Pest Management Strategic Plan
for
Pacific Northwest Mint Production

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Working Group Members

CALIFORNIA
Alan Albaugh, Grower, McArthur, CA
Harry Carlson, Farm Advisor, Extension Service,UC-Davis

IDAHO
Drew Eggers, Grower, Meridan, ID
George McClelland, Grower, Fruitland, ID
Tom Mowry, Entomologist, UI

OREGON
Fred Crowe, Extension Agent, Pathologist, OSU Extension Service
Gale Gingrich, Extension Agent, OSU Extension Service
Mark Mellbye, Extension Agent, OSU Extension Service
Mark Morris, Field Representative, A.M. Todd Co.
John Reerslev, Grower, Junction City, OR
Bryon Quibbeman, Crop Consultant, LaGrande, OR

MONTANA
Kirk Passmore, Grower, Kalispell, MT
Steve Street, Grower, Kalispell, MT

WASHINGTON
Rick Boydtson, Weed Scientist, USDA-ARS
Dennis Johnson, Pathologist, WSU
Curtis Parrish, Grower, Toppenish, WA
Devin Dekker, Grower, White Swan, WA
Rocky Lundy, Executive Director, Mint Industry Research Council

OTHERS PRESENT AT WORKSHOP
Sharon Collman, EPA, Region 10
Len Coop, Entomologist, OSU
Joe DeFrancesco, Entomologist, OSU
Ronda Hirnyck, Pesticide Program Coordinator, UI
Jeff Jenkins, Environmental Toxicologist, OSU
Paul Jepson, IPM Coordinator, OSU
Rick Melnicoe, Western Region Pest Management Center, UC-Davis (facilitator)
Lana Unger, Entomologist, UI (manuscript assistance)

The use of trade names does not imply endorsement by the working group or any of the organizations represented. Trade names are used as an aid in identifying various products.

Background: Acreage, Regions, Production Requirements

Mint is a perennial crop grown primarily for its oil, which is used as a flavoring in chewing gum and dental products, and other confectionery and pharmaceutical products. The United States is the largest producer in the world of peppermint oil and spearmint oil. The Pacific Northwest region of the United States (Oregon, Washington, Idaho, Montana and northern California) is the center of USA mint production, accounting for about 80% of the USA acreage and approximately 90% of the USA mint oil production. In 2001, the Pacific Northwest had 79,900 acres of mint in production, which yielded 7,640,000 pound of oil.

Mint Oil: Harvested acres, oil yield and US ranking, 2001 crop year.

	Peppermint			Spearmint			All Mint	
	Harvested Acres	USA Acreage (%)	Oil Yield (lb./A)	Harvested Acres	USA Acreage (%)	Oil Yield (lb./A)	Harvested Acres	USA Acreage (%)
Washington	21,500	27	94	10,600	54	140	32,100	33
Oregon	26,000	33	84	1,100	6	120	27,100	28
Idaho	14,000	18	92	900	5	105	14,900	15
California	3,200	4	76	800	4	100	4,000	4
Montana	1,400	2	75	360	2	100	1,800	2
Pacific Northwest	66,100	84	88	13,760	71	133	79,900	81
USA	78,500	- - -	81	19,500	- - -	105	98,000	- - -

In Washington, mint production is concentrated in the central part of the state, east of the Cascade Mountains, in the Columbia Basin area. Counties that grow mint include: Adams, Benton, Franklin, Grant, Kittitas, Lincoln, and Yakima. Mint in also grown in Clark County, which is on the west side of the Cascade Mountains.

In Idaho, mint production is primarily in the southwestern part of the state, with most of the acreage located in counties of Ada, Canyon, Elmore, Gem, Gooding, Owyhee, Twin Falls, and Washington. Mint is also grown in the northern part of the state in Kootenai County.

In Oregon, about a ¼ of the mint production occurs in the moist and moderate Willamette Valley on the west side of the Cascade Mountains and the other ¾ of the production is on the east side of the Cascade Mountains, where summers are warmer and drier, and winters are cold. Counties west of the Cascade Mountains that grow mint include Benton, Columbia, Lane, Linn, Marion, Polk, Tillamook, and Yamhill. Central and Eastern Oregon counties that produce mint include Crook, Deschutes, Klamath, Lake, Malheur, Umatilla, Union, and Grant.

In California, mint is grown in the northeastern part of the state, primarily in Lassen, Modoc, Shasta and Siskiyou Counties.

In Montana, mint production occurs primarily in the northwestern part of the state and includes Flathead, Lake and Sanders Counties. Mint is also grown in Ravalli County, which is located in the southwestern part of the state.

Mint requires warm days (85-95° F) and cool nights (55-60° F) for optimum growth. The areas best suited to mint production are north of the 45th parallel, where sixteen hours of daylight results in the best yield and quality of oil. The long day length triggers flowering and oil production responses in the mint plant, and the sunny days ensure lush foliage for high amounts of hay from which to extract mint oil. All commercially grown mint is very dependent upon environmental and physical factors, including temperature, day length, and soil type. The differences in environmental and physical factors among the various growing regions in the Pacific Northwest are responsible for the distinctive differences in mint oil characteristics and yields between regions. Mint is grown on a variety of soil types but soils with good drainage, a pH of 6.0-7.5, and high organic matter are best suited for mint production.

Most of the mint-growing regions of the Pacific Northwest are semi-arid and require irrigation for optimum production. The water requirements for the majority, if not all, of the mint grown in the Pacific Northwest are fulfilled by supplemental water in the form of irrigation. The water requirements for a good mint crop are from 30 to 40 inches per year. To maximize yields, the mint plant needs approximately one inch of water per week when it first breaks dormancy until it reaches 12 inches high; from then until harvest, it requires 1.5 to 2.0 inches of water per week during the growing season. Fertilizer is an integral part of mint production and most mint requires up to 250 pounds of nitrogen fertilizer per season.

