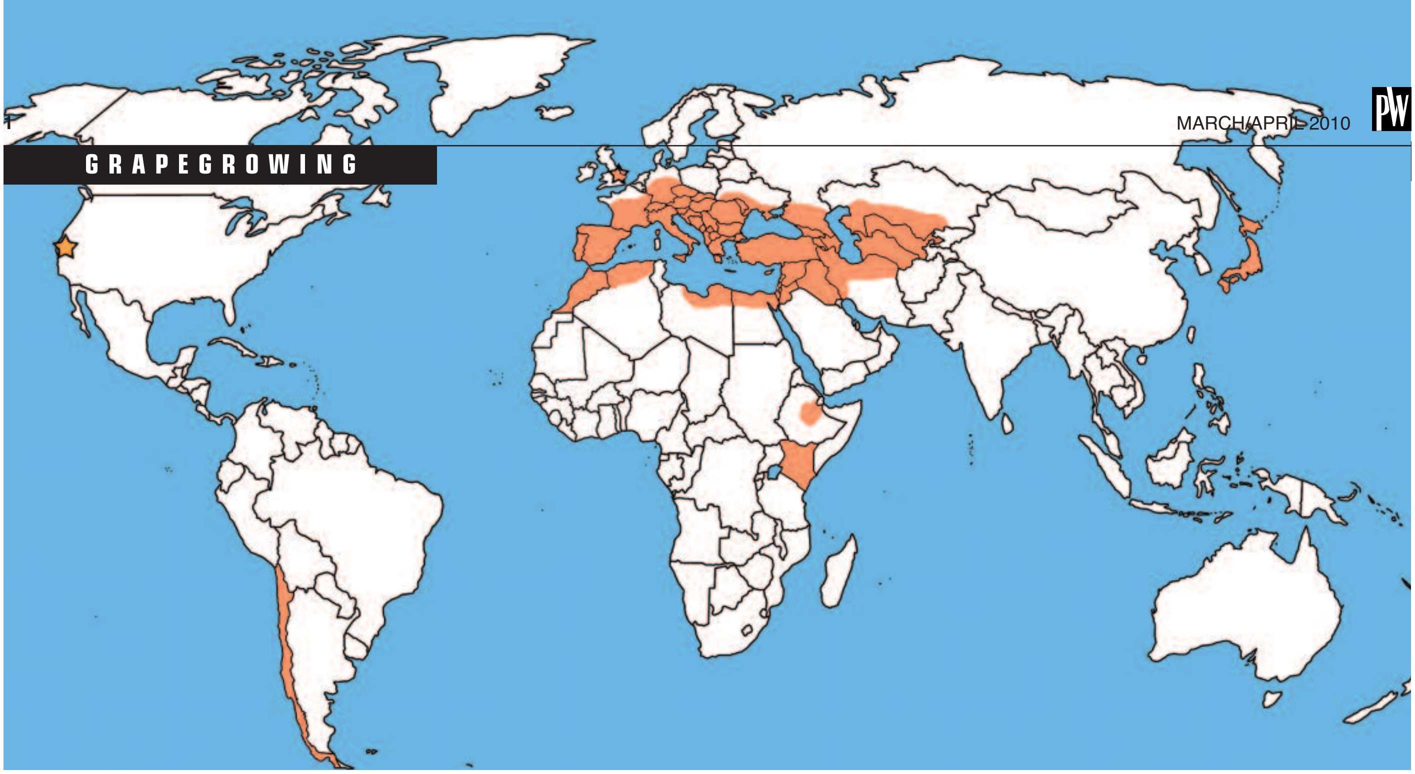

Figure 1. World distribution of *L. botrana* adapted from Distribution Maps of Pests (CIE 1974), with additions of findings reported later.

MONITORING, CONTROL, GRAPE DAMAGE

European grapevine moth, *Lobesia botrana*, in Napa Valley vineyards★

BY Lucia G. Varela,
Rhonda J. Smith,
Monica L. Cooper,
Richard W. Hoenisch,
University of California

European grapevine moth, *Lobesia botrana*, has recently been found for the first time in the United States. This moth belongs to the family Tortricidae. Unlike other tortricid moths that are grapevine pests, such as the orange tortrix (*Argyrotaenia franciscana*) and omnivorous leafroller (*Platynota stultana*), European grapevine moth larvae do not roll or feed on leaves — they feed on flower parts and inside the berries.

In Europe this moth also has the common names berry and vine moth; these names are shared with similar species worldwide including the eastern U.S. It is important to verify the scientific name *L. botrana* when searching the literature for information on this pest.

