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Profiles

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Ecology and Management of the Alfalfa Weevil (Coleoptera: Curculionidae) in Western United States Alfalfa

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Abstract

Alfalfa weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae), is a pest of concern in alfalfa (*Medicago sativa* L.) fields throughout the western United States. This introduced pest is most problematic in the early season causing defoliation and reduced hay yield and quality. Both adults and larvae feed on alfalfa, damaging terminals, foliage, and new crown shoots, but the larvae cause the majority of the damage. Three strains of alfalfa weevil, all *H. postica*, can be found in the western United States: the Western, Eastern, and Egyptian alfalfa weevil, *H. brunnipennis* (Boheman). Cultural, chemical, and biological control options are all viable strategies to include in an integrated management plan for alfalfa weevil, regardless of strain. We highlight research findings to best inform effective use of early harvest, grazing, insecticides, intercropping, and conservation biological control in alfalfa production systems.

Key words: alfalfa weevil, *Hypera postica*, alfalfa, hay, *Medicago sativa*

Alfalfa weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae), is a pest of concern in alfalfa (*Medicago sativa* L.) throughout the western United States. This introduced pest is most problematic in the early season, causing defoliation and reduced hay yield and quality. Both adults and larvae feed on alfalfa, but the larvae cause the majority of the damage to terminals, foliage, and new crown shoots (Radcliffe and Flanders 1998). Damage inflicted by alfalfa weevil can cause significant loss of biomass, especially leaf tissue, and also slow growth and delay crop maturity (Onstad and Shoemaker 1984, Hutchins et al. 1990). Although biological control agents largely keep alfalfa weevil populations under control in the northeastern United States (as reviewed in Kuhar et al. 2000), it continues to be the most problematic insect pest of alfalfa in the western United States and a major priority for alfalfa producers.

Alfalfa weevil is an exotic pest that was first discovered in 1904 in Utah. This population was the origin of the Western strain of this species (as reviewed in Kingsley et al. 1993). Introductions in Arizona in 1939 and in Maryland in 1951 established the Egyptian and Eastern strains of alfalfa weevil, respectively. Originating in Europe, South Central Asia, and Northern Africa, alfalfa weevil found their way to the United States likely by way of imported goods. Lacking natural enemies from its native Palearctic region, alfalfa weevil thrived and rapidly became one of the most destructive insect pests of alfalfa crops in the United States. Between 1904 and 1940, alfalfa weevil expanded its range from Utah to the Pacific Coast, and across to western Nebraska, then occupying nine states (Hamlin et al., 1949). Strains throughout Maryland spread aggressively to 25 states within 15 yr of introduction. Today, alfalfa weevil has been found in all of the lower 48 states.

Eastern and Western strains coexist just east of the Rocky Mountains, and Western and Egyptian strains coexist in the southwestern United States (Bundy et al. 2005). Differentiating between strains according to morphology is very difficult, but strains do differ according to behavior, ecology, and physiology in ways that are relevant to pest management (Bundy et al. 2005, Achata Bottger et al. 2013). Eastern and Egyptian alfalfa weevils can defend themselves against *Bathyplectes* parasitoid wasps by encapsulating them but the Western strain cannot (Salt and van den Bosch 1967, Maund and Hsiao 1991). Eastern and Egyptian alfalfa weevil pupate in cocoons attached to the alfalfa plant, whereas the Western alfalfa weevil pupates in plant litter on the soil surface (Bundy et al. 2005). Finally, *Wolbachia*, an endosymbiotic bacterium, exists in Western alfalfa weevil, and prevents cross-breeding with Egyptian or Eastern strains (Leu et al. 1989).

Life Stages

Egg

Female alfalfa weevil lay clusters of 5–20 eggs in alfalfa stems (as reviewed in Radcliffe and Flanders 1998). Eggs are yellow, oval in shape, and ∼0.5 mm in size (Fig. 1; Brewer et al. 2008). As eggs develop, they turn olive-brown, with the black head capsules of developing larvae visible through a semitranslucent casing. Eggs typically hatch within 1–2 wk after laying.

