United States Department of Agriculture

Animal and Plant Health Inspection Service

Plant Protection and Quarantine

New Pest Response Guidelines

Cydalima perspectalis (Lepidoptera: Crambidae) (Walker, 1859)

Box Tree Moth

First Edition Issued 2017

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Chapter 1

Introduction

New Pest Response Guidelines (NPRGs) are developed by Plant Protection and Quarantine (PPQ) in preparation for those plant health emergencies that occur when a new pest with the potential to seriously impact U.S. plant resources arrives in the U.S.

The purpose of an NPRG is to provide the basic information likely to be needed by the initial PPQ response team in the first 30 to 60 days following a detection of the pest in the U.S.

This guideline for box tree moth, *Cydalima perspectalis*, includes the following:

- Summary of relevant pest biology
- Guide to identification or screening for the pest in the field
- Preliminary method for conducting a delimiting survey
- Summary of known potential control/management options
- Summary of knowledge gaps

Note: This document is based on the best information available at the time of development; however, at the time of the emergency new scientific and technical information may be identified. In addition, each pest incursion has unique, site-specific characteristics that are impossible to predict. Therefore, this document should be considered a general guideline only. As the pest situation evolves and new information is gathered, the response implemented—including survey protocols—may need to be modified from the original recommendations.

Chapter 2

Pest at a Glance

Pest Summary

Cydalima perspectalis Walker (Lepidoptera: Crambidae) is native to Asia, where it feeds on *Buxus* spp. It was detected in Western Europe in 2007 and has spread widely through flight of adults and trade in ornamental *Buxus* spp. (Nacambo *et al.*, 2014). It is now a serious pest of horticultural *Buxus* spp. in European gardens, parks and cemeteries, as well as a destructive pest of the native *Buxus sempervirens* L., an understory tree species in European broadleaf forests Nacambo et al., 2014).

Justification

The native range of *C. perspectalis* is Asia. It has spread rapidly to native and horticultural *Buxus* spp. in Europe since its introduction, demonstrating its potential to spread and become an established pest of horticultural *Buxus* spp. in the U.S. This would negatively impact the U.S. nursery industry as well as U.S. homeowners. Of equal concern, an introduction into Puerto Rico and the U.S. Virgin Islands could threaten Vahl's box, *Buxus vahlii* Baill, a native, endangered boxwood in the U.S. (USDA–NRCS, 2017).

In the U.S. in 2012, there were 1,958 operations selling boxwood (*Buxus* spp.). The value of sales was $126.4 million (USDA–NASS, 2014). Losses in Europe (Wan *et al.*, 2014) suggest that the unquantified potential value of losses and of the cost of control would be substantial were the species to become established in the U.S.

Key Information

- Host range: *Buxus* spp. (boxwood), *Ilex purpurea* (purple-leaved holly), *Euonymous alatus* (burning bush), *E. japonicus* (Japanese spindle plant)
- Impact in invaded range: Feeding on *Buxus* spp. foliage and bark in Europe has killed trees
- 3–5 generations per year

- Overwintering stage: Larvae in silk cocoons on host leaves
- Native range: Humid subtropical regions of East Asia
- Current range: Asia, Europe north of the Tropic of Cancer
- Has the potential to spread throughout the entire continental U.S.
- Natural dispersal: 5–10 km per year
- Likely pathway: Trade in ornamental plants
- Surveyed with pheromone traps, light traps and visual inspection of hosts
- Controlled using chemical sprays and *Bacillus thuringiensis kurstaki* (Btk) (spray-formulated spores)

Previous PPQ Pest Reports and Assessments[1]

- **New Pest Advisory Group (NPAG)** – approval date 30 December 2015
- **Global Pest Disease Database (GPDD)** – pest record created 13 January 2009; last updated 11 September 2015
- **PestLens Articles**
  - First report of the box tree caterpillar, *Cydalima perspectalis* (Lepidoptera: Crambidae), in Ukraine (22 June 2017)
  - First report of the box tree caterpillar, *Cydalima perspectalis* (Lepidoptera: Crambidae), in Serbia (20 April 2017)
  - First reports of the box tree caterpillar, *Cydalima perspectalis* (Lepidoptera: Crambidae), in Greece, and in Bosnia and Herzegovina (13 August 2015)
  - First report of the box tree caterpillar, *Cydalima perspectalis* (Lepidoptera: Crambidae), in Bulgaria (12 February 2015)
  - First report of the box tree caterpillar, *Cydalima perspectalis* (Lepidoptera: Crambidae), in Croatia (7 March 2013)
  - First reports of the box tree caterpillar, *Cydalima perspectalis* (Lepidoptera: Crambidae), in the Czech Republic, Hungary, and Turkey (28 June 2012)
  - Nomenclature change for the box tree caterpillar, *Cydalima perspectalis* (Lepidoptera: Crambidae), previously *Diaphania perspectalis* (1 July 2010)
  - Box tree caterpillar, *Diaphania perspectalis* (Lepidoptera: Crambidae), found in England (22 April 2010)
  - First report of the pyralid *Diaphania perspectalis* in the Netherlands (18 December 2008)

[1] As of 1 September 2017

Chapter 3

Pest Overview

Pest Information

Scientific Name

Cydalima perspectalis (Walker, 1859)

Taxonomic Position

Animalia: Arthropoda: Insecta: Lepidoptera: Pyraloidea: Crambidae

The current taxonomy can be located in Encyclopedia of Life (2016).