General Philosophy of Pest Management in Mint Production

The Mint Industry Research Council (MIRC) takes a proactive role in the registration and re-registration of pest control products to ensure their availability for mint growers. The MIRC encourages the adoption of Integrated Pest Management (IMP) practices for the production of mint. The MIRC defines IPM as an overall pest management concept and not any one component used in mint production systems. Mint IPM is based on providing growers with the widest array of pest control options that include cultural, biological, chemical and genetic techniques. The ultimate goal of IPM in mint is to ensure the production of an abundant, high quality crop in an environmentally and economically sound manner.

Growing mint is a challenge because it is extremely susceptible to diseases, insects and weeds, all of which can alter the oil quality and/or reduce yield. Emphasis on good soil tilth, practices that maintain plant vigor, and monitoring (scouting) of soil moisture, plant health, pests, and beneficial arthropods are crucial to successful crop production. The pest control compounds and strategies used for mint production are selectively chosen

based upon the impacts to natural pest predators and beneficial insects. The presence of endemic natural enemies, in many situations, keeps pest numbers low. Practices which conserve natural enemies have proven to be more effective than costly augmentative releases.

In general, insecticides applied to control insect herbivores often greatly reduce and even eliminate the local populations of predator and parasite insects. Even reduced application rates can be more lethal to these natural enemies than to the target pest. At least part of the reason for this is that insect herbivores have an evolutionary history with their host plants that includes detoxifying plant defensive compounds. This history does not exist for predators and parasites. Consequently, herbivores often have enzyme systems that are better able to cope with introduced toxins (e.g. insecticides) than do the insects that prey upon them.

Insecticide applications can affect the local herbivore balance through disruption of their natural enemies in two fundamental ways. First, the target pest may be less susceptible to the insecticide, allowing for some level of survival while predators and parasites may be eliminated. The target pest population then rebounds more quickly in the absence of natural enemies and additional insecticide applications may be required. Second, predators and parasites may be naturally controlling insect herbivores other than the target pest and, when natural enemies are eliminated, a secondary pest outbreak may occur. Careful consideration should be given the insecticide control program at the local field level and growers should be aware of the minor pest complex and the potential control of these insects by natural enemies. If insecticide application is necessary, it is advisable to use those compounds that have the greatest specificity for the target pest and the least toxicity to natural enemies.

Sanitation practices must be employed by mint growers to prevent the introduction and spread of debilitating mint pests from field to field, farm to farm and region to region. Mint growers should clean and disinfect all tillage and harvesting equipment between fields or farm-to-farm, and always leave work in known infested fields until last. Growers should thoroughly clean and disinfect equipment and protective foot coverings and clothing should also be worn when entering a field used as a mint rootstock nursery and other fields. Proper sanitation practices must be employed to prevent the introduction and spread of debilitating mint pests from field to field, farm to farm, and region to region.

Foundation for the Pest Management Strategic Plan

The remainder of this document is a compilation of the common pests that can cause significant damage and economic losses during the various growth stages of mint (Pre-plant; Vegetative growth, Post-harvest vegetative growth; Dormancy) and the field and worker activities that occur during these stages. This document also summarizes current and potential management practices for these pests, and lists what the mint industry believes are the research, regulatory, and educational needs for dealing with these pests.

Summary of the Most Critical Needs in PNW Mint Pest Management

Research:

- Develop a long term, interdisciplinary research program that investigates the critical interactions of pests in the mint crop and rotational sequences, utilizing a systems approach
- Develop new pesticides for resistance management
- Develop new, more effective, practical and cost effective control measures for root feeding insects and nematodes
- Investigate control measures for hard-to-control perennial weeds (e.g. field bindweed, yellow nutsedge, yellow toadflax)
- Investigate ways to reduce pesticide inputs
- Develop high yielding, disease and pest resistant cultivars
- Develop an assay for *Verticillium*, which will also distinguish between the mint strain and other strains of *V. dahliae*
- Develop a replacement for Tough (pyridate)

Regulatory:

- Register Mocap (ethoprop)
- Register Prowl (pendimethalin)
- Maintain workable REI's and PHI's during the risk assessment processes

Education:

- Continue to educate regulators about interactions of pesticides and predators
- Educate growers concerning new research developments
- Develop and distribute symptom-identification field guides
- Create list-serve discussions
- Develop and disseminate educational materials for growers concerning cultural and biological control (e.g. site selection, crop histories)
- Educate growers about using new techniques with existing control measures (more conventional pesticides and methodology)
- Educate the general public on the benefits and safety margin of most agricultural chemicals

I. PRE-PLANT THROUGH PLANTING

Mint is planted either in the fall (October-November) or early spring (March-May). New mint stands are started by rhizomes or stolons (rootstock). Use of certified mint rootstock and tip cuttings (in California) reduces the risk of introducing diseases, weeds or insects that may be associated with contaminated planting material. The adoption of a certification program for mint is an effective method for preventing the introduction of diseases and other pests. Commercial spearmint and peppermint cultivars are propagated and planted by vegetative methods that can cause disease problems. Pathogens that are already present in plant material will persist and be passed on in new cuttings and/or roots. The cut surfaces of stems, roots and stolons also provide open wounds for infection. Industry and state programs, therefore, have been devised to provide certified planting material to mint growers. A system in which these materials are tested and inspected several times each growing season ensures that the certified planting material is free of any diseases or other harmful pests. Although planting certified material is an added input cost, it results in lower pesticide use, increased mint yield, and a longer life of the mint field.

Mint is planted in rows and can be harvested the first season, but at a lower yield than subsequent years. By the second growing season, the plants are allowed to spread out to create a solid mat. However, in areas where furrow irrigation is used, rows and furrows must be maintained annually. A typical mint stand will stay in production for about three to five years. It is often rotated with other crops, with the field returning to mint after three or more years.

Mint is a perennial crop and the rotation of mint with other crops aids in the control of nematodes, diseases and weeds prior to planting. After the rotational crop is removed, the ground is prepared for planting by plowing and disking, which also removes annual weeds that may be present. Pre-plant soil fumigation is sometimes used (in nurseries) and helps control nematodes, diseases (Verticillium wilt) and weeds. Site selection is often utilized by growers when planting mint to avoid fields that have high populations of debilitating pests. Irrigation method (furrow vs. sprinkler) will impact subsequent pest management practices. Irrigation can also impact pesticide efficacy.

