Eurygaster integriceps

Scientific Name
Eurygaster integriceps Puton, 1881

Synonyms:
None

Common Names
Sunn pest, Cereal bug, Senn pest, Wheat shield bug

Type of Pest
Shield bug

Taxonomic Position
Class: Insecta, **Order:** Hemiptera, **Family:** Scutelleridae

Reason for Inclusion in Manual
CAPS Pest of Economic and Environmental Importance, 2017-present
CAPS Small Grain Commodity Survey, 2017-present

Figure 1. *Eurygaster integriceps* adult. Natasha Wright, Cook's Pest Control, Bugwood.org

Pest Description
Eggs (Fig. 2): The egg is spherical and about 1mm ($\sim{}^{1}/_{25}$ in.) in diameter (Javahery et al., 2000). On oviposition, the eggs are light-green, nearly translucent, with white spots arranged in a ring around the operculum (Javahery et al., 2000). The chorion is translucent, so as the embryo develops, the egg becomes dark, eventually appearing pink with an orange, anchor-shaped mark at the apex (Javahery et al., 2000; CABI, 2018).

Nymphs (Fig. 2): *Eurygaster integriceps* has five nymphal instars (Malipatil, 2008). Nymphs are spherical. At eclosion, the first instar is1.5 mm ($\sim{}^{1}/_{17}$ in.) in diameter and light in color. The nymph becomes black within a few hours as the exoskeleton hardens (CABI, 2018). Nymphs are colored similar to adults, with two to three paired black dots midway between the lateral margin and midline of the abdomen (USDA-APHIS-PPQ, 1980). The nymphs are not reliably distinguished from closely related species and must be reared to adults for species determination (Malipatil, 2008).

Adults (Fig. 1, 3): Body semi-elongate oval shaped, and varies from gray to creamy brown, to reddish or black (Ali and Khidhir, 2016). Color is highly variable and has no taxonomic value (Ionescu and Popov, 1976). Body about 10-12 mm ($\sim{}^{13}/_{32}$ -${}^{31}/_{64}$ in.) long and 6.1- 7.1 mm ($\sim{}^{1}/_{4}$ -${}^{9}/_{32}$ in.) wide, upper surface slightly concaved with the big scutellum covering almost all of the abdomen, underside of each connexival segment

Figure 2. *Eurygaster integriceps* eggs (left), and a nymph just after egg hatch (right). ICARDA, CC 3.0 .

with a blackish spot, lower surface convex (Ali and Khidhir, 2016). Head semi-triangular in shape, approximately 1.8–2.6 mm (~$^{1}/_{16}$ -$^{7}/_{64}$ in.) × 3.2–3.3 mm (~$^{1}/_{8}$ -$^{9}/_{64}$ in.); clypeus elongated, convex and brown (Paulian and Popov, 1980; Ali and Khidhir, 2016). Pronotum is dorsally shield-like, 3.1–3.3 mm (~$^{1}/_{8}$ -$^{9}/_{64}$ in.) × 6.4–6.6 mm (~$^{1}/_{4}$ -$^{17}/_{64}$ in.), and is pale brown and ornamented with black punctures; the scutum and prescutum are black, with the scutum measuring 6.3–6.7 mm (~$^{1}/_{4}$ -$^{17}/_{64}$ in.) × 4.7–4.9 mm (~$^{3}/_{16}$ -$^{13}/_{64}$ in.) and nearly covering the entire abdomen (Ali and Khidhir, 2016). In males, the first segment of the abdomen is fused with the metathorax. The female abdomen is wider than the male's in appearance (Ali and Khidhir, 2016).

Biology and Ecology

The life cycle of *E. integriceps* consists of five stages, including inactive adult phases during summer and winter (Banks et al., 1961; USDA–APHIS–PPQ, 1980). During the inactive phases, diapause hosts provide shelter in leaf litter or in dense, compact low-growing vegetation (Brown, 1962a; USDA-APHIS-PPQ, 2017). One generation occurs per year (Banks et al., 1961). The developmental time from egg to adult ranges from 35-60 days depending on environmental conditions and host availability (Critchley, 1998). Optimum temperatures for survival are between 6-25°C (42.8-77°F), and the population begins to decline at temperatures above 37°C (98.6°F) (Banks et al., 1961).

