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INTEGRATED PEST MANAGEMENT FOR THE WHEAT HEAD ARMYWORM COMPLEX IN THE PACIFIC NORTHWEST

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Integrated Pest Management for the Wheat Head Armyworm Complex in the Pacific Northwest

Abstract

The wheat head armyworm complex (WHAC) is comprised of two armyworm species, *Dargida diffusa* (Walker) and *Dargida terrapictalis* (Buckett), which caused recent, intermittent damage to cereal crops in the Pacific Northwest (PNW). This was the first record of *D. diffusa* as a pest in the PNW. While *D. terrapictalis* is native to the region, it has not been recorded previously as a pest.

This publication covers identification, biology, and integrated pest management for WHAC. We emphasize pest monitoring and field scouting methods, and also discuss natural insecticides.

Introduction

The wheat head armyworm complex is comprised of two armyworm species, *Dargida diffusa* (Walker) and *Dargida terrapictalis* (Buckett), which caused recent and sporadic damage to cereal crops in the Pacific Northwest (PNW). Genetic sequencing studies indicated that the two species are closely related. For this reason, we refer to them as the wheat head armyworm complex (WHAC).

Idaho first reported WHAC damage in 2005 in Bonneville County. The same species were responsible for damaged grain at harvest in Lincoln County, Washington, in 2007 (Figure 1). An infestation of WHAC in 2008, also between Reardan and Davenport, resulted in 10,000 acres of grain being sprayed with insecticide. The WHAC also caused crop damage in Umatilla County, Oregon, in 2007.

Researchers noted a 35% yield loss due to the insect in 2007 and 2008 in spring wheat trials conducted by Washington State University (WSU) near Davenport, Washington. These losses were likely intensified by the variety trials being located away from commercial fields; moths hatching from pupae in surrounding fallow ground congregated on the nearest green plants (Roberts 2008, 2009a, and 2009b).

Following the initial occurrences, crop damage was not seen for several years, although adult moths of WHAC were found in pheromone (sex attractants specific to the species involved) traps across eastern Washington and Umatilla County, Oregon (Landolt et al. 2011). Outbreaks occurred in the lower Columbia Basin (Oregon) in 2012 and 2014. In 2013 and 2014, WHAC infested about 10,000 acres of cereal grains near Edwall, Washington. This area is south of the portion of Lincoln County that was affected previously.

It is unclear why the pest has occurred in certain areas but not others. No-till (direct seed) farming has been blamed in Lincoln County, Washington. However, where the pest was found in Umatilla County, Oregon, farmers used a mix of conventional and minimum tillage. The outbreak in Bonnevillle County, Idaho, was on conventionally tilled farms.