Worker Activities:
Cultivation
Seedbed preparation
Digging rootstock
Fumigation
Scouting
Soil sampling (for fertility, chemistry, soil arthropods)
Fertilizing/liming
Insecticide applications
Irrigation
Planting activity
Herbicide applications

INSECTS

Soil-dwelling insects, such as wireworms, root weevil larvae, and symphylans, may be found in the soil prior to planting. Symphylans generally do not affect plant vigor but wireworms can be devastating and cause poor stand establishment in newly planted mint. Wireworms can be a problem in rooted tip cutting nurseries.

Wireworms

Cultural control - None
Biological control - None
Chemical control - Fumigation with Vapam (sodium methyldithiocarbamate) or Telone II (dichloropropene) but not for this pest alone, due to economics

Symphylans

Cultural control - None
Biological control - None
Chemical control - Mocap (ethoprop): Sec. 18 only in Oregon's Willamette Valley
- Lorsban (chlorpyrifos): registered but the label claims suppression only

Root weevil

Cultural control - None
Biological control - None
Chemical control - None

Scarab grubs

An occasional, rare pest: no control measures used

CRITICAL NEEDS FOR MANAGEMENT OF INSECTS IN MINT (Pre-plant through Planting)

Research:

- Develop economic threshold or action level for wireworms in field nurseries established from rooted tip cuttings

Regulatory:

- Obtain full registration for Mocap (ethoprop) in all growing regions
- Maintain availability of Vapam (sodium methyldithiocarbamate) for fumigation in nurseries

Education:

- Educate growers about the benefits of using certified root stock
- Emphasize the need for pre-plant soil sampling

DISEASES

Verticillium wilt is a major impediment to long-term mint production in most areas that currently produce mint. After a field is contaminated with wilt, microsclerotia can remain in the soil for long periods of time and infect future mint plantings. It is estimated that more than 50% of all PNW mint fields are infected with wilt. The soil fumigants, Telone C-17 (dichloropropene + chloropicrin) and Vapam (sodium methyldithio-carbamate), are expensive but provide temporary suppression of Verticillium wilt. Wilt-resistant cultivars have been developed but are moderately resistant to the disease, not immune to it, and yield less than standard cultivars that have not been infected with wilt. Planting certified clean rootstock reduces the risk of introducing and spreading Verticillium wilt through planting material. Plant rotation to a non-Verticillium host may help reduce the effects of Verticillium wilt on mint in a particular field. Growers use crop rotation effectively to prevent buildup of Verticillium wilt.

Verticillium Wilt

Cultural control - Certified rootstock
- Cultivar selection
- Site selection

Biological control - None

Chemical control - Fumigation: use of Telone C-17 (dichloropropene + chloropicrin) or Vapam (sodium methyldithiocarbamate) reduces population which offers up to two years of acceptable results but this approach is not widely practiced because it is not cost effective

CRITICAL NEEDS FOR MANAGEMENT OF DISEASES IN MINT
(Pre-plant through Planting)

Research:

- Develop a disease resistant mint cultivar
- Identify and quantify economically viable rotational crops that will reduce Verticillium populations
- Conduct long-term, large-scale, rotational studies
- Investigate economics and efficacy of fumigation when mint is a secondary target (i.e. fumigation of onions, sugarbeets)
- Investigate use of antagonistic fungi for disease control
- Develop preplant rootstock and rooted-tip fungicide treatment to control soil diseases
- Develop a reliable, time efficient, in-field Verticillium wilt assay method

Regulatory:

- Maintain registrations of current fumigants

Education:

- Continue to stress importance of disease-free planting material, and using clean ground
- Educate growers about using proper crop rotations

- Disseminate research results
- Educate growers on cultivar selections

WEEDS

Mint is a perennial crop that is seldom cultivated after planting and has few registered herbicides for perennial weed control. As a result, effective weed management prior to planting and in the preceding crops, especially hard-to-control perennial weeds, is important. Postemergence herbicides such as Roundup (glyphosate) or Stinger (clopyralid) are sometimes applied to perennial weed patches that may be present prior to planting mint. Soil fumigation primarily done for nematode or disease problems, can also provide about 50% reduction in weed pressure depending on weed species present in the seed bank. Plowing and disking in preparation for a new planting kills many annual weeds that have emerged. Irrigation to promote an early flush of weeds followed by tillage or a non selective herbicide such as Gramoxone (paraquat) or Roundup (glyphosate), can reduce weed pressure prior to planting mint. Mint rootstock dug from areas with hard to control perennial weeds (yellow nutsedge, field bindweed, Bermuda grass) or from areas with annual weeds that haven't been introduced in the area to be planted should not be used. Herbicides Treflan (trifluralin) or Sinbar (terbacil) are sometimes applied prior to planting mint, but are often applied soon after planting, but preemergence to weeds. Common perennial weeds infesting mint include Canada thistle, field bindweed, yellow nutsedge, Burmudagrass, and quackgrass. Many annual weeds infest mint and weed spectrum varies by growing region. Some common annual weeds present in mint in most growing regions are mustard sp., common lambsquarters, pigweed sp., kochia, Russian thistle, common groundsel, prickly lettuce, marestail, nightshade sp., barnyard grass, green foxtail, yellow foxtail, bluegrass, downy brome, and crabgrass. Western salsify, a biennial weed, also is common in mint.

Weeds

Cultural control - Pre-irrigation and tillage is used prior to planting to reduce overall weed pressure because it kills the first flush of weeds, but it is not a stand-alone method. Chiseling soil in the fall dries out the soil, which aids in the suppression of perennial weeds. Plant weed-free rootstock.

