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Cooperating State Departments of Agriculture

New Pest Response Guidelines

Spodoptera

February 24, 2005

New Pest Response Guidelines

Spodoptera

February 25, 2005

New Pest Response Guidelines: Spodoptera **was revised and prepared by Susan E. Ellis, USDA APHIS PPQ PDMP and edited by Patricia S. Michalak, USDA APHIS PPQ Manuals Unit.**

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Cover image: ***Spodoptera*** **spp. Image courtesy of Department for Environment, Food and Rural Affairs, UK**

Credits

New Pest Response Guidelines Noctuidae: Spodoptera was revised and prepared by Susan E. Ellis, PPQ/PDMP and edited by Patricia S. Michalak, PPQ/PDMP.

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Table of Contents

Chapter 1. Introduction

Purpose

Use *New Pest Response Guidelines: Spodoptera* as a guide when designing a program to detect, monitor, control, contain, or eradicate an infestation of spodoptera. If the pest is detected in the U.S., PPQ personnel and state cooperators will produce a site-specific Action Plan based on this document. We hope that state personnel and others concerned with developing local survey or control programs for this pest may find this document useful.

PPQ develops each *New Pest Response Guidelines* through discussion, consultation, or agreement with staff at Animal and Plant Health Inspection Service (APHIS), Agricultural Research Service (ARS), and with university advisors.

Pest status

The species reported are pests or show promise of being pests. Most species are polyphagous and may utilize new hosts in a new environment. For that reason, unrecognized species could also prove to be pests, especially if established in a new environment.

Disclaimers and document comprehension

This document provides a foundation to assist further work. Some key articles were not available at the time of writing, and not all specialists and members of the research community were consulted for their advice. For the most current information on this pest, consult with agricultural experts. Conduct your own literature search. Search websites frequently, since material is updated periodically.

Commercial suppliers or products

References to commercial suppliers or products should not be construed as an endorsement of the company or product by the U.S. Department of Agriculture.

Contacts

When an emergency program for this pest has been implemented, its success depends on the cooperation, assistance, and understanding of other involved

groups. The appropriate liaison and information officers should distribute news of program progress and developments to interested groups, including:

- Other federal, state, county, and municipal agricultural officials
- Grower groups (such as specific commodity or industry groups)
- Commercial interests
- Academic entities with agricultural interests
- Land-grant universities with Cooperative Extension Services
- State and local law enforcement officials
- Public health agencies
- Foreign agricultural interests
- National, state and local news media, and
- The public

Initiating an emergency pest response program

An emergency pest response program or incident response consists of detection and delimitation, and may be followed by programs in regulation, containment, eradication and/or control.

If a newly detected exotic or imminent pest threat does not have a current New Pest Response Guidelines document for reference, the New Pest Advisory Group (NPAG) evaluates the pest. After assessing the risk to U.S. plant health and consulting with experts and regulatory personnel, NPAG makes a recommendation to PPQ management for a course of action.

Follow this sequence when initiating an emergency pest response program:

1. A new or reintroduced pest is discovered and reported.
2. The pest is examined and pre-identified by regional or area identifier (see chapter 3).
3. Pest identity is confirmed by national taxonomic authority (see chapter 3).
4. New Pest Response Guidelines are consulted or NPAG is assembled to evaluate the pest.
5. Depending on the urgency, official notifications are made to the National Plant Board, cooperators, or trading partners.
6. A delimiting survey is conducted at site of detection (see chapter 4).
7. An Incident Assessment Team may be sent to evaluate the site.

8. A recommendation is made, based on the assessment of surveys, other data, and recommendations of the Incident Assessment Team and/or an NPAG, as follows (see chapter 6 and chapter 5):
    - Take no action
    - Regulate the pest
    - Contain the pest
    - Suppress the pest
    - Eradicate the pest
9. State Departments of Agriculture are consulted.
10. If appropriate, a control strategy is selected.
11. A PPQ Deputy Administrator authorizes a response.
12. A command post is selected and the Incident Command System is implemented.
13. Further detection surveys are conducted (see chapter 4).
14. Field identification procedures are standardized (see chapter 3).
15. Data reporting is standardized.
16. Environmental assessments are completed as necessary.
17. Treatment is applied for required pest generational time (see chapter 6).
18. Environmental monitoring is conducted if appropriate.
19. Pest monitoring surveys are conducted to evaluate program success (see chapter 4 and chapter 6).
20. Programs are designed for eradication, containment or long-term control of the pest (see chapter 6).

Program safety

Safety of the public and the program personnel has priority in pre-program planning and training, and throughout operations. Safety officers and supervisors must enforce on-the-job safety procedures.

Support for program decision making

The USDA/APHIS/PPQ Center for Plant Health, Science and Technology (http://www.cphst.org/) provides technical support to emergency pest response program directors concerning risk assessments, survey methods, control strategies, regulatory treatments, and other aspects of pest response programs.

Chapter 2. Pest Information

Classification

- Phylum: Arthropoda
- Class: Insecta
- Order: Lepidoptera
- Family: Noctuidae
- Genus: *Spodoptera*
- Previously known as: *Xylomyges*, *Laphygma*, *Prodenia*

History and distribution

The genus *Spodoptera* includes 25 species and contains some of the most economically important insect pests of cultivated crops. Some species have cosmopolitan distribution. Some are widespread in Africa and South America, where most of the species are concentrated. Currently recognized species of economic importance are listed in Table 2.1.

Table 2.1. Economically important spodoptera.

Prevalent in the continental U.S.	
S. eridania (Stoll)	Southern armyworm
S. exigua (Hubner)	Beet armyworm
S. frugiperda (J. E. Smith)	Fall armyworm
S. ornithogalli (Guenee)	Yellowstriped armyworm
S. praefica (Grote)	Western yellowstriped armyworm
Absent from the U.S.	
S. exempta (Walker)	Nutgrass armyworm[2]
S. littoralis (Boisduval)	Egyptian cotton leafworm[1]
S. litura (Fabricus)	Rice cutworm[2]
S. mauritia (Boisduval)	Lawn armyworm[2]

[1]Not established in the U.S.

[2]Established in Hawaii

Spodoptera littoralis

Establishment of *S. littoralis* would have devastating consequences on the quantity and quality of food and fiber crops in the U.S. (Lightfield 1996; CABI/EPPO 1997). In the late 1930's, *S. littoralis* lowered yields of cotton by as much as 75% (USDA 1982).

According to CABI/EPPO (1997), this pest remains "one of the most destructive agricultural lepidopterous pests within its subtropical and tropical range. It can attack numerous economically important crops all the year round." *S. littoralis* is particularly problematic on vegetables, ornamentals, and leguminous forage in the Mediterranean (Inserra and Calabretta 1985, CABI/EPPO 1997) and on cotton in Egypt (Inserra and Calabretta 1985, CABI/EPPO 1997).

The economic consequences of establishment by *S. littoralis* would not be limited to its direct effects on production agriculture: *S. littoralis* could adversely affect access to foreign markets. The pest has quarantine status with the following organizations (CABI/EPPO 1997, EPPO 1999):

- European and Mediterranean Plant Protection Organization (EPPO) Caribbean Plant Protection Commission (CPPC)
- Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA)
- North American Plant Protection Organization (NAPPO)

Ecological range

Many of the economically important exotic spodoptera are found in Africa and Asia (Table 2.2). Of the minor pests, *S. pecten* is found in Asia, *S. ochrea* is found in Peru, and *S. marima* occurs in Brazil. *S. cilium* and *S. triturata* are found in Africa.

Table 2.2. Current range of economically important exotic spodoptera.

Species	Ecological range
S. littoralis (Boisduval)	Africa, southern Europe, Near East
S. exempta (Walker)	Africa, Australia, Hawaii
S. litura (Fabricus)	Australia, Pacific Islands, Asia
S. mauritia (Boisduval)	Madagascar, Saudi Arabia, Asia, Pacific Islands, Hawaii

Potential range

The potential U.S. range of most spodoptera may be limited to the west coast through the lower southwestern and southeastern U.S., reaching as far north as Maryland (Figures 2.1, 2.2). Migratory species may be capable of periodic spread into northern states and even Canada by late summer or early fall.

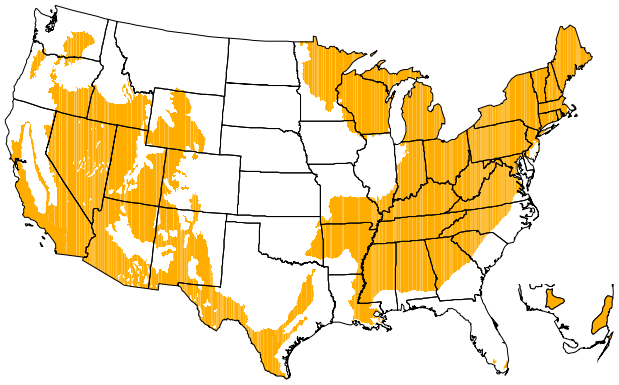

Figure 2.1. Predicted distribution of *Spodoptera littoralis* in the continental U.S. Southern Florida is enlarged for detail. Images courtesy of Venette and Davis (2003).

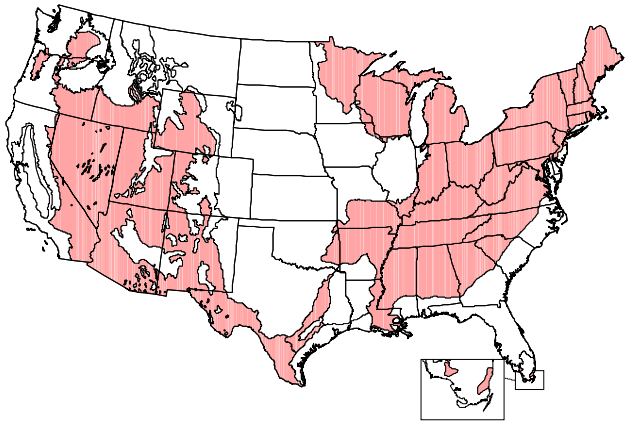

Figure 2.2. Predicted distribution of *Spodoptera litura* in the continental U.S. Southern Florida is enlarged for detail. Images courtesy of Venette and Davis (2003).

Economic impact and host range

Spodoptera are a potential threat to a wide variety of U.S. crops, including vegetable, field, oil, ornamental and fruit crops (Appendix A). Medicinal

plants on which leaves are important for essence can suffer great economic damage. On grapes, larvae skeletonize leaves or eat stalks and grapes. Grape vines may suffer so severely that development is retarded in the following year.

In deciduous orchards, larvae may cause severe damage to trees by feeding on leaves and terminal growing points. Young orchards suffer great damage. Larvae can completely defoliate ornamental plants and fruit trees in nurseries. If food is in short supply, large numbers of larvae may migrate *en masse* to new cropland. On pasture, some spodoptera prefer to feed on legumes over grasses.