Synonym(s)

- Originally *Phakellura perspectalis* Walker
- *Diaphania perspectalis* (Walker, 1859)
- *Glyphodes perspectalis* (Walker, 1859)
- *Palpita perspectalis* (Walker, 1859)
- *Neoglyphodes perspectalis*
- *Glyphodes albifuscalis* (Hampson, 1899)
- *Phacellura advenalis* (Lederer, 1863)

Common Names

- **Box tree moth**
- Box tree pyralid
- Box tree caterpillar

Biology and Ecology

Life Cycle

Generations

The number of generations observed has varied with the number of developmental degree-days (DD) allowed by latitude and longitude (Nacambo *et al.*, 2014). One to five generations per year have been reported in the literature from Japan, China, Switzerland, Germany, Hungary and Ukraine (Gottig *et al.*, 2017; Maruyama and Shinkaji, 1987; Nacambo *et al.*, 2014; Nagy *et al.*, 2017; Wan *et al.*, 2014).

Overwintering stage

The overwintering stage reported in Japan, China and Europe has varied from the second to fifth instars (Maruyama and Shinkaji, 1991; Nacambo et al., 2014, citing She and Feng, 20016). The larvae overwinter in a silk cocoon spun between host leaves (Nacambo *et al.*, 2014). Winter diapause was induced by daylight ranging from 12 to 14 hours (Maruyama and Shinkaji, 1991; Nacambo et al., 2014, citing Xiao et al., 2011). At 12 hours of daylight, when the temperature was decreased from 25 °C/77 °F to 20 °C/68 °F, a greater proportion of fifth instars entered diapause than fourth instars (Maruyama and Shinkaji, 1991). In northwest Switzerland, the overwintering stage was the third instar, with diapause induced by a 13.5-hour day length in September (Nacambo *et al.*, 2014).

Minimum developmental threshold temperatures and number of developmental degree days required to complete one generation

In northwest Switzerland, larvae that entered diapause in September were observed to terminate diapause in December (Nacambo *et al.*, 2014). In a laboratory study, diapause terminated after 1.5 to 2 months at 2 °C/35.6 °F (Nacambo et al., 2014). Nacambo *et al.* (2014) determined the developmental threshold temperatures and developmental degree-days for larvae (8.38 °C/47 °F; 323 DD), pupae (11.5 °C/52.7 °F; 133 DD) and eggs (10.91 °C/51.6 °F; 49 DD). Development from egg to adult at 20 °C/68 °F occurred in about 40 days (Korycinska and Eyre, 2011). In Japan, the two summer generations required a minimum developmental threshold temperature of 10.5 °C/50.9 °F and 610–620 DD to complete development (Maruyama and Shinkaji, 1987).

Nacambo *et al.* (2014) calculated developmental degree-days for two generations of *C. perspectalis* observed in northwest Switzerland. The overwintering larvae required 518 DD above the developmental threshold (10.5 °C/50.9 °F) to complete development. The subsequent progeny of these overwintered-generation adults, the “summer generation,” required 430 DD to develop into adults.

Developmental life stages

Adults: Adults of the overwintered generation appeared from May through July, depending on location. Adults of the “summer generations” appeared from July through October, depending on location.

Adults of the generation that had overwintered as larvae appeared from May to late June in Japan (Maruyama and Shinkaji, 1987); from late June or early July, with a mid-July peak, in northwest Switzerland (Nacambo *et al.*, 2014); from mid-June with a mid-July peak in Germany (Gottig *et al.*, 2017) and in June in eastern Hungary and western Ukraine (Nagy *et al.*, 2017). Adults of the subsequent “first summer generation” appeared from late July to late August in Japan (Maruyama and Shinkaji, 1987), from the second half of August through early October in northwest Switzerland (Nacambo *et al.*, 2014) and from mid-August to October with a peak in early September in Germany (Gottig *et al.*, 2017). In eastern Hungary and western Ukraine, summer-generation moths emerged for an extended period from the end of July through October, with two peaks, one beginning in early August and the other in late September (Nagy *et al.*, 2017).

