Cultural Control of Giant Sugarcane Borer, Telchin licus (Lepidoptera: Castniidae), by Soil Mounding to Impede Adult Emergence

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Cultural control of giant sugarcane borer, *Telchin licus* (Lepidoptera: Castniidae), by soil mounding to impede adult emergence

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Abstract

The giant sugarcane borer, *Telchin licus* (Drury) (Lepidoptera: Castniidae), also known as the banana stem borer, is an economically important pest of sugarcane in eastern Colombia. The presence of larval and pupal stages within stalks makes biological control of this pest difficult, and growers often resort to insecticide applications. Hilling up the soil around the base of plants, or soil mounding, is a cultural practice sometimes used to improve rooting in sugarcane. Because mature larvae cut holes in stalks close to ground level through which they can emerge as an adult, we hypothesized that soil mounding would impede adult emergence, and thus contribute to population reduction. Two experiments were conducted in fields with significant infestations of this pest in Puerto López, Meta, Colombia, during the seasons of adult emergence in this region (Apr–May and Oct–Nov). Manual mounding of soil to a height of 20 cm was tested in the first trial, and mechanized mounding of soil in the second, which also compared 2 mounding heights (10 and 20 cm). In both cases, 2 m row transects of plants were caged to collect emergent adults. Adult emergence was reduced up to 65% in all mounding treatments, whether manual or mechanical, and regardless of mounding height, demonstrating that this cultural practice could be a useful tactic for inclusion in an integrated management program for this pest. However, as with any other cultural practice in pest management, region-wide implementation likely would be required to impact local population densities, and efficacy will depend further on low levels of moth immigration from alternative host plants.

Key Words: banana stem borer; *Saccharum officinarum*; soil insect pest; cultural control

Resumen

El barrenador gigante de la caña de azúcar *Telchin licus* (Drury) (Lepidoptera: Castniidae), también conocido como el gusano tornillo del plátano, es una plaga de importancia económica de la caña de azúcar en el este de Colombia. Sus hábitos de barrenador dificultan el control haciendo recurrente la aplicación de insecticidas. El aporque es una práctica usada para mejorar el enraizamiento al amontonar suelo en la base de la planta. Debido a que las larvas hacen agujeros en los tallos cerca del nivel del suelo por donde emergen los adultos, planteamos la hipótesis de que el aporque impide la emergencia de los adultos, contribuyendo a la reducción de la población. Se realizaron dos experimentos en campos con altas infestaciones en Puerto López, Meta, durante las temporadas de emergencia de adultos en esta región (abril–mayo y octubre–noviembre). En el primer ensayo se probó el aporque manual a una altura de 20 cm, y en el segundo el aporque mecanizado, que comparó dos alturas del suelo (10 y 20 cm). En ambos casos se enjaularon transectos de plantas de 2 m en hileras para recolectar adultos emergentes. La emergencia de adultos se redujo en aproximadamente un 65% en todos los tratamientos de aporque, manuales o mecánicos, e independientemente de la altura dejada por la labor, demostrando que esta práctica cultural es una táctica útil para su inclusión en un programa de manejo integrado de la plaga. Sin embargo, como en el caso de cualquier otra práctica cultural en el manejo de plagas, se requeriría una implementación regional para afectar las densidades de población local, siendo que su eficacia también dependería de una baja migración desde hospederos alternos.

Palabras Claves: gusano tornillo del plátano; *Saccharum officinarum*; plagas del suelo; control cultural

The giant sugarcane borer, *Telchin licus* (Drury) (Lepidoptera: Castniidae), also known as the banana stem borer, is one of the most important pests of sugarcane in Central and South America (Mendonça 1996; Bustillo 2013), although it also attacks banana and pineapple (Lamas 1993). This pest has caused production losses in sugarcane ranging from 20% to 60% in Bolivia, Brazil, Colombia, Central America, and the Caribbean (Rios & Gonzalez 2011; Valencia et al. 2014). In the central region of Colombia, the pest can be problematic in sugarcane grown for panela, a local unrefined sugar product, whereas in the western and eastern regions, it damages cane grown for refined sugar and ethanol production. Feeding damage by *T. licus* not only reduces biomass and sucrose content, but also reduces the ratoon available for planting the next crop (Bustillo 2013; Gonzalez et al. 2017).