Spodoptera exempta

S. exempta is limited to feeding on grasses in the families Gramineae and Cyperacease. Other grasses may prove to be hosts if *S. exempta* became established in North America.

Spodoptera littoralis

S. littoralis is a general feeder on hosts belonging to 44 families including crucifers, deciduous fruit trees, grasses, legumes, medicinal crops, ornamentals, and many vegetables. Eight families constitute more than 50 percent of the known hosts: Leguminosae, Solanaceae, Malvaceae, Moraceae, Compositae, Gramineae, Chenopodiaceae, and Cruciferae.

Spodoptera litura

S. litura is a general feeder on over 100 hosts, including crucifers, legumes, millets, deciduous fruit trees, and various ornamentals and vegetables.

Spodoptera mauritia

S. mauritia is limited to feeding on members of the families Gramineae, Cyperaceae, and Typhaceae. Other species may prove to be hosts in North America.

Spodoptera pectin

This species is restricted to feeding on members of the families Gramineae and Cyperaceae.

Damage

Spodoptera larvae prefer to feed on young, tender leaves. They may also feed on growing points, young shoots, stalks, bolls, buds, and fruits, often gnawing holes which allow disease or rot to enter the host.

On newly infested hosts, young larvae feed at numerous small feeding points that eventually spread over the entire leaf. Older instars chew large holes or wholly consume leaves, or mine their way into young shoots or bare sections on young stalks, bolls, and buds. They may destroy fruit such as tomatoes and peppers. If larvae feed on a young plant heavily, the plant's development is retarded and it may only produce small or late fruit.

Biology

Spodoptera littoralis

Adults emerge over a brief period in warm weather and mate immediately. In cold areas, adults may wait 2 to 11 days before mating (El-Sayes 1977). The female moth lays eggs in batches of 30 to 300, shedding hairs from her abdomen onto the eggs. She may lay eggs on any part of a plant, but seems to prefer the lower surface of leaves in the upper third of the plant. In her lifetime, the female moth lays an average of 1,000 eggs, but may lay up to 3,700 eggs.

Natural mortality of eggs is very low; a larva hatches from almost every egg. This species may have up to eight generations each year, with some overlapping of generations. In colder areas, there may be only three generations per year.

Typically, larvae in the first two instars cluster on the upper third of herbaceous plants, where they feed in small groups on the undersurfaces of leaves. Larvae feed throughout the day and night. They are extremely sensitive to climatic conditions, especially combinations of high temperature and low humidity. Temperatures above 104 °F (40 °C) or below 55 °F (13 °C) may cause mortality to increase.

Natural mortality of larvae is high, and most succumb to one of many parasites or diseases. Unfavorable climatic conditions such as rain, falling temperatures, and short days serve to increase mortality and prolong the larval period.

The digestive system of larvae is remarkably adapted to food scarcity. If food is scarce, their digestive systems retain and process the nutrients efficiently. When food is abundant, food passes quickly and inefficiently and the larvae consume far more food than their subsistence requires. In field crops where host material is plentiful and dense, larvae are profligate consumers and the damage they can cause is extensive.

This species overwinters best as late instar larvae. The larvae develop slowly during the winter and pupate in the spring.

Natural mortality of the pupae is high, especially in areas with a cold winter period. Soil temperatures of 78.8 °F or greater cause over 50 percent mortality. Short days can also increase mortality and prolong the pupal period.

In some areas, pupae appear to be more tolerant of cold conditions than larvae.

Spodoptera litura

Female moths of *S. litura* lay eggs at night, leaving batches of up to 300 eggs on the undersurface of host leaves. Sometimes, females lay eggs on other flat surfaces such as the walls of houses (Bishara 1934).

Newly hatched larvae are very susceptible to dry heat, usually staying on lower leaf surfaces during the day and feeding at night. In their last two instars, they feed only at night and seek shelter during the day under the lowest leaves or in the soil at the base of the host. Males can fly up to 3.1 miles per night when temperatures exceed 68 °F. Males mate once each night and avoid previously-mated females (Brown and Dewhurst 1975).

Life cycle

Members of the genus *Spodoptera* undergo complete metamorphosis and pass through the following stages:

- Egg
- Larva (caterpillar)
- Pupa
- Adult (moth)

Spodoptera over-winter as adults or pupae in plant debris. In spring, adults emerge at dusk in search of mates.

Spodoptera littoralis

The life cycle of *S. littoralis* requires from 19 to 144 days. Host plant species may influence the length of time necessary for development.

Incubation of eggs requires from 2 days (in warm weather) to 26 days (in cold weather). Larvae develop through five or six instars. Larval development requires from 12 days (during hot summer months) to 85 days (in winter). Pupation takes place in cells 1 to 2 inches below the soil surface and varies from 5 days (in summer) to 31 days (in winter).

Newly emerged moths are active from dusk to dawn. Females begin calling within 1 hour of dusk. Females mate once or twice at most, while males may mate up to six times. Females live for periods of 2 days (in summer) to 22 days (in winter). Females live longer than males (Miller 1977).

Spodoptera litura

Adults emerge between 11 p.m. and 3 a.m. Female moths do not mate until the day after emergence. They lay eggs 2 to 3 days after mating. Within her average lifetime of up to 7 days, a female moth may deposit six to nine egg batches. Eggs hatch in 4 days at 80°F.

Larvae pass through six instars. At 83.5°F, the larval stage lasts 13 days. Pupation occurs within earthen cells in the soil. At a soil temperature of 83.5°F, pupation requires 7.3 days (males) or 6.1 days (females).

Development

The development of a pest will guide program actions and influence the selection and success of eradication treatments, the duration of trapping activities, and regulatory functions. Many factors influence the development of insects, including host availability, pest population densities, photoperiod, rainfall, and temperature.

Temperature is one of the most important factors influencing the development of all insect life stages. Scientists use site-specific temperature data, along with knowledge of insect development, to predict when pests will be most abundant and likely to damage plants at a particular location. Scientists use temperature data in a tool known as the degree day value.

Degree day values are useful for the following:

- Predicting emergence of adults
- Determining the time to begin trapping
- Monitoring cycles of generation during a season
- Monitoring the effect of eradication or suppression measures

Degree day values are based on the threshold temperature of an insect, and are species specific. Threshold temperatures may represent either upper or lower limitations, and may be measurements of air or soil temperature, depending on where the insect lives. For example, the female moth *S. littoralis* develops above ground and has a lower threshold air temperature of 55.4 °F, and requires approximately 840 degree days to develop from the egg to adult stages (Miller 1977). The female moth *S. litura* has a lower threshold air temperature of 50 °F (Rauga Rao et al 1989).

Accumulated degree day values that reflect local conditions may be available from local sources, such as your local Cooperative Extension Service or state university. Or, calculate accumulated degree days using the three-step process that follows.

Step 1. Use thermometers or soil probes to determine the average daily temperature for a 24-hour period:

Average daily temperature = (Maximum temperature – minimum temperature)/2.

Step 2. Calculate the degree days by subtracting the threshold temperature from the average daily temperature:

Daily degree-days = Average daily temperature – Threshold temperature.

Step 3. To monitor development of spodoptera, begin accumulating daily degree days once the average air temperature reaches 42.8 °F. Degree days will accumulate less quickly at lower temperatures, and more quickly at higher temperatures.

Or, use the DDU (Degree-day Utility) available online from University of California, Integrated Pest Management Programs (http://www.ipm.ucdavis.edu/MODELS/DDU/)

For sources of information on predicting insect development, and on collecting local temperature data, see chapter 10.

Behavior

Spodoptera exempta

S. exempta moths usually migrate immediately after emergence. Mating and oviposition may be delayed until both sexes have traveled ten to hundreds of miles, generally downwind. Dense population concentrations tend to occur in areas where winds converge. This behavior appears to be a major difference between *S. exempta* and other exotic spodoptera. Other migratory spodoptera already in North America include*: S. exigua, S. frugiperda, S. dolichos*, and *S. eridania* (Rose 1985).

Spodoptera littoralis

Scientists have not observed migration of *S .littoralis*. This pest tends to spread from overwintering sites at the rate of 2 to 5 miles per generation. A possible explanation for the expansion rate may be that females first mate and lay at least one batch of eggs before they begin to wander and lay more eggs. Females usually lay eggs on the first night after emerging.

Males emigrate many miles from their local area, sometimes in great numbers soon after sunset, in search of females. Successful males remain for the night in the area where they have mated, probably to maximize their mating opportunities.

At sundown, older females release pheromone. Females 24 hours old or less release pheromone later in the night. Females can attract males from as far as 98 yards downwind. The attractive radius is about 11 yards (El-Sayes 1977; Ellis 1980).

Chapter 3. Identification

Introduction

Accurate identification of the pest is pivotal to assessing its potential risk, developing a survey strategy, and determining the level and manner of control.

Authorities

Qualified local personnel may perform pre-identification and screening of suspected spodoptera specimens. Before survey and control activities are initiated in the U.S., a USDA APHIS PPQ/National Identification Service (NIS)-recognized authority must verify the first detection of spodoptera. For verification, contact NIS personnel specializing in Lepidoptera at the following address:

Systematic Entomology Laboratory, USDA
U. S. National Museum of Natural History
Washington, DC. 20560-0168
Telephone: 202-382-1806

Pre-identification

Use this section as a guide to pre-identification of the pest.

Find a two-page Field Guide in Appendix B. Make copies of the Field Guide for use when identifying the pest in the field.

Classification of spodoptera is currently under revision (Pogue 2002). Pertinent revisions will be incorporated into this document as necessary.

Eggs

Egg masses with the following characters are **likely** members of the genus *Spodoptera*:

- Round shape AND
- Upright with a small pore on top AND
- Scales cover the eggs AND
- Outer membrane with about 40 to 50 longitudinal ribs

Scales are from the female's body and may be black, cream, or gray (Figures 3.1 and 3.2).

Figure 3.1. Eggs of *S. eridania*. Scales from the female's body cover the egg mass. The clear chorion indicates the eggs are about to hatch. Intercepted from Jamaica at John F. Kennedy International Airport, New York. Photo courtesy of P. Marquez.

Figure 3.2. *S. litura* larvae hatching from an egg mass. Image courtesy of the Macleay Museum, University of Sydney.

Adults

Adults (Figures 3.3 and 3.4) with the following characters are **likely** members of the genus *Spodoptera*:

- White v-shaped forewing marking that resembles a narrow two pronged fork pointed away from the body, AND
- White, glossy hind wing

Adults with the previous AND following characters are **very likely** members of the genus *Spodoptera,* especially if the moth was found on an appropriate host:

- White patch on the highest point of the forewing, AND
- Oblique whitish band, extending from mid-costa to mid-forewing cell, AND
- Forewings with circular and kidney-shaped spots (could be partially hidden by the oblique band), AND
- Wingspan of 16-44 mm

Figure 3.3. Adult spodoptera. Image courtesy of Department for Environment, Food and Rural Affairs, UK.

