 2011–2012, USDA–NASS 2011), and production of these crops in Arizona was valued at US$145.8 million (Arizona Agricultural Statistics 2011, USDA–NASS 2011).

B. hilaris has become a serious pest of cole crops grown during fall and winter in the desert valleys of southern California and Arizona. Nymphs and adults have been found damaging all known commercial brassicaceous cultivars grown in the desert. Insects feed on direct-seeded plants immediately after emergence of the hypocotyl (Palumbo and Natwick 2010). Many plants are killed at this stage, and seedling mortality in 2009 reached 60% in some fields. In addition to damaging field plots, nursery production of transplants has been devastated, particularly plants destined for organic production. Many nurseries in the Coachella Valley have relocated their cole crop transplant production to more northern California areas where bagrada bug does not currently occur. Concomitant with the damage to agricultural crops, *B. hilaris* has become increasingly problematic in community and private gardens in urban areas. Many ornamental plants, such as candytuft (*Iberis* spp.), stock (*Matthiola* spp.), and sweet alyssum (*Lobularia maritima* (L.) Desvaux), have been damaged by bagrada bugs (Reed et al. 2013).

Pest Biology and Ecology

Life Cycle. *B. hilaris* is a true bug in the family Pentatomidae (stink bugs). It overwinters in the adult stage, and mating pairs frequently are observed on plants during warm days. Eggs are laid on the undersides of leaves, on stems, and in loose soil. Unlike many stink bugs, *B. hilaris* does not lay its eggs in large contiguous masses, but rather singly or in small groups of ≈10 eggs. Newly laid eggs are opaque white (Fig. 1A), and as the embryos mature, the egg color turns from