The adults are large, diurnal moths with clubbed antennae that often are mistaken for butterflies, and mature larvae can reach 14 cm in length. Female moths oviposit at the soil next to the base of stems and, upon eclosion, neonate larvae quickly bore into the stem where they remain feeding on the rhizome and stems until pupation, which generally occurs at the base of the stalk. Adult emergence holes, which are cut by the larva prior to pupation, usually are located close to ground level (Negrisoli et al. 2015). The species has 2 generations per yr, requiring from 4 to 6 mo to complete its life cycle (Bustillo 2013),

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which results in 2 peaks of adult emergence in eastern Colombia, 1 at the beginning of the rainy season (Apr–May) and another at the end (Oct–Nov). The ecology of *T. licus* has been studied in Brazil (Garcia & Botelho 2009) and Costa Rica (Salazar et al. 2018). The complete life cycle requires approximately 180 d: the incubation period lasting from 9 to 13 d, larval development from 98 to 210 d, and the pupal stage from 28 to 35 d, with adults living from 3 to 16 d.

Management of the pest is difficult because of its endophytic habits; attempts to manage *T. licus* with insecticides and entomopathogenic fungi have proven ineffective due to larvae feeding in protected locations within the stalks (Craveiro et al. 2010; Fonseca et al. 2015). Some sugarcane genotypes seem to differ in pest incidence, but truly resistant varieties have not been identified (Dinardo-Miranda 2008). Bacterial sub-species of the *Bacillus thuringiensis* Berliner (Bacillales: Bacillaceae) group have been isolated from the digestive tract of *T. licus*, suggesting the potential for using pathogenic strains of these bacteria against the pest (Rocha et al. 2021), although this approach has not yet been adequately explored. Application of the entomopathogen *Beauveria bassiana* (Balsamo-Crivelli) Vuillemin (Hypocreales: Cordycipitaceae) via sub-surface drip irrigation systems has proven relatively effective in controlling *T. licus* in trials in Brazil (Krontal 2014), but such irrigation systems are rarely used in Colombia. Systemic insecticides (e.g., chlorantraniliprole) are used commonly to manage *T. licus*, either by spraying the stubble post-harvest, or by spraying the regrowth 2 to 3 mo later, which can reduce the larval population by up to 76% (Dario et al. 2014; Negrisoli et al. 2015; Garcia & Botelho 2016). Foliar applications of broad-spectrum insecticides also may reduce adult populations and pest injury in commercial fields (Pabón, data unpublished).

Soil mounding is a cultural practice often employed in annual and perennial crops for a variety of agronomic purposes. In sugarcane production, mounding of soil around the base of plant stems can be used to help anchor plants by increasing the volume of soil available for lateral root growth, reduce weed competition, and improve soil aeration and water infiltration (Cassalet et al. 1995). Mounding can be accomplished manually using conventional tillage tools (hoes and shovels) or mechanically using tractor-driven tillage implements. Typically, the objective is to increase the height of the soil from the bottom of the furrow to the exposed base of the plants by 15 to 20 cm (Ortiz-Cañavate et al. 2012).

Mounding of soil around the base of sugarcane plants is a cultural practice frequently used to control weeds and improve rooting, but its potential for managing pests that attack the rhizome of the plant has not been evaluated. Coverage of rhizomes with harvest residues was reported to reduce sugarcane stalk damage by the stem borer *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae) (Sandhu et al. 2011). However, Cherry & Sandhu (2020) found no effect of tillage treatments on soil arthropods in Florida sugarcane. Given the biology of *T. licus*, we hypothesized that mounding soil over the lower portion of plant stems prior to emergence periods would trap vulnerable callow adults inside sugarcane stalks. The purpose of our study was to determine the impact of this cultural practice on *T. licus*. The study focused on evaluating how either manual or mechanized mounding of soil around the base of stalks could impede the emergence of adult borers under field conditions.

