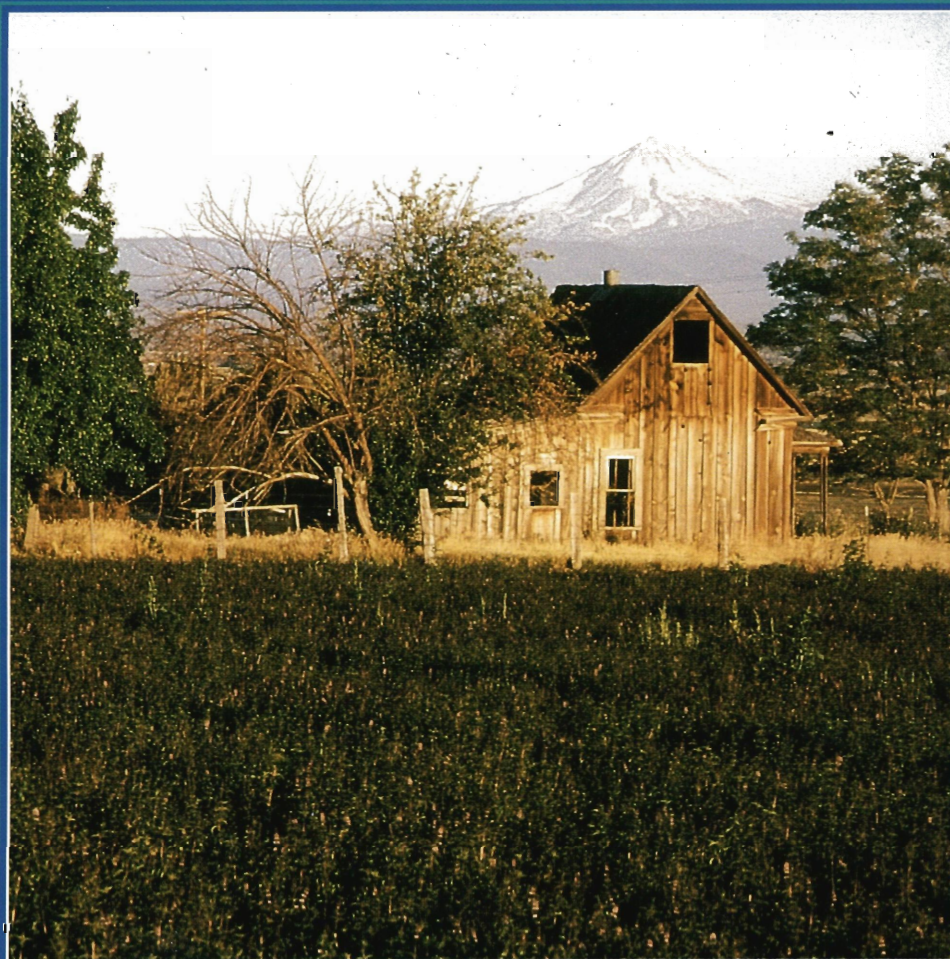

A GUIDE TO

PEPPERMINT

INSECT AND MITE

IDENTIFICATION AND MANAGEMENT



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A Guide to Peppermint Insect and Mite IDENTIFICATION AND MANAGEMENT

PNW 182 • Revised February 1993

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Introduction

Correct pest management decisions depend on an understanding of many related factors, including:

1) stage(s) of the pests, 2) their density and distribution in the field, 3) presence or absence of beneficial insects and mites, 4) occurrence of other pests such as plant diseases and weeds, 5) the stage and health of the crop, and 6) the alternatives available to control the pest(s), if and when necessary.

Pest management begins with accurate identification of insects and mites. Incorrect identification can result in the needless use of an insecticide and destruction of beneficial predators and parasites. Mint fields must be inspected on a regular basis to establish population trends and to determine whether or not control is necessary. The use of treatment thresholds will reduce the unnecessary use of insecticides, which will save money, protect natural predators and parasites and delay the development of insecticide resistance.

Natural parasites and predators may be sufficiently abundant in some mint fields to suppress pest populations without the use of insecticides or miticides. This guide was prepared to help individuals accurately identify and sample mint pests and beneficial insects and mites, and to develop sound pest management decisions based on treatment thresholds. It emphasizes insects and mites on peppermint, but several of the same pests and beneficial insects and mites also occur on spearmint. Identification of pests and sampling procedures are similar in peppermint and spearmint, but additional research is needed to develop treatment thresholds for pests on spearmint.

Much of the information contained in this guide was taken from the results of studies conducted by graduate students and others at Oregon State University, and we particularly wish to acknowledge Len Coop, Craig Hollingsworth, Steve Danielson, Jack DeAngelis, Mike Talkington, Joe Cacka, Mark Morris, Gary Parsons, Don Emmenegger, Joyce Takeyasu, and Elson Shields for their contributions. We also wish to thank Craig Baird, University of Idaho, Southwest Idaho Research Center, Parma; Mark Morris, A. M. Todd Company, Salem, OR; Keith Pike, Washington State University Irrigated Agriculture Research and Extension Center, Prosser; and Jim Todd, Willamette Agriculture Consulting, Salem, OR, for their assistance in reviewing this manuscript. Support for research on peppermint has been provided by the Oregon Mint Commission, the Oregon Essential Oil Growers League and the Mint Industry Research Council.

Some of the information contained in this publication was taken from the manual used to support the computer software for *Insect Pest Management on Peppermint (IPMP)*, OSU Extension Service Special Report 834 (1989, 1993). For more information on using the *IPMP* decision support program on a computer, write Ralph E. Berry, Department of Entomology, Oregon State University, Corvallis, OR 97331-2907.

Insect and Mite Identification on Peppermint

Before using any insecticide in your field, be sure you have accurately identified the insects and mites. If you need help call your county agent, someone at the university, or an experienced individual who is familiar with insects and mites on mint.

Pests Chewing on Leaves

1. Plants cut-off slightly below or above the soil surface; leaves with ragged-edged holes and above ground stems with notches eaten out. **Cutworms** including variegated cutworm (Figs. 3 and 4), spotted cutworm (Fig. 5), black cutworm, Bertha armyworm, western yellowstriped armyworm (Fig. 6), and others. Damage from redbacked cutworm (Figs. 1 and 2) and black cutworm usually occurs in April, May, and June. Other cutworms typically cause injury during July and August.
2. Ragged-edged holes eaten through the leaves and around the leaf margins, particularly on leaves mid-way and higher on the plant. **Loopers** including alfalfa looper (Figs. 7 and 8) and cabbage looper.
3. Terminal leaves and buds tied together with silk. Upper surface of leaves skeletonized or with small holes. **False celery leaf-tier larva** (Fig. 17, adult Fig. 18).
4. Ragged or completely eaten leaves present on plants around the field margins at first, later entire field with a ragged appearance. **Grasshoppers** (Fig. 22).
5. Small semicircular or irregularly shaped notches chewed in the leaf margins. **Strawberry root weevil adults** (Fig. 14). Adult feeding is inconspicuous and is not economically important.
6. Very small holes in leaves giving a shot-hole appearance to the leaves. **Mint flea beetle adults** (Fig. 12).

Pests on Rhizomes, Roots, or Stems

1. Plants cut-off at or slightly below the soil surface in the spring (April, May, early June). Lower foliage with ragged-edged holes. Cutworms found beneath soil surface during the day and feeding on above-ground foliage at night. **Redbacked cutworm** and other *Euxoa* species (Figs. 1 and 2) and **black cutworm**. Redbacked cutworm occurs only east of the Cascade Mountains.
2. Plants show wilted appearance above ground during late August, September, and early October. Rhizomes with tunneling around the nodes or rhizomes hollow. **Mint root borer larva** if 1/2 inch long with three pairs of true legs (Fig. 9, **adult** Fig. 10). If larvae smaller, 1/8 inch long, C-shaped, white legless grub found feeding inside mint stems near the soil surface in Idaho or eastern Oregon, then **mint stem borer** (Figs. 15 and 16).
3. Plants slow to grow in the fall and early spring. Surface feeding injury on the rhizomes, roots and stems. Small C-shaped white legless larvae 1/4 to 1/2 inch long with brown heads in the soil around the roots. **Larvae of strawberry root weevil** (Fig. 13) and other weevil species such as black vine, obscure, and rough strawberry root weevils.
4. Plants slow to grow in the spring. Feeding injury evident on surface of the roots or just beneath root epidermis, brown "tracking" evident just beneath root epidermis. Very small white larvae 1/8 inch long with three pairs of legs and a brown head may be found inside the roots or in the soil around the roots. **Mint flea beetle larvae** (Fig. 11).
5. Plants stunted in irregular spots in the field, often very slow-growing in the spring. Small, 1/8 to 1/4 inch long, white centipede-like animals feeding on small roots leaving few root hairs, roots stunted and discolored with pruned appearance. Found principally west of the Cascade Mountains. **Symphylans** (Fig. 21).

6. Plants appear stunted and slow growing from feeding injury on roots and rhizomes. Tan or dark brown, shiny, segmented larvae, 1/2 to 3/4 inch long, with three pairs of legs and key-hole-like structure on the last abdominal segment. **Wireworms** (larva Fig. 19, adult Fig. 20).

Pests Sucking on Leaves or Stems

1. Feeding injury caused by small, soft-bodied insects often found in large numbers on the undersides of the leaves and along the stems. Feeding may cause stunting, discoloration and leaf curling. Leaves often covered with sticky substance (honeydew) and black sooty mold growing on honeydew. Found principally east of the Cascade Mountains. **Mint aphid** (Fig. 24).

2. Feeding injury caused by small, soft-bodied animals with eight legs visible under 15X magnification. Large numbers found on the undersides of leaves. Leaves may have webbing on the undersides. Feeding causes speckled appearance on the leaves. Leaves may turn brown or bronze and drop from the plant mid-to late season. Predator mites also may be present on the leaves (see Beneficial Insects and Mites). **Twospotted spider mite** (Fig. 23).

Beneficial Insects/Mites

Conserve beneficial insects and mites by using insecticides only when necessary to control pests that have exceeded treatment thresholds. Many nonpest insects and mites may be found in mint fields. Most are actually beneficial and should be conserved to improve soil tilth or help control pests. Spiders, insect and mite predators, and parasites of cutworms and loopers can be quite common.

Predators

Predators effectively control many small, soft-bodied pests such as aphids, mites, small worms and insect eggs. Lady beetle larvae and adults (Figs. 25 and 26), syrphid fly larvae (Fig. 28), green lacewing adults and larvae (Figs. 29 and 30), bigeyed bug (Fig. 33), minute pirate bug (Fig. 34), damsel bug (Fig. 35),

spiders (see McIver and Belnavis [1986] for a list of spiders found in mint in western and central Oregon), and ground beetles are among the most common predators. Predator mites (Fig. 36), particularly *Amblyseius fallacis*, are often abundant in mint fields and may provide biological control of twospotted spider mite.

Lady beetles are common in mint fields in the Pacific Northwest. Adult beetles are about 4 mm long, oval and convex in shape, reddish-orange, usually with black spots on the wings (Fig. 25). Larvae are gray or bluish-gray, with numerous yellow, white, or red spots (Fig. 26). Mature larvae are about 9.5 mm long. Eggs are football-shaped, yellow or orange, and laid on end in clusters on undersides of leaves.

Lady beetles overwinter as adults in aggregations in protected places in wooded or mountainous areas or in crop land. They migrate to fields in March, April, and May and locate aphids. After feeding on the aphids for a short period of time, they deposit eggs on plants infested with aphids. Eggs hatch in 5 to 7 days, and the tiny larvae begin feeding on small aphids or other prey. Soon after the larvae mature, they form a pupa on the plant and adults emerge about a week later. A complete life cycle requires 4 to 6 weeks. There are several overlapping generations each season before adults migrate back to overwintering sites in the fall.