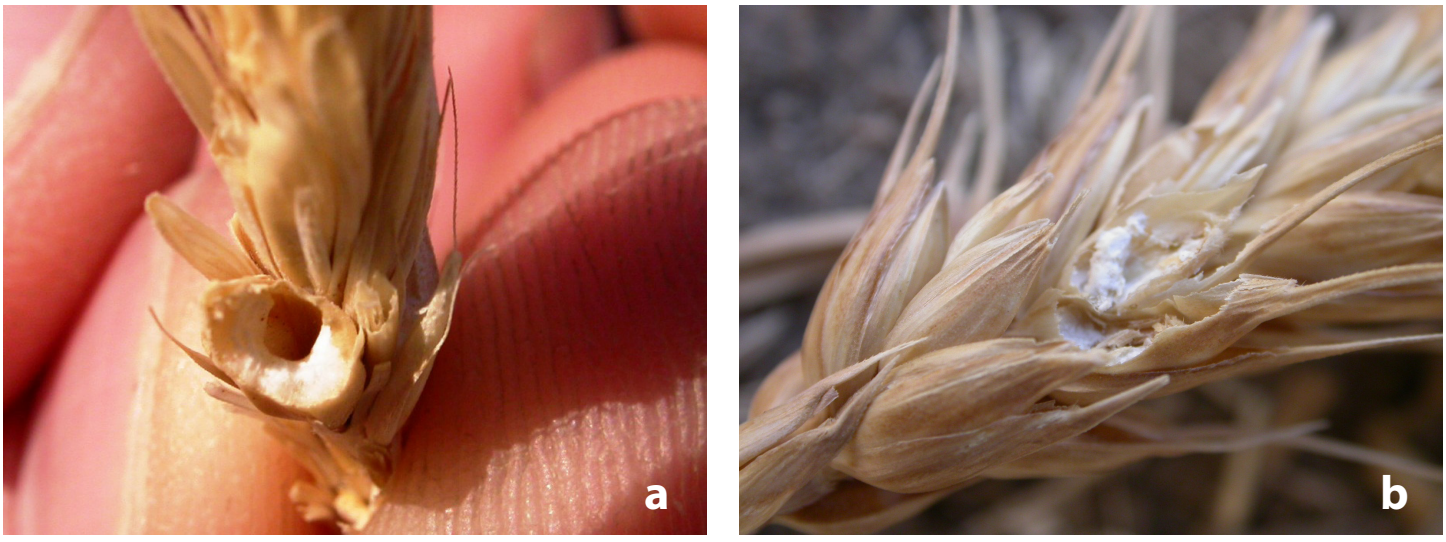

Figure 1 (a) and (b). Wheat head armyworm damage in mature wheat heads. (a) Photo by John Burns, WSU Extension and (b) Photo by Diana Roberts, WSU Extension.

With the recent confirmation of the pest status of *D. terrapictalis*, the question also arises as to why it took over 100 years of wheat farming in the region for this insect to cause noticeable yield loss. Possible reasons include climate variability, increased frequency of spring wheat in crop rotations, fewer frost events in late spring, or changes in soil health and cropping systems.

The Insect Species Involved

Two insect species have been implicated in WHAC infestations reported in the PNW. *D. diffusa* (Figure 2a) is found throughout the United States and Canada, but is more common in high-producing wheat areas including Kansas, Nebraska, Oklahoma, and Colorado (Michaud et al. 2007). The unpredictable and sporadic nature of infestations there has made the pest challenging to study.

We report here the first incidences of *D. diffusa* as a pest in the PNW, and local scientists referred to it initially as the "true" wheat head armyworm (Figure 2a). The second species, *D. terrapictalis*, is native to the western United States (Figure 2b). Its host range and pest status were not previously known (Michaud et al. 2007), and we referred to the pest locally as the "false" wheat head armyworm. Adult moths of the native species, *D. terrapictalis*, were by far the greatest catches in pheromone traps located across eastern Washington and northeastern Oregon in 2009 and 2010 (Landolt et al. 2011). Similar results were obtained from an insect pest survey in eastern Washington in 2015 (Crowder et al. 2015).

Attempts to rear field-collected larvae through to the adult moth in order to confirm the pest status of D. terrapictalis have not yet been successful. While the adult moths have obvious differences, it is not possible to distinguish between the larvae of the two species.

We collected larvae from WHAC-infested fields in Lincoln County, Washington, in 2014 and conducted sequencing studies to determine genetic differences among them for the COI (cytochrome oxidase I) region. However, the two species proved to be virtually identical for this genetic marker. These results indicate that *D. diffusa* and *D. terrapictalis* are recently divergent species (Wanner 2015). This finding suggests that *D. terrapictalis* is also a pest of cereal crops and we recommend farmers manage it accordingly.

The term "armyworm" is used to describe many different moths, and refers to their typical numbers and movement across fields. They are known as pests of a wide variety of plants. It is noteworthy that many reports of armyworms in grain crops east of the Rocky Mountains do not refer to WHAC. The true armyworm *Pseudaletia unipuncta* (Haworth), and the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) both infest cereals and may be referred to as "armyworms" (Capinera 2006); however, neither has been reported as a pest in the PNW.