Materials and Methods

STUDY SITE

Experiments were conducted in sugarcane plantations located in the municipality of Puerto Lopez, Meta, in the eastern region of Colombia. A manual mounding experiment was conducted between 13 Sep and 24 Nov 2019, in a 3 mo old commercial sugarcane plantation (4.223611°N, 72.818333°W; 185 masl) planted with cultivar 'CC 01-1940,' using 1.5 m row spacing. A mechanical mounding experiment was carried out between 13 Apr and 22 Jun 2020, in a 5 mo old sugarcane plantation (4.144722°N, 72.757222°W; 220 masl) planted with cultivar 'CC 01-1228,' also with 1.5 m row spacing. The soil type at both locations was a deep, well-drained Oxisol, with pH ranging from 4.5 to 5.0, and a sandy loam texture (IGAC 2004). Both sugarcane cultivars are planted commonly as commercial varieties in the region and have shown no indication of resistance to the borer. These fields were reported as heavily infested prior to our experiments, but to verify this, the relative abundance of *T. licus* was estimated at both locations 1 wk prior to applying treatments by sampling two 2 m transects of a row per ha, each 100 m apart, and destructively collecting all larvae and pupae from plants.

MANUAL MOUNDING

For the manual mounding experiment, a commercial field of 3 ha was used with a total experimental area of 1 ha. Workers with shovels raised the soil level in treatment plots by approximately 20 cm around the bases of sugarcane plants, whereas the soil was left undisturbed in control plots. A series of 24 plots, each consisting of a 2 m long × 1 m wide section of a row, were arranged in pairs (1 treatment, 1 control) separated by 1.5 m, with the paired plots placed approximately 20 m apart. Bamboo frame cages (2 × 3 × 1.5 m) covered with black sun mesh (providing 35% shade) were installed over each plot to trap emerging *T. licus* adults, which were collected twice weekly for 10 wk.

MECHANICAL MOUNDING

This experiment was conducted in a commercial field of 8.2 ha with a total experimental area of 3 ha. Each experimental plot consisted of a 2 m long × 1 m wide section of a row. Mounding was accomplished using a tillage implement with a 4-bodied, double-disc harrow, with each body bearing 3 low cut discs (60 cm) of 1.5 m working width (Surticampo SAS, Palmira, Colombia), driven by a 110 hp tractor. Two mounding treatments were evaluated, 1 which deposited an additional 10 cm layer of soil around the base of sugarcane plants, the other depositing a 20 cm layer. Soil was left undisturbed in control plots. Tractor operating conditions for mounding were: 5 km per h, 1,500 rpm with the hydraulic arm at an intermediate height for the 10 cm treatment, and 8 km per h, 1,800 rpm with arm at the lowest height for the 20 cm treatment. A series of 36 plots, each consisting of a 2 m long section of row, were arranged in triplets (2 treatments, 1 control) separated by 6 m, with each triplet placed approximately 50 m apart. Mesh cages (as above) were installed over each plot to capture emerging adults, which were collected and counted twice weekly for 10 wk.

STATISTICAL ANALYSIS

All statistical analyses were performed using the Statistix 9 package (Analytical Software 2008). The number of adults emerging in both experiments were analyzed by ANOVA for repeated measures, where cage effects were considered random and the response variable was calculated as the sum of terms for overall mean, treatment effect, time effect, and treatment*time interaction. Sphericity was tested with the response equal to the treatment*cage*time interaction. Mean adult emergence per plot was analyzed by 1-way ANOVA, separately for each experiment, and means were separated by Fisher's LSD test ($\alpha = 0.05$) when more than 2 groups were compared.

Results

MANUAL MOUNDING

Pre-trial sampling in the experimental field estimated *T. licus* density at 2.0 ± 0.5 immature life stages per 2 m of a row, for a total of 6,000 per ha, given a 1.5 m row spacing. Weekly counts of *T. licus* adults were significantly higher in control plots than in treatment plots on all sampling dates. Weekly adult emergence of *T. licus* was affected significantly by treatment ($F = 4.61$; df = 1, 22; $P = 0.043$), but there was no significant effect of wk ($F = 1.85$; df = 6, 22; $P = 0.094$), nor any significant interaction between treatment and wk ($F = 1.62$; df = 6, 132; $P = 0.145$; Fig. 1). Longitudinal comparisons of means were not justified because analysis of orthogonal components indicated non-homogeneity of variance ($\chi^2 = 36.27$; df = 20; $P = 0.014$), rendering pair-wise comparisons dependent on sphericity inappropriate.