Biological control - None

Chemical control - Treflan (trifluralin), Sinbar (terbacil), Roundup (glyphosate), and Gramoxone (paraquat)
- Fumigation, such as Vapam (sodium methyldithiocarbamate), for nutsedge
- Prowl (pendimethalin): Sec. 18's in WA, OR, ID only

CRITICAL NEEDS FOR MANAGEMENT OF WEEDS IN MINT
(Pre-plant through Planting)

Research:

- Develop a new pesticide for nutsedge control
- Investigate pre-plant efficacy of currently registered herbicides

Regulatory:

- Maintain fumigant registrations
- Obtain Section 3 registration for Prowl (pendimethalin)

Education:

- Educate registrants on importance of discontinued products and encourage continued manufacturing
- Educate growers on herbicide resistance management
- Educate growers on benefits and need for crop rotation and site selection to avoid any perennial weeds

NEMATODES

Plant parasitic nematodes are a serious problem facing mint growers in the western U.S.A. Several nematode species, including the mint (needle) nematode (*Longidorus elongates*), the root-knot nematode (*Meloidogyne hapla*), and the root-lesion nematode (*Pratylenchus penetrans*), are capable of causing severe economic damage. Of these three species, *Pratylenchus penetrans* is probably the most important. Not only can this species reduce mint yields by up to 73%, but in the presence of other stress factors such as severe winters, damage can be even more severe. For example, root-lesion nematodes can interact with the soil pathogen, *Verticillium dahliae*, reducing peppermint yields by 40% more than by nematodes alone. The mint (needle) nematode, although not widespread, can cause devastating damage on sandy soils in the Willamette Valley of western Oregon.

Managing damaging populations of nematodes in mint is difficult. Presently, the tools available to the mint industry include pre-plant fumigation, Vydate (oxamyl) nematicide, and crop rotation. Pre-plant fumigation is very expensive and crop rotation has limited effectiveness against the root-lesion nematode because of this species' wide host range. Vydate (oxamyl) has demonstrated inconsistent efficacy across a wide range of studies.

The mint industry has supported research into a number of other nematode control alternatives including pre-plant green manures and biological control. None of these alternatives proved to be practical solutions for nematode control.

Nematodes

Cultural control - Crop rotation (Avoid crops that are known hosts to nematodes: e.g. small grains are commonly a host for *P. penetrans*, which is commonly found in fields of small grains.)
- Plant certified vigorous roots

Biological control - Entomopathogenic nematodes: tested but not economically feasible
- Green manures: tested but not efficacious

Chemical control - Vydate (oxamyl): inconsistent results
- Fumigants: Vapam (sodium methyldithiocarbamate) and Telone II (dichloropropene) both work well; Nemasol-42 (sodium tetrathiocarbonate) is registered but efficacy is unknown

CRITICAL NEEDS FOR MANAGEMENT OF NEMATODES IN MINT
(Pre-plant through Planting)

Research:

- Develop alternative products that are effective on nematodes
- Investigate bio-types and biology of nematodes

Regulatory:

- Obtain registration of Mocap (ethoprop)

Education:

- None

II. VEGETATIVE GROWTH

This stage of the mint production cycle covers the period between emergence from dormancy in the spring and harvest of the mint crop. In most established or newly planted fields, mint emerges in early spring (April/early May) and grows vigorously. It is during this period of active vegetative growth that many insects, mites, diseases and weeds need to be controlled. At this time, fields continue to be scouted for pests, irrigation continues, fertilizers are applied, and pest control measures are implemented, when needed. Hand hoeing is sometimes needed in field where weeds have escaped other control measures.

Propane flaming may be used to control mint rust, spider mites and small weeds in the Willamette Valley of Oregon. In other areas, flaming has not been successful and related costs are higher. Tillage used to re-corrugate furrow irrigated beds can improve soil aeration, pH uniformity and soil nutrient distribution, and control some small weed seedlings, but is not commonly practiced due to the threat of spreading Verticillium wilt. Fertilizer is applied at this time and irrigation is usually initiated. Sampling and monitoring for insects, mites, diseases and weeds begin at the time of spring regrowth and continues throughout the growing season.

Spearmint is harvested when the plants are in full bloom while peppermint is harvested at 10% bloom. Delayed harvest past optimum maturity will cause a rapid deterioration of mint oil quality and yield. The mint hay is allowed to partially dry after the mint is cut and windrowed. It is then chopped and blown into tubs and hauled to the on-farm mint distillery. Most spearmint (especially Native spearmint) and some peppermint acreage is harvested twice, depending on the production region and the needs of mint oil processors. Single harvest of peppermint usually occurs in late July and early August while in a field that is double cut, the first harvest will first occur in late June with the second harvest sometime in September. The mint field continues to be irrigated and fertilized between cuts to encourage vigorous re-growth.

Worker Activities:
Hand hoeing
Fertilizer applications

Moving irrigation pipe
Pesticide applications
Scouting
Spot treatments of herbicides
Check maturity of crop for harvest

INSECTS AND OTHER ARTHROPODS
(Vegetative Growth)

Several species of cutworms, such as the armyworm, redback cutworm, variegated cutworm and spotted cutworm, begin feeding on foliage and rhizomes in early spring and can cause severe damage to, and sometimes death of, mint plants. They are nocturnal feeders and spend the day near or beneath the soil surface. Scouting and sampling determines the need for control. As the growing season progresses the cutworms that were active during early spring regrowth continue to cause damage, as well as other species of cutworms and armyworms. The second generation of the cabbage looper and the alfalfa looper occurs during early summer and can cause serious damage. Cutworm and looper feeding can significantly reduce yield. Orthene (acephate) is the most widely used control; Bt (*Bacillus thuringiensis*) is generally ineffective against the foliar-feeding cutworms. Confirm (tebufenozide) tends to be more effective against young lepidoptera larvae. Metasystox-R (oxydemeton-methyl) is not widely used. Cutworm, and especially looper, populations are kept in check through the activity of a naturally occurring parasitic wasp.

Adult root weevils emerge from the soil in late April through June, but they are relatively long-lived and persist in the field through harvest. Adult feeding causes leaf notching, which is an indication that root weevils are present; they are active at night and it is at this time that sampling with a sweep net is most effective. Because most eggs are laid from mid-summer through fall, insecticide treatment of adults can be effective if applications are made before egg laying begins. Orthene (acephate) or malathion may be used, but they are most effective if applied at night when the weevils are active. Control of adults prior to egg laying is meant to limit infestation of root weevil larvae, which cause the greatest damage to mint. There is no effective or labeled insecticide control of larvae. Parasitic nematodes can be very effective in controlling root weevil larvae, especially if applied when larvae are small. However, these parasitic nematodes are very costly and not currently available in sufficient quantities for effective control.