Eggs (Developmental Duration): Egg clusters of 5 to 20 eggs were deposited in a gelatinous mass on *Buxus* leaves (Leuthardt and Baur, 2013). Moths laid between 6 and 491 egg clusters per female (median = 12.5) (Leuthardt and Baur, 2013). Fecundity in China varied from 199.4 ± 107.6 eggs per third-generation female to 482.5 ± 213.2 eggs per overwintered-generation female (Wan *et al.*, 2014, citing Cheng, 2005).

Egg developmental duration in Japan and China varied with temperature as follows (Wan *et al.*, 2014, citing Maruyama and Shinkaji, 1987 and Tang, 1993):

15 °C, 15.3 ± 0.64 days

20 °C, 7.1 ± 0.23 days

25 °C, 4.0 ± 0.15 days

30 °C, 3.0 ± 0.10 days

Larvae: Maruyama and Shinkaji (1991) observed 5–7 instars per generation that varied with differing temperatures and *Buxus* spp. For two summer generations on five *Buxus* spp., 5 to 7 instars were observed; 3 to 7 instars for the overwintering generation (Leuthardt and Baur, 2013).

Under conditions of 25 °C/77 °F and 24:0 L:D, the duration of instars 1 through 5 was three days per instar, while the duration of the sixth instar (prepupal) was eight days (Maruyama and Shinkaji, 1991). Duration of the larval stage, at 22–24 °C, from egg hatch to pupation, ranged across three generations from 16–24 days (Leuthardt and Baur, 2013).

Pupae: Pupation occurs on the host in cocoons of larval silk and host foliage (Korycinska and Eyre, 2011). The pupal stage lasted 10.0 ± 0.36 days at a constant temperature of 25 °C and 8.8 ± 0.32 days at an average temperature of 26.4 ± 0.68 °C (Wan *et al.*, 2014).

Hosts

In Europe, *C. perspectalis* has been observed to complete development on both wild and horticultural varieties of *Buxus* spp. (Leuthardt and Baur, 2013).

Leuthardt and Baur (2013) also studied the oviposition preference of female moths in the same study. The average number of egg clusters per female ranged from 13 for "Argenteovariegata" and "Faulkner" to 31 for "Rotundifolia" (Leuthardt and Baur, 2013). The differences could not be explained in terms of *Buxus* variety-to-variety differences in foliar area, leaf color, leaf shape or leaf toughness, nor by varietal differences in the composition and concentration of secondary (plant-protective) compounds.

In *C. perspectalis*'s native range, *B. microphylla* occurs in its wild form; whether it also occurs there in horticultural forms is not known (Leuthardt and Baur, 2013).

Table 3-1 List of reported plant hosts of *C. perspectalis*

Scientific name	References
Buxus balearica Lam.	Brua (2013)
Buxus bodinieri H. Lév.	Wan *et al.* (2014)
Buxus colchica Pojark.	Brua (2013)
Buxus harlandii Hance	Wan *et al.* (2014)
Buxus megistophylla H. Lév.	Wan *et al.* (2014)
Buxus microphylla Siebold & Zucc.	Leuthardt and Baur (2013)
Buxus microphylla Siebold & Zuccarini var. *insularis* Nakai	Wan *et al.* (2014)
Buxus microphylla Siebold & Zuccarini. var. *japonica* (Müll.	Wan *et al.* (2014)

Arg. ex Miq.) Rehder & E.H. Wilson	
Buxus rugulosa Hatusima [syn. *Buxus sinica* (Rehder & E.H. Wilson) M. Cheng ssp. *sinica* var. *parvifolia* M. Cheng]	Wan *et al.* (2014)
Buxus sempervirens L.	Leuthardt and Baur (2013)
Buxus sinica (Rehder & E.H. Wilson) M. Cheng	Wan *et al.* (2014)
Buxus sinica var. aemulans (Rehder & E.H. Wilson) P. Brückn. & T.L. Ming	Wan *et al.* (2014)
Buxus sinica (Rehder & E.H. Wilson) M. Cheng	Wan *et al.* (2014)

Dispersal

Natural Dispersal

Published research on flight dispersal for this species is limited. In Germany, spread via adult flight has been reported to occur at a rate of 5–10 km per year (The Food and Environment Research Agency, 2010).

Human-Assisted Spread

At a U.S. port of entry, one live *C. perspectalis* adult was intercepted with automobile parts from China on 19 October 2014 (USDA–APHIS, 2016). No interceptions of *Diaphania perspectalis* or *Glyphodes perspectalis* were recorded in PestID (USDA–APHIS, 2016).

Cydalima perspectalis was initially detected in 2006 in the Netherlands and southwest Germany (Mally and Nuss, 2010). Thereafter, it spread to the European countries listed in Table 3-2. Albert (2009) speculated that it had been vectored by nursery plants (*Buxus* spp.) imported into the Netherlands from China.

Potential Pathways of Introduction

The main potential pathway of introduction is trade in infested *Buxus* plants (The Food and Environment Research Agency, 2010).