Larva

Larvae hatch into sheltered alfalfa stems near the ground, and will typically feed and grow for 2–4 wk before pupating, depending on temperature (Radcliffe and Flanders 1998). Alfalfa weevil transition through four larval stages, or instars. Third and fourth instars are about 8 mm long with a black head capsule, a wrinkled, ribbed green body, and a white stripe running lengthwise along its back (Fig. 2). Younger larvae have essentially the same appearance, but are smaller in size. Once larvae are mature, they pupate and form small, silken cocoons spun near the base of the alfalfa plant.

Adult

After 1–2 wk, adults emerge where they feed on alfalfa for 1–2 wk before leaving the sheltered area they are born into (Hamlin et al. 1949). Adult alfalfa weevils are brown, oval-shaped, and about 3/16" in length (Fig. 3). Young adults are lighter brown with a dark brown band stretching from head to hind. A distinctive snout or rostrum extends from the front of their head, which contains the chewing mouthparts. Adults have been shown to estivate, or enter into dormancy, in the summer months, leaving alfalfa fields to hide under plant litter or tree bark in field edges (Reynolds et al. 1955, Prokopy et al. 1967, Blickenstaff et al. 1972). Interestingly, some suspect that the Egyptian strain of alfalfa weevil may have been introduced via estivating adult weevils in date palm stock shipped from Egypt to Arizona (Reynolds et al. 1955). Adults largely return to alfalfa fields in the fall though some may not until the spring (Prokopy et al. 1967).

Fig. 1. Eggs of the alfalfa weevil inside the stem of an alfalfa plant (Sue Blodgett, Iowa State University, Bugwood.org).

Fig. 2. Alfalfa weevil larvae on alfalfa leaf showing chewing damage. Clockwise from left: second instar, fourth instar, third instar, and first instar (John L. Obermeyer, Purdue Extension Entomology).

Fig. 3. Adult alfalfa weevil (Joseph Berger, Bugwood.org).

Feeding Injury

Damage

The larval stage of alfalfa weevil cause the most damage to host plants from chewing on leaves. Early-season larval damage inflicted by first and second instars appear as pinholes in leaf tissue (Fig. 2), and generally occurs at the growing tips of stems (Fig. 4). Later, third and fourth instars begin feeding on open leaves. In heavy infestations, larvae consume all leaf tissue except for the veins and lower leaf portion, also known as skeletonizing (Hamlin et al. 1949). Skeletonized leaves dry quickly, giving the alfalfa field a gray to white cast (Fig. 4). Severe weevil damage results in reduced yield, decreased growth, and delayed maturity (Berberet et al. 1981, Berberet and McNew 1986). Lower forage quality via reduced crude protein content in leaves has also been shown (Berberet and McNew 1986). Alfalfa weevil is an early-season pest, most problematic prior to the first cutting of hay, although negative effects on the second crop can occur depending on the management practices used (Berberet et al. 1981, Onstad and Shoemaker 1984). Although the majority of feeding damage is caused by larvae, adults may still cause some damage by feeding on new growth in the spring.

Hosts

Alfalfa is the primary host plant for alfalfa weevil. Alfalfa is a forage crop, typically grown and harvested as high quality hay for livestock feed, or seed production. At times grown in combination with grasses, alfalfa is fed to a variety of domestic livestock. Alfalfa is a long-lived perennial legume, with purple loose flower clusters (U.S. Department of Agriculture–Natural Resources Conservation Service [USDA NRCS] 2016). Alfalfa is the preferred host for this pest, but alfalfa weevil has also been shown to feed on other legumes such as white clover (Reynolds et al. 1955, Ellsbury et al. 1992).