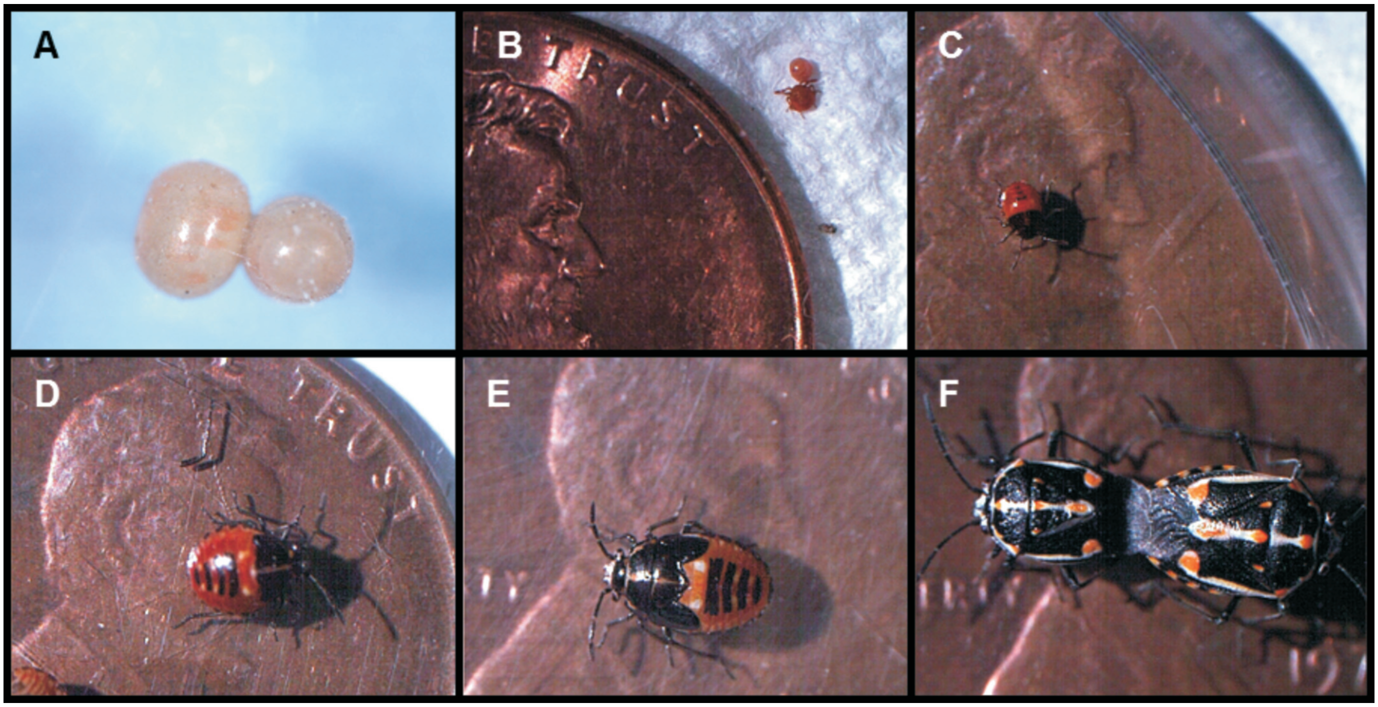

Fig. 1. Life stages of *B. hilaris*. (A) Newly laid eggs. (B) First instar next to unhatched egg. (C) Third instar. (D) Fourth instar. (E) Fifth instar with wingpads. (F) Adults *in copula* with the smaller male on left. (U.S. penny used for scale.)

white to cream to pink to red. Newly hatched and molted nymphs appear bright red or orange, and, within hours, the head, thorax, and legs melanize to dark brown or black. There are five instars (Singh and Malik 1993, D.A. Reed, personal observation); early instars have predominately red abdomens (Fig. 1B and C), but during later instars (Fig. 1D and E), the abdomen takes on a striking appearance with a mixture of red-orange, black, and white markings.

The entire life cycle, egg to adult, can take from 41 days at a constant temperature of 24°C (75°F) to <3 week at 35°C (95°F; D.A. Reed, personal observation). Females lay an average of 100–200 eggs (Hill 1983, Singh and Malik 1993), and although Singh and Malik (1993) report that adults can survive ≈3 week to 1 month, individuals have been observed to survive for 3 months under greenhouse conditions (D.A. Reed, personal observation). Females have a preovipositional period of 3 to 4 days and adults are commonly observed *in copula* (Fig. 1F).

Aggregation Behavior. Bagrada bugs often form large aggregations (hundreds of individuals) composed of both adult and immature stages (Fig. 2). It is these aggregations, along with damaged plants, that first alerted home gardeners, growers, county agents, and researchers to the presence of *B. hilaris* in southern California. Single insects may be easily mistaken for other common Heteroptera, such as the small milkweed bug *Lygaeus kalmii* Stål, the harlequin bug *M. histrionica* (Hahn), or even lady beetles (Coleoptera: Coccinellidae).

Bagrada Host Relationships

Plant Damage. Like many other Heteroptera, the bagrada bug has sucking mouthparts and exhibits a lacerate-and-flush method of feeding (Hori 2000). Multiple stylet penetrations occur in the same location resulting in starburst-shaped lesions (Fig. 3) on foliage, stems, and fruits (Sachan and Purwar 2007, Nyabuga 2008, Ahuja et al. 2008, Palumbo and Natwick 2010). The thrusting action of the mouthparts within the plant's tissues and the injection of salivary enzymes result in cell death. Depending on the maturity of the plant at the time of feeding, leaves may become malformed and feeding injury resembles circular scorching. Damage to tender foliage can result in wilting, with eventual desiccation and death of the tissues. Additionally, feeding on the apical meristems of young seedlings can result in either death of the growing tip or deformation and initiation of adventitious budding.

Host Range. While *B. hilaris* prefers wild and cultivated mustards, it has been reported on a wide range of hosts in a variety of families. These include barley, oats, wheat, artichokes, beetroot, carrot, lettuce, peas (Gunn 1918 in Daiber 1992), lamb's quarters and sowthistle (Singh and Malik 1993), rice and sugarcane, and coffee (Rajpoot et al. 1996). To develop a better understanding of its current host range in the southern California and Arizona deserts, we conducted choice tests in a greenhouse setting. For this study, six to seven adult *B. hilaris* were given the opportunity to feed on three to four different plants from various families for 5 days. These families were representative of plants typically found in and around desert farms.