Geographic Distribution

Ecological Range

The species is native to the humid subtropical regions of East Asia, including India, China, the Far East of Russia, Japan and Korea (Mally and Nuss, 2010), where it feeds on *Buxus* spp.

Box tree moth was initially detected on *Buxus* spp. in the Netherlands and southwest Germany in 2007. The dispersal and spread of invasive populations studied in northwest Switzerland were determined more by abiotic factors (day length, moisture, temperature) than by biotic factors (competition from other herbivores, natural enemies) (Nacambo *et al.*, 2014). Its distribution on native or horticultural *Buxus* spp. includes central China, which has summer mean temperatures above 35 °C/95 °F for multiple days, and the Russian Far East and northern China, where temperatures of −30 °C/−22 °F occur (Nacambo *et al.*, 2014). In northwest Switzerland, no impact on spring population densities was observed after sustained temperatures of −15 °C/5 °F to −25 °C/−13 °F during the winter of 2011–2012 (Nacambo *et al.*, 2014).

In 2010, high populations were reported to occur at lower elevations in eastern France, northern Italy, Switzerland, Austria and southern Germany (Nacambo *et al.*, 2014). Development requires a period of cold below the developmental threshold to terminate diapause and thereafter complete development to the adult stage; thus, distribution is favored in northern latitudes (Nacambo *et al.*, 2014). However, observation of the species in regions of southern China, where temperatures below 10 °C/50 °F rarely occur, suggests adapted populations or geographic biotypes that either do not require diapause or for which diapause is induced and terminated at higher temperatures (Nacambo *et al.*, 2014, citing Wang, 2008).

Table 3-2 Reported worldwide distribution of *C. perspectalis*

Location	Status	References
India	native	Mally and Nuss (2010)
China	native	Mally and Nuss (2010)
Korea	native	Mally and Nuss (2010)
Japan	native	Mally and Nuss (2010)
Russia (Far East)	introduced	Mally and Nuss (2010)
Netherlands	introduced	Wan *et al.* (2014)
Germany	introduced	Wan *et al.* (2014)
Switzerland	introduced	Wan *et al.* (2014)
France	introduced	Wan *et al.* (2014)
Belgium	introduced	Wan *et al.* (2014)

Austria	introduced	Wan *et al.* (2014)
Czech Republic	introduced	Wan *et al.* (2014)
Turkey	introduced	Wan *et al.* (2014)
England	introduced	Wan *et al.* (2014)
Romania	introduced	Wan *et al.* (2014)
Hungary	introduced	Wan *et al.* (2014)
Croatia	introduced	Wan *et al.* (2014)
Italy	introduced	Wan *et al.* (2014)
Slovakia	introduced	Wan *et al.* (2014)
Liechtenstein	introduced	Wan *et al.* (2014)
Slovenia	introduced	Wan *et al.* (2014)
Hungary	introduced	Nagy *et al*. (2017)
Ukraine	introduced	Nagy *et al*. (2017)

Dispersal beyond documented distribution continues. Recent PestLens articles present unconfirmed *C. perspectalis* introductions in Bulgaria, Bosnia and Herzegovina, Greece, and Serbia (see Chapter 2). The species has also recently been reported to be in caucasian Georgia and Iran (Kenis, 2016).

Potential Distribution in the United States

Current distribution of *C. perspectalis* is north of the Tropic of Cancer in Europe and Asia, on *Buxus* spp. (see Tables 3-1 and 3-2). It has been reported on *Buxus* spp. as far north as Russia's Far East (Mally and Nuss, 2010). This distribution on *Buxus* spp. includes Plant Hardiness Zones 4 through 9 (USDA–PERAL, 2013). Thus, it is likely that *C. perspectalis* has the potential to establish in the entire continental U.S. where those host species occur.

Chapter 4

Pest Identification and Damage

Species Description/Morphology

Adults

Adult wing span is reported to range up to 4–4.5 cm (Gutue *et al.*, 2014). Males captured in pheromone-lure traps in South Korea had a wing span of 3.81 cm and a body length of 1.84 cm (Kim and Park, 2013). Wings are predominantly white, with a wide, black edge; some individuals also have predominantly brown-grey wings with binary white points (Albert, 2009). The head is black; the body is predominantly white with last abdominal segments brown or black. Faint gold iridescence characterizes brown areas of the body, while faint purple iridescence characterizes white areas (Korycinska and Eyre, 2009). The brown variant is illustrated in Fig. 4-2.

Figure 4-1 Box tree moth, *C. perspectalis* (photo courtesy of Szabolcs Sáfián, Bugwood.org)

Figure 4-2 Box tree moth, *C. perspectalis*, brown variant (photo courtesy of Szabolcs Sáfián, Bugwood.org)

Eggs

Eggs are initially pale yellow and indistinct, laid in a flat aggregation, usually on the underside of host leaves (Fig. 4-3), occasionally on the upper side. A black spot marking the head capsule of developing larvae becomes evident as eggs mature (Korycinska and Eyre, 2009).

