



Ecology and Management of the Western Bean Cutworm (Lepidoptera: Noctuidae) in Corn and Dry Beans

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J. Integ. Pest Mngmt. 1(1): 2010; DOI: 10.1603/IPM10003

ABSTRACT. The western bean cutworm, *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae), is a native North American pest that feeds mainly on corn and dry beans. The historical geographic range of the western bean cutworm covered the western Great Plains states, including Colorado, Nebraska, and Wyoming. Since 1999, the geographic range of the western bean cutworm has rapidly expanded eastward across the United States Corn Belt, causing significant and economic damage to corn and dry beans in parts of this region. This expansion has led to a resurgence of interest in this pest, particularly in areas where it has most recently caused damage. We summarize the ecology and biology of western bean cutworm and discuss options for scouting and management, with an emphasis in the expanded geographical range.

Key Words: western bean cutworm; Lepidoptera; corn pest; dry bean pest

The western bean cutworm, *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae), is native to North America, first described in 1887 from a collection of Arizona moths (Smith 1887, Douglass et al. 1957, Dorhout and Rice 2008). Douglass et al. (1957) noted that the first record of western bean cutworm as a pest appeared in the 1940s on dry beans, *Phaseolus* L. spp., in Colorado, followed by corn, *Zea mays* L., in 1957 in Idaho, although Hoerner (1948) mentioned feeding on beans in 1915 and 1920. Since its initial description, the range and distribution of the western bean cutworm has expanded, first northward and then eastward (Fig. 1A). The range expansion between the 1940s and early 2000s was relatively slow. In the mid-1950s, Crumb (1956) described the distribution as Idaho, Kansas, Nebraska, Iowa, Utah, Colorado, Arizona, New Mexico, Texas, Alberta, and Mexico. Between 1970 and 1980, the distribution was extended to include Oklahoma, South Dakota, and Wyoming (Blickenstaff and Jolley 1982). Western bean cutworm was only sporadically found in western Iowa before 2000 (Keaster 1999), and the first economic damage in Iowa cornfields was reported in 2000 (Rice 2000). During 2000–2009, the eastward expansion accelerated (Fig. 1B). Western bean cutworm adults have now been collected in 11 additional states and provinces since 1999, spreading from western Iowa into eastern Pennsylvania and southern Québec (see Table 1 for a list of dates and references). As of 2010, economic damage has been reported in Illinois, Indiana, Iowa, Michigan, Minnesota, Wisconsin, and Ontario.

Although the western bean cutworm is primarily recognized as a pest of field corn in many areas of its present range, other hosts include legumes, especially dry beans, where they are grown in abundance (Seymour et al. 2004). Soybean, *Glycine max* (L.) Merrill, is not a known host in the field, although Blickenstaff and Jolley (1982) report that first or second stage western bean cutworm can survive on soybean when transferred from corn. There are no records of western bean cutworm naturally feeding on soybean. Other hosts have been implicated as perhaps ancestral or primary, such as teosinte (*Zea mays* L. ssp. *parviglumis* Iltis and Doebley), tomato (*Solanum lycopersicum* L.), nightshade (*S. nigrum* L.), and ground cherry (*Physalis* L. spp.), but complete larval development and survival on these hosts is poor (Blickenstaff and Jolley 1982). Available evidence suggests that corn and various species of dry beans (*Phaseolus vul-*

garis L., *P. lunatus* L., *P. coccineus* L., and *P. acutifolius* Gray) are the original and current hosts.

Despite its common name, western bean cutworm does not behave like many other cutworms, for example, black cutworm, *Agrotis ipsilon* (Hufnagel). Instead of cutting stems of seedling plants, the western bean cutworm feeds on the reproductive parts of the plants (corn tassel, silks, and kernels, and dry bean pods and seeds). Feeding by western bean cutworms causes both yield loss and reduced grain quality by facilitating mold or disease infection (Hagen 1962, Seymour et al. 2004, North Central Integrated Pest Management [NC-IPM] Center 2005, Catangui and Berg 2006, Rice and Pilcher 2007).

The rapid eastward expansion of the western bean cutworm has prompted the development of resources for identification, scouting, and integrated pest management (IPM) recommendations for much of the Corn Belt where this pest previously did not occur. Here we summarize the current understanding of the natural history and ecology of western bean cutworm, and we present options for scouting and management in corn and dry beans.

Description of Life Stages and Cycle

Adult. Moths are gray-brown and are ≈2 cm (0.75 in) long (Fig. 2). The primary identifying characteristics are found on the forewings of both sexes—a cream-colored stripe along the outer margin of the forewing; a circular spot of similar color approximately halfway along the length of the forewing; and a comma-shaped mark along the same line, ~2/3 of the way to the wingtip. Adults often are confused with spotted cutworm, *Xestia dolosa* Franclemont; yellowstriped armyworm, *Spodoptera ornithogalli* (Guenée); or dingy cutworm, *Feltia jaculifera* (Guenée). All of these species have distributions that overlap part of the western bean cutworm's expanding range.