For each test, four pots, each with a different plant species, were presented to adult bugs within a caged enclosure; one of the four plants was a brassicaceous species. Different plant species have very different morphologies. For example, the leaves of sweet alyssum are much smaller and narrower than the broad leaves of plants like fava bean (*Vicia faba* L.). Therefore, we regulated the amount of seed in each pot to generate comparable amounts of foliage for all species in the study. Each choice test was replicated three times. After the exposure period, bugs were removed and the number of feeding scars was counted on the leaves of each plant species.

These studies showed that bagrada bug caused heavy feeding damage on all plants in the family Brassicaceae (Table 1). These included the cole crops arugula, broccoli, cabbage, collards, Indian mustard, and kale, and the ornamental plant sweet alyssum. They also fed heavily on the cruciferous weeds shortpod mustard (*Hirschfeldia incana* (L.) Lagrése-Fossat), London rocket (*Sisymbrium irio* L.), and shepherd's purse (*Capsella bursa-pastoris* (L.) Medikus). Interestingly, bagrada bugs also caused substantial damage to vetch (Fabaceae) and grasses (Poaceae), including corn and Sudan grass (Table 1).

Damage to Agricultural Crops. The extent of damage by *B. hilaris* varies with both plant morphology and maturity. Leafy, non-head-forming plants (e.g., arugula, kale, and collards) are attacked through-

Fig. 2. Aggregation of *B. hilaris* on senescent shortpod mustard in Riverside, CA, July 2010.

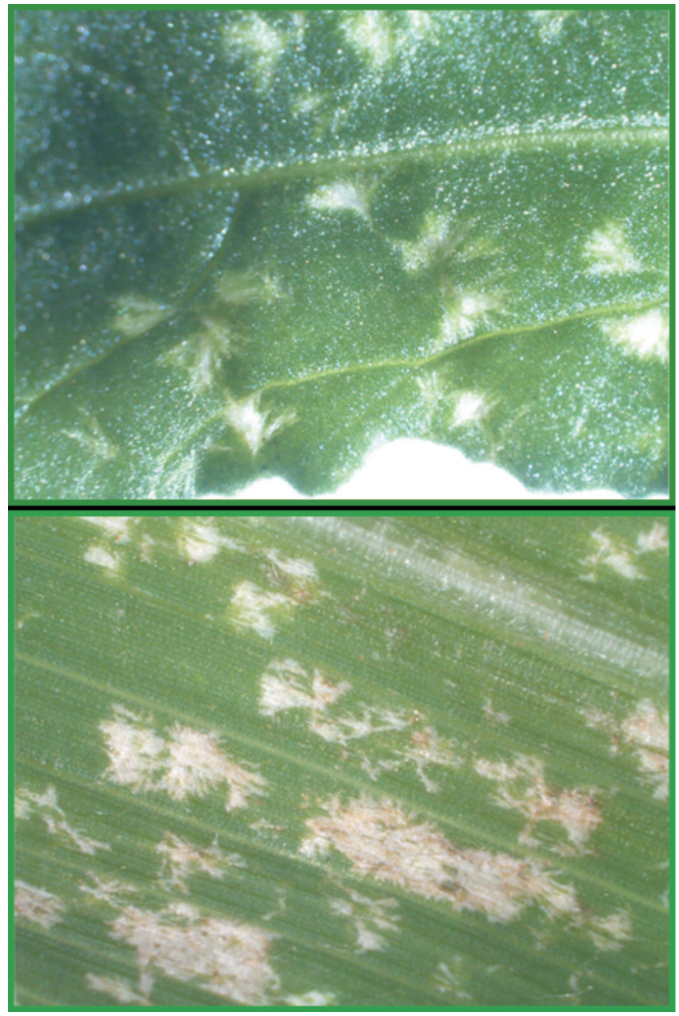

Fig. 3. Star-shaped lesions on kale (top) and corn (bottom) leaves caused by *B. hilaris* feeding.

out the growth period. In these plants, *B. hilaris* prefers the younger leaves, reproductive structures, and growing tips; thus, they are most heavily damaged. In the case of head-forming cole crops (e.g., broccoli, cauliflower, and cabbage), direct-seeded plants are at the highest risk because feeding at the time of plant emergence kills the apical meristem, thereby killing the plant. Heavy feeding during the cotyledon stage can also lead to plant death. For plants that survive, damage to the apical meristem can result in a plant without a reproductive head, referred to as *blind plants* (Fig. 4), or plant deformations that may include adventitious buds or growing points that yield multiple small heads (Fig. 5). Growers often refer to these plants as *forked*, and the heads that develop are small with large stems and few florets. Feeding on young developing leaves surrounding the terminals often results in leaf deformation.