The two-spotted spider mite is an arthropod that is widespread in most mint production areas and can cause serious economic damage. They are multigenerational and populations can increase rapidly during periods of warm temperatures; water-stressed fields are particularly susceptible to damage by mites. The adult spider mite over winters in soil cracks beneath dead plant material. Eggs are laid on the underside of leaves and hatch within 4 to 5 days; depending on temperatures, the life cycle can be completed in another 14 to 16 days. Injury appears as small silvery or dry spots on the upper leaf surface; severely damaged leaves eventually turn brown and drop from the plant. Natural predators often keep mite populations under control; controlled releases of predator mites can augment native predators. Comite (propargite), Kelthane (dicofol) and Onager

(hexythiozox) are registered miticides. Comite (propargite) is widely used when populations warrant chemical control; it is effective and not disruptive to natural predators and one application usually is all that is needed. Kelthane (dicofol) is disruptive to natural predators. Onager (hexythiozox) controls only the mite eggs. Fields that were flamed in fall or early spring tend to have reduced spider mite populations in summer.

Grasshoppers can be occasional pests in hot, dry regions, especially if the mint field is located adjacent to grasslands. Large nymphs and adults feed on mint leaves, causing ragged-edged holes on leaf margins, or they may consume the whole leaf. Sweep net sampling for cutworms and loopers will also indicate presence of grasshoppers. Grasshoppers are easiest to control when they are immature and before they have wings. They are usually controlled at the same time that treatments of Orthene (acephate), Lannate (methomyl), or malathion are applied for control of cutworms, loopers, and adult root weevils.

Aphids are a minor pest problem in most PNW mint growing regions but they can, however, be a serious pest in Idaho, especially during periods of high temperatures. Aphids can weaken the plant by sucking plant fluids, which cause wilting and water stress. Stressed plants are more susceptible to injury from other insect and mite pests. If left uncontrolled, yield losses could reach 30%, along with a decrease in oil quality. Orthene (acephate) is the most preferred chemical treatment for control; Lorsban (chlorpyrifos) and Metasystox-R (oxydemeton-methyl) are also used.

The mint flea beetle is a minor pest but the larval stage can seriously weaken plants by feeding in the roots and rhizomes in early spring. Parasitic nematodes can be applied in early spring after temperatures have warmed and larvae are active. However, control measures are generally directed at the adult beetle, which appears in early summer, before egg-laying begins. Malathion or Lannate (methomyl) are commonly used to control the adult beetle at this time.

The mint stem borer is a minor pest found in eastern Oregon and southwestern Idaho. The larvae appear in summer and feed on the tissue within the mint plant stem and may also burrow into the rhizomes, causing weak plants, wilting and lodging. There are no insecticides registered to control the mint stem borer at any stage; if there were, they would probably be ineffective against the larvae as they feed within the pith of stems and rhizomes. The adult is targeted for indirect control during spring growth when pesticides applied for cutworm and looper control may temporarily reduce the mint stem borer population. However, adults emerge over a long period during the summer and populations usually rebound quickly.

Aphids

Cultural control - None
Biological control - None
Chemical control - Orthene (acephate): very effective
- Malathion: effective

- Metasystox-R (oxydemeton-methyl) is labeled, but not used very much

Note: All OP's are non-selective and disruptive to beneficials; with proper timing these issues can be mitigated.

Cutworms (foliar complex)

Cultural control - None
Biological control - None
Chemical control - Bt: doesn't work well, due to poor coverage and incorrect timing. Difficult to get an accurate count of cutworms at the small larval growth stage when Bt is most effective.
- Confirm (tebufenozide): very effective, less expensive, use 8 oz. rate, aerially applied, reduced-risk, short REI (4 hours)
- Orthene (acephate) and Lannate (methomyl): Lannate is more effective when cutworms are small; Orthene is effective when cutworms are large.
- Metasystox-R (oxydemeton-methyl); labeled, but not used very much

Cutworm (soil complex)

Cultural control - None
Biological control - None
Chemical control - Orthene (acephate) or Lorsban (chlorpyrifos): both are very effective. Orthene results, however, are inconsistent in cool weather.

Flea beetles (An occasional pest in some regions; treatment is not needed every year)

Cultural control - None
Biological control - None
Chemical control - Malathion and Lannate (methomyl): controls adults only

Grasshoppers

Cultural control - None
Biological control - None
Chemical control - Malathion and Orthene (acephate): both are effective and inexpensive but non-selective

Mint Root Borer (This pest is controlled in the fall after harvest.)

Mint Stem Borer (Only a sporadic pest in Idaho and eastern Oregon)

Cultural control - None
Biological control - None
Chemical control - No registered pesticides

Root Weevil complex (adults)

Cultural control - None

Biological control - None

Chemical control - Orthene (acephate): Applied when adults are active at night, before egg- laying. Application is timed to control adults as they emerge from the soil but before egg-laying begins; therefore, multiple applications are necessary. Monitoring and identification are critical; some over-wintering females emerge "egg ready"

Spider Mites

Cultural control - Double flaming (established mint in Oregon's Willamette Valley)
- Early cutting, but can cause lower quality and yield
- Maintain adequate field moisture
- Proper selection of pesticides used to control other pests to avoid mite outbreaks
- Dust control

Biological control - Augmentation of predator mite populations (success difficult to predict due to inconsistent results). When considering the inconsistent results and the low cost of miticides, it is difficult to recognize benefits with use of predator mites.

Chemical control - Comite (propargite)
- Kelthane (dicofol) has short REI
- Metasystox-R (oxydemeton-methyl)
- Onager (hexythiozox) tank mixed with Comite (propargite); Onager is very effective against mite eggs but not adults; however, Onager will cause female mites to lay infertile eggs.