WHAC Biology, Lifecycle, and Behavior

The genus *Dargida* consists of several species within the family *Noctuidae*, which are so named because the adult moths are nocturnal. *Noctuidae* comprise the largest family in the order *Lepidoptera*, which includes moths, skippers, and butterflies. The family also includes numerous pest species such as cutworms and armyworms (Mickel 1932). Although several species of *Dargida* can be found, the only available references to its biology are for *D. diffusa* in the Midwest.

Both WHAC species have straw-colored forewings, which likely provide camouflage protection from predators against a background of dry grasses, including wheat. *D. terrapictalis* has somewhat darker forewings and substantially darker hind wings (Figure 2).

Lepidoptera have four life stages: egg, larva, pupa, and adult. Larvae of noctuids go through five instars, when

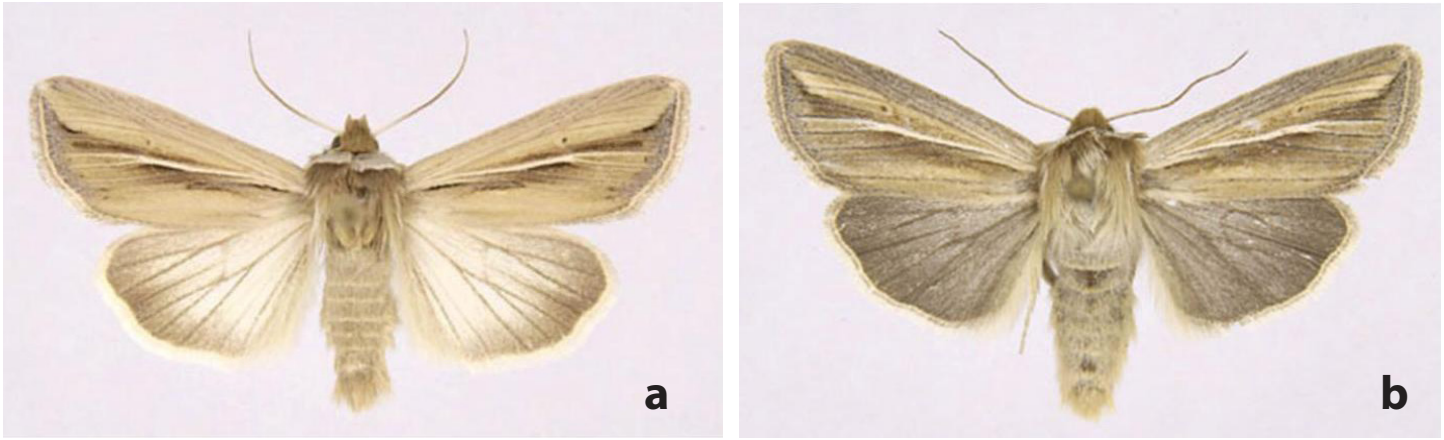

Figure 2. The two adult moths comprising the wheat head armyworm complex (a) *Dargida diffusa* and (b) *Dargida terrapictalis*. (Photos from the Canadian Biodiversity Information Facility, Moths of Canada website.)

they molt the exoskeleton and increase in size (Peairs 2006). The larvae vary in color but have been noted as gray, cream, or green with distinct yellow, white, and brown stripes along the length of the body (Figure 3). Michaud et al. (2007) described the adult moth as yellow-brown with a brown stripe running down the length of each of the forewings (Figure 2). The wingspan measures 1.2 to 1.5 inches.

The insect overwinters in the soil as a pupa. When spring arrives, moths emerge from the pupae. Within a few days, the moths lay eggs on wheat or barley crops (Peairs 2006). Larvae hatch and feed from late May through the remaining crop season, with maximum populations occurring around mid-June (Michaud et al. 2007). This late-spring timing coincides with wheat flag leaf development. Larvae feed on wheat heads, primarily at night, when ambient temperatures are cooler. During the heat of the day, larvae migrate towards the base of the plant (Michaud et al. 2007; Royer 2007).

Figure 3 (a) and (b). Wheat head armyworm complex larvae showing color variation and typical striping as they feed on wheat heads. (Photos by Diana Roberts, WSU Extension.)

