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Western Bean Cutworm (Lepidoptera: Noctuidae) Feeding and Development on Industrial Hemp in the Laboratory and Field

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Abstract

The western bean cutworm (*Striacosta albicosta* (Smith)) is a key pest of corn (*Zea mays* L.) and dry beans (*Phaseolus vulgaris* L.). This observational study demonstrates that in addition to these hosts, western bean cutworm readily feeds on industrial hemp (*Cannabis sativa* L.) and completes development on it under controlled laboratory conditions. In the laboratory, individual larvae were reared on a diet exclusively of hemp inflorescences; 57% survived to form prepupae and 15% emerged as moths. In the field, first instars were caged on hemp plants to investigate larval development in situ. After seven days, 82% were recovered as third instars, the majority of which were found in the plant canopy. At 14 and 21 days, later-instars were increasingly recovered under residue or in the soil during daytime hours but were observed crawling and feeding in the canopy at night. This pattern of behavior is similar to western bean cutworm larvae on dry beans. Additional work is needed to document that western bean cutworm females recognize and oviposit on hemp, and that larvae infest and complete development on the crop under open field conditions.

Keywords: western bean cutworm, *Striacosta albicosta*, hemp, *Cannabis sativa*

The western bean cutworm (WBC), *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae), is native to the western plains of the United States. In that region in the mid-1900s, it was reported as an economic pest of dry beans (*Phaseolus vulgaris* L.) and field corn (*Zea mays* L.) (Hoerner 1948, Douglass et al. 1957). It completes development from egg to adult on both crops (Blickenstaff 1979, Blickenstaff and Jolley 1982). Females lay eggs on the leaves of these hosts, then larvae develop through six instars over a period of roughly 30 days (Smith et al. 2019). Small larvae may feed briefly on leaves, but higher-nutrition reproductive tissue is required for normal and complete development (Paula-Moraes et al. 2012). On corn, larvae feed on tassels and silks, then move into the ear to feed on kernels until the last instar (Smith et al. 2019). On dry beans, larvae initially feed in blossoms and on developing pods. Then they behave as a climbing cutworm until maturity, hiding in crop residue or cracks in the ground during the day and moving up plants at night to feed on beans in pods (DiFonzo et al. 2015). In the fall, sixth instars burrow into the ground and overwinter as pre-pupae in earthen chambers. Moth flight starts in June, peaking in mid-summer (Smith et al. 2018).

There is limited evidence that WBC completes development on hosts other than corn and dry beans. A small laboratory study in the 1950s reported development on fruits of tomato (*Lycopersicum esculentum* Mill.), as well as feeding on groundcherry (*Physalis* sp.) fruits and nightshade (*Solanum nigrum* L.) berries if larvae were first fed on corn or beans (Blickenstaff 1979). But in a larger laboratory study, Blickenstaff and Jolley (1982) reported that survival on tomato, groundcherry, and nightshade alone was poor, calling them "almost totally unsuitable hosts". In the same study, larval survival on broad bean (*Vicia fabae* L.), pea (*Pisum sativum* L.) and cowpea (*Vigna sinensis* L.) was comparable to that on dry beans. In laboratory assays in Michigan and Ontario, a high proportion of larvae survived to 28 days on cucumber, gladiolus, gourd, and squash (Chludzinski 2013). However, none of these studies continued beyond the larval stage to document a complete life cycle. Furthermore, WBC is not known to feed on any of these crops in the field.

In the last 20 years, WBC rapidly expanded eastward out of its original range, reaching the Canadian Maritime provinces by 2017 (Smith et al. 2019). In parts of this expanded range, especially the Great Lakes region, it is now a key pest of corn (Smith et al. 2018) and dry beans (DiFonzo et al. 2015). Across this expanded range, a new crop is being planted: industrial hemp (*Cannabis sativa* L. with <0.3% THC/tetrahydrocannabinol, as defined by Small and

Cronquist 1976). Hemp was introduced into North America from Europe in the 1600s; it remained an important fiber crop into the early 1900s, with production concentrated in Kentucky and few surrounding states (Cherney and Small 2016). After World War II, cheaper synthetic materials, plus concerns about drug abuse, effectively eliminated it as a crop the United States. The 2014 and 2018 Farm Bills (US Congress 2014, 2018) and subsequent federal rules (USDA-AMS 2019, 2021) allowed for its cultivation again as a source of renewable fiber, grain, and oil. The first commercial plantings in Michigan were in 2019.