Lady beetle adults and larvae feed on aphids and other soft-bodied insects. Even though lady beetles are excellent predators, they are often unreliable because they will disperse when aphid populations are low and they do not increase rapidly enough to overcome heavy aphid infestations. Female beetles consume about 100 aphids before depositing eggs, then about two aphids per day for each egg produced.

Syrphid fly adults are 10 to 12 mm long, with bodies marked with yellow, black, or white bands resembling bees or yellowjackets (Fig. 27). Adults feed only on pollen, nectar, and honeydew. Larvae are about 12 mm long, wrinkled or slug-like in appearance,

tapering to a point at the head (Fig. 28). They are usually brown or green with whitish areas. Eggs are chalky white, with faint longitudinal ridges.

Syrphid flies overwinter as pupae in the soil or above ground in leaves and plant material. Adults begin emerging in May and June, about the time aphid populations begin to increase. They lay eggs on leaves and stems of plants infested with aphids or other suitable prey. Larvae feed for 7 to 10 days, then drop to the soil to pupate. A life cycle is completed in 16 to 28 days and there are three to seven generations each year.

Syrphid fly larvae feed on soft-bodied insects, particularly aphids. As many as 400 aphids may be consumed by one larva during its development period. Larvae seize aphids with their mouth hooks and suck out the body contents. These predators are commonly found in mint fields and are important in reducing aphid populations.

At least two species of **green lacewing** and one brown lacewing species may be found in mint fields, but the green lacewing is most common. Adults are green to yellowish-green with four, delicate transparent wings with many veins and crossveins (Fig. 29). Adults are about 18 mm long, with long hair-like antennae and red-gold eyes. Larvae are slender, mottled gray or yellowish-gray, and about 9.5 mm long (Fig. 30). Eggs are pale green, almost white, and are laid singly on long, slender stalks on plant foliage.

Lacewings overwinter as pupae in protected places such as cracks and crevices. Adults emerge in early spring and begin laying eggs almost immediately on plants infested with prey. There are five or six overlapping generations each season.

Adult lacewings feed on honeydew or sweet plant exudates. Larvae feed on many soft-bodied insects, such as aphids, spider mites, immature bugs, and leafhoppers. They are effective predators when prey is available, but their populations often lag behind those of their prey.

Damsel bug adults are tan or grey, with piercing-sucking mouthparts and enlarged front legs for grasping their prey (Fig. 35). They have slender bodies, and are about 10 to 12 mm long. Nymphs resemble adults, except they are smaller and have no wings.

Damsel bugs overwinter as adults in protected places and appear in the field in April or May. Adults begin laying eggs soon after emergence. Eggs are deposited in soft plant tissues. Eggs hatch into nymphs, which feed on small insects or eggs. There are numerous, overlapping generations during the season. Adults and nymphs feed on many soft-bodied insects, including aphids, spider mites, leafhoppers, and small caterpillars.

Bigeyed bug adults are about 3 to 6 mm long, buff gray or blackish in color with large, prominent eyes (Fig. 33). Nymphs resemble adults except in size and absence of wings.

Bigeyed bugs overwinter as adults in trash, crop debris, or other protected areas. Adults appear in the spring and begin feeding on available prey. Females deposit eggs in plant tissues. Eggs hatch into nymphs, which feed on prey for several weeks before becoming adults. There are usually two generations per year.

Bigeyed bug adults and nymphs feed by sucking the body fluids from their prey. Both feed on aphids, spider mites, and other soft-bodied prey.

Minute pirate bug adults are oval-shaped, about 3 mm long, very flat, and marked conspicuously with black and white (Fig. 34). Nymphs are soft-bodied, yellow or amber colored. Nymphs and adults have piercing-sucking mouthparts enclosed in a long beak.

The minute pirate bug overwinters as an adult in protected areas, such as under tree bark or boards, around homes or other buildings and in debris around fields. Adults emerge during early spring and females insert eggs in plant tissue. There are three or four generations each year in the Pacific Northwest.

Minute pirate bug adults and nymphs are very active predators and may be found on all above-ground parts of plants. Active stages feed by sucking the body fluids from aphids, spider mites, and immature stages of many small insects.

Predator mites are effective and widespread predators of injurious plant-feeding spider mites in mint. Predator mites (Fig. 36) are similar to the twospotted spider mite in size, 0.25 to 0.5 mm (Fig. 23), but are more flattened and lack spots. They pass through the same developmental stages, from egg to larva with six legs, through nymph stages to the adult, with eight legs. The life cycle of predator mites is somewhat shorter than plant-feeding mites, averaging 6 to 7 days, depending on the temperature. There are many overlapping generations each year, and like the twospotted spider mite, the female overwinters in protected places beneath plant debris or in cracks and crevices in the soil.

Female predator mites produce 30 to 60 eggs, which is generally equivalent to the number produced by the prey. This phenomenon reduces the lag of predator populations behind that of the prey, and accounts for the effectiveness of many mite predators. Also, the predators respond quickly to increasing abundance of prey, resulting in the ability to rapidly increase their numbers when plant-feeding mite populations are high. In determining need for chemical controls, it is essential that predator mites be counted along with injurious mites when sampling mint leaves. The ratio of predator mites to plant-feeding mites and the population trends may be useful to determine whether or not treatment is needed. Unnecessary treatment with insecticides or acaricides reduces the predator mite population, which could result in a rapid buildup of injurious plant-feeding mites.

Parasites

Parasites control many looper and cutworm larvae, particularly variegated and redbacked cutworm (Figs. 31 and 32), and aphids (Fig. 24). Most are tiny wasps which are easily overlooked. However, they play an important role in controlling insect pests in

mint. In most instances, larvae that have been parasitized die before causing significant leaf injury.

Parasites are either Hymenoptera (wasps, Fig. 31) or Diptera (flies), and range in size from 1 to 20 mm. The stages usually seen in the field are the adults or pupae since many female parasites lay their eggs inside their host. When the eggs hatch, the parasite larva(e) feed on the stored food (fat bodies), the reproductive organs, muscles and other body contents of their prey. When mature, larva pupate inside or outside of their hosts (Fig. 32).

In most instances, development of parasite populations lags behind that of the host, which may result in large numbers of hosts being present before sufficient numbers of parasites are present to control pest populations. Nevertheless, parasites are important regulating factors of pests in mint, particularly cutworms, loopers, and aphids. Parasitized insects are frequently conspicuous enough to be observed in the field, usually swollen and immobile. If the parasite has matured, the host may be covered with tiny cocoons or it may be hollow. Parasites of aphids form cocoons either in or under the swollen, tan, mummified skeleton of the aphid. It is important to look for parasitized insects when fields are being routinely sampled for the presence of pest insects. If a large number of parasitized insects are found, it may not be necessary to treat with an insecticide. When control of pest insects is necessary, beneficial insects may be conserved by spot treatment, using an insecticide with short residual action, or choosing a more selective insecticide.

Parasitic nematodes

Parasitic nematodes (Fig. 37), *Steinernema carpocapsae*, manufactured by Biosys Company under the tradename Biovector-Mint[®] are approved for use in mint to control mint root borer larvae (Figs. 9 and 38), mint flea beetle larvae (Fig. 11), and strawberry root weevil larvae (Fig. 13). Infection of these insect hosts is initiated by the third-stage juvenile nematode (Poinar, 1990). This nematode stage enters its host through natural openings, such as the mouth,

anus, and spiracles. As soon as the infective juveniles enter the host, they initiate development and release a symbiotic bacterium (*Xenorhabdus* spp.) into the insect host. The bacterium, which multiplies in the insect host, are consumed and digested by the developing nematodes. The nematode completes development to the adult stage within its insect host where it deposits eggs which hatch and develop into third-stage juveniles that escape into the soil from their dead insect host.

For insect control on mint, the third-stage juvenile nematodes are injected through sprinkler irrigation at a rate of 1.5 or 3.0 billion infective juveniles per acre depending on insect pest and density (see discussion under Management and Control section, pages 29–31, for rates and application procedures for strawberry root weevil, mint flea beetle, and mint root borer).

Life Cycles and Habits

Pests Chewing on Leaves

Variegated cutworm

Variegated cutworm, *Peridroma saucia* (Figs. 3 and 4), is a common pest of many vegetable and field crops, including mint. They overwinter as half grown larvae in soil or under plant debris in or around mint fields, begin feeding in April, and mature in late April and May. Larvae pupate in earthen cells in the soil. Adults emerge in May and early June and deposit eggs in clusters of 200 to 500 on the undersides of leaves. Eggs hatch in 4 to 7 days and larvae begin feeding on plant foliage. Larvae feed for 4 to 6 weeks and then pupate in the soil. Summer generation adults emerge in late August and deposit eggs. Larvae hatching from these eggs feed until cold weather and then become inactive and overwinter. There are two overlapping generations each year.

Often the larvae of other species occur on and defoliate mint at about the same time as the variegated cutworm. **Bertha armyworm**, *Memestra configurata*, is often seen in mint fields, particularly west of the Cascade Mountains. Its life cycle is about the same as that of the variegated cutworm. However, at times Bertha armyworm larvae may be present before detectable populations of variegated cutworm. Because its leaf feeding damage usually occurs earlier in the growth of mint

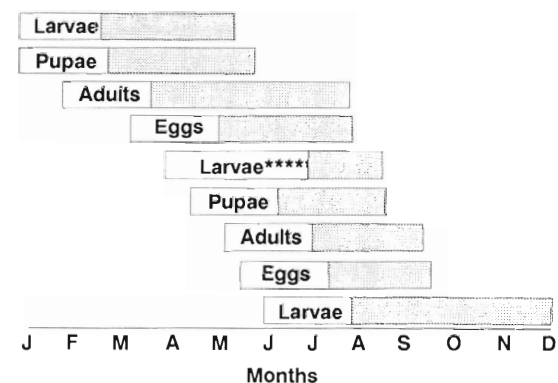
and its population density is generally less than that of variegated cutworm, it is important to distinguish between the two species. An early insecticide application against this species may not necessarily control variegated cutworm. One well-timed remedial application for cutworms and loopers reduces cost and pesticide load on the field, and minimizes other possible problems, such as the induction of spider mite problems, destruction of beneficial insects, and increased pressure for resistance development in pest insects.

Redbacked cutworm

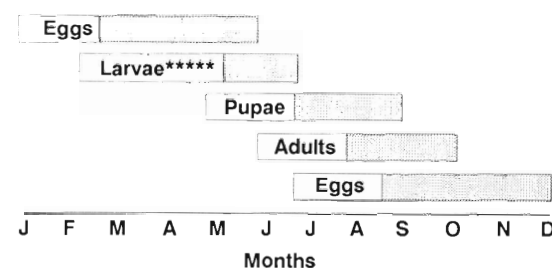
Redbacked cutworm, *Euxoa ochrogaster* (Figs. 1 and 2), and a complex of other *Euxoa* species (*E. olivia*, *E. messoria*, *E. infracta*, *E. septentrionalis*, and *E. recula*) feed on mint and other crops east of the Cascade Mountains. These other cutworm species occur at about the same time as the redbacked cutworm but they have different life cycles and the larval feeding damage overlaps among the different species from March through June.