Figure 3.4. Adult *S. litura*. Image courtesy of Crop Protection and Plant Quarantine Division, Department of Agriculture, Malaysia.

Microscopic identification

Adults

Todd and Poole (1980) provided a list of characters to separate adult spodoptera from similar noctuids in other subfamilies:

- Eyes **not** hairy under moderate magnification (about 100x)
- Tibia of the prothoracic legs **without** spines
- **No** lashes (long thin scales) above the eye below the antenna
- Hind wing venation of the trifid type (3 branches in the medial vein)
- Last tarsal segment with two rows of strong spines

Use the following criteria to identify spodoptera if the specimen is in good condition and the identifier has experience preparing slides of Lepidoptera genitalia:

- Male genitalia with cornuti of aedeagus in a dense patch (Pogue 2002)
- Male genitalia with tip of valve broad and divided, slightly membranous, with a clasper at the apex (Todd and Poole 1980)
- Female with a dense patch of fine scales on A8 which may be colored black, cream, or white (Todd and Poole 1980; Pogue 2002).

Consult Miller et al. (1993) for information on preparing genitalia slides of moths in sticky traps using non-toxic citrus oil solvents. Holloway et al. (1987) summarized the standard procedure for making traditional genitalia slides from pinned moths. To identify *S. litura* and *S. littoralis* using male genitalia, see the illustrations in USDA/APHIS/PPQ (1986).

Similar species

Adults of *S. litura* are very similar in size and coloration to *S. ornithogalli* (USDA 1982). *S. litura* and *S. littoralis* are morphologically similar and were erroneously considered a single species in historical literature (Hafez and Hassan 1969, CABI/EPPO 1997). The species are difficult to distinguish without close examination of the genitalia (Mochida 1973, Brown and Dewhurst 1975, DEFRA 1999).

Collection, rearing and preparation of specimens

Labeling

Label samples with the following information:

- Location

- Host
- Date of sampling
- Survey method used to obtain the sample
- Name of the sampler
- Temperature and habitat

Rearing

If possible, collect eggs, larvae and pupae with sufficient host material for rearing. Adult specimens that were raised from eggs or larvae are easier to identify, compared with specimens collected from traps. Consult with identifiers for instructions on artificially rearing insects. Facilities must meet the security standards for rearing of quarantined insects.

Eggs

Collect eggs carefully by cutting the substrate around the mass. Do not try to lift the eggs off their resting site. Scraping the eggs into a vial, or putting pressure on them, will kill the developing larvae because the chorion is relatively soft. Always rear suspect spodoptera eggs in a quarantine facility.

Maintain humidity at approximately 50%. Before hatching, the eggs will appear black because the head of the developing larvae show through the eggshell. Parasitized eggs also may turn black.

Larvae

Most spodoptera larvae are easy to rear on bean leaves, artificial diet or snap bean pods. Corn leaves or grasses are other favored hosts.

Preserving

Larvae and pupae

Preserve larvae and pupae in 70% ethanol.

Reared adults and captured adults

Do **not** place moths in alcohol, since it makes them difficult to identify to the level of species. Pin moths to a block of foam but do **not** spread the wings. Spreading delays shipment and makes specimens more fragile. Save the pupal and larval cast skins with the moth in a dry vial.

Captured adults on sticky traps (domestic survey)

Cut out the portion of the trap with the moth and pin it in a foam bottom box. Use enough pins to prevent the moth from shaking loose in the mail.

Shipping

Double-box and ship the specimens with at least 2 inches of padding around the sample.

Include PPQ Form 391 (Specimens for Determination) marked "Urgent". See the Airport Maritime Operations Manual for instructions on completing the form.

Send samples to the following address:

Leader, Taxonomic Services Unit
USDA, ARS, BA, PSI
Building 046, Room 101A
BARC-EAST Beltsville, MD 20705-2350

Pertinent references

Andrews 1980
Balachowsky 1972
Barlow 1982
Brown 1962
Brown and Dewhurst 1975
Campion 1975
Capinera and Schaefer 1983
Covell 1984
Ford 1988
Handfield 1999
Heppner 1995
Heppner 1998
Holloway et al. 1987
King and Saunders 1984
Miller et al. 1993
Mochida 1973
Niann-Tai 1981
OTIS 1986
Pinhey 1975
Pogue 2002
Rings 1977
Stibick 1991
Todd and Poole 1980
USDA/APHIS/PPQ. 1986.
USDA/APHIS/PPQ/BATS. 1982
USDA/APHIS/PPQ/NPAG 1986

Chapter 4. Survey Procedures

Introduction

The purpose of a survey is to determine the extent and means of pest spread. Surveys are also used to identify pest-free areas. Human and natural means of dispersal should be considered. Surveys for spodoptera can take place any time during the growing season while plants are actively growing.

Use three survey types for spodoptera: detection, delimiting, and monitoring surveys (Table 4.1).

Table 4.1. Methods of surveying for spodoptera.

IF:	THEN use this type of survey:
You are uncertain that the pest is present OR You have applied a control and need to measure its effectiveness	Detection or monitoring survey. Use visual inspection, sweep net sampling, and/or traps to capture specimens. Place traps or inspect plants at suspect locations. Consult with a Lepidoptera specialist to confirm your identification.
You know the pest is present and you need to define its geographic location	Delimiting survey. Use traps at specific locations and densities to capture specimens according to the plan outlined below. Consult with a Lepidoptera specialist to confirm your identification.

Detection survey

Use a detection survey to detect the presence of the pest. Conduct a detection survey by using a combination of survey tools, including visual inspection of plants, sweep net sampling of vegetation, and/or trapping. In your survey, consider human and natural means of dispersal.

Positive results indicate that the moth is present. However, based strictly on a detection survey, it is not valid to claim that a pest does **not** exist in an area if the trapping results are negative. Negative results are valuable clues to pest movement, particularly when considered with positive trapping results from similar areas. Once you have detected the moth in an area, conduct a traceback investigation to locate the source of the moth.

Delimiting survey

Once you have detected the pest, use a delimiting survey to gather sufficient information about the pest population to facilitate containment, suppression or eradication. Sticky traps with a pheromone lure are efficient tools to use for a delimiting survey of the spodoptera. If necessary, supplement trapping with visual surveys.

Use the delimiting survey decision table (Table 4.2) and the trapping scheme (Figure 4.1) as a guide when conducting a delimiting survey.

Table 4.2. Delimiting survey decision table for spodoptera.

IF you find:	**In an area that is:**	**THEN take this action:**	**AND supplement with:**
One or more adults	Apparently in the original infestation site	Set 36 traps per square mile at or near the original infestation site	
One or more (any stage)	Within a 1 square mile area	Set 36 traps per square mile in 9 square miles around the original area	Visual survey of 100 hosts per square mile in the 9 square mile area
	Within a 6 square mile area	Set 36 traps per square mile in 25 miles around the original area	Visual survey of 100 hosts per square mile in the 25 square mile area

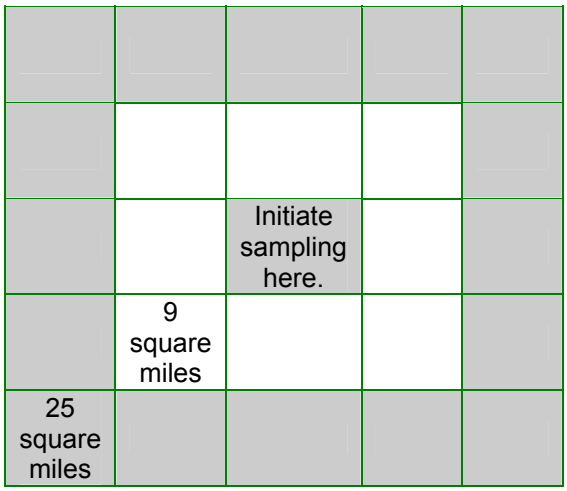

Figure 4.1.Trapping scheme. Begin by setting 36 traps per square mile where spodoptera have been detected. Each block represents one square mile.

Monitoring survey

Use a monitoring survey to evaluate the effectiveness of an action taken to contain, suppress or eradicate the pest. Use the same survey tools as detection and delimiting surveys.

Traceback investigation

Use a traceback investigation to locate the source of an introduction after spodoptera has been detected. Tracebacking helps to determine if an isolated detection is spurious—for example, the moth was conveyed into an area by air currents—or if it is evidence of an established population. Typically, if a single adult spodoptera is found in an area far removed from a port of entry, it is likely that it was transported to the site. The same is true for isolated detections during cool seasons.

Use wind field maps to plot the possible path of the moth. Calculate the estimated day and time of arrival (based on the circumstances at the site and likely air mass movements) and work backward in time and space to construct a logical path.

Site circumstances that provide clues to the estimated time of arrival include the following detections:

- Associated with the arrival of a weather system
- Of adults with no evidence of larval feeding

- Located in inland locations away from obvious ports of entry
- That end abruptly
- Of a new generation or stage in the life cycle
- Of sudden outbreaks or increases in numbers not associated with local breeding populations

Once the path of the moth is plotted, carry out surveys along the path until the likely introduction site is located. Likely origins include port environs, areas where over-wintering is possible, or agricultural areas where hosts are abundant. Allowing for the imprecision of this method, surveys add weight to conjecture about the origin of an introduction.

Computer generated atmospheric trajectory analyses are available to help identify potential sources of infestation and to trace the probable movement of plant pests with air masses. One such program is the Branching Atmospheric Trajectory (BAT) available from:

National Climatic Center
Data Base Administration
Box 34, Federal Building
Asheville, North Carolina 28801
http://www.ncdc.noaa.gov/oa/ncdc.html

Visual inspection of plants

Select plants that are at approximately equal distances, unless damaged plants are observed. Give priority to plants with partly or completely eaten leaves or flowers, gnawed shoots, fallen stalks, fallen or rotting fruit, gnawed heads, or that exhibit poor growth. After checking the cropped area, examine field borders, fencerows, and ditch banks for hosts. If hosts are found, take a separate survey, particularly if the location is within the core area.

Follow a similar sampling pattern for each field surveyed (Figure 4.2). Collect samples at least 75 feet from the edge of five different locations in the field.

At each sample location, inspect at least 10 plants from three adjoining rows (or at equivalent distances apart). Collect eggs and larvae with sufficient host for rearing purposes, if necessary.

Eggs

Visual inspection is the best method to use when looking for eggs. Look for clusters of 30 to 300 eggs covered with scales, on the underside of leaves near growing points of the host.