Two major lepidopteran pests of corn in the United States are also pests of hemp. Hemp is thought to be an original host of the stalk-boring European corn borer (*Ostrinia nubilalis* Hübner) in Europe (Nagy 1976), prior to the introduction of corn from the Americas. Shortly after corn borer was discovered in the United States in the early 1900s, it was recorded as injuring both corn and hemp (Caffrey and Worthley 1927). Corn earworm, *Helicoverpa zea* (Boddie), is a North American native that damages hemp flowers and seeds. It is reported on hemp in many states, where it sometimes causes serious damage (Britt et al. 2021, Cranshaw et al. 2019). Both corn borer and earworm are polyphagous species with dozens of hosts, and it is no surprise that hemp is among them. In contrast, western bean cutworm has a narrow host range. In its original western range, at least 638 acres of fiber hemp were grown at one point in Nebraska in the late 1800s (US Census Office 1902), and wild cannabis (aka feral hemp or ditch weed) has been an escaped weed in the landscape for over 100 years. There were no historical records of western bean cutworm feeding on hemp, but a simple extension question was 'Is it possible?'. In this observational study, I tested the ability of western bean cutworm to feed and develop on industrial hemp in the laboratory and on caged plants in the field.

Materials and Methods

An initial laboratory feeding study was done in 2019, followed by a second laboratory study plus two field observations in 2020. All work was done on the Michigan State University (MSU) campus in East Lansing, Michigan. The industrial hemp fed in the laboratory and caged in the field was Grandi, a dual-purpose fiber and grain variety. The inflorescences of female plants with new leaves, buds, and seeds were specifically used to feed larvae in the laboratory.

Feeding study, 2019. Leaf disks with WBC egg masses were cut from leaves of pretassel corn in Monroe County on 23 July 2019 and held until eggs turned purple (indicating imminent hatch). On 26 July, several egg masses that were beginning to hatch were placed in a 3.8 l container (Pitcher Classic, Newell Rubbermaid Inc. Atlanta GA). The top 20 cm of a hemp plant (leaves plus buds), collected from the field, was added. The top of the container was covered with a mesh square held in place by a large rubber band and it was left on the lab bench at room temperature (~18–24 °C). Feeding on hemp leaves and buds was first noted on 30 July. Fresh hemp tissue (leaves and buds) was added twice. On 5 August, 10 days after hatch (DAH), 50 third instars were transferred to 32-oz deli cups (Deli-Serve, Novolex Brands, Hartsville SC) (Fig. 1A), two larvae per cup (the remaining larvae were mass reared in 3.8 l containers so they could be handled and photographed). A fresh 15 cm hemp top was put into each cup, then each cup was covered with a mesh square held in place by a rubber band. Cups were left on the lab bench at room temperature and checked daily to clean, note survival, and replace hemp as needed. On 16 August, 8 cm of moistened playground sand was added to each cup to allow last instars to burrow and form prepupae (Fig. 1A). By 26 August (30 DAH), all larvae showed signs of burrowing into the sand, so hemp was no longer provided. Cups continued to be monitored as larvae formed prepupae. All individuals had either died or entered the sand permanently by 29 September.

Cups were left on the lab bench at ~18 °C until 2 December 2019, when they were carefully cut down the side and the sand sifted to check for earthen chambers. Chambers were opened to confirm successful formation of prepupae. Since prepupae were often damaged in this process, they were not saved. The pupae that were found were placed in a cup of vermiculite on the lab bench and checked weekly through early March 2020. Pupae were not checked again until early May 2020 because of Covid 19 work-from-home rules.