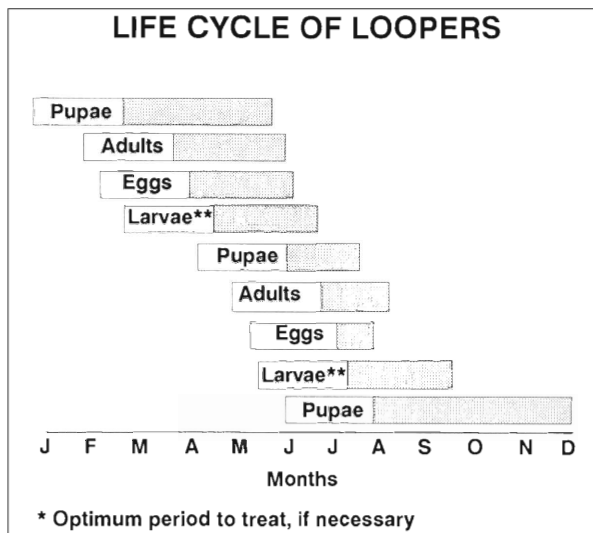
Redbacked cutworm overwinters in the soil either as eggs or larvae. Eggs hatch in March and April as soil temperatures increase. Larvae feed on mint roots beneath the soil surface by day and/or on foliage

VARIEGATED CUTWORM LIFE CYCLE



REDBACKED CUTWORM LIFE CYCLE





during the night. Individual larvae feed for 5 to 8 weeks. Most of the damage occurs in late April, May and early June. When mature, the larvae pupate in earthen cells in the soil.

Adults begin emerging in July and flight continues until late August or early September (Berry, 1975). Moths are active at night. Females deposit eggs during late August and early September. Embryonic development occurs immediately. However, eggs of this species do not hatch until the following spring. There is only one generation each year.

Alfalfa and cabbage loopers

Two species of loopers feed on mint leaves. **Alfalfa looper**, *Autographa californica* (Figs. 7 and 8), and **cabbage looper**, *Trichoplusia ni*, vary in color from light to very dark green. Mature larvae range in size from 1 to 1 1/2 inches long and eat ragged-edged holes through the leaves or in from the leaf margins. Loopers are distinguished from cutworms and armyworms by their "looping" behavior when moving and by having only two pairs of abdominal prolegs (cutworms and armyworms have four pairs).

Both species commonly overwinter as pupae in cocoons in plant debris. Adults begin emerging in late March or

April. Eggs are usually deposited singly on weed hosts, particularly wild mustards. They hatch in 3 to 5 days and the larvae feed for about 2 weeks before pupating in cocoons on the host plant or in plant debris. The total development time from egg to adult requires about 30 days. The second generation adults emerge shortly afterwards. There are two to three generations each year. Larvae of the second generation cause the most serious damage on mint, particularly during late June and July. Larvae of the alfalfa looper and cabbage looper may occur at the same time as the variegated and spotted cutworms and the western yellowstriped and Bertha armyworms.

False celery leaftier

The false celery leaftier, *Udea profundalis* (Figs. 17 and 18), is described here because the adults of this insect are frequently mistaken for adults of the mint root borer (Fig. 10). The false celery leaftier overwinters as a pupa in plant debris in and around the margins of mint fields. First generation adults emerge in the spring and lay flattened scale-like eggs, singly or in overlapping groups on the undersides of leaves near the soil. These eggs hatch in 7 to 10 days and the larvae pass through five instars during a 2- to 3-week feeding period. They do not drop to the soil and tunnel within rhizomes; all larval stages are foliage feeders. Mature larvae form a shelter by rolling the edge of a leaf and fastening it together with threads of silk. Larvae spin a silken cocoon inside this shelter and change to the pupal stage. Adults emerge in about 2 weeks. The length of the life cycle is about 40 to 60 days and there can be three generations each year.

Orange mint moth

The orange mint moth, *Pyrausta orphisalis* (Fig. 39), occurs on peppermint, Scotch, and native spearmint and may be present during the same time of year as the mint root borer and the false celery leaftier. Interestingly, research in Washington has shown feeding by the orange mint moth actually stimulates mint growth and in field experiments has resulted in increased oil yields. For more information on this

insect see Campbell and Pike (1984, 1985), Pike et al. (1987), and Pike et al. (1986).

Grasshoppers

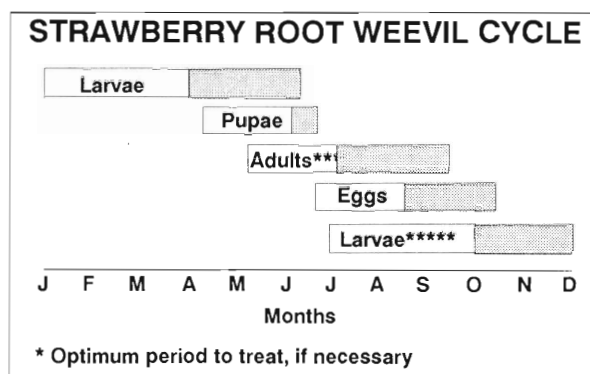
There are many different species of grasshoppers in the Pacific Northwest, but only a few, such as *Melanoplus* sp. (Fig. 22), damage mint. Damage caused by grasshoppers is sporadic, usually most severe in fields close to rangeland, waste areas, or dryland legume and grass fields harvested prior to mint.

Most grasshoppers that feed on mint overwinter as eggs in the soil about 1 to 2 inches deep. Depending on species, eggs are deposited in pods containing 20 to 100 eggs each. Eggs are deposited in field margins, bare sandy areas of mint fields, uncultivated land, and well-defined breeding and egg-laying areas in undisturbed rangelands. Eggs hatch in mid-May, June, and early July. Nymphs feed for 40 to 60 days before becoming adults. Adult grasshoppers disperse to mint and many other crop plants when populations increase and/or food becomes scarce. There is usually one generation each year.

Pests on Rhizomes, Roots, or Stems

Root weevil

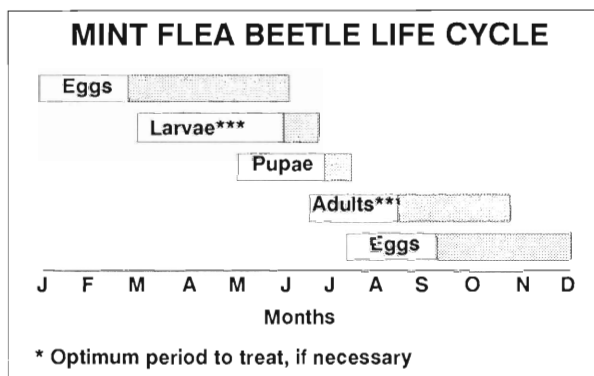
The major root weevil species attacking mint is the **strawberry root weevil**, *Otiorhynchus ovatus*, (Figs. 13 and 14). However, the black vine, *O. sulcatus*, rough strawberry, *O. rugosostriatus*, and obscure root weevil, *Sciopithes obscurus*, also may be present in some mint fields. Most strawberry root weevils overwinter as larvae in the soil, but a few adult weevils also overwinter in protected areas. These adults are the first to deposit eggs the following spring. Overwintering larvae mature during the end of April and early May and form earthen cells in the soil where they pupate. Adults begin emerging during mid-May and early June and are usually present in mint fields through late September (Cacka, 1982; Emmenegger and Berry, 1978; Emmenegger, 1976). All adults are females and, in the absence of fertiliza-



tion by males, begin depositing eggs around the bases of plants about 2 weeks after emergence. Most of the eggs are deposited during late June and July. There is one generation each year.

The accumulation of day-degrees (DD) may be used to predict the occurrence of the different life stages of strawberry root weevil using a base temperature threshold of 8.8°C (48°F) and accumulating DD above the threshold beginning January 1. For instance, in central Oregon, overwintering larvae are found in soil samples until late May or early June (Cacka, 1982). Pupae are present in samples from late April to early June (350 DD). Peak pupation occurs from mid-May to early June (500 DD) and peak adult emergence occurs in mid-June and early July (700 DD). Development of ovaries and subsequent egg laying usually begins about 2 weeks after adult emergence or after about 950 DD have been accumulated. Control of adults with Orthene in central Oregon should be timed to coincide with the accumulation of about 700 to 800 DD in early July. Development of all stages of strawberry root weevil occurs earlier in western Oregon; pupae and teneral adults are present in soil samples in early May and most adults have emerged by early June. Therefore, applications of Orthene for adult control in western Oregon should be made in mid-June.

Larvae begin feeding on small mint roots very soon after emerging from the eggs (the majority of larvae emerge during late July and early August, 1,300 to



1,400 DD). Larvae feed through the summer and early fall, at which time they reduce activity until the following spring when feeding is resumed. In western Oregon and Washington, where winters are mild, the larvae may continue feeding during the winter months.

Adult damage, which may be evident during late May, June, and July, consists of small notches on the leaf margins and stems, particularly near the soil line. Adult feeding on mint is usually inconspicuous and is not economically important. Adults are active on mint foliage at night after sunset and by dawn have usually descended to the soil surface and become inactive during the daytime in cracks or under sheltering debris.

Natural spread of root weevil infestations in and among fields is gradual because adults do not fly. Serious infestations can originate when roots and rhizomes are dug from infested fields and transplanted in uninfested areas. Obviously, growers buying mint rhizomes for new plantings should purchase "weevil free" rootstock, or at least remove as much of the soil as possible from rhizomes to be transplanted.

Mint flea beetle

Mint flea beetle, *Longitarsus ferrugineus* (new species name replaced *waterhousei*, see LeSage, 1988), larvae (Fig. 11) are very small, slender and worm-like. A full-grown larva is only about 1/4 inch long. Larvae are white, with a shiny, pale-brown head and three pairs of legs. Adults (Fig. 12) are small, about 1/8 inch long,

elongate-oval beetles, with brownish-yellow bodies and darker, reddish-brown heads. The hind legs are long and thickened for jumping, hence the name "flea beetle."

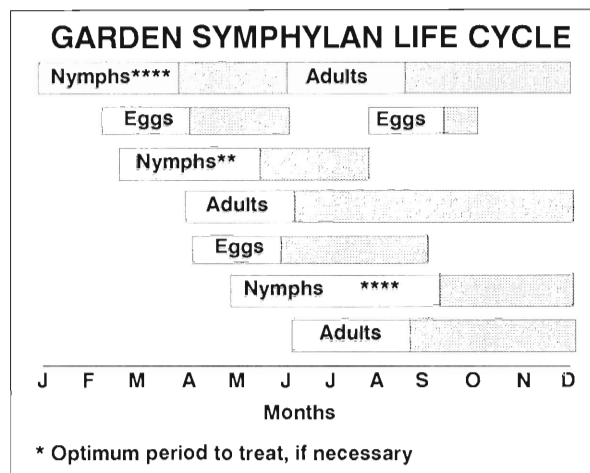
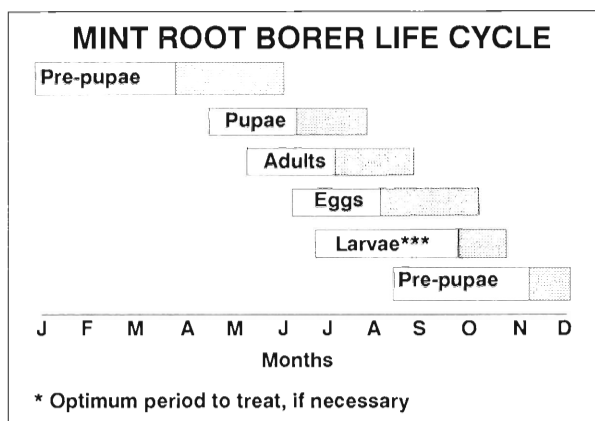
Mint flea beetles overwinter as eggs in the soil near the crown of mint plants. Eggs hatch early April through early May. Larvae feed initially on small mint roots and later tunnel into rhizomes. Larval development is completed during late May and early June. Pupation is in the soil near the rhizomes. The pupal stage is completed in about 3 to 4 weeks. Adults begin emerging from the soil during early July. Damage to mint foliage fed upon by adults is characteristic; the leaves appear riddled as if by shotgun pellets. Adult females usually delay depositing eggs for 2 to 3 weeks after emergence.