The lifecycle begins when overwintered adults migrate to developmental hosts (small grains or other graminaceous species) to feed and oviposit; eggs hatch during spring months. First instar nymphs are least active and are often found clustered near the remains of their eggs (Paulian and Popov, 1980). Active feeding begins with the second instars, and nymphal feeding usually occurs on leaves (Paulian and Popov, 1980). During periods of hot weather, nymphs may retreat to the lower canopy or to the soil during the day (Paulian and Popov, 1980). Development and molting of each of the first through fourth instars takes four to seven days under favorable conditions, and the period for the fifth instar takes ten to eleven days (Critchley, 1998; USDA-APHIS-PPQ, 2017). Individuals of all five instars can be found at the same time. By late June nearly all of the nymphs reach the adult stage (Paulian and Popov, 1980).

Figure 3. *Eurygaster integriceps* adults on wheat. Color varies widely in adults. ICARDA, CC 3.0 .

The lifecycle of *E. integriceps* is characterized by migrations (Brown, 1965). Young adults feed on developmental hosts before flying in large groups from grain fields to summer aestivation sites, where the first inactive period occurs. Aestivation sites are typically 20-30km from developmental hosts, but distances of up to 200km have been reported (Logothetis, 1956; Brown, 1965). Summer aestivation occurs in cooler areas at higher elevations (Parker et al., 2011), and temperature and humidity preferences condition the migration (USDA-APHIS-PPQ, 1980). During autumn, adults move from aestivation sites to hibernation locations, which are sunny areas at lower elevation (Brown, 1965). Hibernation constitutes the second inactive phase. Adults overwinter in soil around grass roots in mountain areas and under litter in valleys (USDA-APHIS-PPQ, 1980). Activity by adults resumes in the spring following overwintering, and adults return to developmental hosts (USDA-APHIS-PPQ, 1980).

Adults migrate back to developmental hosts from February–May, when air temperatures at overwintering sites reach 12–13°C (53.6–55.4°F) (Critchley, 1998) and soil temperature has reached 15°C (59°F) (Canhilal et al., 2005). Females reach reproductive maturity after overwintering (Banks *et al.*, 1961). In developing, vegetative-stage wheat, the overwintered generation feeds and mates, and females oviposit (USDA-APHIS-PPQ, 2017). Eggs are laid in clusters, usually on host leaves, and egg development to hatching takes nine to ten days under optimal conditions (Logothetis, 1956; Critchley, 1998).

Damage

Among the cultivated gramineous plants, wheat is damaged most by *E. integriceps*. Barley is affected to a lesser extent but usually escapes severe damage due to early ripening of the plant (Longothetis, 1956). All parts of cereal plant hosts can be attacked by *E. integriceps*. (Cricthley, 1998). Nymphs prefer to feed on young leaves while adults prefer to feed on kernels and ears (Critchley, 1998). Damage can be severe, particularly when overwintering adults feed on young wheat plants (Cricthley, 1998). In heavily damaged hosts, a ‘deadhart’ may occur from withering of the leaves past their central growing point (Paulian and Popov, 1980). In addition, the terminal bud can be destroyed when young green shoots are attacked (Brown, 1962b). If ears are attacked during the bud stage, grains fail to develop and result in ‘white ears’ symptoms (Fig. 4) (Paulian and Popov, 1980).

A total loss of the kernel may occur if it is attacked during the early ‘milky’ stage of development (Critchley, 1998). Kernals attacked during late maturity largely escape damage but can be slightly shriveled (Paulian and Popov, 1980). A black pinpoint on the grain surrounded by a pale halo is a sign of Sunn Pest damage (Critchley, 1998). The insect also injects toxic saliva into the grain, which can destroy the gluten and result in bread that does not rise properly (Fig. 5) (Critchley, 1998).