European grapevine moth female — photo Jack Kelly Clark, courtesy of UC Statewide IPM Program

Situation in Napa County

In mid-September 2009, the first report of the European grapevine moth in North America was confirmed in Napa County, CA. Based on available data at the end of 2009, geographic distribution within the state of California (at press time) is considered to be limited to Napa County. The greatest number of confirmed specimens has been collected in the Oakville and Rutherford American Viticultural Areas, although

European grapevine larva with dark border on rear edge of prothoracic shield — photo Jack Kelly Clark, courtesy of UC Statewide IPM Program.

European grapevine moth pupa inside partially open cocoon found under the bark. Photo Jack Kelley Clark, courtesy of UC Statewide IPM Program.

an isolated population has also been located east of the town of Napa.

Movement of fruit, personnel, and machinery, as well as natural dispersal and the climatic suitability of various regions of California, make this pest a serious threat to other areas of the state.

Following its detection, a coalition of agencies — the U.S. Department of Agriculture, California Department of Food and Agriculture (CDFA), and Napa County Agricultural Commissioner — deployed 248 pheromone-baited traps in Napa County to aid in delimiting *L. botrana* populations. These traps were monitored from October 7 to October 26, 2009, during which time six male moths were collected. The low number is presumably the result of the population age (late-instar larvae to overwintering pupae) when the traps were deployed.

Ground surveys for immature insects by vineyard, regulatory, and UC Cooperative Extension personnel were more fruitful. Almost 30 individual properties in Napa County are now presumed positive for at least one life stage of *L. botrana*. By November 2009, trapping efforts had ended for the season, concurrent with the lack of a population in the adult stage.

In late winter/early spring 2010, trapping efforts will resume in Napa County, and expand throughout California to determine statewide distribution of *L. botrana*. Considering its status as one of the most damaging pests of grape berries in the Mediterranean region, and its recent rapid spread in Chile, this state-wide monitoring effort will be critical to delimit populations to track the pest's spread and damage in California vineyards.

Currently, the European grapevine moth has been classified as a Q-rated pest by the CDFA, a temporary rating pending determination of a permanent rating. Once adequate information has been collected on its statewide distribution, *L. botrana* will then be assigned an A, B, or C rating.

Pests with an **A-rating** are organisms of recognized economic importance that are subject to state-enforced action involving eradication, quarantine regulation, containment, or rejection; **B-rated** pests generally have established, but not widespread populations, are recognized as economically damaging, and are subject to regulatory action at the discretion of the Agricultural Commissioner at the local level. **C-rated** pests are recognized as generally distributed, and are therefore not subject to regulatory action except to retard spread, and at the nursery level to assure pest-free plants.

During the 2009 harvest, quarantine zones and compliance agreements established for the light brown apple moth (*Epiphyas postvittana*) in Napa County may have limited the movement of European grapevine moth.

Geographic distribution

L. botrana was first described by biologists Denis and Schiffermüller in 1775 in Vienna, from samples collected in Italy, and was classified as a pest in Austria in 1800. It was reported from several European countries and Russia in the 1800s and has since spread to North and West Africa and the Middle East. It was introduced into Japan before 1974 and recently into Chile.

Climates in the area occupied by the pest can be characterized generally as dry or temperate. The currently reported global distribution of *L. botrana* suggests that the pest may be most closely associated with habitats classified as montane scrub, Mediterranean scrub, and temperate broadleaf and mixed forest.

The Chilean department of agriculture, Servicio Agrícola y Ganadero (SAG), issued the first report on *L. botrana* in the Americas on April 23, 2008. Surveys conducted in 2008 and 2009 show infestations in all grapegrowing regions of Chile, a spread of approximately 1,500 kilometers (930 miles).

Hosts

European grapevine (*Vitis vinifera*), American bunch grape (*V. labrusca*), and spurge laurel (*Daphne gnidium*), a common shrub in Mediterranean Europe, are the main hosts. Some researchers theorize that *D. gnidium* constitutes the original host of *L. botrana* and its adaptation to grapes is a relatively recent event.

The larva feeds on all cultivated grape varieties, although they develop better on some than on others. Females lay eggs almost exclusively on flower clusters and berries.

The literature includes about 25 hosts other than grape, however *Lobesia* is found only very rarely or accidentally on other hosts with the exception of *D. gnidium. Vitis vinifera* constitutes the main food resource.