Feeding study, 2020. Leaf disks with WBC egg masses were cut from leaves of pretassel corn in Isabella County on 23 July 2020 and held until hatch on 26 July. After a day on small hemp buds, 150 first instars were moved in groups of ten to deli cups. Each cup was covered by a mesh square held in place by a rubber band. These 15 cups were checked daily, and buds were replaced as needed. Cups were cleaned and survivors counted on 30 July, and 5, 10, and 13 August. On 13 August, surviving larvae were moved individually into small souffle cups with lids (SOLO UR55 5.5 oz, Dart Container Corp.) for the rest of the study. Cups were checked daily for survival and to replace hemp as

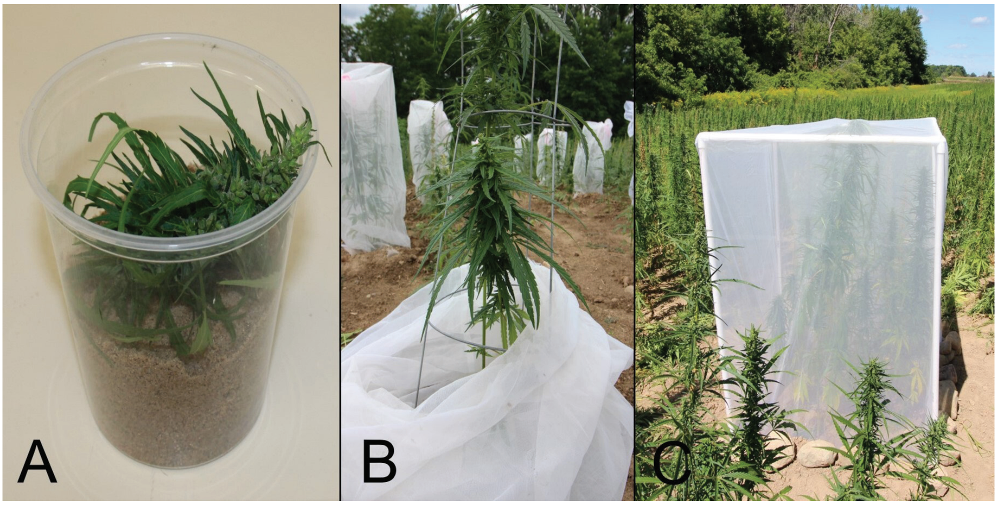

Figure 1. Containers used in western bean cutworm feeding studies on hemp. A. Deli cup used to rear individual larvae in the laboratory; B. Tomato ring covered by a predator-proof mesh sleeve to cage larvae on single plants in the field; C. PVC frame and mesh cube used to cage larvae for night observations.

needed. On 25 August, cups were cleaned, and 4.5 cm of moist vermiculite was added to each. Thereafter, cups were checked daily until 15 September for signs of burrowing into the substrate. Cups were kept on the bench top at ~18 °C and checked approximately weekly for moth emergence into the next year. On 22 March 2021, the vermiculite was carefully tipped out of the remaining cups. Some cups had a dried prepupa in the vermiculite that died prior to forming a chamber, while others had a chamber attached to the bottom of a cup. A small hole was carefully made in the chamber to check for a dead or living prepupa or pupa. Cups with living WBC were kept and checked at regular intervals for moth emergence, until September 2021. At that point, all remaining insects were presumed dead, and chambers were opened to determine if a prepupa or pupa had formed.

Field observations, 2020. In addition to the bench assays, larvae were observed in the field to determine if they fed and developed on plants in situ. On 27 July, after setting up the laboratory feeding study, 12 additional deli cups with a group of ten first instars (120 larvae total) were prepared for the field. The larvae were fed hemp buds in the lab for two days to ensure survival, then on 29 July they were caged on plants in a bulk hemp field planted the first week of June. Twelve female plants with buds, ~1 m in height, were selected for caging. A wire tomato ring was centered over each plant, then covered with a predator-proof mesh sleeve made from a length of tulle netting sewn down one side. The cage was pulled down over the ring and edges covered with soil at the bottom (Fig. 1B). The 10 larvae were carefully moved from the deli cup to the hemp plant using a paint brush, then the cage was tied at the top. Thereafter, a set of four plants was sacrificed on each of three dates: 5, 12, and 19 August (corresponding to 7, 14, or 21 days after infestation). Each cage was opened, then the plant was destructively sampled for larvae from top to bottom, examining plant parts over a white cloth. After each plant was processed, the cage was removed and the ground in and around the ring was examined for larvae, moving soil aside down to four cm. The number of larvae recovered out of the initial 40 (4 cages × 10 larvae), plus their location, was recorded for each date.