Ecology

Abiotic Factors

Development of alfalfa weevil depends largely on temperature (Onstad and Shoemaker 1984, Stark et al. 1993). In general, 8.9 °C is the temperature threshold for the growth of this pest (Whitworth et al. 2011). As a result, weevil oviposition rates and egg survival over winter can vary greatly depending on what ecological region alfalfa fields are located. In the northern United States, spring temperatures are generally ideal for oviposition and fall and winter temperatures rarely allow for oviposition or embryonic development, with winter egg mortality a common occurrence (Stark and Berberet 1994). Conversely, throughout Southern regions which experience less severe winters, alfalfa weevil eggs are deposited earlier and alfalfa weevil may be more likely to survive winter conditions (Stark and Berberet 1994, Kuhar et al. 2000). In Nebraska, Stilwell et al. (2010) compared developmental degree days for alfalfa weevil in three regions across southern, central, and northern Nebraska. In the southern part of the state, fewer numbers of degree days were needed for larvae emergence than in northern regions, demonstrating how differences in latitude, even within a state, can affect alfalfa weevil development and timing of insect activity. Since the early days of investigation into this pest, scientists have summarized that warm, dry weather is good for weevil development, but cold, wet springs can also result in great damage (Sweetman and Wedemeyer 1933).

Natural Enemies

There are a number of natural enemies known to attack alfalfa weevil, including both predators and parasitoids. Without a protective exoskeleton, the soft-bodied larval stage of the weevil life cycle is vulnerable to attack (Klowden 2002). Additionally, smaller larvae (first and second instars) may be more vulnerable than larger larvae because they are easier for predators to handle (Ouayogode and Davis 1981). Common predators found in alfalfa and known to feed on alfalfa weevil larvae include lady beetles (Coccinellidae), damsel bugs (Nabidae), lacewings (Chrysopidae), and some spiders (Ouayogode and Davis 1981). However, such predators often prefer aphids over weevil larvae when given the choice, in part due to the defensive wiggling that weevil larvae use to shake off and deter predators (Kalaskar and Evans 2001).

Parasitoids are another type of natural enemy that kill alfalfa weevil through the process of parasitism. Through release efforts by the United States Department of Agriculture Agricultural Research Service (ARS) and Animal and Plant Health Inspection Service (APHIS), there are eight species of introduced parasitoid wasps now established in the United States that attack alfalfa weevil (Bryan et al. 1993). In the western United States, the most common of these species include the ichneumonid wasps *Bathyplectes curculionis* (Thomson), *Bathyplectes anurus* (Thomson), and *Bathyplectes stenostigma* (Thomson) (Bryan et al. 1993, Brewer et al. 1997, Rand 2013). *Bathyplectes* wasps form distinctive cocoons (Fig. 5) that are useful when estimating parasitism rates of weevil populations, and also may occasionally be found when scouting.

These parasitoid and predator communities can have complex direct and indirect interactions with alfalfa weevil and other pest insects in alfalfa. For example, aphids feed on alfalfa and can be economic pests for producers, but they also produce honeydew that may serve as a sugary food source for adult parasitoids (Wäckers et al. 2008). Aphid abundance has been positively linked to increased life spans of parasitoids and increased parasitism rates of alfalfa weevils in the West (England & Evans 1997, Jacob & Evans 1998). So, aphids can be good for weevil control.

Fig. 4. Alfalfa that was treated and untreated for alfalfa weevil. The alfalfa on the left has been treated and has little to no damage, while the alfalfa on the right was left untreated and showing signs of damage (John L. Obermeyer, Purdue Extension Entomology).

Fig. 5. Cocoons of *Bathyplectes curculionis*, a parasitoid of alfalfa weevil.

Management

Scouting

Scouting and careful field observations are critical measures to maximize economic savings and limit the amount of insecticide applied to alfalfa fields. Several factors influence the decision to treat for alfalfa weevil including weevil density and larval development stage. Scouting procedures are typically based on degree days relating closely to larval development after egg hatch (Peterson and Meyer 1995). Scouting for alfalfa weevil larvae should begin after the accumulation of 350–400 degree days (base 8.9°C; Brewer et al. 2008). This targets scouting for first and second instars, giving producers a short window of time to make management decisions before more damage is caused by later third and fourth instars. In general, scouting should occur at multiple locations within a field, as weevil populations can be patchily distributed (Miller 1972). The "shake-bucket" or stem count sampling method is common and effective (Hoff et al. 2002). This method involves randomly and systematically collecting stems from several locations in a field. Stems should be gently broken off or cut to prevent insect loss during collecting, and are then shaken into a bucket, dislodging alfalfa weevil larvae from the foliage. The number of larvae per stem is determined by dividing the number of larvae in the bucket by the total number of stems collected. The average number of weevil larvae per stem across locations within a field provides an estimate of weevil densities for a given field.