Moth flight begins as early as mid-June, peaks in mid- to late-July, and usually ends by the end of August (Rice 2006, Dorhout and Rice 2008), although substantial variation in emergence from the soil and flight time can occur depending on climate and location. For example, the peak flight for Michigan and Ontario in 2009 did not occur until well into August (C.D.D. and T.S.B., unpublished data), whereas peak flight in Ohio in 2009 occurred during the third week of July (A.P.M., unpublished data). Adults are mostly nocturnal. During the day, adults can be found resting on corn, usually in leaf axils. Female moths mate

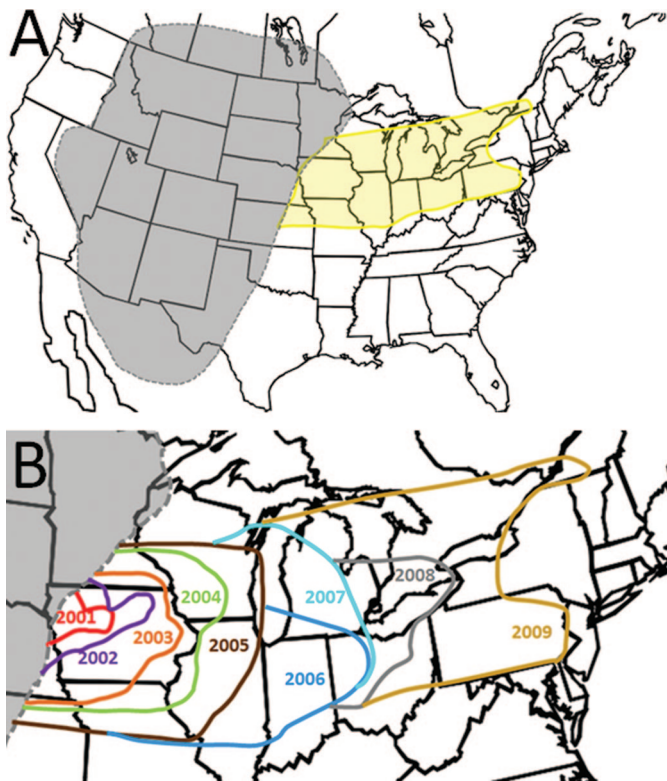


Fig. 1. (A) Historic distribution map (gray shading, Keaster 1999) and range expansion since 2000 (yellow shading) of western bean cutworm. (B) Detailed expansion in the eastern Corn Belt 2000–2009.

Table 1. Date of first western bean cutworm detection during eastward expansion since 1999

State/Province	Date	Source
Minnesota	1999	(O'Rourke and Hutchison 2000)
Illinois	2004	(Dorhout and Rice 2004)
Missouri	2004	(Dorhout and Rice 2004)
Wisconsin	2004	(Cullen 2007)
Indiana	2006	(Dorhout and Rice 2008)
Michigan	2006	(DiFonzo and Hammond 2008)
Ohio	2006	(DiFonzo and Hammond 2008)
Ontario	2008	(Baute 2009)
Pennsylvania	2009	(Baute 2009)
New York	2009	(Baute 2009)
Québec	2009	(Baute 2009)

and lay eggs in July and August. An individual female can lay between 84–627 eggs, and the average per female has been estimated at 321 (Douglass et al. 1957) to 407 (Blickenstaff and Jolley 1982). Oviposition occurs on a variety of cultivated and wild plants, although dry beans and field corn are the most commonly chosen oviposition sites (Blickenstaff and Jolley 1982). Cornfields in the late whorl stage are preferred by female moths seeking to lay eggs on plants that are near, but not past, tasseling (Seymour et al. 2004). When the corn crop is pollinating, moths prefer to oviposit in dry beans where the crop is available (Blickenstaff and Jolley 1982). There is one generation per year.

Eggs. In corn, eggs are laid on upper surfaces of leaves, often on newly unfolded, vertically oriented whorl leaves (Seymour et al. 2004, C.D.D., unpublished data). In dry beans, eggs are laid on the undersides of the leaves, deep within the crop canopy (Hoerner 1948, Blickenstaff 1983). Eggs are laid in masses of 5–200, but usually average around 50 (Seymour et al. 2004) (Figs. 3 and 4). Eggs are white when first deposited (Fig. 4) and become tan and pink as eggs

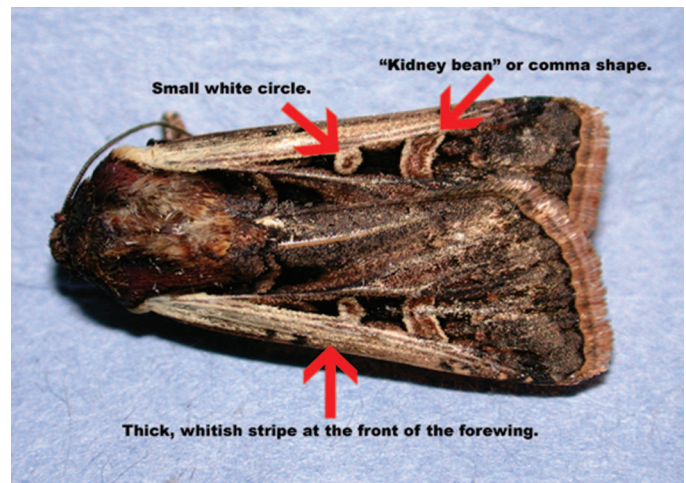


Fig. 2. Western bean cutworm adult moth and identifying characteristics. (J. Obermeyer)



Fig. 3. Western bean cutworm egg mass on an upper leaf of a pretassel corn plant (marked by black circle). (J. Obermeyer)

develop (Fig. 5). In about a week, eggs become purple, indicating that hatch is imminent, usually within 24–48 hours (Fig. 6). Total time of development from oviposition to larval emergence is 5–7 days (Douglass et al. 1957, Seymour et al. 2004).