Cumulatively, almost 3 times as many *T. licus* adults emerged in control plots compared to plots with the mounding treatment, even though statistical significance was marginal ($F = 4.44$; df = 1, 11; $P = 0.058$; Fig. 2). This translated into a reduction of 64%, meaning 3,000 emergent adults fewer per ha with the mounding treatment.

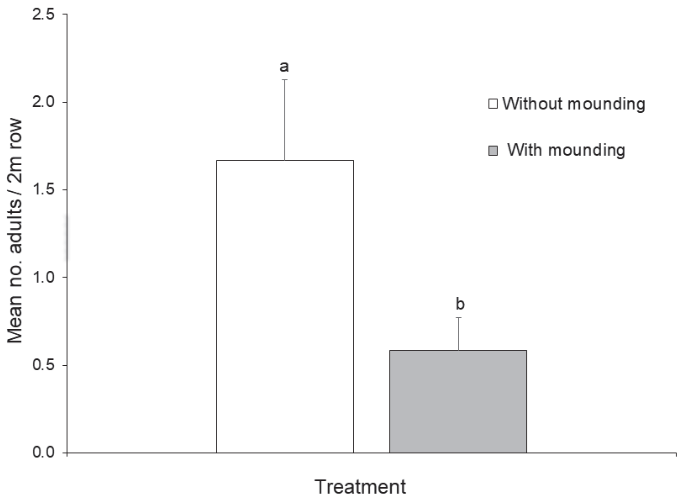

Fig. 2. Cumulative mean number of *Telchin licus* adults (± SE) that emerged in sugarcane plots receiving 1 of 2 treatments: manual mounding of soil to a height of 20 cm around the base of plants, or control with no soil disturbance. Treatments were marginally different (1-way ANOVA followed by Fisher's LSD test, α = 0.05).

MECHANICAL MOUNDING

Pre-trial sampling in the field estimated *T. licus* density at 3.6 ± 0.3 immature life stage per 2 m of a row, for an estimate of about 12,000 per ha, given a 1.5 m row spacing. Weekly counts of *T. licus* adults were higher significantly in control plots than in treatment plots, regardless of mounding height ($F = 5.18$; df = 2, 33; $P = 0.011$). There was also a significant effect of time ($F = 2.14$; df = 9, 33; $P = 0.026$), indicating that more adults emerged over the first 4 wk than later on, but the interaction between treatment and time was not significant ($F = 1.31$; df = 18, 297; $P = 0.177$; Fig. 3). Longitudinal comparisons of means were not justified because analysis of orthogonal components indicated non-homogeneity of variance ($\chi^2 = 161.36$; df = 44; $P < 0.001$), rendering pair-wise comparisons dependent on sphericity inappropriate.

Cumulative adult emergence varied significantly among treatments ($F = 5.26$; df = 2, 22; $P = 0.013$), with almost 3 times as many *T. licus* adults emerging in control plots compared to plots with a mounding treatment, and no difference between mounding heights (Fig. 4). This amounted to a 65% reduction in adult emergence, which translated into a reduction of about 5,600 adults per ha.

Discussion

Soil mounding, whether applied manually or by machinery, significantly impeded the emergence of *T. licus* adults from infested sugarcane stalks, reducing adult moth emergence by 64% and 65%, respectively. Thus, a layer of soil 10 cm in depth around the base of plants was sufficient to prevent *T. licus* adult moths from reaching the soil surface, likely because they lack either tarsi or mouthparts that would enable digging behavior. Thus, control by burial is likely to be less affected