Larvae

Check leaves and flowers for young larvae and signs of feeding. Early instars are likely to be found on lower leaf surfaces during the day. Look at fruit or heads for gnawed, shallow holes or plant decay. Stir up the soil around the base of the plant to find larvae and pupae in the soil. In grassy areas, look for brown patches of grass with blades that have been eaten and appear ragged. Find later instars (4^{th}-6^{th}) and pupae of *S. littoralis* by sieving soil samples (Abul-Nasr and Naguib 1968, Abul-Nasr et al. 1971).

Adults

Look for adults on the underside of leaves, on tree bark, or in herbaceous growth. Tapping foliage with an insect net or similar object will often flush insects out of hiding places in brush. Retain and preserve adults for identification.

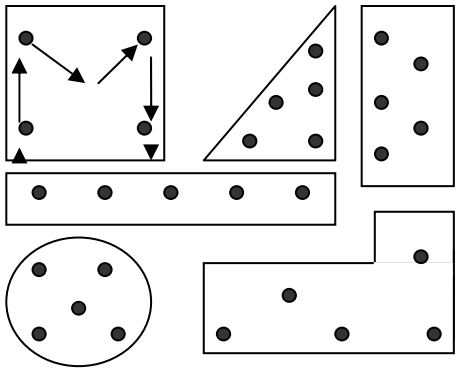

Figure 4.2. Sampling pattern for visual inspection of plants. At each sample location, inspect at least 10 plants from three adjoining rows (or at equivalent distances apart).

Sweep-net sampling

Sweeping plants with an insect net is a useful method for collecting larvae from the undersides of leaves. Sweeping at dusk or dawn will produce the best yield. Perform sweeping in tandem with a visual survey, if necessary.

Sweeping requires a minimum of skill and coordination. Rapid movement of the net in a long series of sweeps (a typical sample unit is 25 sweeps) seems to be most effective. While walking forward through plants, move the net from side to side in front of your path, in a horizontal “figure-8” pattern. Pass the handle from hand to hand at the body mid-point during the down stroke.

Trapping

Use active traps (either pheromone- or light-based) to monitor densities of adult spodoptera (DEFRA 1999).

Pheromone trapping

Use sticky wing traps baited with a pheromone lure to catch spodoptera spp. Pherocon 1C (Figure 4.3) traps work best since their open design facilitates the dispersal of pheromones. Set traps in host plants at the focal point and in each square mile in the first and second buffer areas in a standard grid array (Figure 4.1). Or, hang traps from stakes at the approximate height of the host. Adjust trap height as plants grow. Maintain the traps through three estimated generations of spodoptera after the last detection.

Figure 4.3. Sticky wing trap Pherocon 1C.

Use manufactured pheromone lures whenever possible (Table 4.3) (see chapter 10). If manufactured pheromones are unavailable, you can make your own. Use a plastic stopper or rubber septum injected with 1 milligram of the appropriate mixture of pheromones.

Table 4.3. Laminate pheromone lures used to attract spodoptera; manufactured by Hercon Environmental Corporation.

Species	Lure compounds	Ratio of compounds
S. exigua	Z, E-9, 12-tetradecenyl acetate : Z-9-tetradecenol : Z-11-hexadecenyl acetate	87.2 : 2.5 : 10
S. frugiperda	Z-9-tetradecenyl acetate : Z-7 dodecenyl : Z-11-hexadecenyl acetate	80.3 : 0.5 : 19.2
S. littoralis	Z,E-9,11-tetradecenyl acetate : Z,E-9,12-tetradecenyl acetate	1.99 mg/lure : 0.01 mg/lure
S. litura	Z,E-9,11-tetradecenyl acetate : Z,E-9,12-tetradecenyl acetate	1.76 mg/lure : 0.24 mg/lure

Spodoptera littoralis

The synthetic sex pheromone cis 9-trans-11-tetradecadien-1-y1 acetate is highly effective at trapping male moths of *S. littoralis* (Salem and Salama 1985). Delta traps baited with sex-pheromone remain attractive for approximately 2 weeks, but effectiveness declines after 3 to 4 weeks of use (Ahmad 1988).

Spodoptera litura

Use a mixture of ZE 9, 11-tetradecadienyl acetate and ZE 9,12-tetradecadienyl acetate for monitoring populations of *S. litura* (Yushima and Tamaki 1974). The compounds are most effective in a ratio between 4:1 to 39:1 (Yushima and Tamaki 1974). Rubber septa impregnated with the sex attractant were equally attractive to males for up to 4 weeks (Ranga Rao et al. 1991). Although more moths were captured at a trap density of 4-5 traps per hectare, moth capture per trap was greatest at one trap per hectare (Ranga Rao et al. 1991). In areas where *S. litura* is well established, trap catches have been correlated with larval densities and feeding damage in cotton (Muthukrishnan and Balasubramanian 1992).

Light trapping

Noctuidae are highly attracted to ultra-violet light. They are large, fast fliers and are unable to avoid entering the trap once they have flown sufficiently close for the light to repel them (Southwood 1978). Light traps using a 125-watt mercury-vapor bulb have been used to non-discriminately capture spodoptera (and other insects as well) (Blair 1974; Pawar and Srivastava 1986). Shrivastava et al. 1987 found that capture of *S. litura* moths was affected by the stage of the moon. Traps were least effective during the full moon and most effective during the new moon.

A standard, unadorned light trap is sufficient for trapping spodoptera. An ultra violet light trap fitted with a transparent trap may catch a similar number of moths, but seems to capture fewer beetles, thus eliminating much of the damage the beetles inflict on trapped moths.

Soil survey

Use a survey to locate larvae and pupae in soil and turf.

Sampling soil

Collect samples from soil within a 200-yard radius of detection of a spodoptera larva or egg.

Procedure

Collect at least four soil samples under the host plant. Sample size is 20-square inches (less than a square measuring 4.5-inch on each side). Use a golf-hole borer, soil corer, or metal tube to collect samples. Place each sample in a sealable container; keep samples cool. Label the container immediately.

Place each soil sample in a 4-mm (0.15-inch) sieve and wash with water until all lumps are broken and only solid objects remain in the sieve. Identify and/or rear the collected larvae.

Sampling turf grass

This sampling technique is useful primarily for spodoptera that use grasses as host material.

Procedure

Sample at least one site within 200 yards of detecting a larva, pupa, or egg. Select sites with brownish patches or where the grass has been eaten and looks ragged. Drive a steel cylinder (8-inches in diameter by 8-inches high) into the soil. Treat the sample with 1 gallon of 0.25 percent liquid dish detergent in water by volume. Observe the area continuously for 10 minutes, and collect and hold any larvae that come to the surface. Identify and/or rear the collected larvae.

Note: Soil and turf samples collected from a regulated area require certification prior to removal from the area.

Orientation of survey personnel

Experienced personnel should train their replacements. Adequate training on survey techniques and procedures will likely require three working days.

Survey records

Survey records and data recording formats should be standardized. Maintain survey records, noting the areas surveyed, sites trapped, dates, locations, and hosts.

Chapter 5. Regulatory Procedures

Instructions to officers

Regulatory actions are required until this pest is **eradicated**. Officers must follow instructions for regulatory treatments or other procedures when authorizing the movement of regulated articles. Understanding the instructions and procedures is essential when explaining procedures to persons interested in moving articles affected by the quarantine and regulations. Only authorized treatments may be used in accordance with labeling restrictions.

Find instructions for regulatory treatments in the PPQ Treatment Manual.

Issuing an emergency action notification

An Emergency Action Notification may be issued pending positive identification and/or further instruction from the USDA, APHIS, PPQ Deputy Administrator.

If necessary, the Deputy Administrator will issue a letter directing PPQ field offices to initiate a specific emergency action under the Plant Protection Act of 2000 until emergency regulations can be published in the Federal Register.

The Plant Protection Act of 2000 provides authority for emergency quarantine action. This provision is for interstate regulatory action only. Intrastate regulatory action is provided under state authority. However, if the Secretary of Agriculture determines that an extraordinary emergency exists and that the measures taken by the state are inadequate, USDA can take intrastate regulatory action provided that the governor of the state has been consulted and a notice has been published in the Federal Register. If intrastate action cannot or will not be taken by a state, the PPQ may find it necessary to quarantine an entire state.

PPQ works with state departments of agriculture to conduct surveys, enforce regulations, and take control actions. PPQ employees must have permission of the property owner before accessing private property. If a declared extraordinary emergency is declared or if a warrant is obtained, PPQ may enter private property without owner permission. PPQ prefers to work with the state to facilitate access when permission is denied; each state government has varying authorities regarding accessing private property. A General Memorandum of Understanding exists between PPQ and each state. PPQ officers must have permission of the owner before accessing private property. For clarification, check with the State Plant Health Director (SPHD) in the affected state.

Regulated articles

Regulated articles include the following:

- Fresh fruits, nuts, vegetables, and berries listed as hosts (Appendix A) that exist in the regulated area

- Soil within the drip area of host plants
- Any other product, article, or means of conveyance of any type when an inspector determines that it presents a hazard of spread of spodoptera

Persons in control or possession of the article must be notified that the article is regulated.

Quarantine actions

Regulatory action will be required if:

- More than one moth is found in an area less than 6 square miles within one estimated life cycle; or
- One mated female, or a larva, or a pupa are detected; or
- A single moth is detected that is determined to be associated with a current eradication project

Regulated establishments

Field personnel will attempt to detect the pest within the regulated area at all establishments where regulated articles are sold, grown, handled, moved, or processed. Establishments that might be involved are airports, landfill sites, processing plants, farmer's associations, produce and flea markets, nurseries, flower shops, and any other establishments that handle regulated articles. Surveys may be set up at establishments deemed to be at risk by project personnel. Two pheromone traps or two black light traps per establishment are set and serviced by survey personnel. Service traps weekly if catches of insects are high; or every two weeks if trap catches are low.

Use of pesticides

Both the PPQ Treatment Manual
and this document identify the authorized pesticides, and describe the methods and rates of application, and special application instructions. Concurrence by PPQ is necessary before using any other pesticide or procedure for regulatory purposes.

Approved regulatory treatments

Approved regulatory treatments appropriate for this pest are determined by program management and/or a Technical Advisory Committee in conjunction with the Center for Plant Health, Science, and Technology. Check the PPQ Treatment Manual for current
recommendations.

Treatment options include:

- Fumigation (application of an approved fumigant as a treatment)
- Fumigation/cold treatment (application of an approved fumigant in conjunction with cold treatment procedures)
- Sanitation (removal and destruction of leaves, flowers, stems, stalks, rotting or fallen fruit, vegetables, and other host material)
- Insecticide treatment (an approved ovicide/larvicide treatment applied to above ground parts of hosts)
- Soil treatment (an approved insecticide applied to the soil within the drip line of host plants)

Hold plants for one life cycle after treatment before certifying for movement.