A second type of cage was set up to determine if larvae on hemp behaved as on corn (remaining on plants throughout development) or on dry beans (climbing plants at night to feed). On 19 August, a group of 10 hemp plants was covered with a large mesh cage slipped over, and buried at the base of, a 1.5 × 1.5 × 2m PVC frame (Fig. 1C). A square 'door' in the mesh, closed with Velcro, allowed access to the plants. That same day, 10 late-instars, mass reared in a 3.8 l container in the lab exclusively on hemp, were placed on plants in the cage. After five days, on 24 August, the plants and the ground in the cage were visually searched for larvae at 1600 hrs, for ~30 minutes. This process was repeated in the dark the next morning at 0400 hrs, using a red flashlight and then

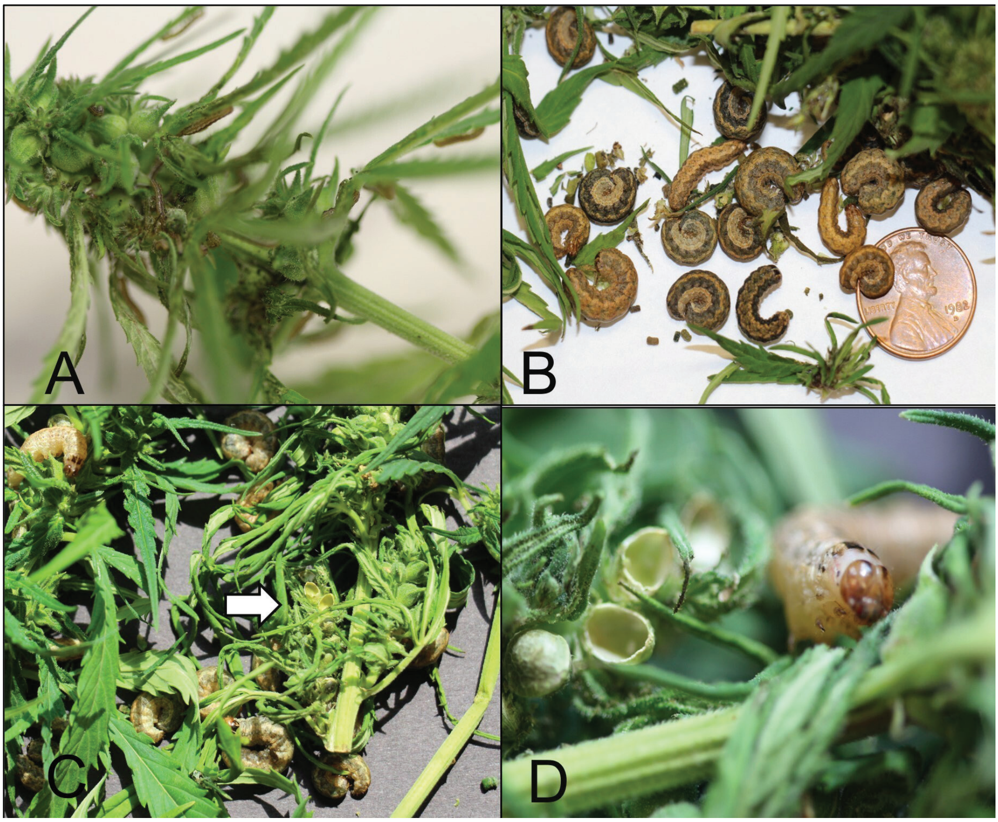

Figure 2. Western bean cutworm larvae developing on hemp in the laboratory. A. First and second instars, four days after hatch (DAH); B. Fourth instars, 15 DAH; C. Fifth instars, 20 DAH, note signs of feeding (arrow); D. Close-up of a caterpillar with damaged seeds.

a blue-light flashlight (GoBe NIGHTSEA light, NIGHTSEA, Lexington, MA) while wearing special 'barrier filter glasses' (FG-RB-2, NIGHTSEA, Lexington, MA). The latter combination makes certain insects fluoresce and stand out from surrounding vegetation (see Woller et al. 2020 for details of this method). Pictures of larvae were taken with an Olympus E-M1 OM-D and 60mm Macro lens using both a regular flash and a yellow lens filter.