The use of day-degrees (DD), using a base temperature of 5°C, accumulated from January 1, is an effective method of predicting the occurrence of different life stages of mint flea beetle in the field (Morris, 1990). The following day-degrees may be used to predict the presence of different stages of mint flea beetle in central Oregon:

Day-degree requirements for different stages of mint flea beetle

1st instar larvae	225 DD
2nd instar larvae	320 DD
3rd instar larvae	430 DD
Prepupae	580 DD
Pupae	760 DD
Adults	865 DD

Females have wings, but seldom disperse by flight. Males are incapable of flight. Therefore, dispersal is usually slow and occurs by hopping or walking. At harvest, adults disperse to adjacent fields or to margins of fields seeking uncut plants. Eggs may either be deposited in mint fields or along field margins. Egg laying continues into the fall until the onset of freezing



temperatures. There is one complete generation each year. Planting infested rootstock is one of the principal ways new mint flea beetle infestations are established.

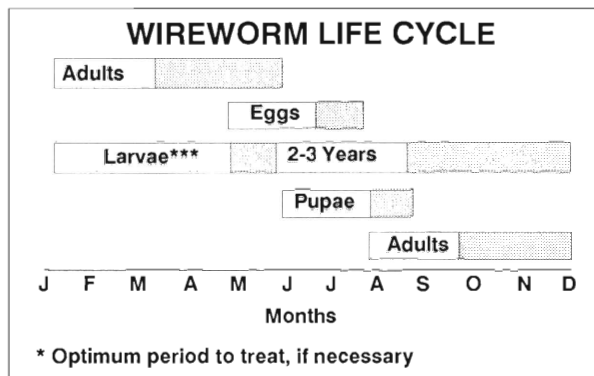
Mint root borer

Mint root borer, *Fumibotys fumalis* (Figs. 9 and 10), overwinters as a prepupa within an earthen cell 1/2 to 1 1/2 inches below the soil surface. Pupation occurs within the cell during April and early May. Adult emergence begins in June and early July, continuing through the summer until early August (Berry, 1974). Peak emergence occurs during July. Females deposit eggs that resemble tiny scales along the leaf veins on both lower and upper surfaces. Each female can deposit 100 to 200 eggs during a 1- to 2-week period. Eggs hatch in 5 to 10 days, and first-stage larvae feed on leaf surfaces for 1 or 2 days before dropping to the soil surface to tunnel into rhizomes at the bases of buds. Individual larvae feed in rhizomes for 70 to 80 days during August, September, and early October. They emerge from rhizomes and construct earthen cells in October in which to overwinter. There is a single generation each year. The mint root borer occurs on peppermint and spearmint in all growing areas in the Northwest (Berry, 1974; Pike et al., 1988).

Garden symphylan

Garden symphylan, *Scutigereella immaculata* (Fig. 21), is primarily a pest of mint in western Oregon and Washington, but may occur in other production areas. Mature symphylans are 1/8 to 1/4 inch long, white, soft-bodied, centipede-like animals, with prominent, many-segmented antennae. They move very rapidly when disturbed, vigorously vibrating their antennae. Symphylans are not true insects, since they possess 12 rather than 3 pairs of legs in the adult stage. However, newly hatched nymphs have only six pairs of legs. An additional pair of legs is added at each molt, until the adult stage is reached.

Eggs, nymphs, and adults can be found in any month of the year. Peak egg laying occurs primarily during the early spring months with another, smaller peak in the fall. Nymphs and adults are active in the late winter and spring. They are found in increasing numbers in the upper 6 to 8 inches of soil from about April through August. Eggs are deposited in clusters of 4 to 25 at various depths, depending on soil temperature, moisture, and soil structure. Eggs are covered with a network of tiny ridges and white when first laid. They gradually turn light tan in color. Eggs hatch in 30 to 40 days and nymphs feed on small roots and root hairs. The total developmental time from egg to adult requires about 5 months at 10°C. Nymphs and adults

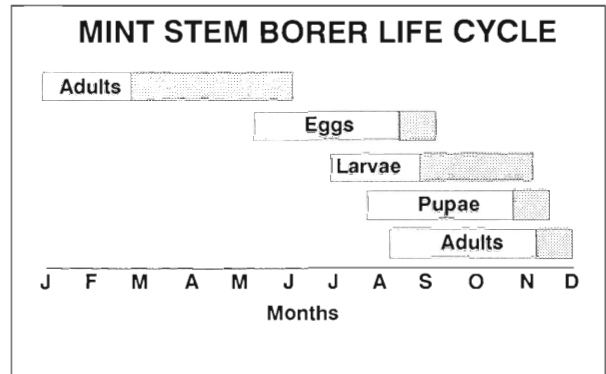


move freely in the soil and seek depths where favorable temperature and moisture occur. Cold temperatures during the fall and winter and extreme dryness in the summer cause them to migrate deep in the soil. There are one to two generations per year. For additional information see Berry and Robinson (1974), *Biology and Control of the Garden Symphylan*, Oregon State University Extension Circular 845.

Wireworms

Adult wireworms, *Ctenicera* sp., *Limonus* sp (Fig. 20), which are commonly called click beetles, do not generally cause economic damage on established mint in the Pacific Northwest, but larvae (Fig. 19) can be found feeding on mint roots, rhizomes, and stems at the soil surface. Serious infestations occasionally occur on first year mint following potatoes, onions, sugar beets, grass seed, or mint planted in newly recovered land after fallow. The most common species encountered in mint include the Pacific Coast wireworm, *Limonus canus*, the sugar beet wireworm, *L. californicus*, and the Great Basin wireworm, *Ctenicera pruinina*.

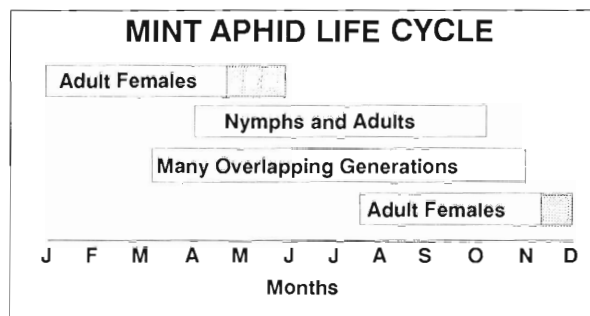
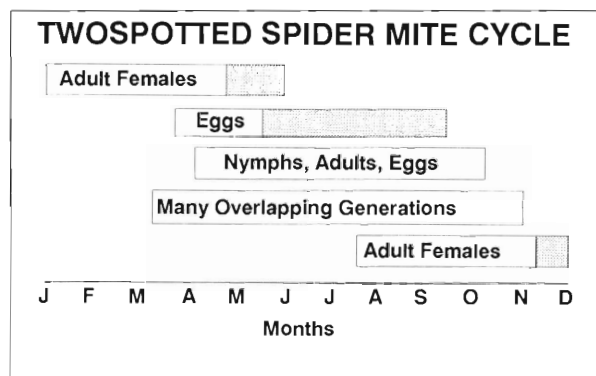
The adult beetles (Fig. 20) are slender, tan to nearly black, and range from 1/2 to 3/4 inch long. Larvae (Fig. 19) are hard, segmented, measure 1/2 to 1 inch long, and vary from yellow to brown. Larvae have three pairs of legs and the last abdominal body segment is elongated and may end in a keyhole-shaped structure.



Wireworms overwinter as larvae or as recently developed adults which do not emerge from the soil until the following spring, usually from early May to June. Adults migrate by flying within fields or to new fields. The females mate and burrow into the soil to deposit eggs. Eggs are laid singly 2 to 6 inches deep in the soil and hatch in 3 to 4 weeks. The larvae move easily through the soil in search of food. They can feed in the soil for 2 to 5 years before pupating in July or August. In the Northwest, most wireworms take about 3 years to complete their life cycles.

Mint stem borer

Mint stem borer, *Pseudobaris nigrina* (Figs. 15 and 16), is a black weevil, about 1/8 inch long, that overwinters in mint fields and becomes active in mid-May to early June. The female, which may deposit as many as 100 eggs during the growing season, chews a hole in a mint stem near the soil line and deposits a single egg in the wound. Larvae hatch in late June and begin feeding on the tissues in the center of the stems and usually burrow into the rhizomes. Larvae feed for about 3 to 4 weeks until late July, although in Idaho some larvae have been found in the stems as late as October. Pupae are found in late July and produce adults that emerge about 2 weeks later. There is one generation each year and apparently a partial second generation in late fields. Overwintering adults are usually found inside hollow stems or in soil debris. The mint stem borer has only been found infesting mint in Idaho and eastern Oregon, where it feeds on



peppermint and native and scotch spearmint. It also feeds on wild mints, goldenrod, and *Kochia*.

For a more detailed description of this pest, see Baird et al. (1990) *The Mint Stem Borer in Idaho*, University of Idaho Extension, Current Information Series 808.

Pests Sucking on Leaves or Stems

Twospotted spider mite

Twospotted spider mites, *Tetranychus urticae* (Fig. 23), are tiny (0.25 to 0.5 mm long) eight-legged arthropods with two large spots on both sides of the body. Mites are typically found on the undersides of leaves but may colonize entire plants during outbreaks. Silk webbing on the undersides of leaves, and bronzing, stippling and burning of leaves are characteristic signs of spider mites.

The female mites overwinter in the soil and in plant debris in and around mint fields. Females become active in the spring as temperatures warm, and they begin depositing eggs on the undersides of leaves. Eggs hatch in 4 to 5 days and the entire life cycle from egg to adult may require 1 to 3 weeks, depending on the temperature. Infestations of mites may occur as early as March during warm weather. During the summer months, mite populations can increase very quickly, particularly in hot, dry weather, along dusty roads, during periods of water stress, and even in

response to insecticide applications. Therefore, fields should be inspected at least weekly to detect the buildup of damaging populations.

The practice of spring flaming mint fields west of the Cascade Mountains to control rust contributes to the suppression of spider mite populations (Hollingsworth and Berry, 1983). Additionally, predator mites occur in mint fields and can be a significant factor in limiting spider mite populations and problems. Learn to distinguish between spider mites (Fig. 23) and predator mites (Fig. 36).

Mint aphid

Wingless mint aphids, *Ovatus crataegarius* (Fig. 24), are yellow-green to apple-green, mottled with darker green markings. These small soft-bodied aphids range in size from 1.5 to 2 mm long and occur in colonies on mint leaves. The winged forms have dark brown heads and thorax areas with yellow-green abdomens. Winged forms are most common in the spring and fall.

Mint aphids overwinter around the bases of mint plants, on mint roots, beneath plant debris, and in cracks and crevices in the soil. Females give birth to mobile nymphs in the spring. They suck sap from stems and undersides of leaves. Rates of development and population densities increase with temperature. During the summer and early fall, a generation may be completed in 7 to 10 days and as many as 12 to 15 generations may be produced each year.