Larvae. After hatch, first instars consume their eggshells (Fig. 7), making posthatch scouting for empty egg masses difficult. In pretassel and tasseling corn, some of the newly hatched larvae crawl upward to the tassel (Fig. 8) and tassel leaf axil to feed on pollen, whereas other larvae remain in central leaf axils feeding on fallen anthers or pollen, or move down into the silks, if available (DiFonzo 2009; Fig. 9). As pollen shed ends and the tassel dries, larvae at the top of the plant move downward and concentrate in the ear zone. Larvae enter at the ear tip (Fig. 10) or through the side of the ear (Fig. 11) to feed on developing kernels. In dry beans, young larvae feed on leaf tissue and



Fig. 4. Freshly laid western bean cutworm egg mass next to pollen and anthers from the tassel. (J. Obermeyer)



Fig. 5. Developing western bean egg mass. Note the tan and pink hue. (J. Obermeyer)



Fig. 6. Purple western bean cutworm eggs signal imminent egg hatch. (J. Obermeyer)

flowers (Fig. 12) and large larvae chew through pods to feed directly on developing beans (Fig. 13) (Seymour et al. 2004). Larger larvae feed at night or on cloudy days in the bean crop. During the day, they hide in the soil at the base of the plant, making scouting for larvae difficult (Hoerner 1948).



Fig. 7. Newly emerged western bean cutworm larvae consuming egg shells. (J. Obermeyer)



Fig. 8. Injury on developing tassel from western bean cutworm larva. (C. DiFonzo)

Newly hatched larvae are dark with black heads. Their color lightens to a light tan or pink with subtle longitudinal stripes as they develop (Fig. 14). After the fourth instar (13–38 mm or 0.5–1.5 in long; see Table 2), larvae are readily identified by two black rectangles or stripes behind the orange head, and a generally smooth skin or cuticle (i.e., lacking tubercles, warts, or bumps). Detailed information on western bean cutworm development is lacking. Douglass et al. (1957) reported complete larval development, from first to fifth instar, in 22 days, although they did not specify base temperature, degree-days, or host plant. Antonelli (1974) reported that larvae on dry beans, under field conditions, completed development through the sixth instar in 43–70 days, with an average of 55.9 days. A substantial overlapping of instars was observed, even from the same egg mass. In a corn study in Michigan, only one-third of a sampled population was in the sixth instar, 28 days after hatch and 514 growing degree-days (GDD base 50°F) (DiFonzo 2009). There are six, or rarely seven instars (Antonelli 1974), with the last stage the most conspicuous and often found feeding on mature corn ears. Entry holes on the sides or



Fig. 9. Three western bean cutworm larvae of various sizes in a leaf axil. (J. Obermeyer)



Fig. 10. Late-stage western bean cutworm larva feeding near ear tip. (J. Obermeyer)



Fig. 11. Western bean cutworm larva entering side of ear by chewing through husk. (R. Hammond)

tips of ears and/or frass are not always visible, so scouting for larvae must include removing husks from multiple ears in different areas of the field. Larvae move readily within and across rows, so feeding may be found on an ear even if larvae are not present. Infestations are very patchy within or across rows, and several larvae may be present in a



Fig. 12. First instar western bean cutworm feeding on a dry bean leaf. (C. DiFonzo)

single ear. Unlike corn earworm, *Heliothis zea* (Boddie), western bean cutworms are not cannibalistic.

Pupa. In late summer and early fall, sixth-stage larvae drop off the plant and burrow into the soil where they construct earthen chambers using salivary gland secretions (Fig. 15). Burrowing depth is usually 12–25 cm (5–10 in) (Seymour et al. 2004), with an average of 21.6 cm (8.5 in) (Douglass et al. 1957). Sandier soils allow larvae to penetrate deeper into the soil profile, providing greater protection from winter temperatures and tillage equipment, and thereby increasing overwintering survival. The insect remains in a quiescent state (prepupa) throughout the winter, then pupates and completes development early in the following summer.