Other common scouting methods for alfalfa weevil including sweep-net sampling and counting damaged terminals. Sweep-net sampling uses a 38-cm sweep net, swung in a 180° arc to collect weevil larvae from alfalfa foliage (Hoff et al. 2002). As with the shake-bucket method, the number of weevil larvae collected should be divided by the number of sweep samples taken to determine the number of weevil larvae per sweep. In general, sweep-net sampling is only an effective scouting method when alfalfa is at least 20–25 cm high and should be done on calm, sunny days (Blodgett 1996). Scientists compared the reliability of the shake-bucket and sweep-net sampling methods for alfalfa weevil larvae and found that the shake-bucket stem collecting method was more sensitive at detecting small larvae than the sweep-net (Hoff et al. 2002). In addition, sweep-net samples were more variable across operators, and training was key to reducing variability in sweep-net results. Thus, novice scouters will likely get more reliable information from the shake-bucket method, particularly in the early season.

Finally, one more scouting method is to look for damaged alfalfa stem terminals, the place where most feeding damage occurs. Terminals should be randomly selected and examined for feeding damage and the percentage of damage terminals determined. More scouting should be conducted if 30–50 percent of terminals are damaged (Blodgett 1996).

Economic Thresholds

Some University Extension programs in the United States recommend following set alfalfa weevil economic thresholds, such as 1.5 to 3 weevil larvae per stem or 20 weevil larvae per sweep (Evans 1989, Blodgett 1996). However, depending on the cost of treatment and the price of hay, actual economic thresholds may be lower or higher than these set numbers. It is good practice to calculate economic thresholds based on costs and prices for the year to best determine whether pest management is worth the cost. To determine economic thresholds, divide the cost of insecticide treatment (in dollars per acre) by the expected hay price (in dollars per ton). The resulting value will be the yield (in ton per acre) whose value is equivalent to the cost of insecticide treatment. Fig. 6, from the High Plains Integrated Pest Management Wiki (Peairs et al. 2016), illustrates how the number of weevil larvae corresponds to the yield calculated in previous steps. If scouting finds weevil larvae numbers greater than this value, it is economically viable to treat. However, if weevil larvae numbers are below this number, insecticide treatment would cost more than the value of the hay lost to feeding damage.

$$Yield\ Equivalent\ To\ \cos t\ of\ Treatment\ (ton\ per\ acre) = \frac{Insecticide\ Treatment\ (dollars\ per\ acre)}{Expected\ Hay\ Price\ (dollars\ per\ ton)}$$

Management Options: Cultural Controls

The most promising cultural control methods to mitigate alfalfa weevil damage include early harvest, grazing, and intercropping. Early harvest involves taking the first cutting of hay before damage from weevil larvae becomes too severe. Generally, alfalfa is ready for a first cutting before larvae complete development (Onstad and Shoemaker 1984). First cutting can be an effective means to destroy most of the larval population, and fewer eggs are laid during the second alfalfa growth period (Evans 1989). However, after first cutting some damage can also occur to the second growth, as weevil larvae move underneath windrows for shelter and begin feeding on the new growth. Harvest timing in relation to weevil development is critical to avoid this problem. Taking the first cutting too late allows larger larvae (third and fourth instars) to survive, who cause stubble damage and delay regrowth of the alfalfa (Onstad and Shoemaker 1984). Raking postharvest stubble can further destroy surviving weevil larvae. However, care should be taken when plant moisture is above 30%, as it can result in leaf drop and reduce hay quality (Blodgett et al. 2000).