Principal activities

The degree of regulatory activity required depends, among many other factors, on the degree of the infestation. For example, it may not be necessary to safeguard vegetable stands throughout the regulated area if they are engaged in local retail activity only and the infestation is limited. However, if the infestation is severe, mandatory checks of passenger baggage (i.e., for host material) at airports and road patrols and roadblocks may be necessary.

Principle activities for conducting a regulatory program to contain spodoptera include:

- Advise regulated industry(ies) of required treatment procedures
- Supervise, monitor, and certify commodity treatments of commercial lots of regulated articles
- Make regulatory visits to the following:
    - Security and airline personnel
    - Vegetable stands
    - Flower stands
    - Local growers, packers, and processing plants
    - Farmer's associations, produce markets, and flea markets
    - Commercial haulers of regulated articles
    - Public transportation; and
    - Post offices
- Visit canneries and other processing establishments

- Monitor the movement of waste material to and from landfills to ensure adequate disposal of regulated articles
- Monitor the movement of regulated articles through major airports and other transportation centers
- Observe major highways and quarantine boundaries for movement of host materials

Removing quarantines

Project managers identify and remove areas from quarantine requirements after the spodoptera is declared eradicated. Eradication is assumed when sufficient time, equal to three spodoptera life cycles, has passed since the last specimen recovery. At minimum, one life cycle must elapse after control activities have ceased. APHIS will publish a Notice of Quarantine Revocation in the Federal Register when areas are removed from quarantine requirements.

Regulatory personnel

Initially, program personnel will be limited to those already trained or experienced. Experienced individuals train their replacements. A training period of three working days should be sufficient for the orderly transfer of these functions.

Regulatory records

Maintain standardized regulatory records and database(s) in sufficient detail to carry out an effective, efficient, and responsible regulatory program.

Chapter 6. Control

Introduction

Eradication of exotic spodoptera in the continental U.S. is **essential**. Consider all possible methods—biological, cultural or chemical—before beginning a program. Your goal is to eradicate the pest while minimizing negative environmental effects.

Emergency programs

Plant Protection and Quarantine (PPQ) develops and makes control measures available to involved states. Pesticides must be labeled for use on the site, and within the state, of application.

If treatments selected or proposed are not in conformance with current pesticide labels, an emergency exemption can be requested and obtained under Section 18, or 24(c), special local need (SLH), of FIFRA, as amended. For additional information, see the Emergency Programs Manual, Section 14. It is a federal violation to use any pesticide in a manner inconsistent with its labeling.

Environmental documentation

Obtain all required environmental documentation before beginning. Contact Environmental Services staff for the most recent documentation.

Treatment guidelines

The treatments suggested below are the minimum recommended to achieve the program goal of eradication. Continue eradication measures for at least two life cycles of spodoptera. After the termination of eradication measures, monitor the success of the program for at least one life cycle of spodoptera.

Timing of applications

Apply an insecticide immediately upon discovery of an infestation. Apply insecticides in the late afternoon, evening, or at night to coincide with nocturnal habits of adults and most larvae.

Consider delaying applications if weather reports indicate greater than a 50 percent chance of precipitation within 48 hours after application. If rain reduces the effectiveness of an application, retreat as soon as the label permits.

After an estimated two generations of negative trapping and survey, applications may be discontinued.

Treat all plants within the enclosure to eliminate hiding places for the adults and to kill any larvae present on host plants. Direct sprays to the underside of leaves where larvae congregate. Drench the soil beneath each plant/host where older (3^{rd} to 4^{th} instar) larvae hide during the day.

Avoid insecticide resistance

To avoid the development of resistance, rotate the application of recommended insecticides.

Defining the treatment area

Once a decision has been made to eradicate spodoptera, use the decision table (Table 6.1) to define the treatment area.

Table 6.1. Decision table of treatment options for spodoptera.

IF:	**Are detected in an area:**	**THEN treatment will commence and extend:**
1-5 gravid females, larvae or pupae	less than 6 square miles	200 yards beyond the detection site on host(s)
2-5 males or virgin females		
6 or more, any stage	greater than 6 square miles	2 ½ miles beyond the detection site on host(s)

Treatment options

Treatment may include:

- Sanitation and destruction of wild and cultivated hosts, and/or
- Application of recommended insecticides (aerial or ground) and/or
- Application of other cultural controls and/or
- Application of biological controls

Sanitation and destruction of hosts

Carry out sanitation in nurseries, farms, gardens, and other establishments where wild and cultivated hosts are present within the core and buffer areas.

Burn debris

Collect, pile and burn host material if local ordinances permit.

Feed to animals

Use appropriate host material as animal food, and dispose of residue by burning and/or burial at an approved landfill. Exercise caution when considering this disposal option.

Control weeds

Trim grasses and weeds growing along roadsides, fields, or in row crops. At time of pupation, lightly plow or cultivate to destroy pupae.

Bag and bury

Collect and transport host material to an approved landfill. Use a plow to bury residue.

Inspect and clean vehicles

Inspect vehicles, trucks, wagons, and other vehicles used in host fields or used to transport host material to avoid accidental movement of host material with eggs or larvae.

Apply herbicides

Use herbicides to control wild and cultivated hosts.

Application of recommended insecticides

At the initiation of an eradication program, evaluate available insecticides. Select an insecticide after considering environmental consequences, local conditions, survey results, and resistance to pesticides. Consider using an antifeedant or *Bacillus thuringiensis* if spodoptera are resistant to other pesticides, or where chemical control is not feasible. Use the decision table (Table 6.2) to select an insecticide.

Table 6.2. Decision table for selecting an insecticide to control spodoptera.

WHEN applying an insecticide to control spodoptera in this environment:	**THEN select from the following insecticides:**
Indoors	Antifeedants *Bacillus thuringiensis* var. *Kurstaki* *Methomyl* Petroleum oil Thiodicarb
Outdoors	Antifeedants *Bacillus thuringiensis* var. *Kurstaki* Chlorpyrifos Cypermethrin Diflubenzuron Esfenvalerate Methomyl Petroleum oil Thiodicarb Trichlorfon

Antifeedants

Two percent neem kernel suspension is effective against spodoptera larvae. It may also be used after applications of other pesticides. However, since it inhibits feeding, do not use it with other controls that require feeding behavior. Do not treat dense populations since it may prompt larvae to migrate.

A crude methanolic extract of *Trichilia americana* (Meliaceae) may have antifeedant and toxic activity on spodoptera. Wheeler and Isman (2001) found that the extract reduced growth, consumption and the ability of the larvae to use food. The toxic effects of the extract were observed after larvae ate treated food, but not when the extract was applied topically or injected in to the hemocoel.

Persin, a component of avocado fruits, has also been investigated for its antifeedant and growth-inhibiting activity on *S. exigua.* Rodriguez-Saona et al.

(1997) found that treating newly-hatched larvae with persin resulted in less weight gain and greater mortality.

Bacillus thuringiensis var. Kurstaki

Bacillus thuringiensis var. *Kurstaki (BT)* is a bacterium active against the larval stage of many Lepidoptera. It is formulated as an insecticide. When an insect ingests BT, its digestive system fails. Follow these guidelines for successful control when using BT:

- Apply when larvae are small
- Apply when temperatures are mild and larvae are actively feeding
- Apply the proper concentration of formula

Application of other cultural controls

Cultural controls are not suitable for eradicating this pest. However, a combination of cultural and biological control methods may be useful for managing the pest in non-emergency situations. Cultural control may be subject to obtaining environmental documentation under the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). Check with the program manager to make sure documentation is in order.

Flood fields

Flood a crop field and allow the water to remain for at least 2 days. Pupae will suffocate (El Amin and Ahmed 1991).

Build barriers

Contain larvae in a severe infestation by plowing a deep furrow around the infested area or field. The furrow should have straight vertical sides to prevent larvae from crawling out. Dig postholes at a depth of least 1-foot and at a distance of 20 feet apart in the furrow. Destroy larvae trapped in the postholes with soapy water or kerosene. Keep furrows clear of rubbish.

Augment with pheromones

Hang sticky traps baited with slow-release pheromones to interfere with successful mate-seeking (Campion and Murlis 1985).

Application of biological controls

Biological control agents are useful for suppressing pest populations, but rarely eradicate them. Some biological control agents are effective when integrated with insecticides or cultural controls in a pest control program.

Researchers speculate that baculoviruses, and the entomopathogenic nematode *Steinernema carpocapsae* (Rhabditida), may provide some control against many of the spodoptera mentioned in this document. The following list of biological control organisms may be active against spodoptera. Some organisms may require approval from APHIS and/or state regulatory agencies for importation into the U.S.

Biological control is a promising tool in pest control. However, the subject is beyond the scope of this document. Conduct additional research before considering these organisms for control of spodoptera. Find helpful links to more information on how to design a program using biological controls in chapter 10.

Spodoptera exigua

- *Orius* spp. (Hemiptera: Anthocoridae) (Capinera 1999)
- *Geocoris* spp. (Hemiptera: Lygaeidae) (Capinera 1999)
- *Nabis* spp. (Hemiptera: Nabidae) (Capinera 1999)
- *Podisus maculiventris* (Hemiptera: Pentatomidae) (Capinera 1999)
- *Solenopsis invicta* (Hymenoptera: Formicidae) (Capinera 1999)
- *Noctuidonema guyanense* (Nematoda: Acugutturidae)
- *Cotesia marginiventris* (Hymenoptera: Braconidae) (Capinera 1999)
- *Chelonus insularis* (Hymenoptera, Braconidae) (Capinera 1999)
- *Meteorus autographae* (Hymenoptera: Braconidae) (Capinera 1999)
- *Frontina archippivora4* (classification unknown)
- *Lespsia archippivora* (Diptera: Tachinidae) (Capinera 1999)
- *Beauveria bassiana* (Fungi: Ascomycota)
- *Erynia* sp. (Entomophthorales: Entomophthoraceae)
- *Nomurea rileyi* (Fungi: Ascomycota)

Spodoptera littoralis

- *Chiracanthium mildei* Koch (Arachnida: Clubionidae) (Fowler and Lakin 2001)
- *Coccinella undecimpunctata* (Coleoptera: Coccinellidae) (Fowler and Lakin 2001)
- *Microplitis rufiventris* (Hymenoptera: Braconidae) (Fowler and Lakin 2001)
- *Spodophagus* spp. (Hymenoptera: Ptermomalidae)

Spodoptera litura

- *Exorista japonica* (Diptera: Tachninidae) (Herbison-Evans and Crossley 2004)
- *Nomuraea rileyi* (Fungi: Ascomycota)
- *Cypovirus* (Viris Reoviridae) (Herbison-Evans and Crossley 2004)

Sterile insect technique

Sterile insect technique (SIT) is an effective tool in eradication and suppression programs. USDA/APHIS personnel have used SIT to control the following pests:

- Mediterranean fruit fly (*Ceratitis capitata*)
- Screwworm fly (*Cochliomyia hominivorax*), and
- Pink bollworm (*Pectinophora gossypiella*)

SIT employs radiation to sterilize large numbers of insects. When released, the sterilized insects effectively compete with the target pest species, thereby reducing the reproductive success of the native pest. Many factors determine if a particular insect is a good candidate for SIT, including its competitiveness after irradiation, ability to be reared in large numbers, and the development of a pheromone for monitoring.