Injury, Scouting, and Management Options in Corn

Injury. Oviposition and subsequent injury often are patchy from field to field, primarily because of the variation in crop stages across the landscape. Although >20 larvae have been recorded on a single ear (Seymour et al. 2004), there is considerable plant-to-plant movement early in development, which results in infestation of neighboring plants. Larvae from one egg mass can disperse 2–3 m (6–10 feet) from the original plant where they hatched (Seymour et al. 2004). Feeding occurs on tassels and silks but does not seem to inhibit pollination significantly, except when infestations are heavy (NC-IPM Center 2005). Most feeding is concentrated on the ear (Fig. 16A); larvae feed directly into kernels on the ear tip (Fig. 16B) or side, or ‘scrape’ kernels along the side of the ear (Fig. 16C). Yield studies conducted in Iowa and Nebraska showed that an average of one larva per plant throughout the field caused yield loss of 3.7 bushels per acre (Appel et al. 1993, Seymour et al. 2004). Extremely heavy infestations in Colorado resulted in 30–40% yield loss (NC-IPM Center 2005). In addition, ears with damaged tips and holes in the husk are prone to mold and other fungi, decreasing grain quality (Fig. 17) (Hagen 1962). At harvest, many entrance and exit holes may be noticed in dry husks, but these holes are not readily distinguishable from holes made by corn earworms and are not diagnostic on their own. However, the presence of husk damage often is the first indication of a western bean cutworm infestation in fields.

Trapping for Adults. Monitoring for western bean cutworm adults is recommended for timing when to scout for eggs and larvae. Methods involve either black light or pheromone traps. Black light traps were used historically in the western Great Plains states (Hagen 1976, Mahrt et al. 1987). Although reliable for catching western bean cutworm adults, black light traps are expensive and bulky, and their operation depends on a power supply, which limits their use (Mahrt et



Fig. 13. Western bean cutworm injury to developing dry beans in the pod. (C. DiFonzo)

al. 1987). Additionally, they catch many unwanted insects, which can make counting western bean cutworms difficult. A comparison among black light traps and two pheromone trap types showed no significant differences in counts (Mahrt et al. 1987). For most applications, pheromone traps are a better option for monitoring for adults.

The types of pheromone traps used to monitor western bean cutworms include wing traps and milk jug traps, but there seems to be no difference in trap performance between the two types of traps (Mahrt et al. 1987, Dorhout and Rice 2008). The most common and cost-effective trap uses a clear plastic, 1-gallon milk jug (Fig. 18A). Openings are cut on all four sides, leaving a 5 cm (2 in) reservoir to hold preservation liquid (explained below). The trap is attached to a fence stake and placed on the edge of the field (Seymour et al. 2004). One trap per cornfield is recommended. Trap height should be at least 1.2 m (4 feet) (Dorhout and Rice 2008). As in many pheromone-based trapping systems, trap catch is improved by positioning the trap so that



Fig. 14. Early western bean cutworm instars (left) lack the identifying black rectangles that develop on older larvae (right). (J. Obermeyer)

prevailing winds can move through the openings and spread the pheromone plume into the field (Mahrt et al. 1987, Dorhout and Rice 2008). In addition, placing traps in a host plant (e.g., corn) environment rather than in a corn-soybean or a more heterogeneous environment may slightly improve effectiveness (Dorhout and Rice 2008). However, consideration must be given to placing the trap in an area that encourages consistent monitoring.

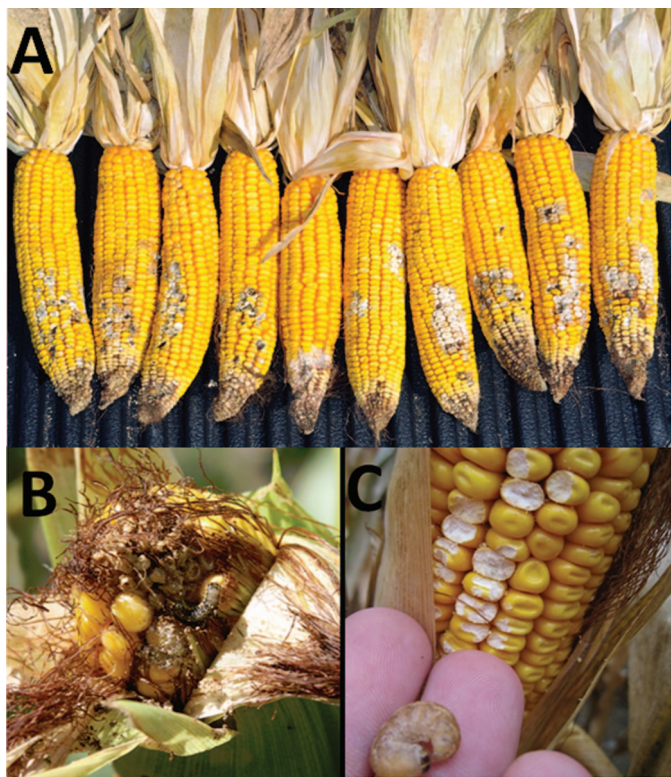
Each milk jug trap is filled to a depth of up to 5 cm (2 in) with 4:1 mixture of ethylene glycol (antifreeze) and water solution, with a few drops of liquid soap added to decrease surface tension. The antifreeze prevents liquid evaporation and helps preserve the moths. The pheromone lure, a sex pheromone that attracts only male moths, is attached to a bent paper clip (Fig. 18B) and hung on the inside of the lid. The cap is replaced to suspend the lure over the solution. The lures are changed every 3 weeks, and the fluid may need to be changed at least once a week. Note that extreme care should be taken to ensure that the trap is placed securely and out of the reach of children and animals because ethylene glycol is highly toxic, even in very low concentrations.