Figure 4-3 Immature eggs of *D. perspectalis* on *Buxus* leaf (photo source: W. Schön, www.schmetterling-raupe.de)

Larvae

In a laboratory study, Nacambo *et al.* (2014) measured the head-capsule width of the first through seventh instars of invasive populations in northwest Switzerland and found wide variation and overlap in the widths. Larvae are green with black hairs and spots and can be found in cocoons made of silk and host leaves or feeding on the lower and upper epidermis of host leaves (Albert, 2009). Neonates are black-headed and greenish yellow. Prepupal larvae are approximately 4 cm in length and have green bodies with black markings and black and white longitudinal lines (Korycinska and Eyre, 2009).

Figure 4-4 *Cydalima perspectalis* neonates (photo source: Colette Walter, http://www.schmetterling-raupe.de/art/perspectalis.htm)

Figure 4-5 *Cydalima perspectalis* larva feeding on common boxwood, *B. sempervirens* L. (photo source: Ferenc Lakatos, University of West Hungary, Bugwood.org)

Pupae

Pupae are formed within a cocoon of white silk (Fig. 4-6) protected by adhesed host leaves and twigs (Fig. 4-6) (Korycinska and Eyre, 2009). Pupae are between 1.5 and 2 cm, initially light green with black bands on the dorsum that mature to brown (Fig. 4-7) (Korycinska and Eyre, 2009).

Figure 4-6 *Cydalima perspectalis* pupae surrounded by white silk and host foliage (photo source: http://www.schmetterling-raupe.de/art/perspectalis.htm)

Figure 4-7 *Cydalima perspectalis* pupae exposed after removal of white silk and host foliage (photo source: http://www.schmetterling-raupe.de/art/perspectalis.htm)

Signs and Symptoms

Larval feeding on leaves causes defoliation; larvae also feed on bark (Nacambo *et al.*, 2014). Bark feeding by larvae has resulted in the trees drying out and dying (Leuthardt and Baur, 2013). The progression of larval feeding is through the lower leaf epidermis and mesophyll to the upper epidermis, ultimately defoliating the host. Signs of prior feeding include green-black frass and silk threads on the host plant and frass and leaf fragments on the soil at the host plant's base (Gutue *et al.*, 2014).

No published records of larval Lepidoptera feeding on *Buxus* spp. foliage in the U.S. were found during the preparation of this document. North American defoliators include *Eurytetranychus buxi* (Garman) (Acari: Tetranychidae) (boxwood mite) (Russell, 2013) and a boxwood blight caused by the fungal pathogen *Calonectria pseudonaviculata* (Crous, J.Z. Groenew. & C.F. Hill) L. Lombard, M.J. Wingf. & Crous (synonym *Cylindrocladium pseudonaviculatum* Crous, J.Z. Groenew. & C.F. Hill) (Jeffers *et al.*, 2016).

Figure 4-8 *Cydalima perspectalis* larva on common boxwood, *B. sempervirens* (photo source: Ferenc Lakatos, University of West-Hungary, Bugwood.org)

Figure 4-9 *Cydalima perspectalis* damage to common boxwood, *B. sempervirens* (photo source: Ferenc Lakatos, University of West-Hungary, Bugwood.org)

Figure 4-10 *Buxus sempervirens* defoliation and webbing due to *C. perspectalis* feeding (photo source: Colette Walter, http://www.lepiforum.de/webbbs/images/forum_2/pic13983.jpg)

Similar Species

In North America, none of the species of Crambidae feed on boxwood. They include the stem-boring *Diatraea saccharalis* Fabricius, sensu Guenee (sugarcane borer) and *Ostrinia nubilalis* Hübner (European corn borer), which feed on sugarcane and maize, respectively (Triplehorn and Johnson, 2005). Crambid foliage feeding species in North America include *Desmia funeralis* Hübner (grape leaf roller), *Diaphania hyalinata* (L.) (melonworm) and *Diaphania nitidalis* (Stoll) (pickleworm) (Triplehorn and Johnson, 2005) and do not feed on boxwood.

Another foliage feeder of *Buxus microphylla* Siebold & Zucc. (littleleaf boxwood) and of *B. sempervirens* (common boxwood) in North America is *Monarthopalpus flavus* (Shrank) (Diptera: Cecidomyiidae) (boxwood leafminer). However, as a leafminer, the maggots of this species remain within intact leaves while feeding, overwintering and pupating, and feeding damage takes the form of leaf discoloration and blistering (Frank and Baker, 2011).