Occasional pests that occur during the vegetative growth stage:

Crane fly, western spotted cucumber beetle, slugs, scarab beetles, thrips

CRITICAL NEEDS FOR MANAGEMENT OF INSECTS AND OTHER ARTHROPODS IN MINT (Vegetative Growth)

Research:

- Investigate effectiveness of Confirm (tebufenozide) for control of Lepidopteran insects
- Investigate control measures for mint stem borer
- Develop additional selective insecticides
- Investigate pest interactions and their impact on pest populations
- Determine the impact of synthetic chemicals on natural predators
- Investigate the use of mint root borer sex pheromone for mating disruption

Regulatory:

- Expedite registration for Success (spinosad), Actara/Platium (thiamethoxam), Acramite (bifenazate), and Fujimite (fenpyroximate)
- Retain seven day REI for Comite (propargite)
- Obtain registration for Acramite (bifenazate), which is needed for the mint tea market, due to EU restrictions on Comite (propargite)

Education:

- Educate growers about the impacts of non-selective synthetic pesticides on natural predators
- Educate regulators on externally imposed restrictions and limitations related to currently registered pesticides when justifying registrations for new pesticides (Sec. 18's and SLN's)
- Educate regulators regarding resistance concerns when they are evaluating new registrations

DISEASES (Vegetative Growth)

In all regions of the Pacific Northwest, spearmint can be severely damaged by mint rust; infected stands can suffer as much as a 70% yield loss. Peppermint is susceptible but generally not affected except in the moist areas of western Oregon and Washington. The pathogen overwinters on mint stubble, and on wild and escaped mint plants, and can be systemic in the plant. It is easily spread over long distances by wind and, also, by rootstock that is dug from infested fields. Flaming with propane in early spring is used for rust control in the Willamette Valley of Oregon, although flaming damages Scotch spearmint. Bravo (chlorothanonil), Rally (myclobutanil), Tilt (propiconazole) and Quadris (azoxystrobin) are commonly applied during the spring and early summer.

Powdery mildew is seldom a problem on peppermint but can be very destructive on Scotch spearmint. Mildew develops rapidly and extensively during prolonged periods of warm, humid, and cloudy weather and with dense mint foliage. Damage by mildew is most serious during the month prior to harvest because it is the leaves that develop at this time that are harvested for oil. High levels of mildew infection earlier in the vegetative growth period can affect mint growth and development. Wettable or flowable sulfur can be used when plants are 5 to 6 inches tall or when the fungus first appears, although there is a risk of increased concentration of sulfides in the mint oil if applied closer than 30 days prior to harvest; sulfur applications are limited to early season. JMS Stylet Oil and Kaligreen (potassium bicarbonate) can be applied closer to harvest although there are limitations with each and effectiveness is marginal. Rally (myclobutanil) is effective but cannot be used within 30 days of harvest.

Stolon decay is caused by *Fusarium solani* and stolon canker is caused by *Rhizoctonia solani*; both fungi live in the soil. Symptoms of both diseases include brown or black rotting areas on roots, stems, rhizomes and stolons and plant vigor is reduced.

Spotted wilt is a disease caused by Impatiens necrotic-spot virus (INSV) or Tomato spotted wilt virus (TSWV). These viruses can hurt first year mint but seem to be self eliminating thereafter.

Mint rust

Cultural control - Flaming (in Oregon's Willamette Valley)
- Double cutting (harvest) to control rust is occasionally used as a management technique in the Willamette Valley

Biological control - None

Chemical control - Rally (myclobutanil): 30 days PHI, effective but expensive
- Bravo (chlorothalonil): 80 days PHI, not effective
- Tilt (propiconazole): use only allowed west of the Cascade Mountains in OR and WA; 90 days PHI; very effective
- Quadris (azoxystrobin): 7 days PHI, very effective

Powdery mildew

Cultural control - Manage plant stress

Biological control - None

Chemical control - Sulfur products: however, sulfides can harm oil quality if used within 30 days of harvest
- Rally (myclobutanil) and Quadris (azoxystrobin) effective

Stolon decay and stolon canker

Cultural control - Healthy, well-managed mint is important to disease prevention.

Biological control - None

Chemical control - No registered fungicides

Black stem rot and White mold

These are diseases that occasionally occur during the vegetative growth stage, especially when the mint is too wet.

Cultural control - Proper irrigation management

Biological control - None

Chemical control - None

CRITICAL NEEDS FOR MANAGEMENT OF DISEASES IN MINT (Vegetative Growth)

Research:

- Investigate the relationship of plant stress or vigor to disease occurrence and severity through interdisciplinary and long term studies.
- Investigate the alternative host for powdery mildew on mint; identify species and strain of powdery mildew that affects mint
- Investigate mint cultivars for disease resistance
- Evaluate new fungicides for resistance management
- Evaluate efficacy of Bravo (chlorothanonil)

Regulatory:

- Reduce PHI to 30 days for Tilt (propiconazole); currently 90 days
- Expand Tilt (propiconazole) label to include all mint growing areas of the PNW (currently registered only west of the Cascade Mountains in OR and WA)
- Obtain registration for spot treatment fumigation with Vapam (sodium methyldithiocarbamate) for Verticillium wilt

Education:

- Educate growers about sequential applications of Quadris (azoxystrobin) and Tilt (propiconazole) to avoid resistance
- Educate registrant about need for spot treatment fumigation for Verticillium wilt

WEEDS (Vegetative Growth)

As mint emerges, so do many annual and perennial weeds. Weeds compete with mint for water, nutrients, and sunlight and when present, reduce mint stand, and hay and oil yield. Shallow cultivation with a tine harrow or power harrow can kill small annual weeds if performed early in the spring, but is not commonly practiced, because it can result in spread of Verticillium wilt, can injure emerging mint, and can promote new weed flushes. Some rill or furrow irrigated fields may need ditches reformed early in the spring, which destroys some emerged weeds. Postemergence herbicides are often applied to weeds that have escaped preemergence herbicide treatments or cultivation. Basagran (bentazon), Buctril (bromoxynil), Tough (pyridate), and Sinbar (terbacil) are used for postemergence annual broadleaf weed control in mint.

