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Ecology, Taxonomy, and Pest Management of Billbugs (Coleoptera: Curculionidae) in Orchardgrass of Virginia

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ABSTRACT. Orchardgrass, *Dactylis glomerata* L. (Cyperales: Poaceae), is a cool season grass, cultivated throughout the United States as a high-value forage crop. Larval feeding by two weevil species (Coleoptera: Curculionidae), the bluegrass billbug, *Sphenophorus parvulus* Gyllenhal, and the hunting billbug, *Sphenophorus venatus vestitus* Chittenden, has caused widespread economic damage to orchardgrass stands in Virginia. The cryptic feeding habits of these species, combined with a lack of effective systemic insecticides, make billbug control extremely difficult in orchardgrass. Here, we present an overview of the biology of orchardgrass and its associated billbug pests, and review the control options for these pests.

Key Words: hunting billbug, bluegrass billbug, Curculionidae, *Sphenophorus* spp., orchardgrass

Orchardgrass, *Dactylis glomerata* L. (Cyperales: Poaceae), is a cool season bunch-type grass, cultivated as a high-value forage crop in the United States. In Virginia, the production value of orchardgrass in 2011 was estimated US$188,772,000, or ≈35% of the total production value of grass hay for the state (National Agricultural Statistics Service [NASS] 2012). The bluegrass billbug, *Sphenophorus parvulus* Gyllenhal, and hunting billbug, *Sphenophorus venatus vestitus* Chittenden, are important pests of orchardgrass in Virginia. A survey conducted in 2005 on over 324 ha (800 ac) of orchardgrass in northern Virginia showed losses of 40–100% attributed to billbugs (R.R.Y., unpublished data). The sheltered feeding habits of these species, combined with the lack of effective systemic insecticides for orchardgrass, make billbug control extremely difficult in orchardgrass. Here, we present an overview of billbug ecology, and control options for these pests in orchardgrass.

Orchardgrass

Orchardgrass is a cool season bunchgrass used for forage throughout the world. Native of Eurasia and northern Africa, it was first described by Linnaeus in 1753 (Peeters 2004). Cultivation of orchardgrass began after its introduction into the United States, presumably in the 1750s, and in 1763, an improved variety from Virginia was reimported to England (Christie and McElroy 1995). Named for its propensity to grow in shady areas such as orchards, orchardgrass is also called cocksfoot in Europe for the likeness of its inflorescence to the foot of a rooster (Balasko and Nelson 2003).

In the United States today, various cultivars of orchardgrass are found in every state, including Alaska and Hawaii, as well as Puerto Rico (Natural Resources Conservation Service [NRCS] 2010); however, it is predominant in the northeastern, north–central, and Pacific Northwest regions of the United States (Christie and McElroy 1995). Orchardgrass has a few marked characteristics that make it easy to distinguish from other grasses (Fig. 1). As a bunch-type grass, orchardgrass plants grow in tight, round clusters (Smith et al. 1986). The leaves of these clusters are limp, somewhat curly, and green to blue-green in color. Each leaf is folded longitudinally at its base within the bud and has a cross-sectional "V"-shape (Christie and McElroy 1995). Stems can reach 20–120 cm in height (Peeters 2004).

Orchardgrass became widely accepted as a forage grass in the United States in the 1940s and is now used for pasture, hay, silage, and green chop (Miller 1984, Christie and McElroy 1995). Key features of this grass include easy and rapid establishment, early maturation, high productivity, shade tolerance, heat tolerance, drought tolerance, and moderate winter-hardiness (Miller 1984). Orchardgrass responds well to nitrogenous fertilizers, by application of animal manure, or by planting with a legume, such as alfalfa, *Medicago sativa* L., or ladino clover, *Trifolium repens* L. (Miller 1984, Christie and McElroy 1995). The first cutting of an orchardgrass stand is best taken at or just before the appearance of the inflorescence, as nutritive value decreases at the onset of anthesis and seed production (Smith et al. 1986). A healthy stand of orchardgrass can produce up to three cuttings annually (Smith et al. 1986).

Billbugs (*Sphenophorus* spp.)