In the desert southwest agricultural regions of the Coachella Valley, Imperial Valley, and Yuma Valley, cauliflower and cabbage typically are transplanted, while broccoli and leafy cole crops are direct-seeded. The exceptionally high mortality during germination and severe damage to plants that survived germination caused large yield losses in 2009 and 2010, consistent with the 70% loss in fall-planted mustard reported in India >20 years ago (Joshi et al. 1989). To deal with these losses, growers have resorted to the use of transplants rather than direct-seeding broccoli. This practice is more expensive and does not eliminate losses caused by blind or forked plants. Estimates by local growers indicated that in 2009, *B. hilaris* caused a 20% loss in cauliflower because of the production of blind plants, while in broccoli, damage estimates ranged from 10 to 25% because of delayed harvest as a result of multiple crowns on plants. More recently, a survey of growers from Yuma, Arizona and the Imperial Valley of California estimated >90% of the broccoli acreage planted in 2010 and 2011 was infested by *B. hilaris*, resulting in stand losses and plant injury exceeding 10% in direct-seeded crops (Palumbo 2012).

Seasonal Distribution in Southern California and Arizona

The growing season for cole crops in the southwestern deserts of the United States typically begins in late August and early September, and harvest is completed by the end of March. Noncultivated cruciferous weeds (e.g., wild mustards, London rocket) grow in the winter months and senesce by middle to late June. The loss of preferred host plants coupled with extremely high daytime temperatures results in a reduction of the *B. hilaris* population during summer. Despite these conditions, adult bugs that survive the summer devastate crops at germination during early autumn.

Observational (Qualitative) Data. To address the question of where and on which plant species the bagrada bug oversummers, we made observations on the phenology of *B. hilaris* in various areas of southern California in 2010. We observed that, from January to April, bagrada bugs were abundant in cruciferous weeds, such as London rocket, shepherd's purse, shortpod mustard, and Sahara mustard (*Brassica tournefortii* Goan). This timeframe coincided with the harvest of cole crops and planting of corn and Sudan grass. From May to