Results

Feeding studies. In both lab studies, WBC completed development from first instar to moth on a diet exclusively of hemp. Leaf feeding was observed, but minimal. Instead, feeding by small larvae (Fig. 2A) was concentrated on hemp buds and seeds; these nutritious tissues were likely necessary for long term survival. Later-instars (Fig. 2B, Fig. 2C) appeared to feed exclusively on the reproductive tissues of flowers, buds, and seeds (Fig. 2D), just as they do on corn and dry beans.

In 2019, of the 50 larvae transferred to individual deli cups as third instars, 100% survived to the sixth instar, 30 days after hatch. By December, 46% survived to form prepupae or pupae in earthen chambers. From the three pupae collected at that time, one moth emerged sometime between March and May 2020, completing development from first instar to adult exclusively on a diet of hemp. This specimen was deposited in the AJ Cook Arthropod Research Collection at Michigan State University.

In 2020, of the 150 first instars followed individually, survival to the third and the sixth instar was 93% and 86%, respectively (Fig. 3). By fall, 57% successfully formed prepupae. Twenty-two (15%) eventually emerged as moths (Fig. 4). Moths emerged in November 2020 (n = 16), March 2021 (n = 4), and June 2021 (n = 2). Seven of

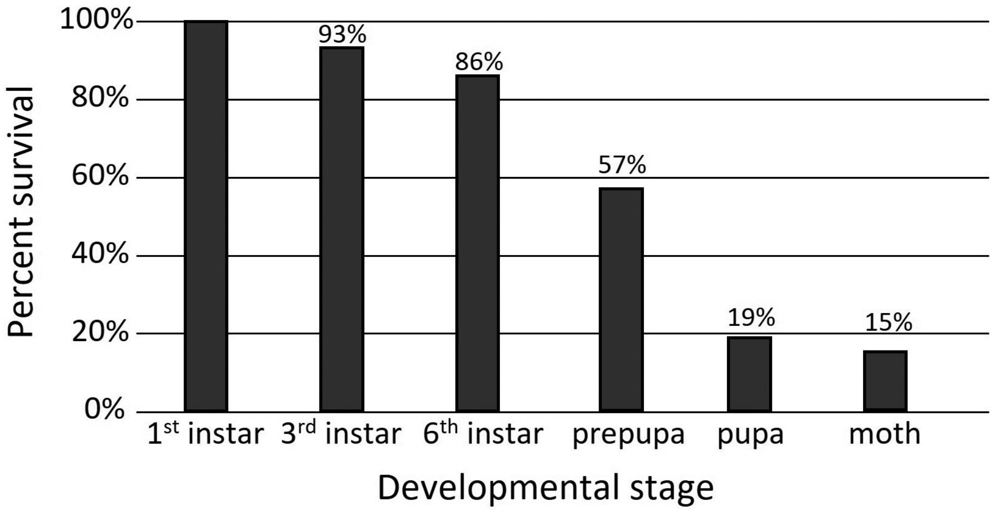

Figure 3. Survival of western bean cutworm larvae, fed exclusively on hemp in the laboratory in 2020, through progressive developmental stages. A total of 150 first instars were followed through moth emergence.

the moths emerging in November (2 males, 5 females) were spread and deposited in the AJ Cook Collection. They appeared to be smaller than 11 voucher specimens—all males from pheromone traps—submitted from previous dry bean field studies (Chludzinski 2013). The wingspan of moths reared on hemp averaged 37.1 mm (range 35–40 mm), 14% less than the average of 43.1 mm (range 40–45 mm) of the dry bean vouchers.

Field observations. Larvae fed and developed on hemp plants in field cages and as they did so, they spent more time on the ground (Fig. 5). Seven days after first instars were caged on individual plants, 33 out of an initial 40 (82%) were recovered

Figure 4. Western bean cutworm moths which completed development exclusively on hemp in the laboratory, emerging November 2020.