The beginning of moth flight varies depending on location. Historical studies in the western Great Plains revealed that moths were rarely collected before July, whereas moths were collected as early as June 18, 2007 in Iowa (Rice 2007) and June 19, 2009 in Ohio (A.P.M., unpublished). However, traps deployed by late June should efficiently catch adults such that peak flight can be estimated. Each trap should be inspected at least weekly, but if large numbers of moths are caught, it is advisable to check and empty traps more frequently. Moth flights usually taper off by the end of August or mid-September. Traps should stay up until no moths are caught for at least two consecutive weeks.

Scouting in Corn. Corn plants should be inspected for western bean cutworm eggs and larvae after moths are detected. Rice and Pilcher (2007) recommended that scouting should be initiated when 25% of adults have emerged (1,319 GDD at base 50°F). However, recent anecdotal reports suggest that correlations of moth emergence to degree-days may not be consistent in the Northeastern Great Lakes region. Because of this and because degree-day data may not be readily accessible in all regions, scouting should begin when moths are collected on consecutive nights and with increasing frequency (Rice and Pilcher 2007). Initially, monitoring efforts should focus on pretassel cornfields that are just beginning to or soon will shed pollen. Pretassel fields are preferred by gravid females for oviposition. As tassels in early developing cornfields emerge and dry, female moths may seek later-developing cornfields or dry beans for oviposition. Unfortunately, although pheromone traps are good predictors of western bean cutworm presence, they are poor predictors of potential damage to corn (Mahrt

Table 2. Measurements of western bean cutworm instars (Antonelli 1974)

Instar	Larval body		Larval head
	Length (mm/in)	Width (mm/in)	Capsule width (mm/in)
First	1.9–3.3/0.07–0.13	0.3–0.5/0.01–0.02	0.3–0.5/0.01–0.02
Second	3.6–7.5/0.14–0.29	0.6–1.1/0.02–0.04	0.5–0.8/0.02–0.03
Third	8.2–11.5/0.32–0.45	1.1–1.4/0.04–0.05	0.8–1.0/0.03–0.04
Fourth	16.0–19.2/0.62–0.75	2.1–2.4/0.08–0.09	1.1–1.7/0.04–0.07
Fifth	19.0–27.2/0.74–1.05	3.0–3.6/0.12–0.14	1.8–2.5/0.07–0.10
Sixth	28.0–37.1/1.09–1.45	5.0–5.7/0.20–0.22	2.7–4.1/0.11–0.16

**Fig. 15.** Western bean cutworm prepupa in an earthen cell, found nine inches (23 cm) deep in sandy soil. (J. Obermeyer)**Fig. 17.** Mold growth in ears fed on by western bean cutworm. (J. Obermeyer)**Fig. 16.** (A) Range in severity of ear injury caused by western bean cutworm larvae (J. Obermeyer); (B) Ear tip feeding (R. Hammond); (C) Injury caused by “scraping” of kernel. (K. Currah)

et al. 1987), which is true for many caterpillar pests. Therefore, it is important to scout for egg masses when moth flight is detected and numbers are increasing in the pheromone traps.

Scout cornfields for eggs and larvae by examining the upper surfaces of new and not-yet unfolded leaves of plants (usually the top three leaves) in multiple areas of the field. A minimum inspection should consist of 20 consecutive plants in at least five locations in a field. Infestations are very patchy, and oviposition occurs over several weeks, so multiple field visits may be required. Fields with uneven growth stages or planted with different hybrids (e.g., a refuge block) should be inspected thoroughly, given the preference of western bean cutworm females for pretassel corn. Eggs can sometimes be spotted on sunny days by looking for shadows on the leaf surfaces (Fig. 19). Upper leaf axils, tassels (before pollen shed), and silks should also be examined for young larvae. Newly hatched larvae consume their egg shells, so egg masses are difficult to find after hatch. In addition, small larvae often are very difficult to find on plants, especially after the larvae enter whorls or ears, so both scouting and the insecticide treatment window are largely restricted to the period leading up to egg hatch.

Management: Foliar Insecticides. Managing western bean cutworms in corn is challenging because of their patchy distribution, cryptic nature, and protected feeding behavior. Monitoring for adults and early detection of egg masses and larvae are critical for proper timing of application of foliar insecticides. Many insecticides kill young larvae, but it is difficult to ensure that the larvae will encounter a lethal dose before they enter the ears. Data on treatment thresholds is somewhat limited because of the recent emergence of western bean cutworm as a serious pest of corn across the Corn Belt. Appel et al. (1993) recommended an economic threshold of 33 eggs per plant, but counting the number of eggs per mass is difficult in the field. Alternatively, extension entomologists and private crop consultants recommend a nominal threshold of 5–8% of plants with an egg mass or larvae (Wright et al. 1992, Seymour et al. 2004, NC-IPM Center 2005, Rice and Pilcher 2007; Krupke et al. 2009). To date, no side-by-side comparison of these thresholds has occurred, but the most often used