The weevils (Coleoptera: Curculionidae) currently belonging to the genus *Sphenophorus* (known as "billbugs"), have a long and confusing nomenclative history, explained in detail by Vaurie (1951) and O'Brien and Wibmer (1982). The genus currently known as *Sphenophorus* was originally described as *Calendra* Clairville and Shellenberg, but was spelled as *Calandra* (with an "a") in one figure (Schellenberg and Clairville 1798). This caused years of confusion, as different authors used one spelling over the other (e.g., Schoenherr 1838, Pierce 1925). In 1959, the matter was finally settled when the International Commission on Zoological Nomenclature (ICZN), following recommendations of specialists around the world, suppressed the names *Calendra* and *Calandra* in favor of the name *Sphenophorus* (ICZN 1958, 1959). The last major revision of the genus was made by Vaurie (1951).

Several taxonomic keys have been written for the identification of various life stages of weevils to the genus- and species-level of *Sphenophorus*. Anderson (1948) provided a generic key to larvae of the curculionid subfamily, Calendrinae (now Dryophthorinae), which included *Calendra*. It should be noted that no species-level key for the larvae of *Sphenophorus* yet exists; however, Satterthwait (1931b) devised a species-level key to the pupae of *Calendra* in the United States. Species-level keys for *Sphenophorus* adults were written by Blatchley and Leng (1916) for Rhynchophora (now Curculionoidea) of eastern North America, Vaurie (1951) for *Calendra* of the United States, Johnson–Cicalese et al. (1990) for those species in this genus that are pests of turfgrass in the United States, and Downie and Arnett (1994) for beetles of the United States. Vaurie (1951) also included a key to differentiate the five *S. venatus* subspecies.

Bluegrass Billbug. The bluegrass billbug, *S. parvulus*, was described by Leonard Gyllenhal in 1838 (Schoenherr 1838). Since that time, it

Fig. 1. Orchardgrass (*D. glomerata*): mature plants (left), a late-summer inflorescence (center), and three examples of the feeding holes on orchardgrass caused by billbug adults (right).

has been reported as a pest of many grass species throughout the United States, and in particular corn, *Zea mays* L., and Kentucky bluegrass, *Poa pratensis* L. (Bruner 1890, Webster 1892, Forbes 1902, Blatchley and Leng 1916, Tashiro and Personius 1970, Lindgren et al. 1981). Additional hosts include barley, *Hordeum vulgare* L., wheat, *Triticum aestivum* L., rye, *Secale cereale* L., ryegrass, *Lolium* spp., bentgrass, *Agristis* spp., and yellow nutsedge, *Cyperus esculentus* L. (Satterthwait 1931b, Johnson–Cicalese 1988). Although there are many publications that associate this species with injury to various grasses and plants, few authors have connected the bluegrass billbug to orchardgrass. Satterthwait (1931b) included orchardgrass as a potential host plant for the bluegrass billbug; Turner (1955) reported it as a pest of orchardgrass in Virginia; and Kuhn et al. (2013) confirmed its presence in orchardgrass fields in Virginia. The bluegrass billbug is currently found in nearly every state of the continental United States as well as Ontario, Canada (Vaurie 1951, O'Brien and Wibmer 1982, Johnson–Cicalese 1988, Watschke et al. 1995).

Eggs of the bluegrass billbug are off-white and shaped like beans, with a size of ≈1.6 by 0.6 mm (Vittum et al. 1999). The larvae are small, with soft white bodies and sclerotized head capsules, which range from yellowish in teneral larvae to dark reddish after maturation (Fig. 2). They are legless, somewhat curved, although shorter and stockier than scarabaeiform larvae, and grow to be 4–6 mm in length (Watschke et al. 1995). Pupae begin off-white in color, darken to a rusty brown, and have a length of 5.5–10 mm (Satterthwait 1931b). Bluegrass billbug adults are 5–6.5 mm in length (Blatchley and Leng 1916) and range in color from rusty brown, after eclosion, to black in color (Figs. 2 and 3). This coloration can also be lightened by mud, which frequently covers the body (Vittum et al. 1999). The pronotum

Fig. 2. Two billbug (*Sphenophorus* spp.) larvae (right and bottom) and bluegrass billbug (*S. parvulus*) adult (center) on the head of a penny. Scale bar = 1 mm.