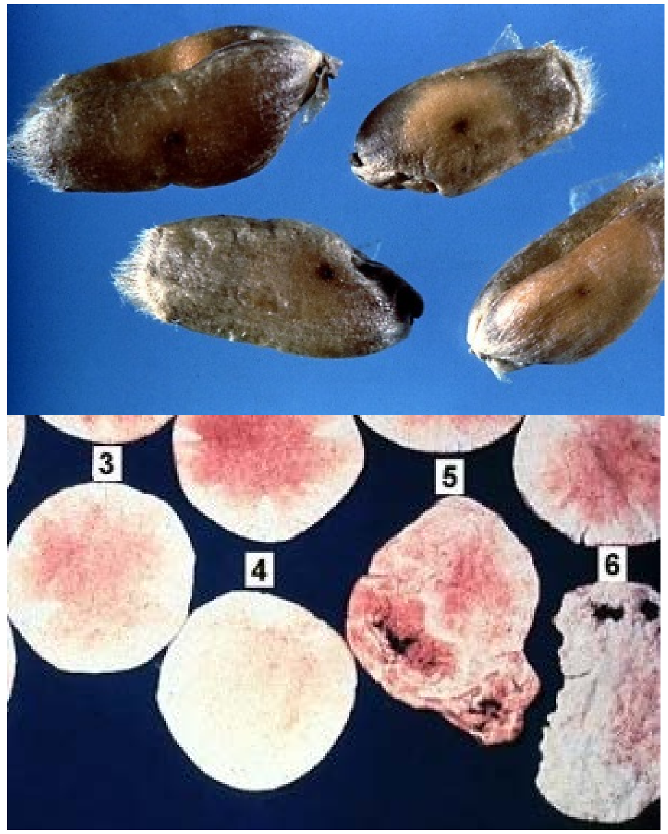

Figure 5. Wheat grain which has been attacked by Sunn Pest (top). Bread made from healthy grains, and bread made from infested grains (bottom). ICARDA, CC 3.0

An examination of infested wheat grain showed that *E. integriceps* most frequently damages the embryo (~83% of cases), and less commonly damages the middle (~9%) or apical (~8%) zones (Grigorov, 1989). The germinating capacity of seeds damaged in the embryo (19.5-21%) was found to be much lower than that of seeds with damaged middle or apical zones (up to 76.6%). Damaged grain had lower absolute weight and higher moisture permeability. In seeds damaged in the embryo, shoot length was reduced by 54% and root length by 20-25%. These lengths were also usually reduced in seeds damaged in the other zones (Grigorov, 1989).

Pest Importance

Eurygaster integriceps is one of the most destructive pests of wheat in the Middle East (Crichtley, 1998; Karimzadeh et al., 2011). Although the losses vary considerably, they are seldom less than 25 percent of the crop. In severe outbreaks this pest can cause complete losses of the crops over large areas (Logothetis, 1956). Economic loss can reach 100 percent in the absence of control measures (Kivan and Kilic, 2006), and an entire wheat crop in Iran has been lost in some seasons (USDA-APHIS-PPQ, 1980). Chemical control is difficult and not environmentally sustainable (Mardoukhi and Heidari, 1993; Parker et al., 2011).

Wheat is one of the most important crops in the United States. In 2017, wheat was grown on 46,012,000 acres, and it was grown commercially in 42 states (USDA-NASS, 2018). The estimated value of the wheat harvest was over $8.1 billion (USDA-NASS, 2018). Barley, another important crop, was planted on over 2.4 million acres in the United States in 2017 (USDA-NASS, 2018). The estimated value of the barley harvest was $614.2 million (USDA-NASS, 2018).

Eurygaster integrecips is listed as a harmful organism in Brazil, Ecuador, Egypt, Honduras, Japan, Peru, and South Korea (USDA-PCIT, 2018). In addition, *Eurygaster* is listed as a harmful organism at the genus level in Pakistan (USDA-PCIT, 2018). There may be trade implications with these countries if this pest becomes established in the United States.

Known Hosts

Major hosts
Triticum aestivum (wheat), *Triticum turgidum* L. (durum wheat) (Banks, 1961; Banks and Brown, 1962a; Critchley, 1998).

Minor hosts
Avena spp. (oat), *Hordeum vulgare* (barley), *Secale cereale* (rye), *Sorghum bicolor* (sorghum) (Brown, 1962a; Critchley, 1998).