Chapter 5

Delimitation Survey

Delimitation Area

The total delimitation area may depend on information from trace-back and trace-forward investigations; the nearby host distribution, including the extent of natural and artificial dispersal; agency resources and logistics. The delimiting survey boundaries can be as specific as production sites or as broad as political or geographical boundaries.

Along with other factors, the delimited area depends on the flight capacity of the exotic pest. The delimitation area may also be influenced by other specifics that are only known at the time of introduction. For instance, the location of introduction, occurrence of high-risk pathways, density and distribution of hosts near the initial detection area, wind direction and available surveillance resources at the time of introduction all may influence the delimitation area.

Published research on flight capacity for this species is limited. In Germany, spread via adult flight has been reported to occur at a rate of 5–10 km per year (The Food and Environment Research Agency, 2010). On the basis of the currently available information, a delimitation survey area of 20 × 20 km is recommended. At the time of an actual detection, flight capacity may be better defined.

Survey Techniques for Delimitation

Visual Inspection

Visible host damage

Visible symptoms of damage that the box tree moth may cause to its hosts include the following:

- Windowing of leaves
- Defoliation

- Dry trees
- Dead trees

Visible pest stages

Stages of box tree moth development that are visually identifiable on host plants include the following:

- Egg sheets on foliage
- Webbing on foliage
- Pupal cocoons between leaves

Trapping

Pheromone traps

- Pheromone combination: 5:1 (Z)-11-hexadecenal:(E)-11-hexadecenal
- Pheromone dispenser: photo-setting resin on polypropylene film (2 × 1.5 cm)
- Pheromone load per dispenser: 0.6 mg
- Trap type: Unitrap
- Trap height: 1.5 m above soil surface
- Distance between traps: 10 m
- Trap service period: 2 weeks (Kim and Park, 2013)

Other trapping techniques

- Light traps (Nacambo *et al.*, 2014)
- Feeding attractant traps (phenylacetaldehyde– and iso-amyl alcohol–based lures) (Nagy *et al.*, 2017)

Timing of Surveys

- Overwintering generation: Survey when temperatures are ≥8.38 °C/47 °F; May through July, depending on location
- Summer generations: Survey when temperatures are ≥ 10.5 °C/50.9 °F; July through October, depending on location.

Chapter 6

Eradication and Control Options

Overview

This chapter presents known control options available for this pest and summarizes how widely used they are in the U.S.

This information can be used by PPQ decision-makers after a detection to assess the suitability of potential actions to eradicate, contain or suppress *C. perspectalis*. The efficacy and feasibility of each control option will depend on the pest situation at the time of detection. Factors such as where the pest is detected (*i.e.*, natural or urban environment, agricultural crops, greenhouses, orchards), how widespread the pest is, the climatic region, the time of year, the phenology of the host and what current practices are already in place contribute to determining whether a particular control option is appropriate.

Current Practices in Place

Insecticidal spray options in the U.S. for suppression of *Monarthopalpus buxi* (boxwood leafminer) populations and of populations of foliage-feeding Crambidae (*Desmia funeralis* Hübner (grape leaffolder), *Diaphania hyalinata* (L.) (melonworm), *Diaphania nitidalis* (Stoll) (pickleworm)) are presented in Table 6-1 below.

Table 6-1 Insecticidal sprays for suppression of the larval stages of North American foliar-feeding species similar to *C. perspectalis*

Active Ingredient	Insecticide Class	IRAC MoA (2011)[1]	Boxwood Leafminer[2]	Grape Leaffolder[3]	Melonworm[2]	Pickleworm[2]
abamectin	avermectin	6	+	-	-	-
acephate	organophosphate	1B	+	-	-	-
acetamiprid	neonicotinoid	4A	+	-	-	-
azadirachtin	azadirachtin	18B	+	-	-	-
Bacillus thuringiensis kurstaki (spray-formulated spores)	bacterially produced insecticidal protein	11	-	+	-	-

bifenthrin	pyrethroid	3A	+	-	-	-
carbaryl	carbamate	1A	-	-	+	+
chlorantraniliprole	diamide	28	+	-	+	+
clothianidin	neonicotinoid	4A	+	-	-	-
cryolite	cryolite	unknown	-	+	-	-
cyantraniliprole	diamide	28	-	-	+	+
cyfluthrin + imidacloprid (Discus)	pyrethroid + neonicotinoid	3A + 4A	+	-	-	-
dinotefuran	neonicotinoid	4A	+	-	-	-
flubendiamide	diamide	28	-	+	+	+
imidacloprid	neonicotinoid	4A	+	-	-	-
indoxacarb	indoxacarb	22A	-	-	+	+
methoxyfenozide	diacylhydrazine	18	-	+	+	+
permethrin	pyrethroid	3A	+	-	-	-
pyriproxyfen	juvenile hormone mimic	7C	+	-	-	-
"registered pyrethroid"[2]	pyrethroid	3	-	-	+	+
spinetoram	spinosyn	5	-	+	+	+
spinosad	spinosyn	5	+	-	-	-

[1] Insecticide Resistance Action Committee Mode of Action (IRAC International MoA Working Group, 2011)

[2] Source: North Carolina Cooperative Extension (2017)

[3] Source: UC ANR (2016)

Eradication Options

In the absence of recurring introductions, the probability of successfully eradicating a small, geographically isolated *C. perspectalis* population is greatest when infested hosts are removed and destroyed.