Buctril (bromoxynil), and Buctril (bromoxynil) plus Sinbar (terbacil) tank mixes, result in some temporary injury to mint especially when mint is stressed. Postemergence broadleaf herbicides are most effective when applied to small annual broadleaf weeds. Multiple applications of Basagran (bentazon) may be used to suppress perennial broadleaf weeds, such as yellow nutsedge and Canada thistle, but are costly. Stinger (clopyralid) is most commonly used to control Canada thistle, but sometimes used to control other composite weeds (prickly lettuce, groundsel, salsify, dandelion). Assure II (quizalofop-ethyl), Poast (sethoxydim), and Select (clethodim) are applied postemergence to control annual and perennial grass weeds. Some hand weeding is performed in early spring to remove weeds that have escaped other control measures. In itself, hand weeding is not an economical weed control practice. No herbicides or control practices are available for field bindweed except spot treatment with Roundup (glyphosate), which also kills the mint plant. Weed control prior to harvest is critical, as any weeds that are harvested and distilled with the mint can impart an off flavor and color to the oil.

Weeds

Cultural control - A healthy stand of mint competes well with weeds and withstands herbicide applications
- Hoeing

- Proper fertilization and irrigation practices

Biological control - None

Chemical control -

Annual grass weeds:

-- Poast (sethoxydim), Assure II (quizalofop-ethyl), Select (clethodim), Sinbar (terbacil)

Annual broadleaf weeds:

-- Buctril (bromoxynil), Basagran (bentazon), Tough (pyridate), Stinger (clopyralid), Sinbar (terbacil)

Perennial grass weeds:

-- Poast (sethoxydim), Assure II (quizalofop-ethyl), Select (clethodim), Sinbar (terbacil)

Perennial broadleaf weeds:

-- Stinger (clopyralid), Roundup (glyphosate) via ropewick and spot spray

CRITICAL NEEDS FOR MANAGEMENT OF WEEDS IN MINT (Vegetative Growth)

Research:

- Develop and evaluate an herbicide for control of field bindweed
- Investigate affect of herbicide on beneficial organisms
- Investigate interaction of herbicides with diseases (plant stress)
- Investigate herbicide-resistant weed management
- Determine efficacy of herbicide chemigation
- Determine efficacy of tank mixes and tank additives
- Develop alternative to Tough (pyridate) for postemergence control of pigweed
- Investigate bio-control of perennial weeds

Regulatory:

- Support registration of MCPB for field bindweed suppression

Education:

- Educate growers about risk of moving new weeds into new areas

NEMATODES (Vegetative Growth)

Nematode feeding can cause weakened plants with short, weak root systems; damage will appear in patches throughout a field. The root-lesion nematode is the most serious of the many nematodes found in mint as they interact with *Verticillium dahliae* to cause more severe symptoms of wilt. Nematode populations fluctuate throughout the year but are usually highest in early summer and thus, a good time to sample for population density

Nematodes

Cultural control - Keep fields vigorous and healthy

- Scouting

Biological control - None

Chemical control - Vydate (oxamyl): inconsistent results in western OR, sandier soils respond better to Vydate

CRITICAL NEEDS FOR MANAGEMENT OF NEMATODES IN MINT (VegetativeGrowth)

Research:

- Continue to screen nematicides for efficacy
- Investigate the relationship of plant stress or vigor to nematode issues through interdisciplinary and long term studies.

Regulatory:

- None

Education:

- None

III. POST-HARVEST VEGETATIVE GROWTH

In some production areas (e.g. Willamette Valley and central Oregon), fields are often flamed after harvest for suppression of *Verticillium* Wilt. Some growers apply a reduced rate (less than springtime rates) of fertilizer after harvest to encourage vegetative growth. Moisture is needed for rhizome growth after harvest and, if available, irrigation continues if weather is dry but is discontinued once weather turns cool or rainy.

Worker Activities:
Insect & weed scouting
Herbicide applications, as needed
Insecticide applications, as needed
Irrigation

INSECTS (Post-Harvest Vegetative Growth)

The mint root borer is a widespread and very serious insect pest in all mint growing regions. The adult moth usually appears in late June through early August (presence of adult moths can be determined by sweep net sampling) and lays eggs that hatch into larvae within one to two weeks. Larvae feed inside the mint rhizomes during August, September and October. Damage that results from feeding injury weakens the mint stand, which overwinters poorly and regrows slowly in the spring.

Soil and rhizome samples should be taken in late August or early September to evaluate population density and determine if treatment is needed. If samples are taken too early in August, larvae will be very small and may be overlooked; if taken in late September or early October, the larvae in the sample will have already caused damage. If soil sampling indicates that populations have reached the threshold of two to three larvae per sample, control measures can be implemented after harvest

Lorsban (chlorpyrifos) is the only insecticide labeled for control of the mint root borer and is applied after harvest. However, best control is achieved when it is chemigated with enough water to move the insecticide into the root zone for contact with larvae emerging from the plant. Application of Lorsban (chlorpyrifos) followed by sufficient irrigation is possible but provides marginal results. Control of the mint root borer with

Lorsban (chlorpyrifos) is possible only in sprinkler-irrigated mint; Lorsban (chlorpyrifos) is completely ineffective in furrow-irrigated fields. This means that there is no effective control measure for the mint root borer in furrow-irrigated mint. Tillage after harvest can significantly reduce mint root borer populations by exposing larvae to predation, desiccation, and/or freezing, although tillage can spread Verticillium wilt and is used only in fields where wilt is not a concern.

Following harvest, mint stem borer adults become very active and begin searching for energy-rich resources, such as goldenrod and rabbit brush. They move out of the mint field and feed on the pollen from these and, possibly, other high pollen producing plants which bloom in late summer to build up energy reserves for overwintering. When pollen stores decline, mint stem borers move back into the mint field where they overwinter in ground debris. This behavior presents the opportunity for developing a trap crop strategy for attracting and controlling mint stem borer adults following harvest. The adults aggregate in very large numbers on pollen sources, rendering them quite vulnerable to chemical and/or cultural control methods. Because a trap crop (e.g. goldenrod) would not be intimately involved with the mint crop, various chemicals may be available for limited applications in these situations. This strategy would require consideration of bee activity on the pollen-rich trap crop. Alternatively, the cultural strategy of carefully removing and destroying the trap crop, without disturbing the mint stem borers, may be employed.