WHAC in the Pacific Northwest

WHAC was first reported on wheat in Washington State in 2007, when grain harvested in Lincoln County was docked for broken kernels (Figure 4). A local crop consultant, suspecting armyworm damage, subsequently found pupae, corresponding to the description for WHAC (Figure 5), one inch down in the duff layer of an affected no-till field (K. Reed, personal communication).

Pheromone traps set up across eastern Washington and Umatilla County, Oregon, in 2009, attracted both species comprising WHAC. *D. diffusa* occurred only in Spokane, Lincoln, and Adams Counties, while *D.*

Figure 4. Wheat sample with broken kernels attributed to damage by the wheat head armyworm complex. (Photo by Diana Roberts, WSU Extension.)

Figure 5. Pupae of the wheat head armyworm complex collected in Lincoln County in 2007. (Photo by John Burns, WSU Extension.)

terrapictalis was trapped (at low levels) in all the counties surveyed (Figure 6).

We set up this same system of traps in Lincoln and Spokane County, Washington, and Umatilla County, Oregon, in 2010 (Figure 7). Traps captured only *D. terrapictalis* moths in Umatilla County, with numbers peaking in mid-May. In Washington, moths of both species began to emerge in late May and populations peaked around the third week of June. *D. terrapictalis* moths comprised the bulk of the catch, versus the almost negligible numbers of *D. diffusa*. We expect there will be seasonal variations in these dates.

We recommend that in areas prone to WHAC infestations, crop consultants set out pheromone traps

Figure 6. Distribution of counties trapped (gray shading) and positive trap captures for *D. diffusa* (stippling) and *D. terrapictalis* (hash lines) moths in eastern Washington and Umatilla County Oregon, 2009. (Source: Landolt et al. 2011. Journal Kansas Entomological Society. Used by permission.)

as winter wheat enters the boot stage (Feekes Stage 10). This is approximately the last week of April in Umatilla County and mid-May in Spokane and Lincoln Counties. They should monitor moth catches on a weekly basis for the next month or until moth numbers are negligible. They should commence surveying adjacent fields for WHAC larvae about seven days after the peak occurrence of moths, or as soon as the wheat heads are half emerged from the boot (Feekes Stage 10.3). Catches of WHAC moths from the fall flight were negligible in both 2009 and 2010, so at this time we do not recommend monitoring populations in the fall.

WHAC moths lay eggs soon after emerging from pupae, and larvae are predicted to hatch about 10 days later, depending on heat and moisture conditions. In Lincoln County in 2008, newly hatched larvae, presumably of WHAC, were found on June 25 (Figure 8). It appeared that WHAC moths laid eggs on the flag leaf and the larvae fed on the upper layer of leaf tissue as they made their way down the leaf and into the boot to feed on the developing wheat head.

Holes chewed into the wheat floret are typical of WHAC damage (Figure 9), and feeding larvae leave telltale frass (feces) on the wheat head.

Feeding

WHAC larvae occur most commonly along field margins. The pest may feed on all parts of grass and cereal crops, but seems to prefer cereal heads. Larvae feed by inserting their mouthparts into the base of the floret, boring a small hole (Figure 10) through which