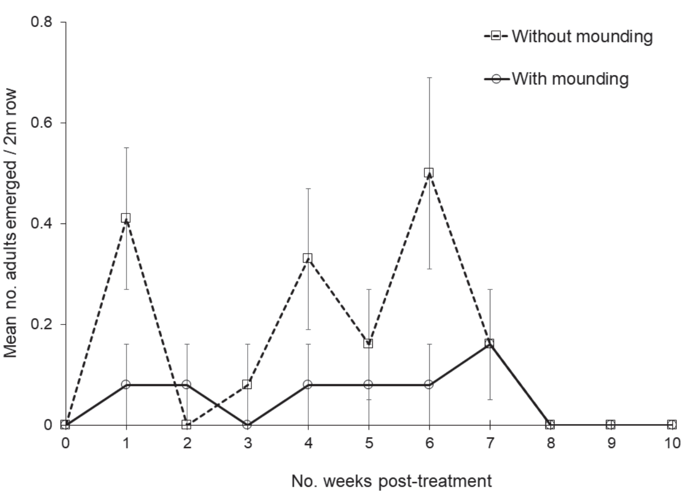

Fig. 1. Mean number of *Telchin licus* adults (± SE) emerging weekly per sugarcane plot. Plots received 1 of 2 treatments: manual mounding of soil to a height of 20 cm around the base of plants (circles, solid line), or control with no soil disturbance (squares, hatched line). The effect of treatment was significant (repeated measures ANOVA, $P < 0.05$), but effect of time and treatment*time interaction were not ($P > 0.05$).

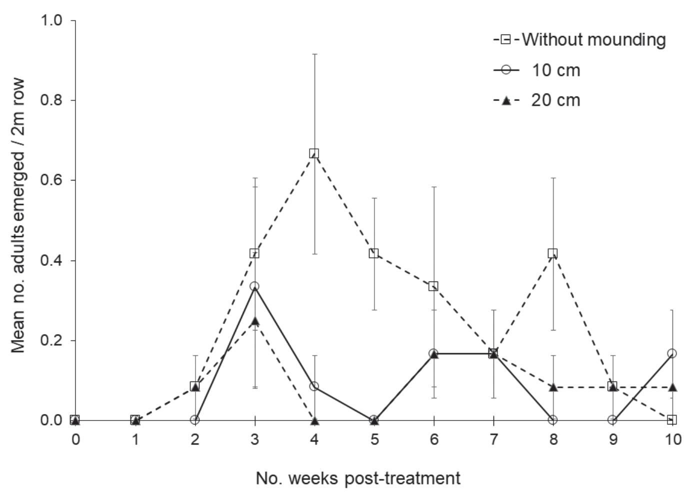

Fig. 3. Mean number of *Telchin licus* adults (± SE) emerging weekly per sugarcane plot. Plots received 1 of 3 treatments: mechanical mounding of soil to a height of either 10 cm (circles, solid line) or 20 cm (triangles, hatched line) around the base of plants, or control with no soil disturbance (squares, hatched line). Main effects of treatment and wk were significant (repeated measures ANOVA, $P < 0.05$), but the interaction between treatment and time was not ($P > 0.05$).

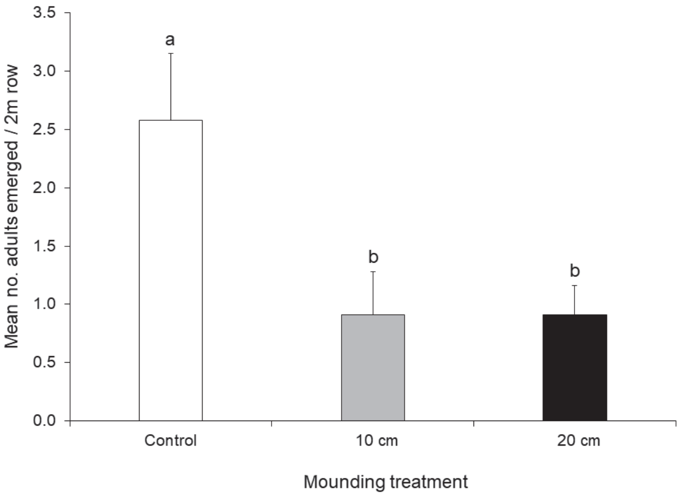

Fig. 4. Cumulative mean number of *Telchin licus* adults (± SE) that emerged in sugarcane plots receiving 1 of 3 treatments: mechanical mounding of soil to a height of either 10 or 20 cm around the base of plants, or control with no soil disturbance. Means bearing different letters were significantly different (1-way ANOVA followed by Fisher's LSD, α = 0.05).

by soil properties such as texture, moisture content, temperature, or degree of compaction than it is for other insects that naturally pupate in litter or soil (Chen & Shelton 2007; Renkena et al. 2012; Matlock et al. 2017; Hooper & Grieshop 2020). Similarly, mounding of soil around the base of apple rootstocks can provide 76 to 99% control of dogwood borer, *Synanthedon scitula* (Harris) (Lepidoptera: Sesiidae) (Gut et al. 2005). However, in the latter case, rather than impeding adult emergence, mounding functioned largely by preventing callous burr formations that neonate larvae use to enter the trunk via associated cracks and fissures.