Figure 1. Redbacked Cutworm Larva



Figure 2. Redbacked Cutworm Adult



Figure 3. Variegated Cutworm Larva



Figure 4. Variegated Cutworm Adult



Figure 5. Spotted Cutworm Larva



Figure 6. Western Yellowstriped Armyworm



Figure 7. Alfalfa Looper Larva



Figure 8. Alfalfa Looper Adult



Figure 9. Mint Root Borer Larva



Figure 10. Mint Root Borer Adult



Figure 11. Mint Flea Beetle Larva



Figure 12. Mint Flea Beetle Adult



Figure 13. Strawberry Root Weevil Larva



Figure 14. Strawberry Root Weevil Adult



Figure 15. Mint Stem Borer Larva



Figure 16. Mint Stem Borer Adult



Figure 17. False Celery Leaf-tier Larva



Figure 18. False Celery Leaf-tier Adult



Figure 19. Wireworm Larva



Figure 20. Wireworm Adult



Figure 21. Garden Symphylan



Figure 22. Adult Grasshopper



Figure 23. Twospotted Spider Mite



Figure 24. Mint Aphids



Figure 25. Lady Beetle Adult



Figure 26. Lady Beetle Larva



Figure 27. Syrphid Fly Adult



Figure 28. Syrphid Fly Larva



Figure 29. Lacewing Adult



Figure 30. Lacewing Larva



Figure 31. Ichneumonid Wasp Parasite



Figure 32. Parasitized Cutworm Larva



Figure 33. Bigeyed Bug Adult



Figure 34. Minute Pirate Bug Adult



Figure 35. Damsel Bug Nymph



Figure 36. Predator Mite

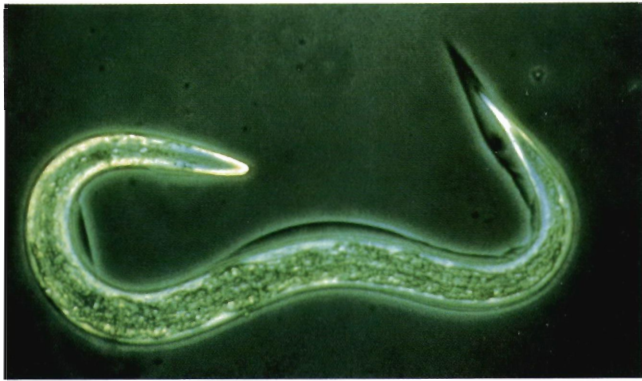


Figure 37. Parasitic Nematode



Figure 38. Mint Root Borer Parasitized by Nematode



Figure 39. Orange Mint Moth Adult

Management and Control

Management of insects and mites on mint is based on the following approaches: 1) planting pest-free root stock, 2) correctly identifying pests and beneficials, 3) sampling and monitoring pests and beneficials, 4) protecting beneficial insects and mites, 5) employing cultural practices, such as flaming, tillage, and crop rotation, if possible and 6) using insecticides as a last resort and only when necessary based on treatment thresholds.

Insect and mite pest management practices in peppermint are varied and can include the benefits of accepted cultural practices and naturally occurring biological control, as well as judicious application of insecticides and miticides. The financial incentives to use IPM techniques are:

- decreased expenses of seasonal pesticides (the excessive use of which can actually create other pest problems such as the release of mites from biological control and the imminent need to apply a miticide, not only once but sometimes twice or more prior to harvest),
- proper pesticide selection, timing, and rate adjustment for optimum pest control with minimal application,
- increased stand life of peppermint fields for sustained, optimum yields because of timely detection and delineation of a problem(s), and
- sustained or increased oil yield with little or no increase in insecticide or miticide use (often a decrease in pesticide use, as much as 50 percent in a season).

Certain cultural practices used in mint production for purposes unrelated to insect and mite control contribute greatly to the suppression of pest populations. This knowledge alone makes it worthwhile to understand these aspects of pest management. Fall or spring tillage in certain areas of the Northwest has often resulted in economic control of mint root borer the subsequent year by mechanical destruction and deep burial of the overwintering stages. Tillage disturbs the layers of carbon and organic matter that accumulate in fields that are flamed, enhances soil structure, distributes soil

nutrients, and may suppress certain species of weeds, such as common groundsel (Talkington and Berry, 1986). Spring flaming for rust control also delays the development of mite populations and often reduces them below levels needing control later in the growing season. Planting pest-free roots and rotating out of mint every 4 to 5 years will help reduce the buildup of soil pests.

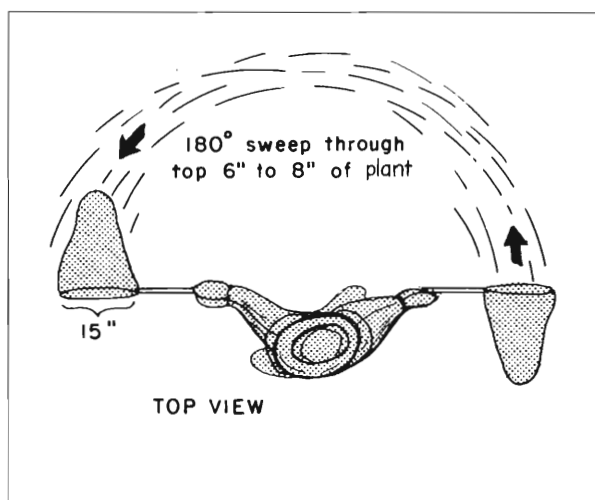
IPM is correct identification of insects and mites. Insecticides have been needlessly applied to mint for the control of noninjurious March fly larvae mistaken for mint root borer or for control of springtails, diplurans, centipedes or millipedes assumed to be symphylans.

Detection and Population Sampling

Know when, where, and how to look for pests before crop loss occurs. Wireworms for which no legal or effective insecticides are labeled as postemergence treatments continue to be a factor in the loss of portions of new mint plantings. Preplant sampling techniques can help recognize this potential problem. Timely detection of mint root borer in late August or September by observing wilted plants and confirming infestations by sampling soil and rhizomes results in proper insecticide timing. Application of soil insecticides to control mint root borer in October when visual plant damage can be seen is ineffective. Damage has already been sustained, and insecticides will not control the insect which has usually ceased feeding and is hibernating in a cell nearly impervious to insecticides.

Sweeping mint fields with an insect-gathering net and examining plants for evidence of insect injury may help avoid unnecessary insecticide applications, and assure proper timing of applications.

A standard sweep net has a diameter of 15 inches. The bag or net should be attached to a sturdy wire frame with a handle 26 inches long. Sweep nets can be made or purchased. Some insecticide dealers keep them in stock. If not, the dealers or your Extension agent can determine a source.



In using a sweep net, develop a uniform sampling technique. This permits comparisons. Each sweep should cover an arc of 180 degrees, with the net striking the upper 6 to 8 inches of the plant as shown in the diagram above.

Even though economic damage levels have not been determined for some insects on mint, the use of a sweep net will establish the presence of insect pests and beneficial species on the upper foliage and can help growers and field representatives assess potentially damaging populations.

Monitoring

Strawberry root weevil is a pest that once was, but no longer is, satisfactorily controlled during the larval stage with postharvest insecticide applications in the fall. With monitoring adult emergence in the spring and observing for egg development, an insecticide application can be correctly timed to control adults before eggs are laid in the soil. An insecticide application too early in the spring barely reduces the egg-laying adults. An insecticide application too late in the summer does little to control subsequent larval damage because a substantial number of eggs have already been laid.

Treatment Thresholds or Action Levels

The treatment thresholds provided in this guide are based on university research and field experience. Where available, they relate numbers of insects per unit (sq ft soil sample, mites per leaf, cutworms and loopers per sq ft of soil surface) to the probable need for a control measure to prevent economic loss. Remember, these are numbers that can vary depending on the price of oil, the cost of control, the need to sustain a stand for future production, the vigor and age of a mint stand, the occurrence of natural control by weather or biological agents, and the presence of other pests — to name a few impending factors. The value of using treatment thresholds is evident when comparing fields treated using thresholds with fields treated in the absence of their use. For example, large numbers of mites may be found on leaves on plants near field edges, but very few mites may be found on leaves in other areas of the field. Symphylans are found in localized areas in fields and treating the entire field may not be necessary.

This section on management and control provides suggestions for proper and efficient methods of sampling for insect and mite pests, treatment thresholds that are research-based and have been used in commercial fields as guidelines for action, and various management tactics that may be used to reduce pest populations, if necessary.

Pests Chewing on Leaves

Foliage-feeding armyworms and cutworms include the variegated cutworm (Fig. 3, Table 1), and other foliage-feeding cutworms such as spotted cutworm, *Amathes c-nigrum* (Fig. 5), western yellowstriped armyworm, *Spodoptera praefica* (Fig. 6), and the Bertha armyworm. These different cutworm species may occur together in the same field during July and early August. The sampling program and treatment threshold described below for the variegated cutworm also may be used for the aggregate of these species.

Variegated cutworm

Inspect fields closely from mid-June to just prior to harvest, remembering that if an insecticide application is

considered, the preharvest interval must be observed. Growers may want to consider harvesting earlier to avoid further crop injury. Sweep net samples can be used to sample small larvae (first, second, and third instars). Usually 10 straight line sweeps at 5 different sites in fields up to 30 acres are sufficient to evaluate larval populations. Add an additional site for every additional 10 acres. Largest collections of these smaller larvae will occur on cool, overcast days, or when fields are sampled early in the morning or near dusk on still days. Avoid sweep net sampling when mint is water-stressed or foliage is wet. Very often, more than 50 percent of the cutworms found in samples will be parasitized; this may alter the treatment thresholds shown in Table 1 (see discussion on how to determine parasitism, page 25).

The decision to apply an insecticide is usually based on the average number of larvae found per 1,000 sq cm (cm²)—an area slightly larger than 1 sq ft—on the soil surface. To estimate larval populations of fourth, fifth, and sixth instars, inspect the soil surface by first vigorously shaking mint foliage and closely observing and recording the number of larvae per 1,000 cm² randomly through the field. Take a ground search sample every 5 acres for fields up to 30 acres. Add an additional site for every 10 acres in fields that exceed 30 acres. Look very closely for small and curled-up larvae under and in folded leaves on the ground. Remember that larvae can fall into cracks on the soil surface. When leaf-chewing is quite evident and cutworm counts from ground searches are low, consider returning after dark and sampling with a sweep net when the larvae actively feed on the foliage. Consult Table 1 to determine the treatment threshold for variegated cutworm based on ground search samples.

Sequential sampling plans have been developed for variegated cutworm using sweep net samples to estimate larvae (instars 2 to 4) and for ground search samples (1,000 cm²) to estimate larval instars 4 to 6 (Coop, 1987). Using these plans, treatment of larval instars 2 to 4, sampled with a sweep net, is recommended if 60 larvae are collected from a minimum of

10 different field sites (a minimum of 10 sweep net samples should be taken at each site). Treatment is not recommended if fewer than 44 larvae are collected in sweep net samples. For ground search sampling, treatment of larval instars 4 to 6 is recommended if 24 larvae are collected in 1,000 cm² samples taken from a minimum of 18 different sites. Treatment is not recommended if fewer than 17 larvae are collected in the 1,000 cm² samples.

Note: These sequential sampling plans are based on treatment thresholds which were calculated using an oil value of \$12.00/lb and a cost of treatment of \$20.00/acre; as the value of the oil and cost of treatment change, the recommended treatment thresholds also change (see Table 1).

If treatment is justified, apply 1.0 lb a.i./acre Orthene^R (acephate) 75 S or 3/4 to 1.0 lb a.i./acre Lannate^R (methomyl), or 0.9 lb a.i./acre Malathion (Cythion). Orthene and Lannate have a 14-day preharvest interval and Malathion has a 7-day preharvest interval. Orthene generally has been more effective in controlling larger cutworm and looper larvae and grasshoppers. Lannate controls smaller larvae and has been shown to prevent egg hatch in laboratory studies and field observations in other crops. Lannate also satisfactorily controls populations of adult mint flea beetle when present at the time of application — Orthene does not. Research has shown that variegated cutworm feeding on peppermint is less susceptible to insecticides because the terpenes found in mint leaves induce enzymes that detoxify the insecticides (Berry et al., 1981). On the other hand, certain peppermint terpenes have been shown to increase mortality of variegated cutworm larvae and pupae (Harwood, 1988; Harwood et al., 1990).

Bacillus thuringiensis (Bt) applied at 1 to 2 quarts/acre can reduce populations of small cutworms. It benefits from the addition of a spreader sticker or wetting agent and is more effective if applied at night, when larvae are actively feeding on foliage being sprayed, and in the absence of direct sunlight and extreme temperatures. It does not control pests other than loopers,

Table 1. Treatment thresholds for variegated cutworm larvae/1,000 cm²*.

Note: When different species of cutworms and loopers occur together on mint, control measures have usually been applied when numbers reach 1 or 2/1,000 cm².