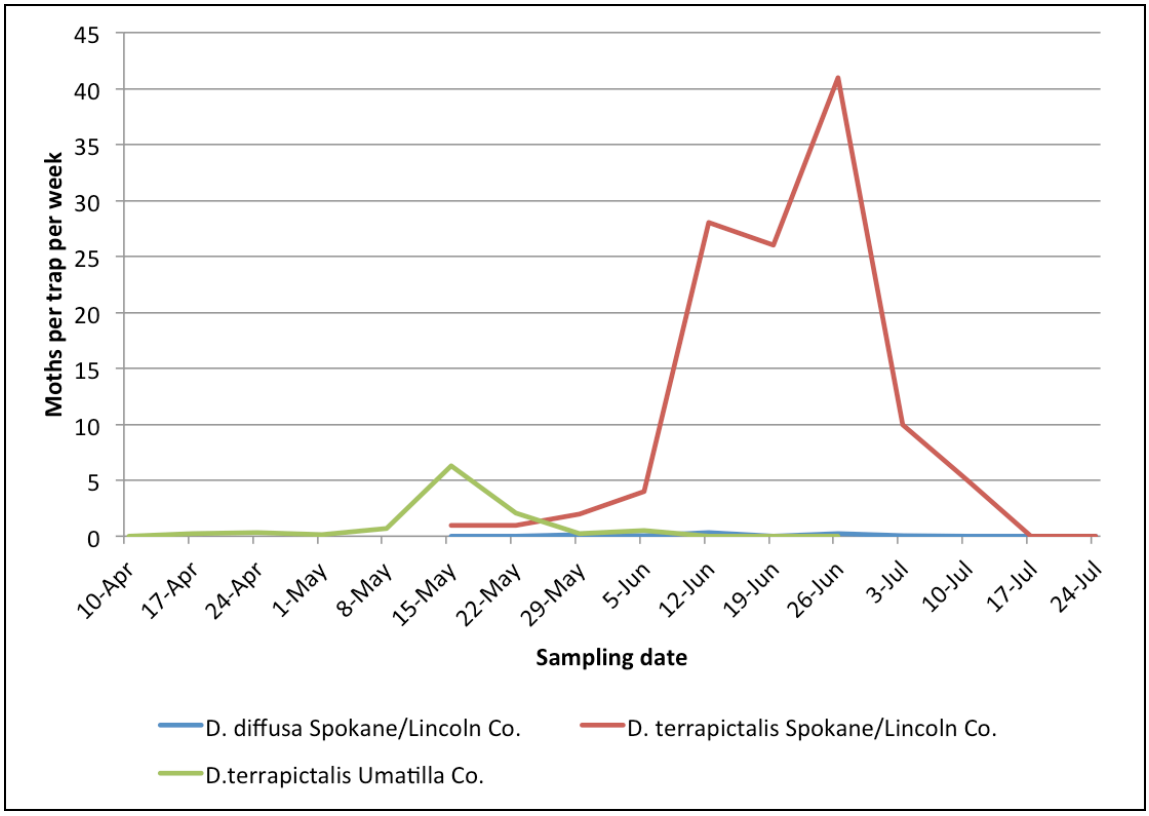

Figure 7. Mean weekly number of *D. diffusa* and *D. terrapictalis* moths caught in pheromone traps for 13 sites in Lincoln and Spokane Counties, Washington, and 25 sites in Umatilla County, Oregon, in 2010.

Figure 8. Newly hatched larvae of the wheat head armyworm complex showing their looper movement, moving down the flag leaf and into the boot of a wheat plant. (Photo by Diana Roberts, WSU Extension.)

Figure 9. Wheat head with feeding wheat head armyworm complex larva hanging upside down, leaving frass excrement, and holes bored in the florets. (Photo by Diana Roberts, WSU Extension.)

they eat out the developing grain. In stored grains, WHAC damage (Figure 1a) may appear very similar to that caused by weevils.

In the PNW, WHAC infests spring wheat fields primarily, although winter wheat and spring barley may also be affected. Michaud (2007) reported that Timothy grass (*Phleum pratense*) is also a host crop. The larvae generally feed at night and early in the morning. They hang upside down from the slender bristles on the head (awns) and hollow out the kernels.

WHAC Management

WHAC intermittently causes economic damage to cereal crops. The problem usually goes unnoticed until the crop is harvested and damaged kernels are found. Scouting for WHAC is unlikely to be justified unless it is part of an integrated pest management program or if infestations have occurred previously in a specific area. At present, control measures based on research are limited (see Chemical Control section), and scientifically tested economic thresholds for treatment are not available. We do not recommend growers spray at the first sign of the insect.

Monitoring the Pest

WHAC larvae cannot be identified to the species level based on appearance. Submit samples of moths, larvae, and damaged plants to your local county Extension office for identification.