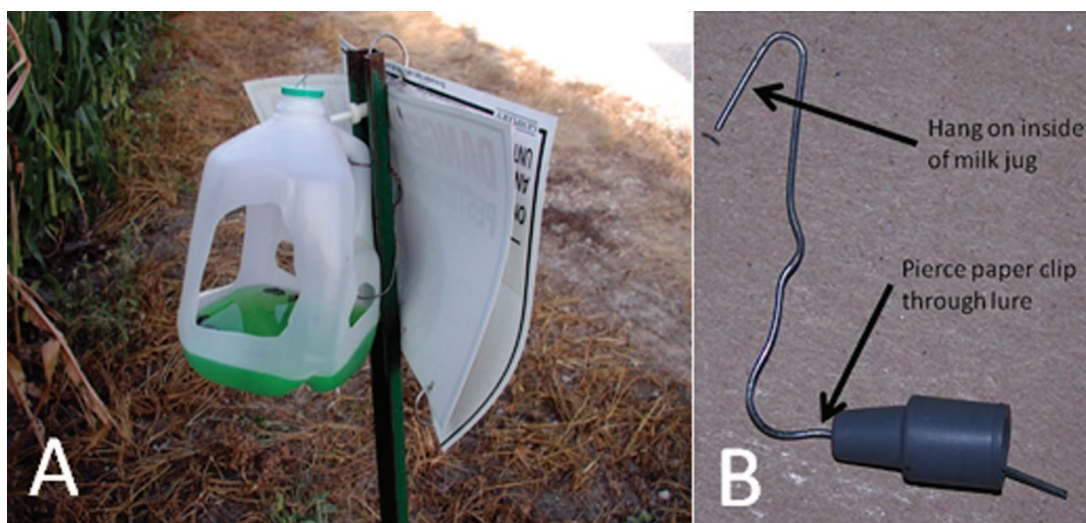


Fig. 18. (A) Milk jug pheromone trap for western bean cutworm (M. Rice); (B) Lure and paper clip for placement in milk jug. (A. Michel)



Fig. 19. Western bean cutworm eggs appear as shadows on upper surface of leaf. (C. DiFonzo)

threshold is the 5–8% infestation threshold. As corn prices increase (e.g., corn for ethanol production) or damage thresholds are reduced (e.g., corn for silage) in response to regional market pressures, this threshold may be adjusted downward. Furthermore, thresholds may need to be adjusted downward in the eastern range of the western bean cutworm because of the potential for increased survival of eggs and larvae in higher humidity. In the western states, the recommended timing of insecticide application is when 90–95% of tassels have emerged. If tassels have already emerged and larval hatch is underway, treatment is recommended when 70–90% of larvae have hatched from eggs. Effective control occurs only when larvae encounter the insecticide before entering the ear. After the larvae enter the ears, they are protected from insecticides, making control nearly impossible. In years with widespread delayed planting or slow crop development, infestations in whorl-stage cornfields can occur, and feeding on the unemerged tassel has been observed (T.S.B. and C.D.D., unpublished data). Very little is known about survival of western bean cutworms on whorl-stage corn and whether thresholds should be adjusted accordingly.

For corn, pyrethroids are the most effective and commonly recommended insecticides for control of western bean cutworm. However, other pests and beneficial insects in the field should be considered before application of these broad-spectrum insecticides. For example, the use of pyrethroids in corn can increase the risk of outbreaks of spider mites (*Tetranychus urticae* Koch), as these chemicals are ineffective for spider mite control.

Management: Cultural Methods. Seymour et al. (1998) listed a few cultural practices for control of western bean cutworm but cautioned that none offer reliable control. Because the period of adult emergence and oviposition is so long and the environmental factors are too variable, adjusting planting dates as a way to avoid crop injury is not effective (Douglass et al. 1957). Deep soil disturbance through tilling may cause mortality of overwintering western bean cutworms, but no studies have directly tested the impact on larval survival. Furthermore, western bean cutworms overwinter at different average depths in different soil types, so the optimal depth of tilling to obtain significant mortality may differ across the landscape. It has been theorized that the increasing prevalence of reduced tillage (and the associated increase in larval survival) partially explains the range expansion of western bean cutworm. A reversal of these trends is neither likely nor advisable given the scarcity of information available about the viability of this practice and the agronomic benefits of reduced tillage and soil conservation.

Management: Transgenic Corn. There are options for control of western bean cutworms with transgenic corn containing *Bacillus thuringiensis* proteins. However, not all Bt hybrids control western bean cutworm. Hybrids with Cry1A, Cry1Ab, or Cry2Ab proteins, which protect against European corn borer, *Ostrinia nubilalis* (Hübner), have no activity against western bean cutworm. Only Bt corn hybrids that express the Cry1F protein offer effective control of western bean cutworm. For example, Catangui and Berg (2006) reported no infestation of western bean cutworm in ears of plants expressing the Cry1F protein in South Dakota in 2003, whereas ears of plants expressing the Cry1Ab protein had infestations ranging from 7.5 to 57.5%. Hybrids that express the Cry1F protein are marketed under the Herculex I, Herculex XTRA, and SmartStax brands, and provide control generally equal to a well-timed insecticide application. However, recent data indicate that even the Cry1F protein does not provide complete control (Eichenseer et al. 2008). In an Iowa field study, 76 and 62% of ears were damaged in non-Bt corn and in corn expressing the Cry1Ab protein, respectively (NC-IPM Center 2005). Ear damage was significantly less in corn expressing the Cry1F protein, but was still 24%. Thus, although corn expressing the Cry1F protein offers good control of western bean cutworm, feeding on these hybrids can, and does,

occur in field situations. Damaged ears may still be infested with quality-reducing mold and fungi (Fig. 20), which may be a more serious problem than the damage itself, particularly in areas where corn is used to feed livestock.