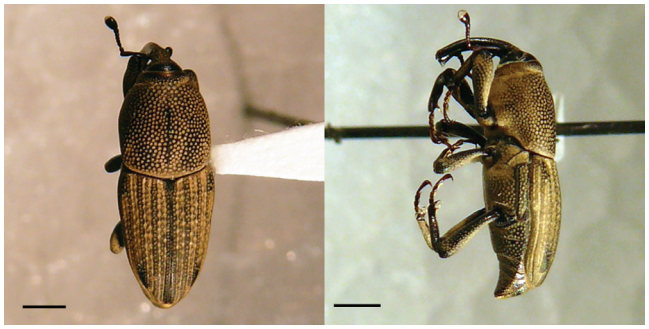

Fig. 3. Bluegrass billbug (*S. parvulus*) adult, dorsal (left) and lateral (right) views. Scale bar = 1 mm.

is covered with tiny evenly spaced and uniformly sized pits; deep punctate furrows run down the elytra, which resemble parallel chains (Watschke et al. 1995). The antennae are geniculate and clavate, and arise near the base of the long slender rostrum (Blatchley and Leng 1916).

Although most information available on the life history of the bluegrass billbug is based on its study in turfgrass, the life history appears to be similar in orchardgrass according to observations by Turner (1955). The bluegrass billbug undergoes a univoltine life cycle in much of its distribution, where newly eclosed adults overwinter under rocks, boards, sticks, dead leaves, and dead vegetation near its host plants (Bruner 1890, Forbes 1902, Blatchley and Leng 1916, Watschke et al. 1995, Vittum et al. 1999). However, Bruner (1890) reported a second early fall generation in Nebraska, which overwintered as a pupa. Two or more generations per year may occur in the warmer regions of its distribution.

As the weather warms in the spring and the soil temperature at 2.5 cm below the ground surface reaches 18.3–20.0°C (67–69°F; typically mid-March in Virginia; W.R.K., unpublished data), billbug adults first emerge from their overwintering sites and search for suitable host plants (Watschke et al. 1995). After a brief period of feeding, oviposition occurs from late April into June and early July (Webster 1892, Blatchley and Leng 1916). The female chews holes in the stems of the host, just above the soil surface, and deposits one to three eggs into or nearby each hole (Webster 1892, Watschke et al. 1995). Smith (1913) reported one female laying 255 eggs over a 3-mo period. The egg hatches in ≈6–7 d, and the larva begins feeding up and down within the stem, filling it with powdery frass (Webster 1892, Smith 1913, Satterthwait 1932, Watschke et al. 1995). Once a larva becomes too large to fit inside the stem, it generally burrows out, drops to the ground, and begins feeding internally and externally on the crown and roots of the plant (Webster 1892, Satterthwait 1932). Some larvae, however, can remain inside the plant throughout the larval stage (Watschke et al. 1995). The larval period has been reported to last from 23 to 60 d, and is followed by pupation in a soil cell near the host plant (Webster 1892, Forbes 1902, Watschke et al. 1995). Adults emerge after 8–10 d and are abundant in late August through September (Forbes 1902, Blatchley and Leng 1916, Watschke et al. 1995). Newly eclosed adults feed briefly on nearby host plants, then seek out overwintering sites (Forbes 1902). Although some adults are capable of flight, it is rarely seen (Watschke et al. 1995, Young 2002).

Hunting Billbug. The hunting billbug, *S. venatus vestitus*, was first described by Frank Hurlbut Chittenden (1904) as *S. vestitus*, and later designated as a subspecies of *S. venatus* along with four other subspecies: *confluens* Chittenden, *glyceriae* Chittenden, *reticulaticollis* Boheman, and *venatus* Say (Vaurie 1951). These five subspecies are geographically distributed across the Atlantic and Pacific coasts and southern United States with little overlap between them. In the mainland United States, the hunting billbug ranges from Washington, DC, to Florida and as far west as New Mexico and southeastern Kansas

Fig. 4. Hunting billbug (*S. venatus vestitus*) adult, dorsal (left) and lateral (right) views. Scale bar = 1 mm.