Pheromone trapping and field scouting are helpful practices for monitoring WHAC populations in areas where the pest has caused damage in previous years.

Figure 10. Wheat head armyworm complex feeding damage on flag leaf, boot, and florets of wheat. (Photo by Diana Roberts, WSU Extension.)

Pheromone traps are useful for detecting the presence of WHAC moths in cereal grain fields and determining the optimum time to scout for larvae, but trap counts cannot be used directly to make management decisions, without additional scouting. The pheromone is a sex attractant, which in this case is specific to the male moths of *D. diffusa* and *D. terrapictalis*. The pheromone used is obtainable from commercial sources and is marketed as "wheat head armyworm pheromone."

The pheromone lure is placed in a basket at the top of a universal moth trap (Figure 11), which is mounted on a stake and located on the upwind side of a (spring) wheat field (Figure 12) to carry the pheromone molecules across the field. Male moths follow the scent into the trap, where they are killed by fumes of insecticide impregnated in a strip of tape (Vaportape) stapled to the inside of the bucket trap.

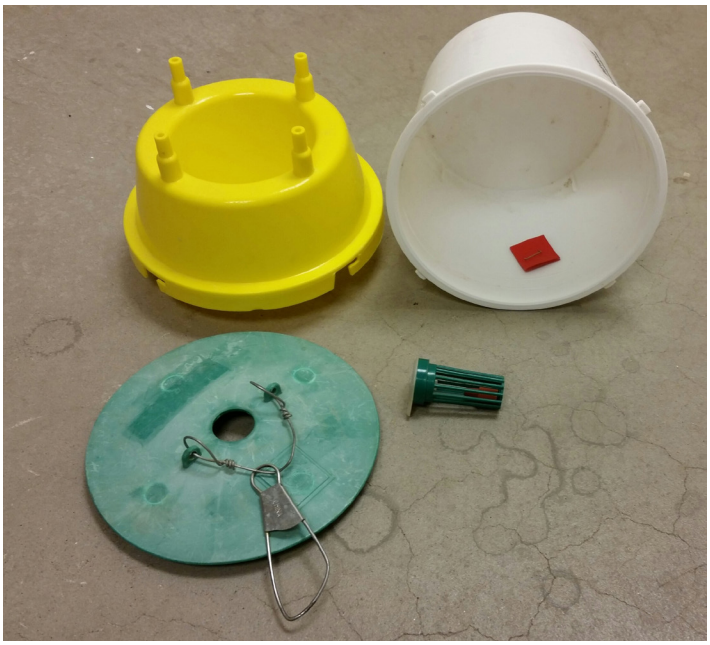

Figure 11. Components of a bucket trap showing lure in the top basket and Vaportape attached inside the lower bucket. (Photo by Diana Roberts, WSU Extension.)

Figure 12. Assembled bucket trap located at the upwind edge of a spring wheat field and suspended with the bottom of the trap level within the crop canopy. (Photo by Diana Roberts, WSU Extension.)

At least two traps (per hundred-acre field) should be set up as wheat enters the boot stage (Feekes Stage 10) and left in the field about four to five weeks until flowering is complete (at Feekes Stage 10.5.3). The pheromone plug and Vaportape should last this long. The trap height should be adjusted weekly as the plants grow so the bottom of the trap is level with the crop canopy (Figure 12). WHAC moths in the trap should be counted on a weekly basis and removed, along with other insects that were attracted to the bright colors of the trap.

Cost of wheat head armyworm complex trap and components for 2017, available at www.alphascents.com

Universal body trap:	$13.00 ea.	$262.50 for 25
Wheat head armyworm lure:	$2.75 ea.	$35.00 for 25
Vaportape (1" x 4" strip serves 4 traps):	$2.10 ea.	