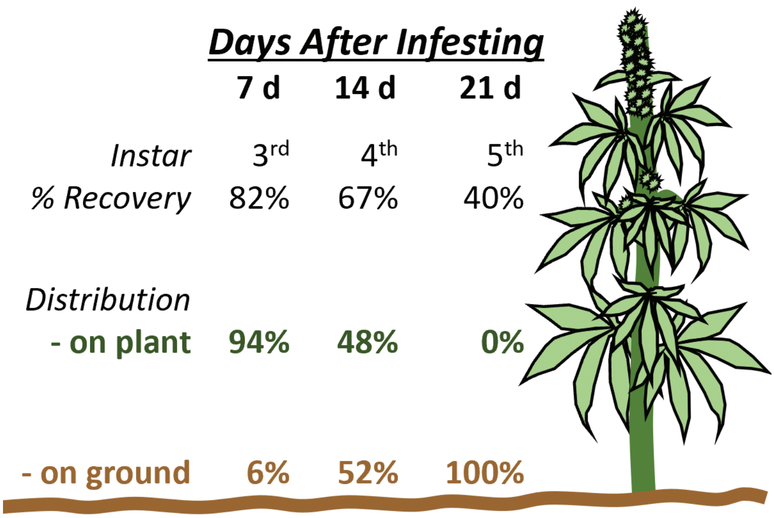

Figure 5. Proportion recovered, instar, and distribution of western bean cutworm larvae 7, 14, and 21 days after infestation of individually-caged hemp plants in the field. Ten first instars were caged per plant and four plants were destructively sampled per date, for an initial total of 40 larvae per timing.

from four sacrificed plants. The majority (94%) of larvae were found in the plant canopy (Fig. 6A). Injury on buds was observed (Fig. 6B) and caterpillars were third instar, indicating that feeding and development had occurred. At 14 days after infestation, 27 of 40 (67%) larvae were recovered from cages. These fourth instars were evenly distributed between the plant canopy and the ground under crop residue. At 21 days after infestation, larval recovery dropped to 40%. No caterpillars were found on caged plants. Those recovered—all fifth instars—were under crop residue or hiding deep in cracks in the soil (Fig. 5), and some may have escaped by burrowing out of the cage.

In the larger PVC-framed cage, no larvae were visually observed on plants or the soil surface at 1600 hrs. However, at 0400 the next morning, larvae were quickly located

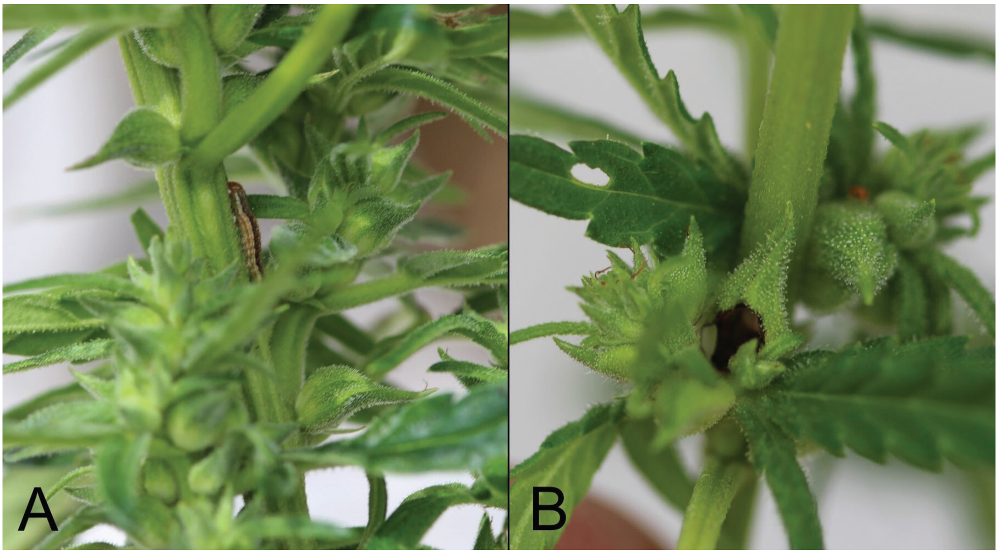

Figure 6. A. Third instar western bean cutworm on hemp in the field, seven days after caging first-instars on the plant; B. Larval injury to a bud on the same plant.