Aestivation/Diapause hosts
Acacia spp. (acacia), *Acantholimon spp.* (acantholimon), *Acanthophyllum* spp., *Agrostis spp.* (bentgrass), *Artemisia herba-alba* (white wormwood), *Astragalus spp.* (milkvetch), *Bassia spp.* (smotherweed), *Bromus* spp. (bromegrass), *Camphorosma monspeliaca* (camphorfume), *Crotalaria juncea* (sunn hemp), *Dactylis spp.* (orchardgrrass), *Ephedra pachyclada*, *Euphorbia spp.* (Spurge), *Eurotia levatoides, Festuca spp.* (fescue), *Gundelia tournefortii* (a'kub), *Helichrysum armenium*, *Lactuca orientalis*, *Lolium spp.* (ryegrass), *Nerium oleander* (oleander), *Ononis spinosa* (restharrow), *Phlomis* spp., *Pinus* spp. (pine), *Poa spp.* (bluegrass), *Prosopis farcta* (Syrian mesquite), *Pycnocycla nodiflora*, *Quercus spp.* (Oak), *Scorzonera intricate*, *Stachys inflate*, *Verbascum* spp. (mullein) (Brown, 1962a; Critchley, 1998; Parker et al., 2002, 2011).

Wild hosts
Agropyron spp. (wheatgrass), *Alhagi* spp. (camelthorn), *Cirsium vulgare* (common thistle), *Convovulus* spp., *Cornucopiae cucullatum*, *Helianthus annus* (sunflower), *Heteranthelium piliferum*, *Linum usitatissimum* (flax), *Panicum miliaceum* (French millet), *Setaria spp.* (foxtail millet), *Taeniatherum crinitum* (medusahead)*, Trifolium spp.* (clover), *Vicia* spp. (vetch) (Logothetis, 1956; Banks et al., 1961; Brown et al., 1962ab; USDA-APHIS-PPQ, 1980, 2017; Critchley, 1998, Parker et al., 2002, 2011).

Pathogens or Associated Organisms Vectored
This species is not known to be associated with pathogens or other organisms.

Known Distribution
Africa: Algeria. **Asia:** Afghanistan, Armenia, Azerbaijan, Georgia, Iran, Iraq, Israel, Jordan, Kazakhstan, Kyrgyzstan, Lebanon, Pakistan, Syria, Tajikistan, Turkey, Turkmenistan, Uzbekistan. **Europe:** Bulgaria, Cyprus, Greece, Macedonia, Moldova,

Romania, Russia, Serbia, Ukraine (Brown and Erlap, 1962; Stavraki, 1979; USDA-APHIS-PPQ, 1980, 2017; Popov et al., 1996; Javahery et al., 2000).

Pathway

The most likely pathway of introduction for *E. integriceps* is by transport on cargo (USDA-APHIS-PPQ, 2017). There have been recorded interceptions of *Eurygaster* spp. from Italy (2), France (1), Netherlands (1), and Spain (1) (AQAS, 2018). While *E. integreceps* is not known to be present in these countries, the interceptions demonstrate the ability of *Eurygaster* spp. to be transported long distances.

The transport of plant host material also poses a risk for entry of *E. integriceps*. Since 2007, *Triticum aestivum* has been intercepted 58 times from 12 different countries where *E. integriceps* is known to be present. At least 16 of these interceptions contained live nymphs or adults, including interceptions from Iran (4), Pakistan (3), Turkey (3), Jordan (2), Lebanon (2), and Serbia (2). These interceptions occurred on baggage, permit cargo, and stores (AQAS, 2018).