(Chittenden 1904, Vaurie 1951, O'Brien and Wibmer 1982). In addition, it has been reported in Hawaii, Puerto Rico, Mexico, the Bahamas, the Dominican Republic, Martinique, and Japan (Marsden 1979, O'Brien and Wibmer 1982, Hatsukade 1997). Among the subspecies, only *S. v. confluens* and the hunting billbug have been reported in orchardgrass (Kamm 1969, Kuhn et al. 2013). The hunting billbug is also called the zoyziagrass billbug because it is a pest of zoysiagrass, *Zoysia* spp. (Kovitvhadi and Kerr 1968). Its additional host species include Timothy hay, Bermuda grass, *Cynodon dactylon* (L.), wheat, yellow nutsedge, corn, and sugarcane, *Saccharum officinarum* L. (Satterthwait 1931b, Satterthwait 1932, Woodruff 1966).

Although it is not currently possible to differentiate between the eggs or larvae of the hunting or bluegrass billbugs, the pupae and adults of these species may be distinguished from one another. The pupae and adults (Fig. 4) of the hunting billbug are slightly larger than the bluegrass billbug, ranging in size from ≈9 to 12.75 mm and 6 to 11 mm, respectively (Satterthwait 1931b, 1932). The pronotum of the adult has a series of nonuniform pits and callosities, which together resemble the letters "Y" or "V" framed by parentheses (Watschke et al. 1995). The hunting billbug also has chain-like furrows on its elytra, but they are less distinct than those of the bluegrass billbug.

The life history of the hunting billbug appears to be similar to that of the bluegrass billbug. However, Huang (2008) found that hunting billbug adults are nocturnal, and that eggs may be deposited in or around feeding "notches" created by the female on grass stems. The hunting billbug may have multiple generations in the southern United States, reproducing continually throughout the year, or may overwinter as a larva or pupa in cooler regions (Watschke et al. 1995, Young 2002, Huang and Buss 2009).

Billbug Injury, Scouting, Natural Enemies, and Control in Orchardgrass

Billbug feeding can destroy a stand of orchardgrass or go completely unnoticed, depending on the size of the billbug population and weather conditions. In addition to causing direct injury to the plant, feeding can also provide the opportunity for infection by rot-inducing bacteria and fungi (Hanson et al. 1950). Adult feeding is evidenced in late spring by the appearance of oblong, typically paired holes (≈1–5 mm in diameter) that occur singly or in sets on the leaves of the host plant (Fig. 1). Each set of holes begins as a single hole made by an adult feeding at the folded base of a leaf, and then unfurls into a mirrored pair as the leaf grows. These holes are a diagnostic feature of billbug adult feeding, which appears on orchardgrass, corn, and other grass species (Forbes 1905, Satterthwait 1932, Kamm 1969, W.R.K., unpublished data), and therefore represent a method to detect billbug presence. Larvae feed within the stems and roots in midsummer and damage appears as irregularly shaped patches of brown grass (Watschke et al. 1995). Damage caused by larvae is often more evident in dry than well-watered grass, despite being equally infested (Bruner 1890). Later in the growing season, infested stems break off easily and the larval frass, which resembles sawdust, spills out of these hollowed stems (Tashiro and Personius 1970). Feeding by larvae in later instars causes the most damage (Turner 1955).

Several methods have been devised to sample for billbugs. To extract billbug eggs from turfgrass, Tashiro (1987) used a blender to break up the turfgrass material and a series of stacked sieves to filter out the resultant turfgrass fragments, leaving the eggs. Larvae can be found by examining the upper layers of soil cores or square-foot samples (Watschke et al. 1995). Adult billbugs may be found in turfgrass by drenching the grass with water (Vittum et al. 1999), monitoring sidewalks and pavement for adults (Watschke et al. 1995, Vittum et al. 1999), using "suction or vacuum samplers" (Watschke et al. 1995), and using pitfall traps (Johnson–Cicalese et al. 1990, Watschke et al. 1995, Vittum et al. 1999). In addition, Doskocil (2010) found several commercial blends of aggregation pheromones from four non-*Sphenophorus* weevil species to be effective attractants for hunting billbug adults in a laboratory setting.