S. frugiperda, *S. exigua, S. litura* and *S. littoralis* exhibit inherited sterility and are good candidates (Carpenter and Wiseman 1992; Carpenter, Hidryani and Sheehan 1996; Seth and Lehgal 1993; Sallam and Ibrahim 1993). Inherited sterility (also known as F1 sterility) is most common in members of the family Lepidoptera. After treatment with radiation, all females will be sterile; and all males will be fertile and carry a gene for sterility that is passed to the next generation.

The release of completely sterile females and partially sterile males (able to produce sterile F1 progeny when mating with feral females) may be an effective strategy to control spodoptera. However, more research is necessary.

Orientation of control personnel

Only trained and experienced personnel will be used initially. These personnel will train replacements. A training period of three working days should be sufficient for the orderly transfer of these functions.

Records

Program personnel must maintain records and maps noting the locations of all detections, the number and type of treatments, and the materials and formulations used in each treated area.

Monitoring

Program personnel must implement an effective monitoring program to evaluate program efforts, pesticide use, and environmental impact, including any concerns of the agency or cooperators. Personnel must provide data for assessment of application method. Include the following analyses in any monitoring program:

- Determine pesticide efficacy against the target pest
- Evaluate dye cards to monitor aerial applications for:
    - Droplet size information
    - Droplet distribution information
    - Bait distribution information
    - Identification of wind drift components
    - Verification of spray block boundaries and
    - Identification of skips
- Evaluate environmental impact by sampling:
    - Water, to detect insecticide levels resulting from direct application, leaching, and runoff
    - Soil, to determine insecticide levels and residues
    - Foliage, to identify residues
    - Biological organisms before, during and after applications and post treatments, to determine impact of pesticides on non-target organisms; and

- Air, to determine presence of residual airborne pesticides
- The monitoring program must be a combined effort between PPQ and the state in which the emergency program is being conducted

Chapter 7. Environmental Concerns

Introduction

Environmental Services (ES) is a unit of APHIS Policy and Program Development Staff. ES manages the preparation of environmental documentation, such as environmental impact statements and environmental assessments, to aid in program operational decisions. ES also coordinates pesticide registration and approvals for APHIS pest control and eradication programs, ensuring that registrations and approvals meet program use needs and conform to pesticide use requirements.

Disclaimer

All uses of pesticides must be registered or approved by appropriate federal, state, and/or tribal agencies before application. Pesticide labels may not reflect all state or local restrictions. Read and abide by the label, including labeling that has been approved for the particular state or locality. Comply with all federal, state, tribal, and local laws and regulations relating to the use of the pesticide. APHIS program staffs are responsible for their compliance with applicable environmental regulations.

Chapter 8. Pathways

Introduction

Since 1985, interceptions of spodoptera have been reported over 1,759 times on fruits, vegetables, ornamentals, and other plants and on more than 230 taxa. Interceptions identified as *S. littoralis* have been reported 65 times, and interceptions identified as *S. litura* have been reported 279 times. *S. littoralis* and *S. litura* present the greatest approach risk. For the same period, *S. exempta* was intercepted four times, *S. mauritia* was intercepted 13 times, and *S. pectin* was intercepted 14 times (USDA Port Identification Network Database 2003).

Commerce

Commerce appears to be the most likely pathway for introduction of spodoptera. The majority of interceptions have been associated with permit cargo (62%) and general cargo (22%).

Natural

The lifestyle of exotic spodoptera precludes natural spread through wind, attachment to or transport by another organism or through other natural means. For example, the risk of introduction of *S. littoralis* through natural means is low since eggs are attached to lower regions of plants, the larvae hide in the soil when not feeding, and pupation occurs in the soil. One exotic species, *S. exempta,* has demonstrated only weak migratory abilities (often facilitated by wind currents).

Travel

International airline passengers accounted for 16% of interceptions.

Countries of origin

The majority of *S. littoralis* were intercepted in permit cargo flowers from Israel. Interceptions of *S. litura* predominate in orchids entering as permit cargo.

Destinations

S. littoralis has been intercepted at 49 international ports of entry, including ports in Hawaii. The majority of interceptions were reported from JFK

International airport (52%), Honolulu (17%), Miami (8%), Los Angeles (5%), Houston (2%), Atlanta (2%), and San Francisco (2%).

S. litura has been intercepted at 49 international ports of entry, including ports in Hawaii. The majority of interceptions have been reported from JFK International airport (47%), Honolulu (17%), Los Angeles (9%), Miami (8%), Houston (2%), and San Francisco (2%).

Cargo or passengers were destined for 34 states (including the District of Colombia). The most commonly reported destinations were New York (45%), California (21%), Florida (10%), Hawaii (4%), Texas (4%), New Jersey (3%), Pennsylvania (2%), Washington (2%), Georgia (2%), and Massachusetts (2%).

Many of the areas are likely to provide a suitable climate, in terms of temperature and moisture. Because of its very broad host range, this genus is likely to find a suitable host.

Chapter 9. Definitions

Aerial treatment Application of insecticide to a treatment area by aircraft.

Array The arrangement of traps within one square mile.

Array sequence The layout of traps (arrays) from the core area outward to the perimeter (buffer areas).

Block Units (e.g., 1 square mile area) of a detection survey in which all survey activities are conducted.

Buffer area Survey area that is:

- Beyond the core block
- 1-2 miles from the perimeter of a regulated area, or
- 50 miles from the core of a regulated area (in an extended survey)

Calling Emission of sex pheromones by the female moth to attract mates.

Cold treatment Exposure of a host product to cold temperatures lethal to a target pest. May be used alone or with fumigants.

Confirmed detection A positive identification by a recognized expert.

Containment Application of phytosanitary measures in and around an - infested area to prevent spread of a pest.

Control Suppression, containment or eradication of a pest population.

Core area An area of 1 square mile surrounding a confirmed detection.

Crepuscular Of an organism, active in twilight hours.

Degree day A measure of physiological time using the accumulation of heat units (degrees) above an insect's developmental threshold for a 24-hour period.

Delimiting survey Determination of the extent of an infestation (e.g., distribution, density) in an area where an exotic species has been detected.

Delta trap A five-sided insect trap, configured with three lateral sides arranged triangularly, equipped with a lure (i.e., pheromone), a baffled edge, and an adhesive surface inside to capture and secure attracted insects.

Detection The collection of any life stage of an exotic species.

Detection survey An activity conducted in a susceptible area not known to be infested with an exotic species to determine its presence.

Developmental threshold The minimum and/or maximum temperatures that support physiological development for a species.

Diurnal Of an organism, active during the day.

Eclosion Of an insect, leaving the egg or the terminal molt into an adult.

Eradication Application of phytosanitary measures to eliminate a pest from an area.

Epicenter The initial site of an infestation.

Exotic species An organism or pest species not native to or historically resident in North America.

Fumigation The application of an approved insecticidal chemical that enters the target pest's tracheal system in volatile form.

Generation The offspring of a parent population that move through the life cycle together.

Ground spray Insecticide application in droplet form, from equipment positioned on the ground or at the vegetation level.

Host A species that provides food, shelter or reproductive requirements for another organism.

Host collection/Holding The collection and retention of infested host material for the purposes of determining characteristics of a pest's use of the material.

Infestation The collection of:

- Two or more of an exotic species
- A pupa, larva, or mated female from an area, or
- The detection of a single adult associated with a current infestation

Infested area An area surrounding a single detection site or a group of sites. The standard designated area of 2.5 miles is used, unless biotic or abiotic factors dictate adjustment of this area.

Migratory species A species in which individuals habitually move from place to place especially in search of mates or egg-laying sites.

Monitoring/Evaluation survey Conducting visual and/or trapping surveys in an area that has been treated with insecticide to evaluate the effectiveness of the treatment.

Natural enemies Living organisms found in a natural community that kill, weaken, or inhibit the biological potential of a pest species.

Nocturnal Of an organism, active at night.

Non-migratory A species in which individuals typically do not move far from the area of their birthplace.

Parasites Parasites live on the host (frequently the adult stage) at one or multiple life stages. Parasites sometimes kill but usually merely debilitate the host.

Parasitoid Parasitoids live on the host (often an immature stage) when immature, but are free-living as adults. Parasitoids always kill the host. Like parasites, these organisms are typically host-specific, and some are obligate on certain hosts. They find hosts effectively even when host population numbers are not particularly dense.

Pathogen An agent, usually microbial, that induces illness. Entomopathogens induce illness in insects. These include baculoviruses (primarily those in the genus Nucleopolyhedrovirus), nematodes and fungi. Many are species-specific, and cause no collateral infection of other organisms.

Phenology The timing of recurrent biological events.

Predator Free-living organisms that consume substantial numbers of prey. They generally do not prey exclusively on one target species over the course of a season. However, when the population of one species is dense (e.g., when swarming or aggregating to mate; when larvae cluster on hosts), they can be very efficient.

PPQ/APHIS/USDA Plant Protection and Quarantine, Animal and Plant Health inspection Service, U.S. Department of Agriculture.

Regulated area An area that extends at least 2 1/2 miles in any direction from the epicenter of an infestation.

Regulated articles All known or suspected hosts of a confirmed infestation of an exotic species, including soil and any other suspected product or article.

Regulatory survey A trapping or detection program conducted around establishments where regulated articles are sold, handled, processed or moved.

Sex pheromone A chemical substance that is secreted by an insect to attract or to advertise reproductive competence to the opposite sex of the same species.

Soil treatment The application of an approved insecticide to the soil of nursery stock or within the drip line of host plants.

Suppression The application of phytosanitary measures in an infested area to reduce pest populations.

Sweep net A survey method in which a mesh net suspended around a hoop is swept through the air or around vegetation to collect insects.

Trace back investigation Investigation to determine the source of an infestation.

Trap survey Determination of the presence of a pest through the use of randomly or strategically placed devices that capture insects (sometimes aided

by an attractant). These traps are maintained and serviced on a schedule dictated by the goal of the survey.

Visual survey Examination of areas for eggs, larvae, pupae, cocoons, or other evidence that a particular insect species is present.

Wing trap A disposable, adhesive-coated capture device used primarily for surveying moths.

Urban/residential An area containing a number of multiple- or single family dwellings.