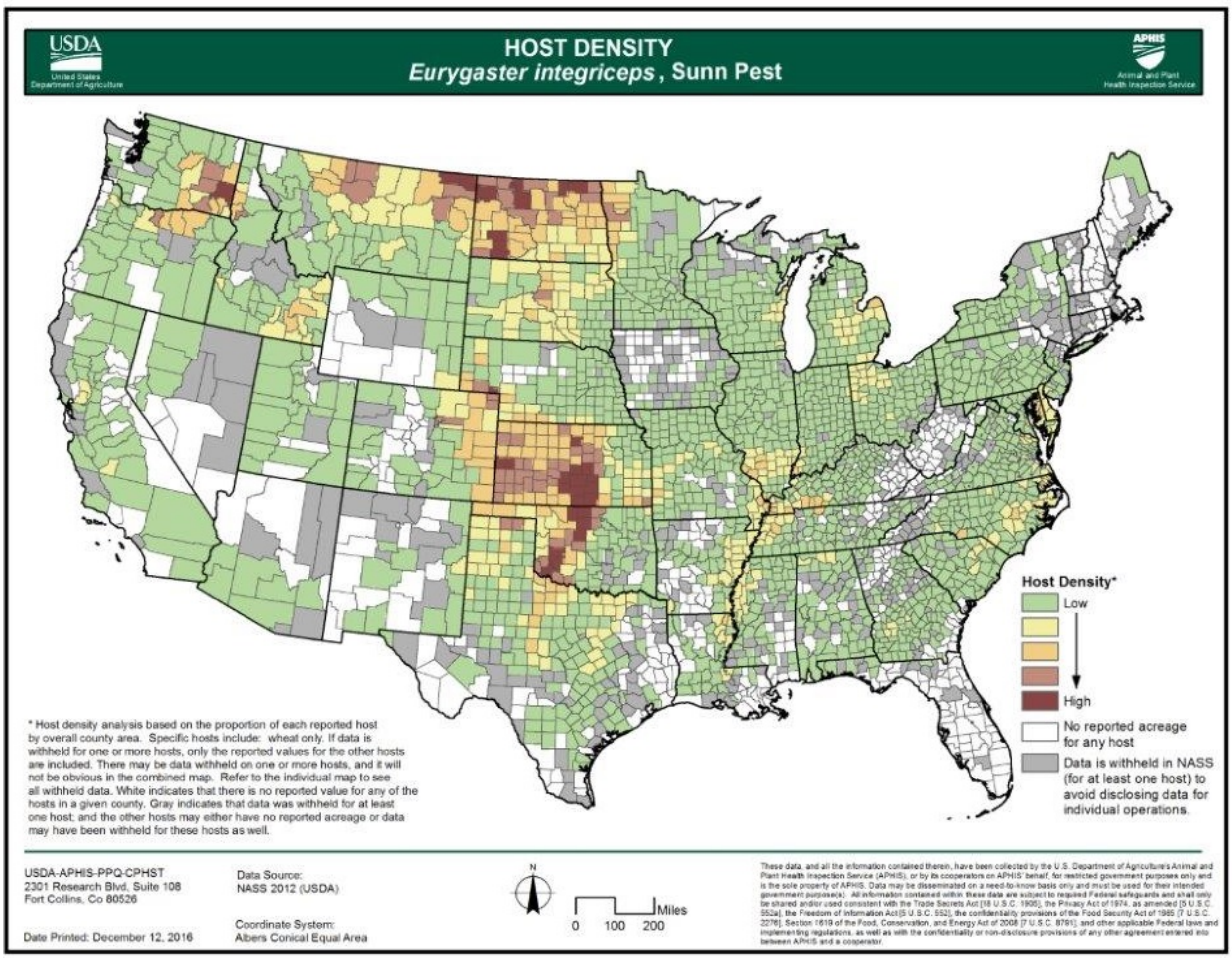

Figure 6. A combined host density map for *Eurygaster integreceps*. Map courtesy of USDA-APHIS-PPQ-CPHST.

Potential Distribution within the United States

Based on winter minimum temperatures and the presence of host plants, *E. integriceps* may be able to establish throughout the continental United States (USDA-APHIS-PPQ, 2017). According to a combined host density map, the areas at most risk for establishment of *E. integriceps* based on developmental host presence are in the Midwestern United States, the Columbia River valley, and the lower Mississippi River valley (Fig. 6). The leading wheat growing states in 2016, by acreage planted, were Kansas, North Dakota, Montana, Oklahoma, Texas, Colorado, Washington, South Dakota, Nebraska, Minnesota, and Idaho (USDA-NASS, 2018). The leading barley producing states in 2016 were Idaho, Montana, and North Dakota (USDA-NASS, 2018).

Survey

Approved Methods for Pest Surveillance*:

There are two approved survey methods for *Eurygaster integriceps*: 1) visual inspection and 2) sweep-netting around host material for specimen collection.

Visual survey

Visual survey is appropriate for all life stages. Small clusters of eggs are visible on the upper surface of the leaves and occasionally the stems of graminaceous plants. Adults and nymphs feed toward the top of the plant but move to the lower leaves or soil to avoid high afternoon temperatures (Critchley, 1998). Direct feeding damage appears as white or brown discoloration (Garjan et al., 2007) on leaves, stems, and ears. More severe symptoms include 'deadheart', dead or withered center leaves; 'white ears' (Fig. 4), grain heads without kernels, or kernels with a dark pinhole surrounded by a contrasting pale halo (Fig. 5) (Paulian and Popov, 1980).