Grazing by livestock is another cultural control, which may fit easily into management practices if dormant alfalfa fields are already used for winter pasture. Grazing recommendations to manage weevil depend largely on climate conditions and timing of grazing. In colder climates, alfalfa weevil eggs are not able to overwinter and are laid in the early spring by overwintering adults. However, in warmer climates eggs laid in the fall can overwinter successfully (i.e., Kuhar et al. 2000). Separate trials in Oklahoma have shown both winter and spring grazing of alfalfa to be successful for controlling alfalfa weevil, as overwintering eggs are crushed or eaten by livestock (Senst and Berberet 1980, Cummings et al. 2004). In more northern regions, grazing for effective weevil reduction should occur in early spring, before 63 growing degree days (base 8.9°C) when alfalfa weevil adults become active and start oviposition (Goosey 2012). Based on research in Montana with sheep, grazing should continue until 251 to 583 degree days at stocking rates of 251 to 583 sheep days per hectare (Goosey 2012).

Intercropping alfalfa with grasses holds promise as a strategy to mitigate weevil damage. Diverse plantings have long been touted as a strategy to reduce pest infestations compared to monocultures (Root 1973). Alfalfa–grass mixtures are commonly grown as forages, and have been shown to reduce weevil densities when compared to pure alfalfa stands (Roda et al. 1996, DeGooyer et al. 1999). However, these studies did not see effects in all years of the study or with all species of grass, so further research in intercropping practices as related to alfalfa weevil is merited. Other cultural methods mentioned in Extension literature include flaming and burning during alfalfa dormancy and using weighted rollers to squash eggs (Brewer et al. 2008, Whitworth et al. 2011).

Management Options: Host Plant Resistance

Host plant resistance is generally the first line of defense against pest attacks. There are several varieties of alfalfa that are rated as moderately tolerant to alfalfa weevil and may withstand some feeding injury. One mechanism for tolerance in these varieties is having more axillary buds and branches that continue to grow despite feeding damage to terminal stems (Brewer et al. 2008). Although these varieties can handle some damage, the current consensus from University Extension programs across the western region of the United States is that other management strategies are necessary for dealing with heavier infestations (Blodgett 1996, Brewer et al. 2008, Kinney and Peairs 2011). In addition, alfalfa producers have other factors to consider when selecting a variety such as dormancy requirements, winter hardiness, seed price, and availability. Recent laboratory research demonstrated the potential for genetically engineered (GE) alfalfa to provide resistance against alfalfa weevil larvae (Tohidfar et al. 2013), but at the time of writing this publication, the only GE alfalfa variety available commercially is herbicide-resistant.

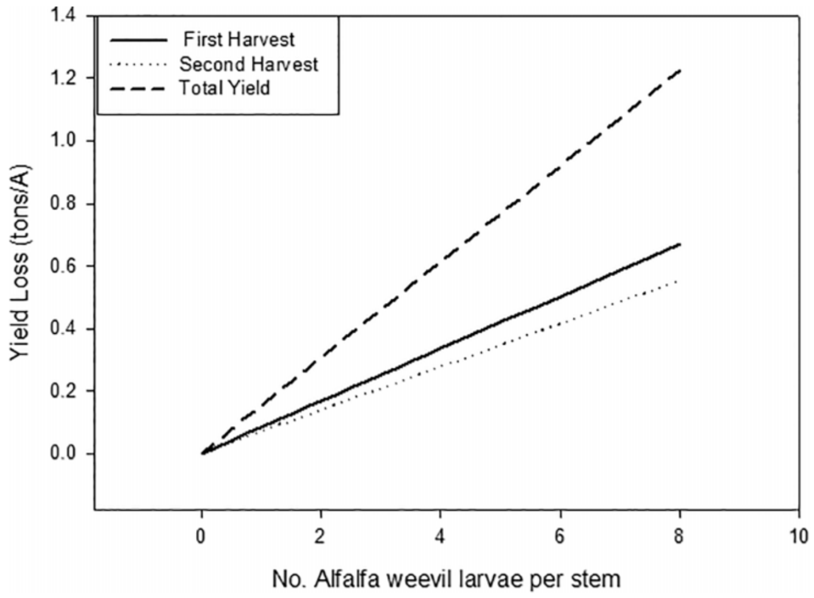

Fig. 6. Alfalfa weevil expected yield loss in tons per acre for the first and second hay cuttings on alfalfa, up to 15 inches tall, based on densities of alfalfa weevil larvae per stem (Peairs et al. 2016).