Oil Value (\$/lb)	Cost of Treatment (\$/acre)							
	14	16	18	20	22	24	26	30
Early Harvested Fields (28 July – 10 Aug.)								
\$12.00	1.2	1.4	1.6	1.8	1.9	2.1	2.3	2.6
\$14.00	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.3
\$16.00	0.9	1.1	1.2	1.3	1.4	1.6	1.7	2.0
\$18.00	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.8
\$20.00	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.6
\$22.00	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.4
Mid-Harvested Fields (11 Aug. – 20 Aug.)								
\$12.00	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.8
\$14.00	1.1	1.3	1.5	1.6	1.8	2.0	2.1	2.4
\$16.00	1.0	1.1	1.3	1.4	1.6	1.7	1.8	2.1
\$18.00	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.9
\$20.00	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.7
\$22.00	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.6
Late Harvested Fields (21 Aug. – 1 Sept.)								
\$12.00	1.6	1.8	2.0	2.2	2.5	2.7	2.9	3.3
\$14.00	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.9
\$16.00	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.5
\$18.00	1.0	1.2	1.3	1.5	1.7	1.8	1.9	2.3
\$20.00	0.9	1.1	1.2	1.3	1.5	1.6	1.7	2.0
\$22.00	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.8

* 1,000 cm² is slightly larger than one ft².

cutworms, and armyworms. Activity on variegated cutworm and other cutworms and armyworms is variable, depending on the trade product and its formulation. The major disadvantage of the use of Bt is the fact that the dense mint foliage prevents penetration and coverage of the leaves with Bt.

A sex pheromone is commercially available and can be used to detect and monitor adult males of the varie-

gated cutworm in the spring. Trapping males could provide valuable early season information to growers concerning the potential need to control cutworm larvae during June and July (Coop, 1987). Pheromone traps baited with this lure can be set in fields in late April and monitored weekly or biweekly through June. Although action levels for an insecticide or Bt treatment have not been developed based on moth catches, it is likely that large and continual catches greater than

25 per week will result in similarly large populations of larvae being observed approximately 2 weeks following peak trap counts. The real value of pheromone traps lies in the fact that they signal when to begin inspecting fields for larvae, thereby greatly improving timing of an insecticide application, if one is necessary. Also be aware that, occasionally, large trap catches will not result in large larval populations. This is particularly true when the mint field does not have a resident population of variegated cutworm and the trap catches are a result of males being lured into traps from other crops. Conversely, a small trap catch does not necessarily mean that an action level will not be exceeded by the larvae.

Naturally occurring predators and parasites (Figs. 31 and 32) play an important role in suppressing cutworm populations throughout all mint-growing areas in Oregon. The percentage of parasitism may reach 80 to 90 percent in some fields. The principal parasites of cutworms and loopers on mint are *Meteorus communis*, *Nepiera* sp., *Camptoplex* sp., and *Copidosoma* sp. (Coop, 1987; Coop and Berry, 1986). Growers and consultants are urged to consider that it is likely that a significant proportion of the larvae in samples may be parasitized. Leaf consumption by parasitized larvae is much reduced and there is very little reduction in oil yield caused by these larvae (Coop and Berry, 1986). Parasitized larvae can be distinguished from nonparasitized larvae only by dissection. Select some of the largest larvae from the sweep or ground search sample. With each, cut the head off, and pull the larva apart. If the larva is parasitized, another smaller larva of the parasite will be found inside the cutworm larva. If time permits, larvae can be reared to determine the number parasitized. Depending on the percentage of larvae parasitized, you can increase the suggested action thresholds listed in Table 1.

Redbacked cutworm

Redbacked cutworm (Figs. 1 and 2, Table 2), black cutworm and other *Euxoa* species. These cutworms are most common east of the Cascade Mountains. Soil samples should be taken from mid-April through June

(Danielson, 1976; Danielson and Berry, 1978). Wilted plants cut off at the soil surface and slow-growing mint in the spring may indicate the presence of cutworms. The larvae can be seen on the foliage or the soil surface on warm nights with a flashlight. Square foot soil samples to a depth of 2 to 3 inches should be taken in mint fields from early April to mid-June to determine if this cutworm is present and numerous enough to warrant chemical control. At least one soil sample should be taken for every 1 to 2 acres with a minimum of 25 samples per field. The treatment threshold depends on the age and vigor of the field (Table 2). See Shields and Berry (1982), *Soil Samples for Redbacked Cutworm in Peppermint*, EC 1009, for detailed information on the construction of sampling equipment, its use, and treatment thresholds for redbacked cutworms in differently aged fields.

Sequential sampling plans have been developed for redbacked cutworm in differently aged fields (Danielson 1977; Danielson and Berry, 1978). For established fields, treatment is recommended if an average of 7.0 larvae/1,000 cm² are found in 25 samples taken from different sites in the field. Treatment is not recommended if the average number of larvae per sample is less than 3.0/1,000 cm². In newly planted fields, treatment is recommended if an average of 1.5 larvae/1,000 cm² are found in 25 samples taken from different sites. If the average number of larvae per sample is less than 0.5/1,000 cm², no treatment is necessary. Vigorously growing plants can withstand more cutworm injury than plants growing under stress. In addition, fields greater than 6 to 8 years old that have other pests such as weeds, nematodes, or diseases are likely to be more susceptible to cutworm injury.

Note: These sequential sampling plans are based on treatment thresholds which were calculated using an oil value of \$13.00/lb and a cost of treatment of \$27.00/acre; as the value of the oil and cost of treatment change, the recommended treatment thresholds also change (see Table 2).

If treatment is justified, apply 4.0 lbs a.i./acre Dyfonate[®] (fonophos) 14G. Apply 3 weeks prior to

Table 2. Treatment thresholds for redbacked cutworm larvae infesting fields that are 6 years of age or more or in weak condition.

Note: First-year fields or low vigor fields are most susceptible to damage. Vigorous fields can tolerate higher numbers of cutworm larvae. EC 1009 provides additional tables for two other classes of fields: first-year and vigorous fields that are less than 5 years old.

Oil Value (\$/lb)	Cost of Treatment (\$/acre)							
	20	22	24	26	28	30	32	34
	Average Number of Larvae/1,000 cm ² *							
\$12.00	0.43	0.47	0.51	0.55	0.59	0.64	0.68	0.73
\$14.00	0.36	0.40	0.44	0.47	0.51	0.55	0.58	0.62
\$16.00	0.32	0.35	0.39	0.42	0.45	0.48	0.51	0.54
\$18.00	0.29	0.31	0.34	0.37	0.40	0.43	0.45	0.48
\$20.00	0.25	0.29	0.31	0.33	0.35	0.39	0.41	0.43

*1,000 cm² is slightly larger than 1 sq ft.

Sinbar[®] (terbacil) or longer if new mint, poor vigor, or on sandy soil. Lightly incorporate granules and irrigate to seal soil surface. As an alternative, apply 1.0 to 2.0 lbs a.i./acre Lorsban[®] (chlorpyrifos) 4E or 1.0 lb a.i./acre Orthene 75S. Lorsban has a 90-day preharvest interval and Orthene has a 14-day preharvest interval. Lorsban is most effective when lightly incorporated and irrigated in immediately after application.

Natural parasites occur in mint fields in central Oregon and have been shown to decrease the populations of *Euxoa* sp. by as much as 80 percent. Refer to page 25 for a discussion of how to determine if the cutworms you collect are parasitized. The principal parasites in areas east of the Cascade Mountains are Porizintinae species and *Copidosoma* sp.

Alfalfa and cabbage loopers

Alfalfa and cabbage looper (Figs. 7 and 8) larvae are usually found in mint from mid-June to early August. Take 10 sweep net samples in at least five different sites in fields up to 30 acres. Add an additional sample site for every additional 10 acres. Count the number of

larvae and calculate an average number per sweep net sample. Field inspections for loopers are usually done at the same time as sampling for variegated cutworm. Loopers and variegated cutworm will both be found in sweep net samples and ground search samples. Loopers, unlike the variegated cutworm, can usually be found on foliage during the day.

In practice, the number of loopers and other foliage-feeding cutworms can be combined to determine whether or not to apply an insecticide.

Note: Early season (early June) populations of loopers alone may not need control because, in most cases, feeding occurs on leaves that will be shed by the plant as a result of shading prior to harvest (Coop, 1987). Also, the percentage of parasitism or diseased loopers usually exceeds 50 percent in most fields most seasons and does not cause significant leaf injury. Parasitized loopers can usually be distinguished from non-parasitized loopers by the presence of a black spot on the back of the looper near the back end. Parasitism can be detected by selecting some of the larger loopers

from the sweep samples, cutting off the head of each, and pulling each larva apart. A smaller parasite larva will be found inside the looper larva. It is important for growers and consultants to realize that many loopers found in samples are parasitized and will not cause leaf injury. If treatment is justified, use the same insecticides as recommended above for the variegated cutworm. The biological insecticide, *Bacillus thuringiensis* (Bt), may provide very good control of loopers and small cutworms when applied by ground with a sticking agent and in sufficient water to provide thorough coverage.

False celery leaf-tier

False celery leaf-tier (Figs. 17 and 18) larvae feed on the undersurfaces of foliage and on buds, but do not feed on roots of mint as does the mint root borer. The larvae produce a silk web that may enclose several leaves or just draw parts of a single leaf together. Feeding damage is most evident in the spring when plants are small. Severe damage seldom occurs, and this insect is not usually considered to be economically important on mint.

Grasshoppers

Grasshopper (Fig. 22) adults and nymphs may be sampled at the same time as cutworms and loopers, using a sweep net from mid-June to early August. Grasshopper damage on mint generally occurs during mid-June, July, and early August, when nymphs move into mint fields from margins or when adults migrate from adjacent areas that have already been harvested. Occasionally, egg beds occur within a field in shallow sandy areas and nymphal infestations occur in the field's interior. Large nymphs and adults feed on mint leaves, causing ragged-edged holes beginning at the margin and progressing inward, or they may consume the entire leaf. Small nymphs can cause holes in the interior of the leaf resembling damage caused by cutworms, armyworms, and loopers. Serious yield losses may result if the population reaches six to eight per square yard. Grasshopper populations can be estimated with a sweep net during May, June, and July when fields are being sampled for cutworms and

loopers. Grasshoppers are easiest to control when they are immature and before they have developed wings.

Grasshoppers are usually controlled at the same time that treatments of Orthene, Lannate, or malathion are applied against cutworms, loopers and adult root weevils. Since most grasshopper infestations begin on the field margins, a border treatment may be enough to control the infestation.

Pests on Rhizomes, Roots, or Stems

Strawberry root weevil

The immature or larval stage of the strawberry root weevil (SRW, Figs. 13 and 14, Table 3) causes damage to mint by feeding on roots. However, it has become obvious that the best way to control this pest is in mid-June or early July with Orthene 75S applied in the evening (after sunset for best success) as a foliage spray to kill the adults.

SRW larvae are best estimated by taking 1,000 cm² soil samples after harvest in late August and September or the following spring in March, April or early May. In western Oregon, samples for root weevils may be combined with samples for mint root borer. In central Oregon, they may be combined with samples for redbacked cutworm in April and May. Take at least 25 soil samples from different areas of the field (one site per 2 1/2 acres), screen the soil, count the number of larvae and calculate the average number per sample. If the average number of root weevil larvae exceeds two per sample, treatment of adults with Orthene applied at 1.0 lb a.i./acre is recommended (or see Table 3 for the treatment threshold which includes total larvae, pupae, and adults/1,000 cm²). Malathion applied at 1.0 lb a.i./acre also is registered for adult control, but it is not as effective as Orthene.