L. botrana is considered a major pest only on grapevines. In olive, only the flowers are infested, never the fruit; therefore, olive trees next to vineyards may constitute an important source of infestation of nearby vines by moths in the late spring.

Females select plants to lay eggs on by flying upwind following olfactory cues. Once they land on a plant they also taste the surface with contact chemoreceptors before laying their eggs. Plant surface chemicals stimulate or deter egg laying. The host-plant range in California will need to be studied to establish the role that alternate hosts play in the life cycle of *L. botrana*.

Identification

The adult moth is approximately ¼ inch long. Female moths tend to be slightly larger, although both sexes have mosaic-patterned wings. The first pair of wings is tan-cream and mottled with gray-blue, brown, and black blotches. The second pair of wings is gray with a fringed border.

Unlike other common vineyard tortricids, which lay eggs in overlapping masses, *L. botrana* lays single, elliptical, and flat eggs (0.03 inches in diameter). As it ages, the iridescent, creamy white egg turns yellow, and later blackens as the head of the developing larva forms. The larva hatches from the edge of the egg, leaving the translucent egg shell attached to the plant.

Both sexes have five larval instars; fully grown larvae are approximately ½ inch long with dark thoracic legs. First-instar larvae are creamy white with a black head. Older larvae have lighter, yellowish-brown heads with a dark border at the rear edge (closest to the body) of the prothoracic shield (segment behind the head; see photo). Young larvae have tan bodies, whereas older larvae take on the color of their gut contents and food source (from dark green to shades of maroon).

Fifth-instar larvae spin a grayish-white silken cocoon in which they pupate. The pupa is approximately ¼ inch long.

Life cycle

In the Mediterranean region, *L. botrana* typically completes two to three generations per year. Using 50ºF (lower) and 86ºF (upper) thresholds, we tentatively estimate degree-days Fahrenheit to be 833 for the first generation and 904 for the remaining generations.

First generation flights may begin near bud break and continue for four to five weeks; males begin emerging roughly one week before females. Adults live one to three weeks, fly at dusk (above 54ºF), and mate in flight (1 to 6 days after emergence). Females generally mate once in their lifetime.

Egg-laying begins one to two days after mating, with each female laying 80 to 160 eggs. Eggs of the first generation — laid singly on flat surfaces near or within the flower cluster — hatch in 7 to 11 days. Larvae web together individual flowers to form "nests" prior to and during bloom, and feed inside the web.

Under optimal conditions of 80º to 85ºF and 40% to 70% relative humidity, larval development is completed in 20 to 30 days. Pupae form inside webbed cocoons in the flower cluster, in a folded lobe of a leaf blade, under the bark, or in soil cracks. Adults emerge 6 to 14 days after pupation.

Eggs of second and third generation females — laid singly on shaded berries — hatch in 3 to 5 days. A grape cluster is typically infested with multiple larvae that feed individually inside berries. Larvae fed on higher-quality food (ripe fruit or fruit infested with *Botrytis cinerea*) grow into larger, longer-lived adults that lay greater numbers of eggs. Therefore, later-season generations have the potential to cause greater crop damage than early-season generations.

In autumn, nights longer than 11 hours during egg and/or larval development initiate diapause (a resting state). A diapausing pupa withstands colder temperatures than a non-diapausing pupa and can tolerate even the coldest northern European winters. In early February, during post-diapause development, prior to adult emergence, pupae may die at temperatures below 46ºF.

Damage

L. botrana larvae feed on all parts of the flower cluster in early spring, but more importantly they feed on berries in midsummer and again in late summer, continuing through harvest and into leaf-fall. Feeding triggers infections by the fungus *Botrytis cinerea* and other rot organisms resulting in bunch rots that are the main cause of fruit loss.

Larvae of the first generation of *L. botrana* hatch from eggs laid in flower clusters and damages portions of the cluster.

Second generation larvae hatch from one egg per berry prior to veraison, starting about when berries are pea-size and feed inside webbing. Damage is caused by direct feeding on the berries. A dark spot surrounds the point of larval feeding and several berries can be damaged.

Third generation larvae can cause the most damage to clusters, preventing them from being harvested for wine grape production. Larvae penetrate and feed on ripening fruit immediately after hatching.

Infested clusters contain shriveled berries, webbing, and excrement. Feeding holes can be seen in several berries. Shreds of berry epidermal tissue loosely attached to pedicels are present, as are dry, somewhat intact "skins" of fully excavated berries. Bunch rot is present, and depending on climate, the summer bunch rot complex will develop which includes secondary fungal invaders.