Sweep netting

1.1 Sampling

When sweeping for *Eurygaster integriceps*, surveyors should focus primarily on graminaceous fields but may also sweep adjacent hedgerows and wood-lines. Sweeping is most effective when conducted in the morning or late afternoon when adults and nymphs are feeding at or near the tops of host plants (Paulian and Popov, 1980; Critchley, 1998).

Surveyors should complete twenty sweeps at each sampling site. All insects collected during a set of sweeps constitute one sample. Once 20 sweeps have been completed at the sampling site, the bag of the net should be flipped over or quickly closed. The net bag should be inverted into a gallon-sized re-sealable bag or other container for transportation back to the lab. All arthropods in the net should be emptied into the plastic bag or other container. The bag/container should be placed in a cooler for transportation.

1.2 Sample Processing, Sorting, and Screening

At the lab, the entire re-sealable bag or container should be placed in the freezer for a minimum of 24 hours. After this time, bag contents should be dumped into a sorting pan.

Sorting samples: remove debris and non-target species. The taxonomic level of sorting will depend on the expertise available on hand and can be confirmed with the identifier. Some states may have taxonomic support, access to local training aids, or identification guides.

If possible, screen for the target pest. Screening is a process of eliminating non-target families, genera, or "look-a-like" species in the sample. When in doubt, forward the specimens to the identifier.

1.3 Submitting the Sample
Once sorting and screening (if possible) have been completed, place specimens into vials of 75-90% ethanol and submit for identification. Each vial should only contain samples collected at the same site on the same date. See Procedures for Submitting Survey Samples to Domestic and Other Identifiers for additional guidance on sample submission.

Survey site selection:
Surveys for adults, eggs, and nymphs in small grain fields and adjacent hedgerows and wood-lines. Nymphs and adults feed toward the top of the host plant in the morning and late-afternoon, but may retreat to the lower leaves or soil during the hottest hours of the day (Paulian and Popov, 1980; Critchley, 1998).

Time of year to survey:
Eurygaster integriceps is active for only 2.5 to 3 months of the annual lifecycle. Adults migrate from overwintering sites to small grains fields once air temperatures reach 12 to 13 °C (53.6 to 55.4 °F). Migration can begin as early as February, but usually occurs from late March to early May (Paulian and Popov, 1980; Critchley, 1998). Egg deposition begins in early April and continues to early June and nymphs begin emerging early June to late July (Paulian and Popov, 1980). Nymphs develop into adults in 26 to 37 days after hatching, depending mainly on temperature (Critchley, 1998). When air temperatures reach 25 to 37°C (77 to 98.6 °F), new adults migrate to summer aestivation sites (Banks et al., 1961). Timing fluctuates from year to year based on climate (Paulian and Popov, 1980), so air temperature is a more reliable indicator of when to initiate survey. The timing of migration often coincides with the wheat harvest (Critchley, 1998).

*For the most up-to-date methods for survey and identification, see Approved Methods for Pest Surveillance on the CAPS Resource and Collaboration Site, at https://caps.ceris.purdue.edu/approved-methods

Literature-Based Methods:
Banks and Brown (1962) describe sweep net survey protocols in wheat fields. In their study, sweep nets were used to collect specimens at the top of wheat plants. Surveys can take place on vegetative grains in spring when air temperatures have reached 12°C (53.6°F) and can occur until grains are harvested (USDA-APHIS-PPQ, 2017). In a study

by Karimzadeh et al. (2011), sampling began when wheat plants were at the stem jointing stage and ~25cm high. When small grains have matured, surveyors should also inspect the soil at the base of the plants for adults that have ceased feeding (USDA-APHIS-PPQ, 2017).

Key Identification

Approved Methods for Pest Surveillance*:

Morphological. *Eurygaster* nymphs lack distinguishing morphological characteristics and must be reared to adult to identify to species (Malipatil, 2008). *Eurygaster integriceps* adults can be distinguished from other congeners based on morphological differences described in Ali and Khidhir (2016) including body size, the groove pattern on the clypeus, and the curve of the prothorax. The male genitalia is also a key character, specifically, the black thecal appendages on either side of the aedeagus (Fig. 7) (Ali and Khidhir, 2016).