Quarantine and Regulatory Procedures

Regulatory procedures

- Hold notices: After an infestation is known to exist, operations personnel will issue hold orders on all properties known to be infested with *C. perspectalis*
- Emergency quarantine: An emergency quarantine could be adopted if any of the infestation criteria listed under *Eradication Activities* (below) are fulfilled

Criteria for declaration of an infestation and initiation of eradication activities

NOTE: There is currently no published scientific research in which flight distances of adults have been directly measured.

Use the following criteria to determine whether to declare an infestation:

- Two or more adults within 10 km of each other and within a time period equal to one life cycle of the moth
- One mated female, **or**
- One larva or pupa

Environmental Assessment and Public Notifications Regarding Eradication Treatments

At the time of an eradication treatment, a site specific Environmental Assessment will be completed and a Finding of No Significant Impact (FONSI) signed, and the public will be notified regarding the findings.

The purpose of notification is to comply with state and federal law and to present accurate information to concerned groups in an understandable, non-threatening format. Local and state elected representatives of the residents in the treatment area will be notified and apprised of major developments before and during treatment. In the event of ground treatment activities, any resident whose property will be treated with foliar sprays following the discovery of infested *Buxus* on or near their property will be notified in writing prior to treatment. Treatment notices include the name of the pest to be eradicated, the material to be used and a phone number to call in case of additional questions on project operations. Following treatment, a completion notice will be left detailing any precautions the homeowner should take, including post-treatment interval. Treatment without prior notification may be necessary on a small number of properties if active larvae are detected; however, reasonable efforts will be made to contact the homeowner.

Host Removal

Note that published research on flight capacity for this species is limited. In Germany, spread via adult flight has been reported to occur at a rate of 5–10 km per year (The Food and Environment Research Agency, 2010). At the time of an actual detection, flight capacity may be better defined.

On the basis of currently available information, following a detection, infested hosts found within the delimitation area should be removed and destroyed.

- Host destruction can be by burial, chipping, or burning
- Nearby hosts should be visually inspected for infestation
- Un-infested nearby hosts should be prophylactically treated with a pyrethroid or organophosphate (see *Chemical Control*, below)

Alternative Control Techniques

Chemical Control

Chemical insecticides used against *C. perspectalis* include pyrethroids (deltamethrin, cypermethrin), organophosphates (chlorfluazuron), spinosyns (spinosad) and phenylpyrazoles (fipronil) (Wan *et al.*, 2014). As an alternative, diflubenzuron is also efficient and less toxic than the insecticides mentioned above. Spinosad and fipronil are most effective when applied on early instar larvae (Kenis, 2016).

Labeling

Although a proposed formulation may be approved for an effective eradication or control program, it may not be labeled, at the time of pest detection, for the specific use required. If a formulation is not labeled for the necessary use, one can request a federal crisis or quarantine exemption from the EPA under section 18 of FIFRA. The prescribed formulation must be labeled for use on the site at which it is to be applied and must be registered for use in the state in which the eradication program is occurring. All applicable label directions must be followed, including requirements for personal protection equipment, maximum treatment rates, storage and disposal.

Cultural Control and Sanitary Measures

In Europe, manual larval removal and removal via water-spraying has been advised for control on ornamental box trees—as distinct from control in forests of native *Buxus* spp. (Wan *et al.*, 2014). However, manual removal can only be carried out on a few small trees at once, and water-spraying is not easy to apply since, to be efficient, strong pressure must be applied, which may damage the tree (Kenis, 2016).

Behavioral Control

In Europe, pheromone traps are sometimes used for mass trapping in very limited areas (Kenis, 2016).

Biological Control

Bioinsecticides based on Btk are now the recommended control method in Europe (Lefort *et al.*, 2014). Neem oil has been used in China, but tests have shown limited efficiency (Lefort *et al.*, 2014; Wan *et al.*, 2014). Gottig *et al.* (2017) demonstrated suppressed oviposition on *Buxus* twigs treated with Elder and Thyme oil and with aqueous Thyme extract. Thyme oil also reduced larval feeding and survival (Gottig *et al.*, 2017).

In China and Japan, three species of tachinid flies (Diptera: Tachinidae) have been reported to parasitize *C. perspectalis* larvae: *Compsilura concinnata* (Meigen), *Exorista* spp. and *Pseudoperichaeta nigrolineata* (Walker) (Diptera: Tachinidae) (Wan *et al.,* 2014).