A sequential sampling program has been developed for SRW in central Oregon (Cacka, 1982). This sampling plan is based on taking a minimum of 25 1,000 cm² soil samples and accumulating the number of adults, pupae, and larvae found in each sample. Using this method, treatment is recommended if the total accumu-

Table 3. Treatment thresholds for strawberry root weevil larvae only or for samples combining larvae, pupae, and adults in central Oregon.

Oil Value (\$/lb)	Cost of Treatment (\$/acre)							
	14	16	18	20	22	24	26	28
Average Number of Larvae/1,000 cm ² *								
\$ 6.00	5.25	6.01	6.76	7.19	7.51	8.26	9.01	9.76
\$ 9.00	3.51	4.01	4.51	4.80	5.01	5.51	6.02	6.52
\$12.00	2.63	3.00	3.38	3.60	3.75	4.13	4.50	4.88
\$15.00	2.10	2.40	2.70	2.88	3.00	3.30	3.60	3.90
\$18.00	1.75	2.00	2.25	2.40	2.50	2.75	3.00	3.25
\$21.00	1.5	1.72	1.93	2.06	2.15	2.36	2.57	2.79
Average Number of Larvae, Pupae & Adults/1,000 cm ²								
\$ 6.00	8.96	10.25	11.53	12.27	12.81	14.09	15.37	16.65
\$ 9.00	5.99	6.84	7.70	8.19	8.55	9.41	10.26	11.12
\$12.00	4.48	5.12	5.76	6.13	6.40	7.04	7.68	8.32
\$15.00	3.59	4.10	4.61	4.91	5.12	5.64	6.16	6.66
\$18.00	2.99	3.42	3.84	4.01	4.27	4.70	5.12	5.55
\$21.00	2.56	2.93	3.29	3.51	3.66	4.02	4.39	4.76

*1,000 cm² is slightly larger than 1 sq ft.

lated number of adults, pupae, and larvae exceeds 5.5 weevils/1,000 cm². Treatment is not recommended if the total weevils/sample is less than 2.7/1,000 cm². These sequential sampling plans are based on treatment thresholds which were calculated using an oil value of \$10.00/lb and a cost of treatment of \$20.00/acre; as the value of the oil and the cost of treatment change, the recommended treatment thresholds also change (Table 3).

All SRW are females capable of laying eggs without fertilization. In general there is a 2-week period before the females begin laying eggs after emergence from the soil. This biological fact helps time an insecticide application for optimum control when most of the adults have emerged from the soil, but prior to any egg laying (see previous discussion on using day-degrees to predict adult emergence, page 9). In practice, mint fields suspected of being infested

with SRW should be sampled with a sweep net in the evening a couple of hours after sunset. Still, warm and dry evenings are best. Windy, cool and/or rainy periods produce fewer weevils per sweep, giving the impression of a smaller field population than is actually present. Take 10 sweep samples in at least five different sites in fields up to 30 acres. Add one additional sample site for each additional 10 acres.

Even though no treatment threshold has been developed for adult SRW, we have seen that, once an infestation becomes established in a field, it can be difficult to control. An evening application of Orthene against adults may be justified even if the population is at a relatively low level. If treatable populations occur, apply 1.0 lb a.i. Orthene/acre in the evening after 90 to 100 percent of the adults have emerged, and prior to egg laying in June or early July. Weevils will not have mature eggs in their bodies until about 2

weeks after emergence (Cacka, 1982). Therefore, monitor for the presence of eggs in the weevils by collecting five or ten adults and, after squashing their bodies, inspecting for small round yellow eggs through a 15x hand lens. If you spray too soon, there will be a residual population of weevils emerging postspray to lay eggs. If you spray too late, egg laying will have already occurred. Field observations indicate that two applications of Orthene may be required in central Oregon, but only one west of the Cascade Mountains.

The parasitic nematode, *Steinernema carpocapsae*, marketed under the tradename Biovector-Mint[®] by Biosys Company, is labeled for control of strawberry root weevil larvae in mint. For best results, applications should be injected through sprinkler irrigation after harvest in the evening or at night at a rate of 3.0 billion juvenile nematodes per acre (refer to the detailed application procedures in mint root borer discussion, page 31). Applications of Biovector-Mint applied post-harvest can control both strawberry root weevil larvae and mint root borer larvae. Applications to control strawberry root weevil in the spring have been less successful largely because of low soil temperatures (<60°F). Therefore, proper timing of applications is more critical in the spring than in the fall for SRW.

A carabid beetle, *Pterostichus vulgaris*, found in western and central Oregon mint fields, feeds on strawberry root weevil adults, pupae, and larvae and may substantially reduce the population (Cacka, 1982). However, populations of this important predator may be significantly reduced by summer applications of Orthene used for adult strawberry root weevil control.

Mint flea beetle

Mint flea beetle (Figs. 11 and 12, Table 4) continues to be a pest in central and western Oregon in the spring. This is the time of year when root damage caused by the larvae of the mint flea beetle can readily be seen. Spring regrowth of mint injured by this pest is slow and characterized by spotty stands and reddish plants that are stunted and stressed. These symptoms are also

Table 4. Suggested treatment thresholds for mint flea beetle larvae.

Oil Value (\$/lb)	Cost of Treatment (\$/acre)			
	25	30	35	40
Average No. Larvae/Soil Sample				
\$10.00	0.8	0.9	1.1	1.2
\$15.00	0.5	0.6	0.7	0.8
\$20.00	0.4	0.5	0.5	0.6
\$25.00	0.3	0.4	0.4	0.5
\$30.00	0.3	0.3	0.4	0.4

typical of other factors, such as water stress or damage from symphylans or nematodes.

Recognition of adult flea beetle feeding damage on mint leaves is the easiest clue to determine if this pest is present. Feeding is interveinal, and appears as many small "shot holes" through both leaf surfaces. A sweep net can be used in late June and July to monitor for adult mint flea beetles (usually after the accumulation of 850 to 900 day-degrees, see page 10). The small yellowish-brown beetles are most efficiently sampled early in the morning on dry foliage. Sample at least five sites for every 20 acres taking 10 to 20 sweep net samples through the foliage at each site. Record the total number of beetles in the net at a given site and then divide by the number of sweeps taken at that site to obtain the average number of adults per sweep. No treatment threshold has been developed for adult flea beetles, but yield reductions have been observed when an average of 5 to 10 adults are found per sweep sample. Adult control is optimized when Lannate[®] is applied at 0.90 lbs a.i./acre by ground equipment and thorough coverage is achieved.

To sample for larvae, begin taking soil samples in late May and early June or after 300 to 400 day-degrees have been accumulated (see page 10). Take a minimum of 25 samples per field. Every 1 to 2 acres take a

5 by 7 inch sample of soil and roots to a depth of 4 inches. This can be done with a small shovel or hollow metal core sampler. Soil samples can be screened in the field or placed in Berlese funnels to collect the larvae (see Morris, 1990 and Shields et al., 1981, *Sampling For Soil Insect Pests: An Inexpensive Way to Build a Berlese Funnel*, EC 1079). If you are using Berlese funnels, we recommend separating the soil and rhizomes to enhance recovery of larvae. In the field, carefully inspect the soil and roots for small cream-colored larvae from 1 to 2 mm long with brown heads. They can be found in black or brown "tracks" within tissue just below the surface of the root. Occasionally they will be in the soil near the root, or protruding from the root itself. An average of 0.5 to 1.0 larvae per sample may cause injury to mint (see Table 4 and Morris, 1990).

No insecticides are registered to control mint flea beetle larvae. However, the use of Vydate[®] (oxamyl) to control nematodes in May can provide control of mint flea beetle larvae if applied when the larvae are in the first and second instars—usually after the accumulation of 200 to 300 day-degrees.

Spring applications (June) of the parasitic nematode (Biovector-Mint) at a rate of 3.0 billion juvenile nematodes per acre may provide control of mint flea beetle third instar larvae, prepupae, pupae, and teneral adults. Applications should be made in the evening through sprinkler irrigation after soil temperatures exceed 60°F in the spring and after about 400 day-degrees have been accumulated (refer to the detailed application procedures in mint root borer discussion below). Early spring applications may be less effective because of cold soil temperature, small size of larvae, and their concealment in rhizomes. In areas east of the Cascade Mountains, cool spring temperatures and the lack of adequate irrigation water require careful timing of early spring applications.

Mint root borer

Mint root borer larvae (Fig. 9) cause damage by feeding inside peppermint and spearmint rhizomes from late July through mid-September (Berry, 1974;

Berry, 1977; Pike et al., 1988). Damage resulting from feeding injury weakens mint stands, which overwinter poorly and regrow slowly in the spring.

Inspect fields during the growing season when adults are active. When disturbed, adults fly a few feet and land on the underside of a leaf. Collect moths by sweeping foliage, then shaking net contents to the bottom and slapping lightly against a hard surface. Empty net contents onto a light background and remember to distinguish mint root borer adult (Fig. 10) from false celery leafminer adult (Fig. 18). Presence of adults in a field should serve as a signal to take postharvest soil samples for larvae in late August or early September.

Important: If samples are taken too early in August, larvae will be very small and only found by the most skilled observer. Late September and October soil samples will usually only detect larvae after damage is done and results of chemical control will normally be poor. Soil samples (1 sq ft in size) should be taken from several locations in the field. We recommend that two samples be taken for every 2 1/2 acres. Take a minimum of 25 samples per field at several different sites. Samples should include soil and rhizomes to a depth of 2 to 3 inches. These samples also may be used to estimate the population of root weevil larvae and symphylans in the fall, although the depth of samples may be too shallow to collect a representative sample. Samples may be sorted by hand in the field, but we recommend the use of Berlese funnels to separate the larvae from the sample. If using Berlese funnels, separate the soil and rhizomes to enhance recovery of larvae. If samples are inspected in the field, be sure to inspect rhizomes for damage and larvae which may be within the rhizome. Depending on soil texture and moisture, the use of screens to sieve soil may speed up the process of locating larvae in the samples that have exited rhizomes.

Treatment is justified if an average of two to three larvae are found per square foot sample. The only insecticide registered to control mint root borer is Lorsban, which should be applied after harvest at a rate

of 2.0 lbs a.i./acre. Lorsban must be immediately irrigated into the soil to be effective and, since Lorsban has low solubility in water (Pike and Getzin, 1981) and may tie up in the carbon and organic matter layer on the soil surface, it requires at least 1 inch of water. Treat only the acreage that can be irrigated immediately. Lorsban 4E also may be applied through sprinkler irrigation systems as a postharvest broadcast application to control mint root borer. Before injecting Lorsban, irrigate the field with a minimum of 1/4 inch of water to pre-wet the soil surface.

Important: Before applying Lorsban through a sprinkler irrigation system, thoroughly read and follow the directions on the label.

The parasitic nematode, marketed by Biosys Company under the tradename Biovector-Mint[®], is approved for use on mint to control mint root borer larvae. For best results, Biovector-Mint should be injected through sprinkler irrigation during late July or early August (preharvest) at a rate of 2.0 billion infective juvenile nematodes per acre. Postharvest applications during late August or September should be injected through sprinkler irrigation at a rate of 1.5 or 2.0 billion juvenile nematodes per acre. The low rate is recommended for fields that have a low mint root borer density (ca. less than 1.0/ft²), and the high rate is recommended for fields that have densities greater than 1.0/ft².

Important: Parasitic nematodes must be applied in the evening or at night because the nematodes are vulnerable to ultraviolet light during the daytime. Before injecting the nematodes, irrigate the fields with a minimum of 1/4 inch of water to prewet the soil surface. Immediately following injection, 1/2 to 1 inch of sprinkler irrigation should be applied to the field. The nematodes may also be sprayed on the field in the evening with a ground sprayer calibrated to deliver at least 50 gallons of water per acre, followed immediately with 1/2 to 1 inch of irrigation. Carefully follow the directions on the label to insure proper handling and injection of the parasitic nematodes.