Table 1. Feeding damage by *B. hilaris* on host plants in greenhouse trials

Plant family	Plant species	Common name	Feeding damage[a]
Amaranthaceae	*Chenopodium* sp.	Goosefoot	No
Amaranthaceae	*Spinacia oleracea* L.	Spinach	No
Apiaceae	*Coriandrum sativum* L.	Cilantro	No
Asteraceae	*Senecio vulgaris* L.	Groundsel	No
Asteraceae	*Lactuca sativa* L.	Lettuce	No
Asteraceae	*Sonchus* sp.	Sowthistle	No
Asteraceae	*Helianthus annuus* L.	Sunflower	Yes
Brassicaeceae	*Eruca sativa* Miller	Arugula	High
Brassicaeceae	*Hirschfeldia incana* (L.) Lagrèze-Fossat	Shortpod Mustard	High
Brassicaeceae	*Brassica oleracea* L. (*Italica* group)	Broccoli	High
Brassicaeceae	*B. oleracea* (*Capitata* group)	Cabbage	High
Brassicaeceae	*B. oleracea* (*Botrytis* group)	Collards	High
Brassicaeceae	*B. juncea*	Indian mustard	High
Brassicaeceae	*B. oleracea* (*Acephala* group)	Kale	High
Brassicaeceae	*Sisymbrium irio* L.	London rocket	High
Brassicaeceae	*Capsella bursa-pastoris* (L.) Medikus	Shepherd's purse	High
Brassicaeceae	*Lobularia maritima* (L.) Desvaux	Sweet alyssum	High
Curcurbitaceae	*Cucumis melo* L.	Cantaloupe	No
Curcurbitaceae	*Cucumis sativus* L.	Cucumber	No
Curcurbitaceae	*Curcurbita foetidissima* Kunth	Wild gourd	No
Curcurbitaceae	*Curcurbita pepo* L.	Zucchini squash	No
Fabaceae	*Lotus corniculatus* L.	Birdsfoot trefoil	No
Fabaceae	*Vigna unguiculata* (L.) Walpers	Cowpea	Slight
Fabaceae	*Vicia faba* L.	Fava bean	No
Fabaceae	*Phaseolus lunatus* L.	Lima bean	Slight
Fabaceae	*P. vulgaris* L.	Snap bean	Slight
Fabaceae	*Glycine max* (L.) Merrill	Soybean	No
Fabaceae	*Vicia sp.*	Vetch	High
Malvaceae	*Gossypium* sp.	Delta Pine cotton	No
Malvaceae	*Gossypium* sp.	Fungicide cotton	Slight
Malvaceae	*Gossypium* sp.	Smooth leaf cotton	No
Poaceae	*Zea mays* L.	Bantam corn	High
Poaceae	*Sorghum bicolor v. sudanense* Piper	Sudan grass	High
Solanaceae	*Capsicum annuum* L.	Bell pepper	No
Solanaceae	*Solanum nigrum* L.	Black nightshade	No
Solanaceae	*S. lycopersicum* L.	Tomato	No
Solanaceae	*Nicotiana glauca* Graham	Tree tobacco	No

[a] No = no feeding, Slight = <5 feeding lesions, likely probed for moisture, Yes = >5 feeding lesion but minimal plant damage, High = very heavy feeding damage resulting in wilting and scorching. Adult *B. hilaris* were allowed access to plants for 5 d.

July, the weeds senesced, and as temperatures increased and wild plants dried down, the insects left these plants and moved into the corn and Sudan grass, where they remained until harvest in late summer. In August and September, after most of its preferred hosts had died, bagrada bugs attacked almost anything green, including the young leaves of various trees (including citrus). In late August to early October, with the return of cooler temperatures, the presence of weed hosts, and the planting of cole crops, *B. hilaris* severely damaged the emerging cole crops as described earlier. There appeared to be two main peaks in the *B. hilaris* seasonal cycle, April to May and September to October.

Similar peaks have been reported in India (Singh and Malik 1993). In those earlier studies, the peaks coincided with the senescence of cultivated and wild *Brassica* spp. in the late spring and then a buildup in the early fall coinciding with planting of cole crops and weed germination after fall/winter rains. Adult bugs overwinter in cracks and crevices near their food sources (Guarino et al. 2008), and we have observed the same behavior in the field in California (D.A.R., unpublished data). The presence of young nymphs in early January suggests that there is no winter diapause. To refine these observations and determine possible refugia for the fall influx of bagrada bugs, we conducted a systematic survey for *B. hilaris* throughout 2011.

Sampling Methods and Quantitative Data. Three general areas were selected for monthly sampling: two desert agricultural areas (Coachella Valley, CA, and Yuma, AZ) where cole crops are grown and one urban area with abundant brassicaceous weeds surrounding the University of California, Riverside, CA. Within each of these areas, a minimum of five survey sites were established where either previous sightings of *B. hilaris* occurred during 2010 (urban) or cole crops were scheduled to be planted in the fall (agricultural). Sites were monitored monthly for changes in plant species, growth of vegetation, and presence or absence of *B. hilaris*. Upon reaching a given site, plants were randomly searched for the presence of bagrada bugs. If bugs were detected, we then conducted 10-minute timed searches as described below.

Typical sampling techniques for stink bugs such as beat sheet or sweep net sampling (Reay-Jones et al. 2009) are problematic for sampling *B. hilaris*. First, when bagrada bugs are approached, they have a tendency to drop from the plants and hide in cracks in the soil, and in sites with a diversity of plants, it may be difficult to ascertain which plant they were occupying. Second, the clumped distribution of bagrada bug on individual plants within a species can skew monitoring results. Third, *B. hilaris* has a tendency to stay near the soil surface when the temperature is cool in the winter or hot in the summer. Because of this behavior, we sampled only when the temperatures were >25°C (77°F) in the winter/spring and <41°C (105°F) in the summer.