Management Options: Chemical Control

Insecticides for alfalfa weevil management can be registered for use on adults, larvae, or both. The insecticides that target the larval stage include organophosphates, carbamates, and pyrethroids (Wright et al. 2015). For treatment of adults, organophosphates and pyrethroids are the most common (Wright et al. 2015). Some products use a combination of two of these insecticide classes. Decisions about using insecticides should be made by scouting and calculating the economic threshold. Another important consideration in using insecticides to treat for alfalfa weevil is toxicity to bees and natural enemies. Many products registered for use for alfalfa weevil have high or moderate toxicities to natural enemies, and can be highly toxic to bees (University of California's Division of Agriculture and Natural Resources [UCANR] 2015). Risk to bees is heightened when alfalfa is in bloom, therefore labels will specify to "avoid application when bees are actively foraging" or "do not apply this product to crops or weeds in bloom" (Wright et al. 2015). Current information on specific chemical control products, preharvest intervals, and other notes are most reliably located on updated regional Extension websites such as the High Plains IPM Wiki (Peairs et al. 2016).

Management Options: Biological Control

Classical, conservation, and augmentative biological control all have a place in the story of alfalfa weevil in the United States. As described in the natural enemies section, several species of parasitoid wasps were sought out, reared, and released as a classical biological control effort in the decades following the invasion of the alfalfa weevil (Kingsley et al. 1993). Conservation biological control currently holds the most promise as part of an alfalfa weevil IPM plan. This approach involves conserving the natural enemies of alfalfa weevil that are already present in the landscape (Landis et al. 2000). Practices to conserve predators and parasitoids that kill alfalfa weevil include reducing or eliminating insecticide applications (UCANR 2015), leaving refuge strips of standing alfalfa during harvesting (Hossain et al. 2002), or planting field edges to undisturbed natural habitat (Landis et al. 2000, Philips et al. 2014). Flowering habitats in particular could provide food sources to parasitoids of alfalfa weevil, although experimental work testing this phenomenon at the field-scale is limited (Lee and Heimpel 2005). Blooming weeds can serve as floral resources (Ditommaso et al. 2016). However, bloom density of flowering weeds within alfalfa production fields in Wyoming was not associated with parasitism rates of alfalfa weevil (Pellissier 2016). Augmentative biological control is not recommended for alfalfa producers. Purchasing beneficial insects such as lady beetles to release into alfalfa fields has not been shown to be effective against weevil, and this practice generally has serious economic and ecological limitations (as reviewed in Collier and Van Steenwyk, 2004).

Systems-Level Management Decisions

As indicated in detail in our profile, scouting determines if weevil numbers exceed economic thresholds and whether management actions should be taken. Scientists have used scouting data to develop predictive models to evaluate how best to make management decisions for alfalfa weevil given biological realities and economic implications (Onstad and Shoemaker 1984, Lamp et al. 1991). Using data originating from weevil infestations in Maryland, Lamp and colleagues (1991) concluded that a "responsive insecticide program" based on insecticide use in response to scouting was less costly than a "no-action program" and far less costly than prophylactic use of insecticide. A contrasting perspective is provided by Onstad and Shoemaker (1984), who proposed that a robust strategy for managing alfalfa weevil is to always harvest early, whether or not weevil is present. They note that harvesting early no matter what, yields higher quality hay, increases the possibility of more yield late in the season (in areas where the season is long enough for a third cutting), and removes the cost of both scouting and insecticide use. They provocatively argue that simply following a certain cutting schedule (involving an early first harvest) and not investing in intensive weevil monitoring is a solid robust strategy for producers.

These distinctive perspectives are valuable and highlight the importance of developing an integrated pest management plan that is specific to the details of a producer's operation. Some of the approaches suggested in this profile may have increased relevance if an alfalfa producer also raises cattle or grows for a high-value market. Although alfalfa weevil remains a problematic pest in the Western United States, the sizeable body of work we have reviewed here offers potential solutions for managers.

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