This test is extremely sensitive because the pheromone attracts moths from at least 300 yards downwind. Consequently, the number of moths caught in the trap is not representative of the density of insects on a per plant basis, and management decisions should not be made based on these counts. We recommend sampling with a sweep net in fields where weekly moth counts exceed 25 to 30 per trap. In our experience, with lower weekly counts, we have typically not found WHAC larvae feeding on the crop. The weekly moth counts do indicate the peak flight time of the adult WHAC. The moths mate and lay eggs soon after they emerge from pupae, and the eggs hatch about 10 days later. Field scouting should start about one week following the peak moth count.

Field sampling for larvae is best done using a sweep net. It should be done in the cool hours of the morning and evening because WHAC larvae drop down in the canopy during the heat of the day. WHAC (and many other insect pests) are usually found along field borders, so it is important to sample transects well into the center of the field. Alternatively, take one set of sweeps along the field border and another within the field to enable making separate pest management decisions for each area. We recommend that each sample be a set of 50 sweeps, each 180 degrees, through the top of the crop canopy in a random zigzag motion from the edge towards the field center. Repeat the sample at several locations (minimum of three) across the field, and count the WHAC larvae in the net after each sample. Calculate the average number of larvae per sample for the final number.

Research-based economic thresholds have not been established for WHAC because the irregular occurrence of infestations make it a challenging insect to study. In Lincoln County, Washington, crop consultants have used a count of 15 WHAC larvae per 10 sweeps (75 larvae per 50 sweeps) as warranting treatment (J. Merkel, personal communication).

Environmental Factors

WHAC larvae are sensitive to cold temperatures. In Lincoln County, Washington, an unseasonal frost on July 10, 2008, reduced larval counts of WHAC in WSU variety trial plots by 90%. Insecticide treatment of commercial fields in the area was terminated for the same reason. Mid-season frost events do not occur frequently, but if a cold snap is predicted, it may be wise to postpone planned insecticide applications.

Biological Control

Ground beetles, spiders, birds, and rodents all prey on the true armyworm and the fall armyworm, which occur east of the Rocky Mountains. Several species of parasitic wasps and flies also manage their populations (Capinera 2005 and 2006). It is likely that similar predators and parasitoids control WHAC populations in the PNW and account for its inconsistent occurrence. In 2007, pupae of an unidentified parasitic wasp emerged from most of the 70 WHAC pupae collected after harvest in Lincoln County, Washington (Figure 13).

Chemical Control

While no insecticides are specifically labeled for control of WHAC in the PNW, pyrethroids have worked well in the field. They should be used with restraint since they kill natural enemies as well as the pest. For best results, spray early in the morning or late in the evening when the pest is exposed and feeding on the upper part of the plant. If the field is sprayed during the day, the treatment is likely to be less effective because the pest larvae are low down in the crop canopy.

Any registered contact insecticide labeled for cutworms and armyworms on wheat or barley should be effective against the pest. They are shown in the PNW Insect Management Handbook at http://insect.pnwhandbooks.org/agronomic/small-grain. While armyworms are listed on the labels of a number of chemicals, no currently available commercial insecticide specifically names WHAC.

While several chemicals are listed in the handbook, two commonly used insecticides that may be effective against the pest are Warrior II with Zeon Technology, from Syngenta, and Mustang Max EC, from FMC. Warrior has a signal word of warning, a re-entry interval of 24 hours, and a preharvest interval (PHI) of 30 days. This may pose a problem for growers if it is applied close