Pitfall traps, which are often used to capture surface-dwelling arthropods, are the most common method for sampling billbug adults. A basic pitfall trap comprises a container buried in the ground so that its rim is flush with the soil surface. The container is partially filled with a killing solution, such as soapy water, ethanol, or ethylene glycol, to both prevent captive arthropods from escaping and to preserve them from decay until the traps can be checked. Several modifications have been made to the basic trap idea. Linear pitfall traps use a piece of buried PVC pipe with a slit cut dorsally along its length to funnel surface-dwelling arthropods into a collection can at one end (Lawrence 1982), while in a barrier pitfall trap (Hansen and New 2005, Laub et al. 2008), a barrier wedged into the ground diverts arthropods into pitfall traps on either of its ends. In the latter method, multiple pitfall traps may be connected by several barriers, or multiple barriers may be used around a single pitfall trap, increasing the area covered by the trap (Hansen and New 2005).

Although a number of cultural, biological, and chemical control methods have been suggested for billbugs in turfgrass and corn, there has been little focus on control in orchardgrass. Tashiro (1987) and Watschke (1995) reviewed billbug-resistant varieties of turfgrass, but no billbug-resistant varieties of orchardgrass have been reported.

Predators of billbugs include the adults and larvae of carabid beetles (Bruner 1890); a tachinid fly, *Myiophasia metallica* (Townsend); as well as the American toad, alligators, and 26 species of birds (Satterthwait 1932). Natural parasites and parasitoids include the entomopathogenic fungus, *Beauveria* sp. (Kamm 1969); entomopathogenic nematodes of the genus *Mermis* Dujardin or *Gordius* L. (Bruner 1890); mites (Acari) (Forbes 1902); a braconid wasp, *Vipio belfragei* (Cresson) (Satterthwait 1932); and the mymarid wasp, *Anaphes (Patasson) calendrae* (Gahan) (Satterthwait 1931a, Beardsley 2000).

Billbug augmentative biological control has been attempted and has included the introduction of *A. calendrae* into Hawaii in 1928 and 1963. The second introduction was successful, as individuals of *A. calendrae* were found in 1995; however, efficacy against the target weevil species is unknown (Beardsley 2000). For controlling billbug adults and larvae, Watschke et al. (1995) recommended application of various entomopathogenic nematodes (*Steinernema carpocapsae* Weiser, *Steinernema glaseri* Steiner, and multiple *Heterorhabditis* spp.), and moistening turfgrass in the spring to augment the entomopathogenic, soil-borne fungi, *Beauveria* spp.

Watschke et al. (1995) reported that the most effective means of chemical control for billbugs is to target the egg-laying spring adults. Larvae may also be targeted as they leave the stem and drop to the soil to feed on the roots of the plant; however, some larvae remain within the plant and are therefore never exposed to contact or soil insecticides (Watschke et al. 1995). In turfgrass, systemic insecticides are effective for controlling billbug larvae and adults; however, these insecticides are not available for orchardgrass. There are only five insecticides currently registered for grass hay and pasture, which includes orchardgrass: β-cyfluthrin, carbaryl, λ-cyhalothrin, malathion, and

ζ-cypermethrin (Youngman et al. 2013). Of these, however, only λ-cyhalothrin is currently labeled for use on billbugs in grass hay and pasture in Virginia.

Billbugs in Orchardgrass: A Poorly Understood Problem

Billbugs are a major pest of orchardgrass in Virginia; however, most of our current understanding of them is based on studies of their interactions with turfgrass. Further investigations are warranted to verify the life histories of the bluegrass and hunting billbugs on orchardgrass. In addition, other billbug species have been reported in orchardgrass fields, including the southern corn billbug, *Sphenophorus callosus* (Olivier), lesser billbug, *Sphenophorus minimus* (Hart), and Timothy billbug, *Sphenophorus zeae* (Walsh) (Kuhn et al. 2013). Feeding studies are needed to determine whether these species regularly feed on orchardgrass and, if so, how likely they are to become pests. Finally, the current measures available for control of billbugs in orchardgrass are extremely limited. New management tools, insecticides or otherwise, are required to effectively control this pest.

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