Additionally, fields of Bt-corn must contain refuge areas of non-Bt corn. These refuge areas are not protected against western bean cutworm, and therefore must be scouted for egg masses and larvae to determine damage potential. If an insecticide application is warranted, the placement of the refuge in a separate block, rather than in rows, allows for separate management and a reduction in the cost of the application. In addition, the use of Bt corn solely for western bean cutworm control (i.e., hybrids expressing the Cry1F gene) is a prophylactic measure that should only be employed in areas with a high probability of larval damage, or the return on investment would be minimal.

Management: Biological Control. Lady beetles (Coccinellidae), pirate bugs (*Orius* Wolff spp.), lacewing (Chrysopidae) larvae (Fig. 21), and predacious ground beetles consume eggs and/or early stage larvae of western bean cutworms (Seymour et al. 2004). Later-stage larvae and prepupae are vulnerable to predation by birds and ground-dwelling vertebrates (e.g., raccoons, skunks, Krupke et al. 2009), although these vertebrate predators may also cause significant damage to the crop itself. Western bean cutworm is also prone to infection by a microsporidium, *Nosema* spp. (Seymour et al. 2004), although research into this pathogen as a population control regulator is lacking. Although it is unlikely that natural enemies can prevent western bean cutworm populations from reaching pest status in all fields, it is important to recognize their potential to reduce larval numbers without use of insecticides.

Injury, Scouting, and Management Options in Dry Beans

Injury. Oviposition and damage often are patchy in dry bean fields. Dispersal of larvae from one egg mass can be as much as twice the distance typically reported in corn, but movement still tends to be greater within rows than across rows (Blinkenstaff 1983). Injury begins as leaf feeding (Fig. 12), which does not reach economic levels. After maturing to the third instar, larvae begin feeding on the outside of the pods and chew into pods to feed on the developing beans. Entry holes on the outside of the pod (Fig. 13) allow for the introduction of fungi and bacteria, which compromise bean quality. Direct feeding on beans can cause yield loss by reducing pounds harvested. Quality also is affected because of the presence of partially chewed beans large enough to make it through the combine (Fig. 22). These damaged beans often are shrivelled and moldy, and time and money must be expended to separate them from healthy, whole beans. As few as 2%



Fig. 20. Western bean cutworm injury on Herculex XTRA corn expressing Cry1F Bt protein. (K. Currah)



Fig. 21. Lacewing larva feeding on western bean cutworm eggs. (C. DiFonzo)



Fig. 22. Dry bean culls fed on by western bean cutworm compared with noninjured beans. (C. DiFonzo).

partial culls ('pick') can result in down-grading of the beans (Antonelli and O'Keeffe 1981, Blinkenstaff 1979) (Fig. 22). Heavy damage can result in entire loads being rejected. Because dry beans are harvested early in the fall, larvae may still be present when plants are pulled and piled into windrows. These larvae can make it through the combine into trucks, bean cleaning facilities, and bins. Even direct-harvested beans may be contaminated with larvae. However, larvae cannot survive or overwinter in bins.

Trapping for Adults. The milk jug pheromone traps described previously may be used, but two traps should be positioned on opposite ends of each bean field. Trap height is the same as recommended for corn, with placement of the trap along the field's edge in dense vegetation such as beans, alfalfa, or low-lying weeds along the field edge.

Scouting. Scouting for egg masses and larvae in dry beans is extremely difficult. Egg masses typically are laid on the undersides of leaves, deep in the canopy, and larger larvae hide the soil surface

during the day. Thresholds for dry beans are based on the number of larvae per foot of row. However, the difficulty of finding larvae compromises the reliability of these thresholds (Seymour et al. 2004, C.D.D., unpublished data). In the western U.S., Mahrt et al. (1987) found a closer relationship between trap counts and pod and bean damage than for corn. Based on this relationship, pheromone traps are used to determine the number of moths present and time of peak moth flight, followed by scouting to confirm feeding injury and optimum spray timing. The threshold (700 or more moths) is based on the average number of moths accumulated per trap before peak flight. Peak flight is defined as the date after which moth populations start to decline from the previous week's counts. After peak flight has occurred, scouting for both leaf feeding and pod injury is recommended. Insecticides should then be applied ≈ 10 –21 days after peak flight if numbers of moths captured reach the threshold. Injury to pods typically occurs ≈ 3 weeks after peak moth flight. However, this management recommendation does not seem to fit as well in the Great Lakes Region where injury to pods and beans occurs at a much lower accumulated moth catch.