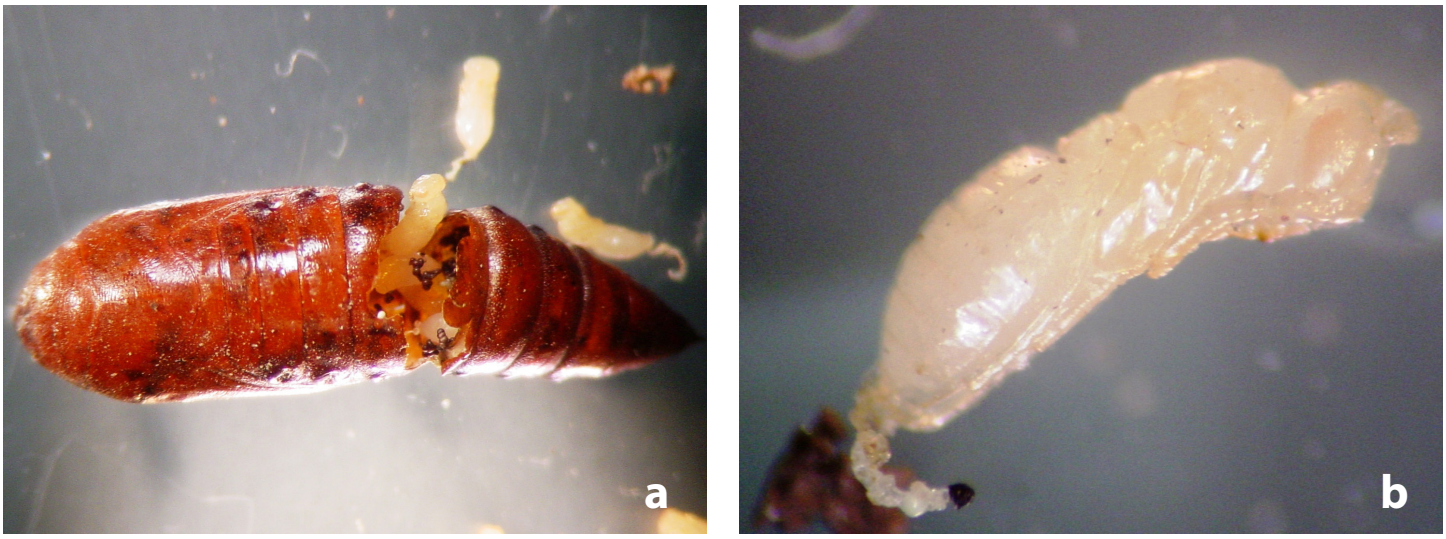

Figure 13. Parasitized wheat head armyworm complex pupa collected in Lincoln County, Washington, August 2007. (a) Wasp pupae emerging from wheat head armyworm complex pupa and (b) single wasp pupa. (Photos by Diana Roberts, WSU Extension.)

to harvest, in winter wheat especially. Mustang Max has a signal word of warning, a re-entry interval of 12 hours, and a PHI of 14 days; and it can only be applied to wheat.

Natural Insecticides

In testing natural insecticides on second instar larvae of *D. diffusa* under laboratory conditions, Reddy and Antwi (2016) found Entrust WP (spinosad 80%) to be effective and fast acting, resulting in close to 100% mortality within three days after application. Spinosad is toxic to many insect species, including bees. Under sunlight conditions, the product breaks down within seven days, so reapplication might be necessary if more WHAC larvae hatch in the field.

Spinosad is available in several formulations. Entrust (wettable powder; Dow Agrosciences) and Success (aqueous suspension; Dow Agrosciences) are labeled for managing armyworms in cereal grains. Entrust may be applied at 1 to 2 ounces per acre, not to exceed 5.6 ounces (0.28 lb active ingredient) spinosad per acre per year. Success may be applied at 3 to 6 fluid ounces per acre, not to exceed 19 fluid ounces (0.28 lb active ingredient) per acre per year. Both formulations have a preharvest interval of 21 days. It is recommended that no more than two applications be used successively to prevent insects from developing resistance to the pesticide.

In the same study, Reddy and Antwi (2016) also evaluated products containing the entomopathogenic (insect killing) fungus, *Beauveria bassiana*. Xpectro OD (*B. bassiana* GHA + pyrethrins) was faster acting than Mycotrol ESO (*B. bassiana* GHA), which took nine days to be fully effective. This was to be expected with a fungus that takes time to develop a lethal infection.

The law requires applicators to **always read and follow all pesticide label instructions when using chemical products**.

Conclusion

At this time, WHAC is an intermittent and localized pest in the PNW. We encourage growers and consultants to employ the scouting techniques described, and to use insecticides with restraint. Virtually all labeled products that help manage WHAC and other pests are also harmful to beneficial insects.

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Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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