Monitoring

Monitoring methods for *L. botrana* in California vineyards may not be identical to strategies used in Europe or other regions where this pest is common; however the objective is the same — to decrease yield losses caused by the feeding damage of this insect. Strategically timed insecticide applications are required to control this pest and, depending on the generation targeted and the material applied, it is essential to identify either the beginning of egg laying or egg hatch.

Monitoring male flights with a commercially available *L. botrana* pheromone lure over the entire 2010 grape growing season is advised at this time. Red delta sticky traps, identical to those used for monitoring vine mealybugs, are ideal for this purpose, and should be attached to the trellis immediately above the canopy. Place one trap per 30 vineyard acres, or at least one per ranch in small vineyards.

The lure should be replaced according to manufacturer's instructions, and insects removed from the trap bottom after counting. Replace soiled traps as needed to maintain a sticky bottom. Trapping for *L. botrana* males should begin at bud break and trap-catch numbers should be recorded weekly.

Trapping is used to determine when the adults are active, which helps predict egg-laying activity. There is no close correlation between the number of trapped males and actual population densities. If very few or no males are caught, little to no damage would be predicted; however, if any males are trapped, it increases the likelihood that webbing found in clusters is caused by *L. botrana*.

First generation — Once peak trap catch has likely been reached, begin to observe 100 flower clusters per block (1 cluster per vine) and look for eggs of the first generation, which are commonly laid on the peduncle (cluster stem). Eggs are lentil-shaped, but slightly smaller. Take note of the egg color and the time it takes to change from white (freshly laid), to yellow, followed by black immediately prior to hatching. A hatched egg can be recognized by the outer shell that remains. If webbing is found, it is important to verify it was caused by a larva and that hatched eggs are also present.

Cool spring temperatures will postpone mating and egg laying. At this time it is not known what effect low temperatures will have on early development of the first generation. Once a degree day model is validated for *L. botrana* in California, the focus of monitoring guidelines for the first generation may be shifted from egg hatch to egg laying.

In Europe, feeding damage to flower clusters is considered low and researchers in Germany have shown that yield is not reduced. As a result, control measures are not directed toward first generation larvae in Europe. Currently in Chile, the first generation is targeted for control measures which are timed according to the presence of eggs.

Because other lepidopteran pests in California cause webbing in grape flower clusters, California growers will have to verify that larvae found in clusters are *L. botrana*. To do so, the larvae must be associated with hatched eggs and adult male trap catches.

In California in 2010, an insecticide application directed to the first generation larvae may be advised if eradication efforts are required. Timing is critical for success; growers and PCAs will have to monitor flower clusters for egg hatch. If larvae are observed and verified to be *L. botrana*, an insecticide can be added to a powdery mildew fungicide application.

Second generation — One week after trapping the first males of both the second and third flights, begin to monitor 100 grape clusters. The berries may be about pea-size when second generation eggs are monitored. Observe a cluster in direct sunlight and look for eggs laid singly on the surfaces of berries. Freshly laid eggs will reflect direct light and appear very shiny and white.

As with the first generation, note the timing of egg development and hatch. An insecticide application with a long residual should be directed to small larvae; thus subsequent larvae are controlled as they emerge from eggs or shortly thereafter.

Third generation — The clusters will be past veraison when eggs are monitoried; eggs will be easier to locate on dark fruit. Note the timing of egg development; as in earlier generations, a treatment must be applied when larvae emerge from eggs.

Sometime in the fall, larvae leave grape clusters and pupate under bark on cordons or the trunk. If the vineyard was not monitored with traps during the growing season and an infestation is now suspected, examine any grape clusters remaining in a hand-harvested block. Look for the damage caused by third generation larvae (webbing and frass), and larvae inside damaged berries.

A suspect vineyard may also be scouted for pupae in the fall. This is the only avenue available to growers and PCAs for a vineyard that was mechanically harvested.

Management

Insecticides — Male moth flight, egg laying, and egg hatch must be monitored in order to correctly time the application of insecticide. Once the larvae begin to web flower parts or feed inside berries, chemical control is less effective. Even though the first generation larvae damage is not of economic importance, if eradication efforts are required or populations are very high, controlling the first generation helps lower population levels in the second generation.

Many insecticides effective against European grapevine moth and other lepidopteran pests have recently been developed. Different classes of insecticides have different modes of action. If more than one insecticide application is needed for the control of *L. botrana* rotating chemicals with different modes of action may help prevent the development of resistance. The Insecticide Resistance Action Committee (IRAC) assigns a group number to each mode of action. The group number appears on insecticide labels.