Tillage after harvest has been shown to significantly reduce mint root borer. In southcentral Washington and parts of Idaho, strip tillage combined with Lorsban applied at 2.0 lbs a.i./acre prior to mid-September provides 90 percent or more control in furrow-irrigated mint fields (Pike and Glazer, 1982). In sprinkler-irrigated fields, plowing and double disking mint fields in late October or early November or in the spring during February or March provides 80 percent or more control (Talkington, 1983; Talkington and Berry, 1986). Pike et al. (1988), in *Mint Root Borer in the Pacific Northwest*, PNW 322, describe these two tillage methods. Tillage may spread verticillium wilt; growers should use this practice only in fields with a low incidence of verticillium wilt. Growers may observe benefits from tillage, such as stand rejuvenation, suppression of some weed species, redistribution of nutrients, disruption of the layers of accumulated carbon and organic matter, and the establishment of uniform pH levels in the upper 4 to 6 inches of soil (Talkington and Berry, 1986).

A sex pheromone is available commercially to sample for mint root borer adult males (Davis and McDonough, 1984; Davis et al., 1991). The successful development of this sex pheromone in a trapping system could provide valuable early-season information to growers concerning the need to control mint root borer larvae. Revealing the presence or absence of mint root borer adults in a field, concentration of adult activity in a certain area, and/or size of an infestation based on trap catches are examples of how pheromones have been used to successfully manage pests in other crops.

Garden symphylan

If soil moisture is adequate, the garden symphylan (Fig. 21) can be observed in mint root borer soil samples. However, postharvest samples for mint root borer are usually too shallow to detect a significant symphylan population in the fall. This is because of the dry soil profile, a natural seasonal reduction in population, and the symphylan's tendency to travel downward in the soil to avoid high temperatures or seek moisture.

The best time of year to sample for symphylans is from March through September. However, to properly control them with an insecticide, you must apply it prior to spring regrowth. Take a shovelful of soil to a depth of 10 inches from several different sites in the field (one site per 1 1/2 acres). Count the number of symphylans per sample and calculate an average number per sample. If an average of four to five symphylans is found per sample, control may be required depending on the vigor of the stand.

A mite predator, *Pergamasus quisquiliarum*, of symphylans commonly occurs in western Oregon soils (Berry, 1973). The developmental period of this predator requires about 17 days, compared to about 87 days for the garden symphylan at 20°C. Therefore, this predator could complete about five generations to one generation of the symphylan at this temperature. Studies have shown that this predator may consume up to 12 symphylans during one generation, indicating that it could be an important factor in regulating symphylan populations.

If treatment is justified, apply Dyfonate at 2.0 lbs a.i./acre and incorporate by irrigation. Apply Dyfonate at least 3 weeks before Sinbar applications. If possible, identify areas in the field where the population is concentrated and treat only those areas. Symphylans prefer heavier soils to sandy soils and often infest ridge or high areas, avoiding low spots where water concentrates.

Note: If possible, incorporate Dyfonate into the soil by tillage, particularly in new plantings of mint.

Wireworms

Wireworm (Figs. 19 and 20) populations can be estimated by taking square foot soil samples to a depth of about 2 to 3 inches around mint plants from several different locations in the field. Usually, wireworm larvae, if present, also will be collected at the same time samples are taken for redbacked cutworm, strawberry root weevil, mint root borer,

and symphylans. Soil should be screened in the field or placed in Berlese funnels to extract these pests.

No treatment threshold has been developed for wireworms on mint. Wireworms seldom cause serious damage on established mint, but they may be devastating to new plantings. Damage may occur if mint is to be planted in fields with a previous history of wireworm injury or in noncrop or fallow land. Fields that have been fallowed for several years or planted in potatoes, cereals, or sugar beets should be sampled before planting mint. Using mint roots free of insects to establish new fields is of utmost importance. If mint is to be planted in fields with a previous history of wireworm injury, growers should consider treating the field with Dyfonate or fumigating the soil prior to planting mint. Use Telone II or C-17 at the rates recommended on the label. Fumigation is expensive and therefore usually used to control multiple pests. If Dyfonate is used, do not apply Sinbar until at least 3 weeks after the Dyfonate application. Fields with a previous history of wireworms may be fallowed and frequently cultivated to kill weed hosts for 1 year prior to planting mint, but, since wireworms may take up to 3 years to complete development, some wireworm larvae may remain in the field even after 1 year of fallow.

Mint stem borer

Mint stem borer (Figs. 15 and 16) occurs in Idaho and Malheur County in eastern Oregon but damage is usually minimal and may not be sufficient to justify treatment (Baird et al., 1990). Adults can be sampled during the daytime with a sweep net from mid-May to mid-June. In Idaho, unpainted wooden lath stakes coated with stickum have been used to monitor adult activity. Stakes should be placed in the field in mid-May and checked twice weekly through mid-June. To sample for larvae, take mint stem samples from several different locations in the field during late June through July. Cut and split the stems just below the soil line and look for larvae or feeding damage. Stems of infested plants appear weakened near the soil surface where the eggs are laid and the larvae are feeding. Plants appear weak with the early visible symptoms of yellowing,

wilting, and lodging. Damage from the mint stem borer is greatest in stressed plants. Healthy, vigorously growing mint usually does not show symptoms or yield loss despite high numbers of adults in the field. In Idaho, mint fields 3 to 5 years old or mint that is under stress (water, fertilizer, root diseases) are most affected by this pest.

Baird et al. (1990) recommend that the best way to control the mint stem borer is to maintain a healthy stand of mint and avoid stressing the plants through proper irrigation, fertilization, and disease management. Management of weeds, particularly wild mints, goldenrod, and *Kochia* is also important since the mint stem borer may increase in these weeds growing along ditch banks, roadways, and in waste areas.

Selecting clean planting stock free of overwintering mint stem borer adults will help insure vigorous plant stands. Also, crop rotation will help maintain healthy, vigorous stands of mint and prevent serious mint stem borer injury.

No insecticides are registered to control mint stem borer. Control with insecticides is very difficult because larvae are protected inside mint stems. However, since adults may be active at about the same time as growers are applying insecticides for cutworm, looper, and strawberry root weevil adult control, growers may see moderately effective suppression of mint stem borer adults with the same insecticide application.

Even though the mint stem borer is presently not widespread in all mint production areas in the Pacific Northwest, it is important to recognize the damage and sample suspected fields to prevent it from spreading to other growing areas, especially in mint planting stock.

Pests Sucking on Leaves or Stems

Twospotted spider mite

Twospotted spider mite (Fig. 23) has become progressively more important as a pest of mint throughout the Northwest. Probable reasons may include: 1) develop-

ment of resistance in populations of mites in mint fields which have been repeatedly treated with miticides such as Kelthane (dicofol); 2) reduced use of flaming for spring rust control; 3) changes in production practices or pesticide use patterns, causing increased mortality of natural enemies; or 4) improved awareness of their pest status and the use of proper sampling methods. Either fall plowing or spring flaming of mint contributes greatly to the cultural control of mites in mint fields by reducing early season populations that are initiated from overwintering female mites (Hollingsworth and Berry, 1982).

Correct sampling procedures for spider mites involve close observation of leaf samples taken from different areas in a field (Hollingsworth, 1981; Hollingsworth and Berry, 1983; Hollingsworth et al., 1984). Include leaf samples from plants in areas that are on high ground, excessively dry, and have had past problems with mites, such as dusty areas or field margins. The use of a 15X hand lens will enable growers to distinguish between spider mites and predator mites (see below). By walking in a "Z" or "M" pattern in the field, randomly collect stems and inspect the leaves from the bottom, middle and top of the stems for mites (count adults, nymphs and eggs). Classify the leaves as "infested" or "not infested" if the mites (adults and nymphs) number five or more.

For each 30 acres, 15 individual field sites should be monitored for mites by examining a total of 45 leaves (15 leaves each from the bottom, middle, and top) from 15 randomly selected mint stems per site. It also is important to count the number of predator mites (Fig. 36) on each leaf. These natural predator mites help reduce spider mite populations below economic levels through harvest. If predator mites are present, the field may not require immediate treatment and should be rechecked at a later date. Treatment of spider mites is justified if there are no predator mites and if 18 or more of the leaves in the 45-leaf sample taken at each site are infested with five or more spider mites. It is also important to estimate the number of spider mite eggs on the leaves, because their number will help predict an emerging infestation. Hollingsworth et al.

(1984), *A Sampling Plan For Twospotted Spider Mites in Mint*, PNW 251, explains an effective system for monitoring infestations of spider mites in mint.

Injury to mint plants **begins** to occur when populations of spider mites reach five per leaf. Feeding injury caused by densities greater than five mites per leaf increases water stress (DeAngelis, 1981; DeAngelis et al., 1982, 1983a), reduces photosynthesis (DeAngelis et al., 1983b), and alters terpene metabolism, resulting in elevated levels of menthol and neomenthol and decreased levels of pulegone (DeAngelis et al., 1983c). Peppermint leaf phenolics reduce spider mite fecundity and increase developmental time (Larson, 1983; Larson and Berry, 1984).

Spider mite populations can increase rapidly during hot, dry weather and even after an insecticide application. Fields should be inspected twice weekly during these times. If treatment with a miticide is justified, apply Omite[®] (propargite) at 1.5 to 2.25 lbs a.i./acre, Comite[®] at 1.6 to 2.0 lbs a.i./acre, Metasystox-R[®] (oxydemeton-methyl) at 0.75 a.i./acre, or Kelthane[®] at 1.2 lbs a.i./acre. Kelthane has a 30-day preharvest interval, and Omite, Comite, and Metasystox-R have a 14-day pre-harvest interval. Even though Kelthane is registered on mint it is highly toxic to predator mites, and, unlike Omite or Comite, its use should be avoided when predator mites are contributing to natural control. The use of Kelthane in the spring is not recommended because it kills predators.

Spring flaming for rust control west of the Cascade Mountains in Oregon and Washington reduces the incidence of spider mites early in the growing season. This may result in fewer applications of miticides during the growing season (Hollingsworth and Berry, 1982, 1983). Fewer miticide applications will help delay the development of mite resistance, protect beneficial predators, and reduce production costs.

Mint aphid

Mint aphid (Fig. 24) has not been a serious pest in most commercial mint fields in the Northwest. Thus, treatment thresholds have not been established. Damage from the mint aphid occurs when the population is very high and the leaves are coated with large amounts of honeydew which may interfere with harvest. The mint aphid population may be estimated using a sweep net during the same time as sampling for cutworms and loopers. In most years and in most production areas, naturally occurring predators such as lady beetles (Figs. 25 and 26), green lacewings (Figs. 29 and 30), and syrphid flies (Figs. 27 and 28) suppress the population. Parasites (Fig. 31), which aid in the suppression of mint aphid, also may be present in some fields.

If treatment is necessary, use malathion applied at 0.9 lb a.i./acre, Metasystox-R applied at 0.75 lb a.i./acre, or Orthene applied at 1.0 lb a.i./acre.

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- Jeffrey Miller, Department of Entomology, Oregon State University, Corvallis. Fig. 3.
- Craig Baird, Entomologist, University of Idaho Southwest Idaho Research Center, Parma. Figs. 15, 16 and 17.
- Mark Morris, Department of Entomology, Oregon State University, Corvallis. Fig. 36 and cover photo.
- Randy Gaugler, Rutgers University, and Kirk Smith, Biosys Company, Vancouver, Washington. Fig. 37.
- Gary Parsons, Department of Entomology, Oregon State University, Corvallis. Fig. 38.
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A Pacific Northwest Extension Publication • Revised February 1993

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Published and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914, by the Oregon State University Extension Service, O.E. Smith, director; Washington State University Cooperative Extension, Larry G. James, interim director; the University of Idaho Cooperative Extension System, LeRoy D. Luft, director; and the U.S. Department of Agriculture cooperating.

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