Chapter 10. Resources

Beneficial organisms

Suppliers of Beneficial Organisms in North America. A free 32-page booklet available online at http://www.cdpr.ca.gov/docs/ipminov/bensuppl.htm from:
California Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring and Pest Management Branch
1020 N. Street, Room 61
Sacramento, CA 95814-5604
Telephone (916) 324-4100

Association of Natural Biocontrol Producers
10202 Cowan Heights Drive
Santa Ana, CA 92705
Telephone (714) 544-8295
http://www.anbp.org/

Weedon, C.R., A.M. Shelton, Y. Li, and M.P. Hoffmann. Biological Control: A Guide to Natural Enemies in North America. Cornell University.
http://www.nysaes.cornell.edu/ent/biocontrol/

Biological Control Virtual Information Center. Center for IPM. North Carolina State University. http://cipm.ncsu.edu/ent/biocontrol/

US Environmental Protection Agency. September 2002. *Beauveria bassiana* strain 447 (128815) Fact Sheet.
http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_128815.htm

Pest management supplies

BioQuip Products, Inc.
2321 Gladwick Street
Rancho Dominguez, CA 90220
Telephone (310) 667-8800
http://www.bioquip.com/

Wards Natural Science
PO Box 92912
Rochester, NY 14692-9012
Telephone 800-962-2660
http://www.wardsci.com/

Carolina Biological Supply Co.
2700 York Road

Burlington, NC 27215-3398
Telephone (800)334-5551
http://www.carolina.com/

Hercon Environmental Corporation
PO Box 467 Aberdeen Road
Emigsville PA 17318-0467 USA
Telephone (717) 764-1191
Fax (717) 767-1016
http://www.herconenviron.com/

Cooper Mill Ltd
RR3
Madoc, Ontario K0K 2K0
CANADA
Telephone (613) 473-4847
Fax (613) 473-5080
http://www.coopermill.com

ISCA Technologies, Inc.
P.O. Box 5266
Riverside, CA, 92521
Telephone (909) 686-5008
Fax (815) 346-1722
http://www.iscatech.com/exec/index.htm

Great Lakes IPM, Inc
10220 Church Road
Vestaburg, Mi 48891-9746
Telephone (989) 268-5693 or (989) 268-5911
Fax (989) 268-5311
http://www.greatlakesipm.com/index.html

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Other

Predicting insect development

University of California Statewide Integrated Pest Management Program 2003 (http://www.ipm.ucdavis.edu/WEATHER/ddconcepts.html#Using or http://www.ipm.ucdavis.edu/MODELS/DDU/)

Collecting local temperature data

- National Oceanic and Atmospheric Administration (NOAA Home Page)
- U.S. Department of Commerce
- Local Cooperative Extension Service
- Private, state, university, or industry sources

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Appendix A. Hosts of spodoptera

A.1. Preferred hosts of *Spodoptera cilium*.

Bermuda grass	*Cynodon dactylon*
Carpet grass	*Axonopus fissifolius* (Raddi) Kuhlm
Blue couch grass	*Digitaria didactyla*

A.2. Preferred hosts of *Spodoptera exempta*.

Acidanthera	*Acidanthera laxiflora*
Barley	*Hordeum vulgare*
Hottentot-fig	*Carpobrotus edulis*
Cotton	*Gossypium hirsutum*
Finger millet	*Eleusine coracana*
Crabgrass	*Eleusine indica*
Maize	*Zea mays*
Oat	*Avena sativa*
Oxygonum	*Oxygonum sinuatum*
Rice	*Oryza sativa*
Sorghum millet	*Sorghum vulgare*
Sugarcane	*Saccharum officinarum*
Tef	*Eragrostis tef*
Wheat	*Triticum aestivum*

A.3. Preferred hosts of *Spodoptera littoralis*

Beans, French and Kidney	*Phaseolus vulgaris*
Beet	*Beta vulgaris*
Berseem clover	*Trifolium alexandrinum*
Brussels sprouts	*Brassica oleracea gemmifera*
Cabbage	*Brassica oleracea*
Carrot	*Daucus carota sativus*
Castor	*Ricinus communis*
Cauliflower	*Brassica oleracea*
Cineraria	*Cineraria hybrida*
Corn	*Zea mays*
Cotton	*Gosssypium barbadense*
Eggplant	*Solanum melongena*
Finger millet	*Eleusine coracana*
Garden pea	*Pisum sativum*
Grape	*Vitis vinifera*
Guava	*Psidium guajava*
Jew's mallow	*Corchorus olitorius*
Kidney beans	*Phaseolus vulgaris*
Lettuce	*Lactuca sativa*
Millet	*Pennisetum glaucum*
Okra	*Abelmoschus esculentus*
Peanut	*Arachis hypogaea*
Potato	*Solanum tuberosum*
Radish	*Raphanus sativus*
Red pepper	*Capsicum annuum*
Sesban	*Sesbania sesban*
Spinach	*Spinacia oleracea*
Sweet melon	*Cucumis melo*
Sweet potato	*Ipomoea batatas*
Tomato	*Lycopersicon esculentum*
Watermelon	*Citrullus lanatus*
White poplar	*Populus alba*

A.4. Potential hosts of *Spodoptera littoralis*.

Amaranth	*Amaranthus graecizans*
Apple	*Malus domestica*
Arborvitae	*Thuja orientalis*
Aster	*Callistephus chinensis*
Banana	*Musa ×paradisiaca*
Bindweed	*Convolvulus* spp.
Blue clitoria	*Clitoria ternatea*
Cacao	*Theobroma cacao*
Cassava	*Manihot esculenta*
Casuarina	*Casuarina equisetifolia*
Confederate-rose	*Hibiscus mutabilis*
Chempedak	*Artocarpus integer*
Chrysanthemum	*Chrysanthemum indicum*
Citron	*Citrus medica*
Coconut	*Cocos nucifera.*
Coffee	*Coffea arabica*
Colocasia	*Colocasia esculenta*
Common mallow	*Malva sylvestris*
Cowpea	*Vigna unguiculata*
Custard-apple	*Annona squamosa*
Datura, white	*Datura* spp.
Date palm	*Phoenix dactylifera*
Egyptian carissa	*Carissa edulis*
Eucalyptus	*Eucalyptus globulus*
Euphorbia	*Euphorbia prunifolia*
Feather asparagus	*Asparagus plumosus*
Fenugreek	*Trigonella foenum-graecum*
Ficus	*Ficus* spp.
Flowering reed	*Canna indica*
Gerocorn	*Penicillaria spicata*
Gum-arabic	*Acacia arabica*
Hemp	*Hibiscus cannabinus*
Hollyhock	*Alcea rosea*
Horseradish tree	*Moringa oleifera*
Indigo	*Indigofera tinctoria*
Jute	*Corchorus capsularis*
Lantana	*Lantana salviifolia*

Lucerne	*Medicago sativa*
Mallow, small flowered	*Malva parviflora*
Mandarin orange	*Citrus aurantium*
Mango	*Mangifera indica*
Spearmint	*Mentha spicata*
Night jasmine	*Cestrum nocturnum*
Onion	*Allium cepa*
Oxalis	*Oxalis crenata*
Papaya	*Carica papaya*
Pigeon pea	*Cajanus indicus*
Plum	*Prunus domestica*
Pomegranate	*Punica granatum*
Poppy	*Papaver somniferum*
Prickly lettuce	*Lactuca scariola*
Prickly pear	*Opuntia* spp.
Purslane	*Portulaca oleracea*
Rice	*Oryza sativa*
Rose	*Rosa* spp.
Sacred fig	*Ficus religiosa*
Sand pear	*Pyrus pyrifolia*
Sesbania	*Sesbania aergyptiacus*
Shallots	*Allium ascalonicum*
Sissoo tree	*Dalbergia sissoo*
Snakeweed	*Polygonum glabrum*
Sodum apple	*Solanum sodeomeum*
Sorrel	*Rumex vesicarius*
Soybean	*Glycine max*
Sugarcane	*Saccharum officinarum*
Sunflower	*Helianthus annuus*
Sweet-William	*Dianthus barbatus*
Sycamore fig	*Ficus variegate*
Tea	*Thea sinensis*
Tobacco	*Nicotiana tabacum*
Turnip	*Brassica rapa*
Turnip rooted celery	*Apium graveolens*
Violet	*Viola odorata*
Wall goose-foot	*Chenopodium murale*
Wheat	*Triticum vulgare*
Zinnia	*Zinnia elegans*

A.5. Common hosts of *Spodoptera litura*.

Amaranth, spiny	*Amaranthus viridis*
Banana	*Musa* spp.
Beet	*Beta vulgaris*
Cabbage	*Brassica oleracea*
Castilloa rubber	*Castilla elastica*
Castor	*Ricinus communis*
Cauliflower	*Brassica oleracea*
Celery	*Apium graveolens*
Chickenweed	*Portulaca quadrifida*
Chickpea	*Cicer arietinum*
Chinese cabbage	*Brassica pekinensis*
Citrus	*Citrus* spp.
Clover	*Trifolium* spp.
Coco	*Erythroxylum coca*
Cotton	*Gossypium* spp.
Cowpea	*Vigna unguiculata*
Crassocephalum	*Crassocephalum crepidioides*
Eggplant	*Solanum melongena*
Eucalyptus	*Eucalyptus* spp.
Flax	*Linum usitatissimum*
Gladiolas	*Gladiolus* spp.
Globe artichoke	*Cynara scolymus*
Grapes	*Vitis* spp.
Hemp	*Cannabis sativa*
Indian bean	*Catalpa bignonioides*
Zollinger's indigo	*Indigofera zollingeriana*
Jute	*Corchorus capsularis*
Lentil	*Lens culinaris*
Lettuce	*Lactuca sativa*
Lucerne	*Medicago sativa*
Maize	*Zea mays*
Mulberry	*Morus* spp.
Okra	*Abelmoschus esculentus*
Onion	*Allium cepa*
Papaya	*Carica papaya*
Peanut	*Arachis hypogaea*
Pigeon pea	*Cajanus cajan*

Potato	*Solanum tuberosum*
Rose	*Rosa* spp.
Sorghum	*Sorghum bicolor*
Soybean	*Glycine max*
Spinach mustard	*Brassica rapa*
Sweet potato	*Ipomoea batatas*
Taro	*Colocasia esculenta*
Tea	*Camellia sinensis*
Til	*Sesamum orientalis*
Sesame	*Sesamun indicum*
Tobacco	*Nicotiana tabacum*
Tomato	*Lycopersicon esculentum*
Turmeric	*Curcuma domestica*
Turnip	*Brassica rapa*
Tree spinach	*Chenopodium amaranticolor*
Watermelon	*Citrullus lantanus*
Zinnia	*Zinnia elegans*

A.7. Common hosts of *Spodoptera mauritia*.