In each of our survey sites, we observed all plant species that were present at the time; this varied depending on the season. Each site contained a variety of plants with varying morphologies (from low-growing ground cover to tree canopy) and maturities, so we first looked at all plant species to determine the presence or absence of bagrada bugs or feeding damage. If bugs or damage were detected, we would conduct a more thorough 10-minute timed search. During the search we recorded the number of bagrada bugs on the plants and surrounding soil and leaf litter. Counts were made each month from January to December 2011, and numbers from all plants per site, at all

Fig. 4. Comparison of healthy (left) and "blind" (right) cauliflower plants as the result of feeding by *B. hilaris*. The upper photograph shows a close-up of a plant with no apical meristem.

Fig. 5. Cole crops exhibiting changes in plant morphology as a result of feeding damage by *B. hilaris*. "Forked" plant (top) and multiple adventitious stems (bottom).

of the five sites within each area (urban, California desert agriculture, and Arizona desert agriculture) in a given month were pooled.

The appearance and abundance of bagrada bugs were similar within the agricultural valleys of Coachella, CA, and Yuma, AZ (Fig. 6). These locales exhibited two peaks of abundance, one in late spring and the other in early fall. By late spring, the cole crops were harvested except for some residual plants that had bolted, producing flowers and seed. Weedy mustards, such as Sahara and shortpod, also had matured at this time, leading to an increase in bagrada bug numbers. Coinciding with the drying of the mustards was the vegetative growth of planted sweet corn and Sudan grass. Often, we observed feeding damage in sweet corn but generally did not find large aggregations of insects because of the dense growth pattern of these grasses. Bagrada bugs again became evident during cole crop germination and transplantation in late August and early September (Fig. 6). These plantings also coincided with harvest of the corn and Sudan grass.

Relative to the agricultural regions, fewer *B. hilaris* were found in the urban areas during the spring (Fig. 6). We suspect this was because of cooler temperatures and slower growth of host plants. The primary plants supporting bagrada bugs in this area were London rocket, shepherd's purse, and shortpod mustard. Occasionally, bugs were found on Russian thistle (*Salsola australis* Robert Brown) and telegraph weed (*Heterotheca grandiflora* Nuttall), but these were always in proximity to nearby senesced shortpod mustard. Shepherd's purse, London rocket, and shortpod mustard germinated after fall/winter rains and were available into June.

Pest Management Strategies

Monitoring. Cole crops and other leafy vegetables produced in the southwestern United States are intensively monitored for insect pests during the growing season and particularly at stand establishment when plants are most susceptible to feeding damage (Palumbo and Castle 2009). At present, no reliable sampling plans or monitoring tools are available for *B. hilaris*. Observations suggest that inspecting plants for the presence of *B. hilaris* in seedling cole crops should be conducted from mid-morning (1000 hours) to late afternoon (1600 hours) when ambient temperatures are >29°C (85°F); during this time, *B. hilaris* is most active (Huang et al. 2013). It is recommended that monitoring begin immediately upon seedling emergence because adult *B. hilaris* have been observed feeding on broccoli seedlings as the plants emerge from the ground. Sampling should include careful inspection underneath the cotyledons for the presence of adults and fresh feeding symptoms. On larger seedlings and transplanted crops (i.e., two- to three-leaf stage or larger), the undersides of leaves, as well as the stem and soil surface below the plant, should be examined (Palumbo 2012b).

Biological Control. Although there is documentation of generalist predators attacking *B. hilaris* (Bundy et al. 2012, D.A.R., unpublished data), there are no native natural enemies that specifically target the bagrada bug in the United States. In Africa and India, there are reports of parasitoid wasps attacking eggs (Chacko and Ketiyar 1961, Mani and Sharma 1982, Ghosal et al. 2005) and tachinid fly parasitoids (Rakshpal 1954) attacking adults. Some of the wasp parasitoids that attack other stink bugs in the United States also will attack eggs of *B. hilaris* in the laboratory (D.A.R., unpublished data). However, it is unknown whether they do so in the field. The tendency of *B. hilaris* to lay eggs individually in the soil rather than in easily exploited egg masses on foliage may result in lower parasitism in the field.