In China, species of Hymenopteran egg parasitoids include *Chelonus tabonus* (Sonan) (Braconidae) and *Tyndarichus* spp. (Encyrtidae); larval parasitoids include *Dolichogenidea stantoni* (Ashmead) (Braconidae) and *Casinaria* spp. (Ichneumonidae) and there is one pupal parasitoid, *Brachymeria lasus* (Walker) (Chalcidae) (Wan *et al.*, 2014). Some of these Asian parasitoids could be considered classical biological control agents for releases in regions where the box tree moth is established. Since its detection in 2007, natural enemies of *C. perspectalis* have not been widely observed in Europe (Nacambo *et al.*, 2014). However, in Switzerland, *P. nigrolineata* has been identified as a larval parasitoid and *Apechthis compunctator* (L.) (Hymenoptera: Ichneumonidae) has been identified as a pupal parasitoid (Wan *et al.*, 2014) .A *Trichogramma* egg parasitoid is presently sold in Europe for inundative releases in parks and gardens (Biotop, 2017). However, its efficiency has not been described in a scientific publication (Kenis, 2016). In a lab study (Gottig *et al.*, 2017), one of eight *Trichogramma* spp., *T. dendrolima,* parasitized 44 percent of *C. perspectalis* eggs.

Aeolothrips spp. (Thysanoptera: Aeolothripidae) and unidentified spiders are reported to be egg predators in China (Wan *et al.*, 2014).

The fungal pathogen *Beauveria bassiana* shows some promise, but more research is needed before it can be recommended against the moth (MacGillycuddy and Lefort, 2016). Entomopathogenic nematodes *Steinernema carpocapse* and *Heterorhabditis bacteriophora* applied to larvae caused *C. perspectalis* mortality rates of greater than 92 percent in a lab study (Choo *et al.*, 1991). Rose *et al.* (2013) demonstrated the susceptibility of neonates that fed on *Buxus sempervirens* leaf disks treated with *Anagrapha falcifera* nucleopolyhedrovirus (AnfaNPV). A synthetic mixture of three *C. perspectalis* larval-frass volatiles reduced oviposition on *B. sempervirens* in a cage test (Molnar *et al.*, 2017).

Host Resistance

In Europe, *C. perspectalis* has been observed to develop completely on both wild and horticultural varieties of *Buxus* spp. (Leuthardt and Baur, 2013).

Moderate variation in oviposition preference (response range: 13–31 egg clusters per female) was measured for five varieties of *B. sempervirens* and *B. microphylla* frequently planted in northwestern Switzerland private and public gardens

(Leuthardt and Baur, 2013). Leuthardt and Baur (2013) stated that the oviposition-preference differences they had observed could not be explained in terms of *Buxus* variety-to-variety differences in foliar area, leaf color, leaf shape or leaf toughness, nor by varietal differences in the composition and concentration of secondary (plant-protective) compounds. Other tests were performed in Europe to assess the susceptibility of *Buxus* varieties and species. For example, Brua (2013) showed that several *B. sempervirens* varieties subspecies, as well as the Asian *B. sinica* and the European *B. balearica*, are equally susceptible.

Chapter 7

Research Needs

New technology, research or assessment is needed to:

- Develop a diagnostic aid to present genital features for species confirmation
- Confirm and quantify the efficacy of pheromone-lure traps for low population density situations (for an early warning program at ports of entry)
- Measure the flight capacity of adults to rationalize the magnitude of delimitation-survey and quarantine areas
- Assess the susceptibility of American box tree species (several species occur in Puerto Rico and the Caribbean, Mexico and Central America). If they appear as susceptible as the European species, then the introduction of the moth could lead to the decline and local eradication of plant species and associated species and ecosystems
- The ecology of the moth and its natural control should be better studied to develop more efficient management methods, in particular biological control, which appears as the only control option in natural boxwood stands
- Test the use of *Trichogramma* and fungal pathogens as control agents in parks and gardens
- Investigate the possibility of using the pheromone for mating disruption
- Develop and test integrated pest management methods
- Determine the ecological impact of the moth in invaded natural boxwood stands

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Cover Image

Upper left: Pest-free common boxwood, *Buxus sempervirens* L. Photo courtesy of John Ruter, University of Georgia, Bugwood.org

Upper right: *Cydalima perspectalis* adult. Photo courtesy of Szabolcs Sáfián, University of West Hungary, Bugwood.org

Lower left: *Cydalima perspectalis* larva on common boxwood, *Buxus sempervirens* L. Photo courtesy of Ferenc Lakatos, University of West Hungary, Bugwood.org

Lower right: *Cydalima perspectalis* damage to common boxwood, *Buxus sempervirens* L. Photo courtesy of Ferenc Lakatos, University of West Hungary, Bugwood.org