Alexandra palm	*Archontophoenix alexandrae*
Arrowroot	*Cannas pp.*
Bamboo	*Bambusa* spp.
Barley	*Hordeum vulgare*
Bermudagrass	*Cynodon dactylon*
Blackeye pea	*Vigna catjang*
Blue couch grass	*Digitaria didactyla*
Buffalo grass	*Paspalum conjugatum*
Bufflegrass	*Cenchrus ciliaris*
Cabbage	*Brassica oleracea*
Cattails	*Typha* spp.
Cereal rye	*Secale cereale*
Clover	*Trifolium repens*
Cluster palm	*Actinophloeus macarthuri*
Coconut	*Cocos nucifera*
Cotton	*Gossypium barbadensis*
Cowpea	*Vigna unguiculata*
Creeping paspalum	*Paspalum scrobiculatum*
Cryptomeria	*Cryptomeria* spp.
Cyperus	*Cyperus kyllingia*
Dalligrass	*Paspalum dilatyatum*
Dragon trees	*Dracaena* spp.
Fescue	*Festuca* spp.
Finger millet	*Eleusine coracana*
Foxtail	*Setaria sphacelata*
Foxtail, Bristly	*Setaria verticillata*
Garden bean	*Phaseolus vulgaris*
Garden pea	*Pisum sativum*
Giant reed	*Arundo donax*
Goose grass	*Eleusine indica*
Grasses	*Digitaria henryi*
Guinea grass	*Panicum maximum*
Hand-of-Mary	*Vitex trifolia*
Iris	*Iris* spp.
Isachne	*Isachne globosa*
Johnsongrass	*Sorghum halepense*
Kikuyu grass	*Pennisetum clandestinum*

Lettuce	*Lactuca sativa*
Lovegrass	*Eragrostis tenuifolia*
Madagascar palm	*Chrysalidocarpus lutescens*
Maize	*Zea mays*
Manila grass	*Zoysia matrella*
Molasses grass	*Melinis minutiflora*
Nutgrass	*Kyllinga monocephala*
Nutgrasses	*Cyperus* spp.
Nutsedge	*Cyperus rotundus*
Oats	*Avena sativa*
Papaya	*Carica papaya*
Pearl millet	*Pennisetum glaucum*
Perennial ryegrass	*Lolium perenne*
Pointed fimbristylis	*Fimbristylis acuminata*
Potato	*Solanum tuberosum*
Quickgrass	*Agropyron repens*
Reeds	*Phragmites* spp.
Rhodes grass	*Chloris gayana*
Rice	*Oryza sativa*
Slender sedge	*Cyperus gracilis*
Smilax	*Asparagus asparagoides*
Sorghum	*Sorghum bicolor*
St. Augustine grass	*Stenotaphrum secundatum*
Sugarcane	*Saccharum officinarium*
Tobacco	*Nicotiana tabacum*
Tomato	*Lycopersicon esculentum*
Triodia	*Triodia* spp.
Tropical carpetgrass	*Axonopus compressus*
Wheat	*Triticum aestivum*

A.8. Secondary hosts of *Spodoptera ochrea*.

Alfalfa	*Medicago sativa*
Beets	*Beta vulgaris*
Carrots	*Daucus carota*

A.9. Secondary hosts of *Spodoptera pectin*.

Purple nut sedge	*Cyperus rotundus*
Rice	*Oryza sativa*
Sugarcane	*Saccharum officinarum*

A.10. Secondary hosts of *Spodoptera triturata*.

Bermuda grass	*Cynodon dactylon*
Maize	*Zea mays*
Sugarcane	*Saccharum officinarum*

Appendix B. Field guide

Eggs

Egg masses (Figure B.1) with the following characters are **likely** members of the genus *Spodoptera*:

- Round shape AND
- Upright with a small pore on top AND
- Scales (black, cream or gray) cover the eggs AND
- Outer membrane with about 40 to 50 longitudinal ribs

B 1. Eggs of *S. eridania* (left); larvae of *S. litura* (right) hatching from an egg mass. Images courtesy of P. Marquez and the Macleay Museum, University of Sydney.

Adults

Adults (Figure B.2) with the following characters are **likely** members of the genus *Spodoptera*:

- White v-shaped forewing marking that resembles a narrow two pronged fork pointed away from the body, AND
- White, glossy hind wing

Adults with the previous AND following characters are **very likely** members of the genus *Spodoptera* especially if the moth was found on an appropriate host:

- White patch on the highest point of the forewing, AND
- Oblique whitish band, extending from mid-costa to mid-forewing cell, AND
- Forewings with circular and kidney-shaped spots (could be partially hidden by the oblique band), AND
- Wingspan of 16-44 mm

B 2. Top: *Spodoptera* spp. (Courtesy of Department for Environment, Food and Rural Affairs, UK.). Bottom: *S. litura*. (Courtesy of Crop Protection and Plant Quarantine, Dept of Agriculture, Malaysia.)

This report is authorized by law (7 U.S.C. 147a). While you are not required to respond your cooperation is needed to make an accurate record of plant pest conditions. *See reverse for additional OMB information.*

FORM APPROVED
OMB NO. 0579-0010

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE

SPECIMENS FOR DETERMINATION

Instructions: Type or print information requested. Press hard and print legibly when handwritten. Item 1 - assign number for each collection beginning with year, followed by collector's initials and collector's number. Example (collector, John J. Dingle): 83-JJD-001.
Pest Data Section – Complete Items 14, 15 and 16 or 19 or 20 and 21 as applicable. Complete Items 17 and 18 if a trap was used.

FOR IIBIII USE
LOT NO.

PRIORITY

1. COLLECTION NUMBER

2. DATE

MO	DA	YR

3. SUBMITTING AGENCY
☐ State Cooperator ☐ PPQ ☐ Other _____

SENDER AND ORIGIN

4. NAME OF SENDER

6. ADDRESS OF SENDER

ZIP

INTERCEPTION SITE

5. TYPE OF PROPERTY *(Farm, Feedmill, Nursery, etc.)*

7. NAME AND ADDRESS OF PROPERTY OR OWNER

COUNTRY/ COUNTY

PURPOSE

8. REASON FOR IDENTIFICATION *("x" ALL Applicable Items)*

A. ☐ Biological Control (Target Pest Name)	E. ☐ Livestock, Domestic Animal Pest
B. ☐ Damaging Crops/Plants	F. ☐ Possible Immigrant *(Explain in* REMARKS*)*
C. ☐ Suspected Pest of Regulatory Concern *(Explain in* REMARKS*)*	G. ☐ Survey *(Explain in* REMARKS*)*
D. ☐ Stored Product Pest	H. ☐ Other *(Explain in* REMARKS*)*

9. IF PROMPT OR URGENT IDENTIFICATION IS REQUESTED, PLEASE PROVIDE A BRIEF EXPLANATION UNDER "REMARKS".

HOST DATA

10. HOST INFORMATION
NAME OF HOST *(Scientific name when possible)*

11. QUANTITY OF HOST
NUMBER OF ACRES/PLANTS
PLANTS AFFECTED *(Insert figure and indicate* ☐ Number ☐ Percent*):*

12. PLANT DISTRIBUTION
☐ LIMITED
☐ SCATTERED
☐ WIDESPREAD

13. PLANT PARTS AFFECTED

☐ Leaves, Upper Surface	☐ Trunk/Bark	☐ Bulbs, Tubers, Corms	☐ Seeds
☐ Leaves, Lower Surface	☐ Branches	☐ Buds	
☐ Petiole	☐ Growing Tips	☐ Flowers	
☐ Stem	☐ Roots	☐ Fruits or Nuts	

PEST DATA

14. PEST DISTRIBUTION
☐ FEW
☐ COMMON
☐ ABUNDANT
☐ EXTREME

15. ☐ INSECTS ☐ NEMATODES ☐ MOLLUSKS

NUMBER SUBMITTED	LARVAE	PUPAE	ADULTS	CAST SKINS	EGGS	NYMPHS	JUVS.	CYSTS
ALIVE								
DEAD								

16. SAMPLING METHOD

17. TYPE OF TRAP AND LURE

18. TRAP NUMBER

19. PLANT PATHOLOGY – PLANT SYMPTOMS *("X" one and describe symptoms)*
☐ ISOLATED ☐ GENERAL

20. WEED DENSITY
☐ FEW ☐ SPOTTY ☐ GENERAL

21. WEED GROWTH STAGE
☐ SEEDLING ☐ VEGETATIVE ☐ FLOWERING/FRUITING ☐ MATURE

22. REMARKS

23. TENTATIVE DETERMINATION

24. DETERMINATION AND NOTES *(Not for Field Use)*

SIGNATURE

DATE

FOR IIBIII USE
DATE RECEIVED
NO.
LABEL
SORTED
PREPARED
DATE ACCEPTED
RR

PPQ FORM 391 *Previous editions are obsolete.*
(AUG 02)

This is a 6-Part form. Copies must be disseminated as follows:
☐ PART 1 – PPQ ☐ PART 2 – RETURN TO SUBMITTER AFTER IDENTIFICATION ☐ PART 3 – IIBIII OR FINAL IDENTIFIER
☐ PART 4 – INTERMEDIATE IDENTIFIER ☐ PART 5 – INTERMEDIATE IDENTIFIER ☐ PART 6 – RETAINED BY SUBMITTER

OMB Information
According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0579-0010. The time required to complete this information collection is estimated to average .25 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

Instructions

Use PPQ Form 391, Specimens for Determination, for domestic collections (warehouse inspections, local and individual collecting, special survey programs, export certification).

BLOCK	INSTRUCTIONS
1	1. Assign a number for each collection beginning the year, followed by the collector's initials and collector's number **EXAMPLE** In 2001, Brian K. Long collected his first specimen for determination of the vear. His first collection number is 01-BLK-001 2. Enter the collection number
2	Enter date
3	Check block to indicate Agency submitting specimens for identification
4	Enter name of sender
5	Enter type of property specimen obtained from (farm, nursery, feedmill, etc.)
6	Enter address
7	Enter name and address of property owner
8A-8L	Check all appropriate blocks
9	Leave Blank
10	Enter scientific name of host, if possible
11	Enter quantity of host and plants affected
12	Check block to indicate distribution of plant
13	Check appropriate blocks to indicate plant parts affected
14	Check block to indicate pest distribution
15	• Check appropriate block to indicate type of specimen • Enter number specimens submitted under appropriate column
16	Enter sampling method
17	Enter type of trap and lure
18	Enter trap number
19	Enter X in block to indicate isolated or general plant symptoms
20	Enter X in appropriate block for weed density
21	Enter X in appropriate block for weed growth stage
22	Provide a brief explanation if Prompt or URGENT identification is requested
23	Enter a tentative determination if you made one
24	Leave blank

Distribution of PPQ Form 391

Distribute PPQ Form 391 as follows:
1. Send Original along with the sample to your Area Identifier.
2. Retain and file a copy for your records.