Management: Foliar Insecticides. Recent experience in Michigan indicated the need for revisions to the current thresholds developed by Seymour et al. (2004) to accommodate conditions in the Great Lakes Region. A nominal threshold of one larva per foot of row (two larvae per foot of row in irrigated fields), developed in caged beans, is recommended in the western U.S. (Seymour et al. 2004). In Michigan, preliminary data from small, open plots infested by hand showed that four larvae per foot resulted in greater pod damage, and two to four larvae per foot resulted in greater bean damage, when compared with noninfested plots (Jewett et al. 2009a). However, scouting for larvae is difficult because they hide the soil surface during the day (Peairs 2008; C.D.D. and T.S.B., unpublished data). Preliminary data, also from Michigan, showed that as few as one egg mass per 5 feet of row resulted in 20 and 2% of pods and beans damaged, respectively (Jewett et al. 2009b). However, egg masses also are difficult to detect in a dense dry bean canopy.

A more commonly used threshold in the western U.S. is based on milk jug pheromone traps to determine the accumulated moth catch before peak moth flight. An average accumulated catch of fewer than 700 moths per trap indicates that the field is at a very low risk of experiencing damage. An average accumulation of 700–1,000 moths per trap indicates that the field is at moderate risk and that scouting is required to determine whether significant feeding is taking place. An average accumulation that exceeds 1,000 moths per trap suggests a high risk. Scouting is recommended in these high-risk fields to determine the level of feeding and larval infestation, although larvae are difficult to detect. If pod feeding is observed, chemical control is recommended (Mahrt et al. 1987, Seymour et al. 2004). In the Great Lakes Region, thresholds based on captures of moths in traps are not effective for predicting the potential for economic injury (C.D.D., unpublished). Fields with traps that had an accumulation of fewer than 120 moths per trap by peak flight still had yield loss and quality issues with up to 5% culls or pick (Varner 2009).

Although research is underway to develop thresholds that are better suited for dry bean production in the Great Lakes Region, traps for monitoring moth flight are still important for determining which fields to target for scouting. In addition, scouting adjacent cornfields for egg masses, an easier task than scouting for egg masses in dry beans, can also give an indication of local population levels. If the western bean cutworm population in a cornfield has reached a threshold level of egg masses, dry bean fields immediately adjacent to the cornfield may also be at risk, particularly as the neighboring corn becomes less attractive to egg-laying females. These bean fields would be high-priority candidates for scouting. If pod feeding is observed, chemical control is recommended.

Pyrethroids are the most effective insecticides for control of western bean cutworm in dry beans. In dry beans, insecticides applied at

planting (Temik and Thimet), as well as seed treatments (Cruiser) for leafhopper control, did not last long enough to provide any reduction in cutworm infestation in August (Jewett et al. 2009c). Some dry bean varieties were reported to be resistant to western bean cutworm (Antonelli and O'Keefe 1981, Seymour et al. 2004), but these varieties were not well-suited for commercial production. In addition, in a variety trial in Michigan in 2009 with a natural infestation of western bean cutworms, the percentage bean pick varied among varieties, but all varieties had some level of injury (G. Varner, Research Director, MI Dry Bean Research Board, unpublished data).

In conclusion, before 2000, western bean cutworm was a serious concern for dry bean and corn production only in the western Great Plains. Over the past nine years, this pest has rapidly expanded its range to within 200 km (125 miles) of the Atlantic Coast for reasons that remain unclear. This range expansion has placed many new areas of U.S. and Canadian corn and dry bean production at risk and may also affect eastern vegetable production. To counterbalance this risk, significant educational efforts have been coordinated by university and government extension services, crop consultants, and private industry focusing on identification, scouting, and IPM recommendations. This massive education campaign resulted in extensive surveys that tracked western bean cutworm expansion and alerted producers of its presence. However, current management recommendations are based on only a few studies that were conducted primarily in drier, western states and that predate the eastward expansion of this pest. Environments, growing conditions, and crop production practices differ significantly across the expanded western bean cutworm distribution, ranging from the more arid, warmer areas of Nebraska to cooler, humid, snow-belt areas of Michigan and Ontario. The impact of different environmental conditions on life histories, survival, and, ultimately, the damage potential of this pest is unknown. Validations of thresholds in both dry bean and corn production are sorely needed to ensure proper management of western bean cutworms, especially in the eastern part of its range.

Acknowledgments

We thank John Obermeyer (Purdue University), Ron Hammond (OARDC, The Ohio State University), and Ken Currah (Pride Seeds, Chatham, Ontario) for providing photographs. We also acknowledge the efforts of extension personnel, agribusiness representatives, and growers in Indiana, Michigan, Ohio, Ontario, and Pennsylvania for assistance with the western bean cutworm trapping network. J. Tooker (Pennsylvania State University), K. Waldron (Cornell University), and Michele Roy (MAPAQ) provided trapping information from Pennsylvania, New York, and Québec, respectively. Funding for trapping was provided by North Central IPM Center (Ohio), Corn Marketing Program of Michigan (Michigan), Grain Farmers of Ontario, Ontario White Bean Producers (Ontario and Québec), and The Pennsylvania Corn Growers Association (Pennsylvania).

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Received 1 February 2010; accepted 16 June 2010.