These experiments were conducted in the mo of Sep (manual) and Apr (mechanical), respectively, with mounding treatments timed to coincide with biannual generations of the pest, each targeting the pupal cohort just prior to emergence. However, a fraction of adults did emerge successfully in treatment plots, likely through emergence holes located in portions of stems that remained above the soil post-treatment. Furthermore, not all the soil deposited by the mounding treatments resulted in burial of stalks to the same depth, which may have permitted some adults to escape through emergence holes close to the soil surface. Similarly, when larvae of *Cydia pomonella* L. (Lepidoptera: Tortricidae) were buried at different depths, a fraction of adult moths managed to emerge successfully (Baughman et al. 2015).

In mountainous regions of Colombia, manual mounding could be a suitable alternative for managing *T. licus*, whereas mechanical mounding would be appropriate for more industrialized areas with level fields. Soil mounding is relatively easy to apply, inexpensive, and compatible with other control practices. The current cost of mechanical mounding is around USD $16 per ha, whereas insecticide applications cost around USD $22 per ha for control of adults, and around USD $25 to $39 per ha for control of larvae, depending on equipment and active ingredient used. Nevertheless, soil mounding is regarded as a supplementary integrated pest management tactic that can be employed together with others to improve population control and damage reduction. Contrary to expectation, deposition of a deeper layer of soil around the base of plants (20 versus 10 cm) did not increase the level of control obtained in the mechanical mounding experiment, so if a critical depth of soil is required, it is less than 10 cm.

Burial via tillage also can provide effective control of pests that pupate in litter on the soil surface, such as the grape berry moth, *Paralobesia viteana* Clemens (Lepidoptera: Tortricidae) (Matlock et al. 2017). Burial of mature larvae of the codling moth, *C. pomonella*, below a depth of 1 cm resulted in complete mortality of all insects (Baughman et al. 2015). However, tillage and burial also have potential for controlling pests that pupate within plant material or crop residues. For example, tillage does not harm overwintering larvae of the sunflower stem weevil, *Cylindropturus adspersus* (LeConte) (Coleoptera: Curculionidae), but post-harvest burial of sunflower stalks to a depth of 15 to 20 cm provides almost complete control of emerging adults (Charlet 1994). However, burial to a depth of 30 cm was required to prevent emergence of pine shoot beetles, *Tomicus piniperda* (L.) (Coleoptera: Scolytidae) from infested pine logs (Haack et al. 2000).

In annual crops, various forms of tillage can impact pest populations directly via burial or physical injury, or indirectly via effects on the survival of their key natural enemies (Stinner & House 1990). Although no-till production systems tend to enhance biological pest control by increasing arthropod diversity and improving the survival of beneficial species (Tamburini et al. 2015; Mesmin et al. 2020), they also can favor the survival of certain pest species. In cotton, for example, populations of boll weevil, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae), and bollworms, *Helicoverpa zea* Bodie (Lepidoptera: Noctuidae) and *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), are favored by no-till practices because tillage reduces the survival of their pupae in the soil (Henneberry & Clayton 1979; Gaylor & Foster 1987; Henneberry et al. 1991). In apple orchards, survival of mature larvae of the codling moth, *C. pomonella*, can be reduced to zero by burial under 1 cm or more of sand (Baughman et al. 2015).

One assumption implicit in this approach is that a reduction of adult emergence within the crop will result in population reduction and less damage from subsequent generations. This will be the case only if sugarcane-infesting cohorts of this moth rely predominantly on sugarcane to maintain their population numbers, and will be less effective if significant numbers arrive either as emigrants from distant (unmanaged) fields, or from alternative wild host plants. Therefore, further evaluation of the efficacy of soil mounding as a control tactic for *T. licus* will require its continuous implementation in specific localities for several yr, and integration with other control tactics as part of an integrated pest management program, with moth numbers carefully monitored to see if regional populations can be reduced significantly over time.

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