Chemical Control. Preventing adult *B. hilaris* from feeding on plant terminals and small cotyledons is critical to establishing and maintaining a quality stand. Thus, management tactics for the control of *B.*

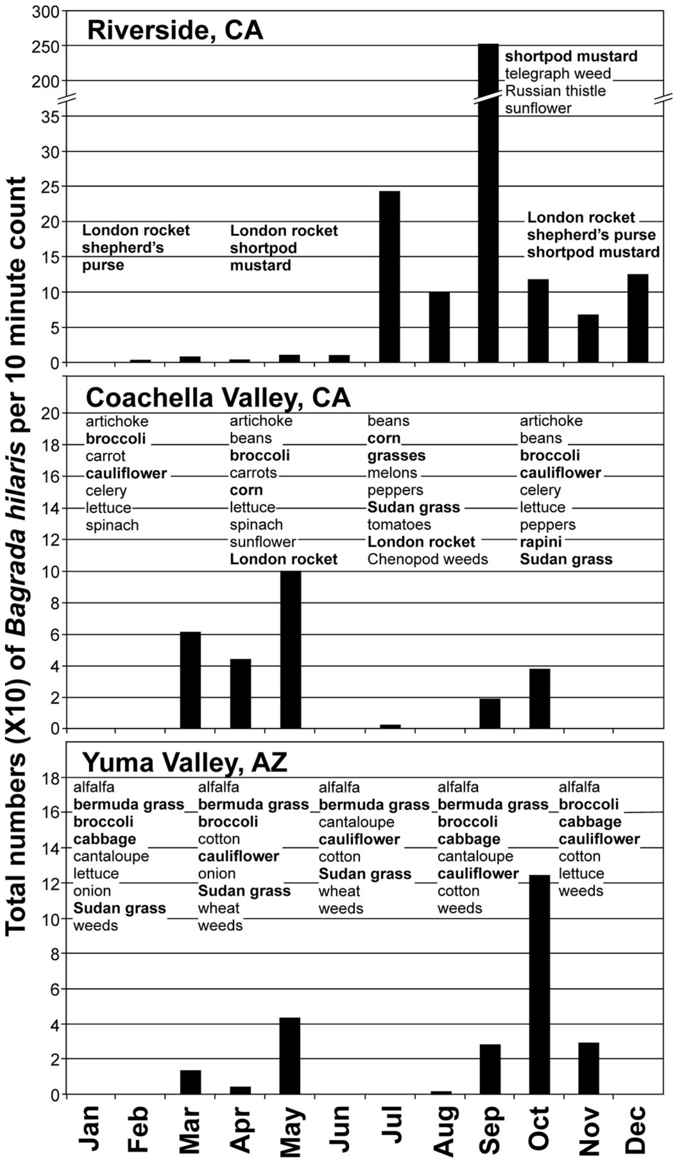

Fig. 6. Total numbers of *B. hilaris*, counted per 10 min and summed across all plants sampled during each month from January through December 2011 in three localities: Riverside, CA; Coachella Valley, California; and Yuma Valley, Arizona. Sampled plant species are shown in relation to the time period in which they were present, and the plants on which bagrada bug were found are bold-faced.

hilaris in conventional cole crop production consist of intensive insecticide usage to protect emerging stands and developing crops. Although an action threshold has not yet been established, preliminary observations suggest that treating plants with a contact insecticide when populations exceed one adult per three row feet of seedlings or transplants can reduce stand losses and unacceptable plant damage. With the devastating losses caused by high numbers of *B. hilaris* in Arizona and southern California, growers have been relying heavily on broad-spectrum insecticides to control outbreaks. In 2010 and 2011, it was estimated that an average of four spray applications were made for *B. hilaris* infestations in fall broccoli fields during stand establishment (Palumbo 2012a), and pyrethroids and neonicotinoids were the most commonly used insecticides.