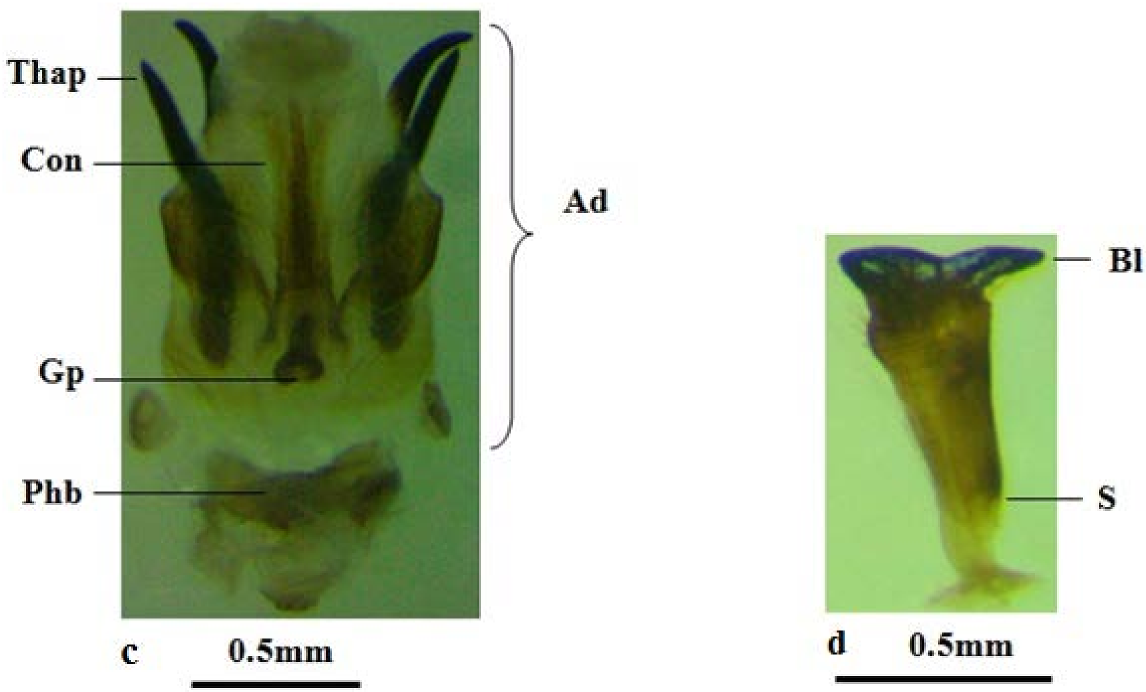

Figure 7. *Eurygaster integriceps* male genitalia: c. phallus; d. paramere. Ad: Aedeagus; Gp: Gonopore; Bl: Blade; Phb: Phallobase (Basal plate); Thap: Thecal appendages; Con: Conjunctiva; S: Stem (Ali and Khidhir, 2016).

Literature-Based Methods:

Brown (1962b) shows illustrations of *E. integriceps* anatomy. Detailed anatomical descriptions of *E. integriceps* adults are also widely described in literature (Paulian and Popov, 1980; Ali and Khidhir, 2016).

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Easily Confused Species

Eurygaster integriceps is difficult to distinguish from two congeners, *E. maura* and *E. austriaca*, without dissection (Brown, 1962b; Cricthley, 1998). The three species are similar biologically (Brown, 1965), but *E. maura* and *E. austriaca* are not considered economically important pests and are not known to occur in the United States (Critchley, 1998; Javahery et al., 2000).

Images and diagnostic characters for *E. maura* and *E. austriaca* are available on the Pest and Disease Image Library (PaDIL) website (http://www.padil.gov.au/):

- *Eurygaster austriaca*: http://www.padil.gov.au/pests-and-diseases/pest/main/136075 (last accessed August 15, 2018)
- *Eurygaster maura*: http://www.padil.gov.au/pests-and-diseases/pest/main/136076 (last accessed August 15, 2018)

There are five *Eurygaster* species present in North America: *E. amerinda*, *E. alternata*, *E. minidoka*, *E. paderewskii*, and *E. shoshone* (Vojdani, 1961; Froeschner, 1988). None of these species are pests of wheat (Moylett and Newton, 2015).

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Reviewers

Jennifer Cook, Ph.D., North Carolina State University, Center for Integrated Pest Management (NCSU-CIPM).

J. B. van Kretschmar, Ph.D., North Carolina State University, Center for Integrated Pest Management (NCSU-CIPM).