The bacterium *Bacillus thuringiensis* (Bt) produces proteins that are toxic to very specific species of insects. These proteins, once ingested by the insect, act as a stomach poison. The Bt toxin is available in several commercial products that are specific to Lepidoptera (moths and butterflies).

Given that a larva must ingest the insecticide for it to be effective, it is best to apply when warm sunny days are forecast, especially in spring, because the larvae will tend to be active and feed at warmer temperatures. Two applications of a Bt product are recommended per generation, because egg laying thus larval emergence occur over several weeks. In addition, Bt has a short residual.

Insect growth regulators are effective against many species of lepidopteran insects. These products have lower toxicity to beneficial insects, mites, and pollinators. This class of insecticide prevents the insect from molting into its next growth stage; thus mortality may take several days. If the insect growth regulator affects both the egg and the larvae, application should begin at the start of **egg laying** rather than at the initiation of **egg hatch**.

Spinosad products must be ingested by the insect; therefore it has little effect on sucking insects and non-target predatory insects. It may be toxic to beneficial parasitic wasps if they feed on contaminated honeydew and to honeybees if they come into contact with the spray. There are several commercial spinosad products, both synthetic and organic formulations.

The spinetoram group of pest control chemicals is derived from spinosad that has been chemically modified, resulting in improved insecticidal activity and longer residual activity. However, the longer residual activity may also result in greater toxicity to parasitic wasps.

Other insecticide groups include rynaxypyr, neonicotinoids, pyrethroids, carbamates, and organophosphates. Although each group has a different mode of action, all of these insecticides block the insects' nerve synapses or the conduction of nerve impulses, ultimately causing muscle paralysis.

Biological control — Parasitic wasps can parasitize the eggs of *L. botrana*. Trichogamma species are known egg-parasites of many Lepidoptera species, and can be a good source of biological control of European grapevine moth. In the fall of 2009, egg parasitism was observed in Oakville in vineyards with *L. botrana* damage.

Studies are needed to determine how early in the season Trichogamma species begin to parasitize *L. botrana* eggs, if other species of native parasites attack the larval or pupal stages, and the impact these parasites may have on moth populations. In France, Italy, and Spain, the highest parasitism is reported on the diapausing pupa stage. In Europe, green lacewings are among the main predators in summer and spiders are important predators of larvae and diapausing pupae.

Mating disruption — Female moths emit a plume of sex pheromone that males follow upwind to find females and mate. Scores of dispensers loaded with synthetic pheromone and deployed throughout a vineyard cause the air to become saturated with the pheromone, such that male moths are unable to locate females, preventing or delaying mating. In the absence of mating or if the female is too old when mated, viable eggs are not laid and no larvae are produced to damage grape clusters.

Mating disruption has proven most effective when European grapevine moth populations are low and when synthetic pheromone is applied to large areas of over 10 acres or area-wide. If moth populations are high, supplemental insecticide applications may be needed.

At press time, no pheromone dispenser product has been registered for use in the U.S., though at least one manufacturer is seeking registration with the U.S. Environmental Protection Agency. The pheromone product undergoing registration is a hand-applied dispenser that is attached to trellis wires or canes.

Mating disruption dispensers must be placed in the vineyard at the beginning of the male moth flight, as indicated by the first catch in pheromone traps. Follow manufacturer recommendations for the application rate of dispensers per acre.

Once mating disruption dispensers are registered for use and deployed in vineyards, the pheromone emitted by the dispensers coupled with the lure pheromone in the traps will cause very few moths to be caught in the traps (trap shutdown). Regardless, traps are useful to monitor a vineyard under mating disruption.

Place pheromone traps along the edges and in the center of the block. The edge traps give an indication of movement of male moths into the vineyard. The center traps should catch very few or no moths. If the center traps are catching males, then mating is not being disrupted and supplemental insecticide applications may be needed. Monitor eggs at peak trap catch and periodically sample grape clusters for the presence of worms or damage.

Sanitation

Sanitation of equipment will be critical to minimize movement of this insect from infested vineyards to non-infested vineyards and to avoid the spread to other regions of California. Equipment should be washed prior to leaving an infested property, preferably with a high-pressure sprayer and hot water. This is especially important for all machinery and containers that come in contact with fruit during harvest.

Larvae can hide in tight places, and fully formed larvae may form a cocoon and pupate in any protected place. When hiring an outside company to harvest fruit, verify that the contractor follows good sanitation practices. Loads will need to be covered during shipment to the winery, and winery waste that does not undergo fermentation will need to be composted. ■

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