Previous research on chemical control of *B. hilaris* in India and other countries is not readily adaptable to cole crop production in the United States because many of the insecticides are not currently registered (Sachan and Purwar 2007, Ahuja et al. 2008, Singh et al. 2009). However, pyrethroids appear to be the most commonly recommended insecticides for use on mustard crops in India (Sachan and Purwar 2007), and older organophosphate products such as chlorpyrifos, malathion, prophenophos, and monocrotophos have also been shown to be effective (Singh et al. 2009). Preliminary research conducted in Arizona has demonstrated that foliar applications of pyrethroids (e.g., bifenthrin, λ-cyhalothrin, and ζ-cypermethrin) and neonicotinoids (dinotefuran, clothianidin) provided rapid knockdown control of adult *B. hilaris*, but residual control was marginal (Palumbo 2011a, J.C.P., unpublished data).

The neonicotinoids are known to provide residual systemic control of a number of piercing-sucking pests such as aphids and whiteflies (Palumbo et al. 2001), and have shown systemic activity against a number of pentatomids, including the harlequin bug *M. histrionica*, on collards and cabbage (Edelson and Mackey 2006, Kuhar and Doughty 2009, Wallingford et al. 2012). Among the neonicotinoids, imidacloprid has been reported to be effective against *B. hilaris*. Ahuja et al. (2008) reported that planting imidacloprid-treated mustard seed in an irrigated production system resulted in lower plant damage and higher seed yields than foliar alternatives. Imidacloprid seed treatments on broccoli and other cole crops are not registered for use in the United States; however, soil applications of imidacloprid and other neonicotinoids at planting are currently used by growers for whitefly and aphid control (Palumbo and Castle 2009). Research trials in Arizona have shown, however, that soil systemic applications of imidacloprid, thiamethoxam, dinotefuran, or clothianidin did not adequately protect emerging seedlings from *B. hilaris* feeding damage in field plots (Palumbo 2011b, J.C.P., unpublished data).

Given the amount of pyrethroid insecticides historically applied to desert vegetable crops and the heavy reliance on neonicotinoids (Palumbo and Castle 2009), alternative insecticide management programs will have to be developed if growers want to sustainably protect cole crops from *B. hilaris.* Several new reduced-risk classes of chemistry (including the diamides, sulfoxamines, and ketoenols) have been developed that have activity against piercing/sucking pests. However, preliminary studies have shown these new insecticides are ineffective against *B. hilaris* on cole crops (Palumbo 2011c, J.C.P., unpublished data).

Summary

The bagrada bug (B. hilaris) is an invasive pest that feeds primarily on brassicaceous plants. This stink bug has rapidly spread from Los Angeles County, CA, where it was recorded in 2008, westward to extreme western Texas and northward into the coastal and central agricultural regions of California. This insect often is found in large clusters, which complicates the development of a sampling program. Bagrada bug numbers are lowest during winter, but rapidly increase during spring because of the insect's ability to use weedy and leafy mustards as hosts. Weedy mustards are particularly plentiful in ecologically disturbed areas at this time. Brassicaceous crops that are severely damaged include head-forming cole crops, leafy green mustards, root mustards (e.g., radish and turnip), and oilseed mustards, such as canola. New feeding damage by the bagrada bug appears as light green star-shaped lesions, whereas older damage appears as bleached or scorched areas. The most damage is caused when bagrada bug feeds on newly sprouted plants, which often are killed as they emerge from the soil. Damage to the meristematic tissue of young seedlings leads to multiple stems and heads. The bagrada bug also uses nonbrassicaceous plants, particularly grasses, during summer months to bridge the time between weedy mustards in the spring and cole crop emergence in the fall. Effective control measures currently are limited to multiple applications of conventional pesticides. Repeated treatment is necessary because the insects immigrate into fields multiple times. Considerable research is necessary to establish reliable sampling methods and treatment thresholds, evaluate the impact of alternative pesticides, and determine whether alternative cultural or biological control strategies will be useful in the management of this important pest.

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