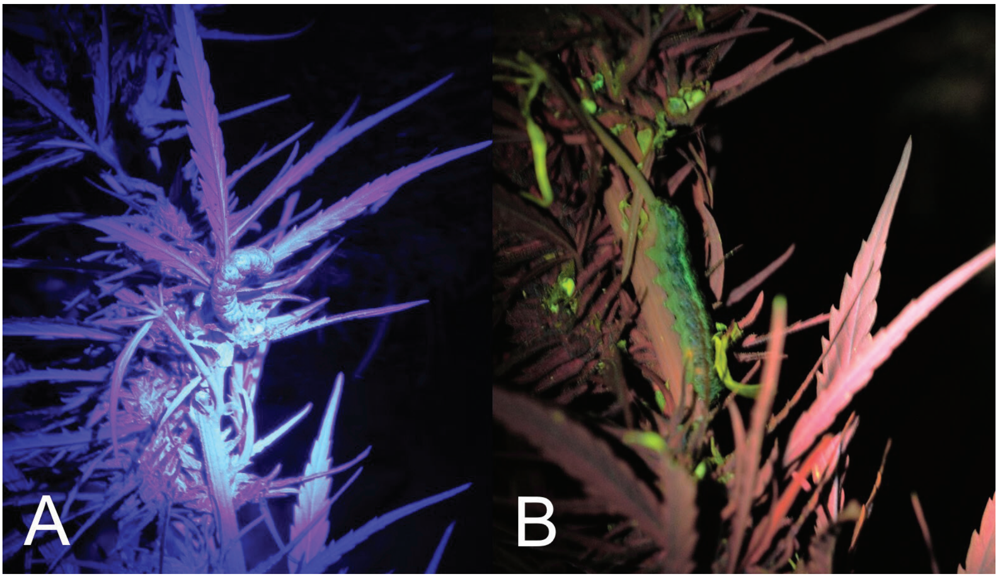

Figure 7. Sixth instar western bean cutworms feeding on hemp at night. Pictures were taken at 0400 hrs on 25 August 2020 with A. an unfiltered lens and regular flash or B. a yellow-filtered lens as larvae were illuminated with a blue-light flashlight (see Woller et al 2020 for details of this method). (Photos courtesy of Gary Parsons, Michigan State University)

in the canopy and observed feeding on buds (Fig. 7A). The blue-light flashlight technique improved detection dramatically, as larvae glowed green against a red background of foliage (Fig. 7B).

Discussion

These preliminary studies showed that western bean cutworm readily fed on industrial hemp in the laboratory and in field cages. Furthermore, it completed development on a diet exclusively of hemp, although percent survival to moth emergence was only 15% in the 2020 feeding study. Most mortality occurred late in development during pupation. The study was done on the lab bench under ambient conditions and under Covid 19 work restrictions; visits to the laboratory were generally once a week. If rearing had been done in an incubator under optimal temperature and humidity conditions for pupation (see the rearing manual supplement to Dyer et al. 2013) and/or checked more frequently to keep the sand moist, moth emergence might have been greater. Such studies need to be done to determine how larval growth, weight, survival, and adult fitness compares among hemp, corn, and dry beans, especially since the moths reared on hemp were smaller than specimens from dry beans.

A key question is if western bean cutworm females recognize hemp as a suitable host for oviposition. Peak moth flight and egg laying typically occur between mid-July and early August (Smith et al. 2018), when hemp buds are present, and pheromone traps placed near hemp detect moths. Studies could show suitability for egg laying by caging gravid females on hemp plants in the laboratory or field. Better proof would be to find western bean cutworm larvae in industrial hemp fields. To date, there are no published reports of this, but absence of evidence is not evidence of absence. Egg masses would likely be difficult to find in a dense hemp canopy, as they are in dry bean fields (Smith et al. 2019). The current study provides evidence that caterpillars are on the ground during the day and climb stems at night to feed, as they do in dry beans (DiFonzo et al. 2015). In daytime scouting, in the absence of a caterpillar, western bean cutworm injury to buds might be attributed to corn earworm, a pest which is readily observed in fields and considered of high importance in hemp production (Cranshaw et al 2019, Britt et al. 2021). Thus, nighttime surveys for larvae may be needed.

Finally, as with corn and dry beans, hemp reproductive tissues were preferentially consumed by western bean cutworm caterpillars. Flowers, buds, and seeds are the most valuable parts of the hemp plant, and injury would contribute to losses in oil or seed yield. As hemp production returns across North America, growers, crop scouts, and extension educators should be aware of the possibility of finding western bean cutworm in the crop, especially in areas where it is already a key pest of corn and dry bean production.

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