Root weevil larvae are actively feeding on mint roots after harvest. The larvae are small at this crop stage, and would be easier to control; if effective control measures were available, they would be applied at this time.

In research studies and pilot commercial projects, entomopathogenic nematodes showed great promise for controlling many of the difficult to control soil inhabiting mint pests including mint flea beetles, mint root borers and root weevils. Although the mint industry has invested much time and effort on research to commercialize this technology, it ultimately failed to produce a cost effective and available product.

Mint root borer

Cultural control - None
Biological control - None (if nematodes were available they would be applied at this time.)
Chemical control - Lorsban (chlorpyrifos), in sprinkler irrigated fields, only (irrigation needed for incorporation). However, control can be marginal in some instances. Best control is achieved with chemigation. In furrow-irrigated fields, there are no chemical controls available.

Root weevil larvae

Cultural control - None
Biological control - None (if nematodes were available, they would be applied at this time.)
Chemical control - None

CRITICAL NEEDS FOR MANAGEMENT OF INSECTS IN MINT
(Post-Harvest Vegetative Growth)

Research:

- Develop a systemic insecticide and other alternatives to (Lorsban) chlorpyrifos for mint root borer control
- Develop a control method for mint root borer in furrow-irrigated fields
- Investigate use of trap cropping control system for mint stem borer
- Develop affordable and commercially available parasitic nematodes
- Develop new delivery agent/surfactant/mechanical devices (such as a spoke wheel injector) to push control products down into the root zone for control of mint root borer and root weevil larvae
- Develop an inoculative release program in the fall, so the predator mites are available in the early spring
- Continue to investigate symphylan control in Oregon's Willamette Valley
- Continue research to find alternative to Mocap (ethoprop)

Regulatory:

- Register granular formulation of Mocap (ethoprop) for mint root borer and symphylan control

Education:

- None

DISEASES (Post-Harvest Vegetative Growth)

Black stem rot is not widespread but can be a moderate to severe problem in certain regions. The fungus is most active during periods of cool, wet weather and appears most often in vigorously growing mint that may be over-watered. Symptoms include dark brown or black cankers on stems and rhizomes. The cankers may girdle the stem and cause plant parts above the infection to wilt and die. There are no registered fungicides to control this disease. Proper amount and frequency of irrigation can help manage this disease.

Verticillium wilt

Cultural control - Flaming, immediately after harvest, can reduce the severity of Verticillium wilt. This practice is not widely used.
Biological control - None
Chemical control - None

CRITICAL NEEDS FOR MANAGEMENT OF DISEASES IN MINT
(Post-Harvest Vegetative Growth)

Research:

- Investigate cultivar improvement for disease resistance

Regulatory:

- None

Educational:

- Continue to educate growers about equipment sanitation
- Disseminate information about new research and new disease management practices
- Educate general population on the benefits and safety margin of most agricultural chemicals.

WEEDS (Post-Harvest Vegetative Growth)

After mint harvest, a new flush of weeds often emerges as the mint begins to regrow. Any preemergence herbicides that may have been used during the dormant stage have dissipated by this time and weed emergence is often greater than during the early spring stage of growth. Postemergence herbicides may be applied again to control emerging weeds. If the mint crop double cut, herbicide applications following the first harvest target mid-summer germinating annual weeds, such as, common lambsquarters, common groundsel, redroot pigweed, and barnyardgrass. Growers must be aware of allowable preharvest intervals to ensure there is adequate time between herbicide application and the second harvest. Herbicide applications following single cut mint or following second mint harvest would likely target more fall-germinating winter annual weeds and would not have preharvest restrictions since a long dormant season would follow.

Weeds

Cultural control - None
Biological control - None
Chemical control - Postemergence herbicides like Buctril (bromoxynil), Basagran (bentazon), Tough (pyridate), Sinbar (terbacil), Stinger (clopyralid), Assure II (quizalofop-ethyl), Poast (sethoxydim), and Select (clethodim) may be applied to control emerging weeds

CRITICAL NEEDS FOR MANAGEMENT OF WEEDS IN MINT (Post-Harvest Vegetative Growth)

Research:

- Develop resistance management options
- Develop residue data to enable feeding of straw to livestock (feeding studies)

Regulatory:

- None

Education:

- Educate growers concerning label instructions for mint straw treated with Stinger (clopyralid)

NEMATODES (Post-Harvest Vegetative Growth)

The best control of the root-lesion nematode (*Pratylenchus penetrans*) occurs in the spring with an application of Vydate (oxamyl), but an application made after harvest in

the fall can also be effective. If pin nematodes (*Paratylenchus* sp.) are present, Vydate (oxamyl) provides good control when applied in the fall. High pin nematode counts are thought to affect the overwintering vigor of mint in central Oregon.

Nematodes

Cultural control - None
Biological control - None
Chemical control - Vydate (oxamyl), but usually applied in the spring for nematode control.

CRITICAL NEEDS FOR MANAGEMENT OF NEMATODES IN MINT (Post-Harvest Vegetative Growth)

Research:

- Develop alternatives to Vydate (oxamyl)
- Develop better control measures for nematodes

Regulatory:

- Support Mocap (ethoprop) registration

Education:

- None

IV. DORMANCY

Dormancy usually occurs between mid-November and late-March/early April. Most field activities cease during dormancy; however, fields are monitored for weeds and herbicides are applied, if needed. Irrigation has been discontinued by this time. .

Worker activities

Herbicide application
Clean up corrugates (furrow irrigation)
Tillage (subsoil, disc, plow) in some regions

INSECTS (Dormancy)

Populations of the mint root borer can be reduced with tillage during dormancy but tillage can spread Verticillium wilt and is used only in fields with a low incidence of wilt. Root weevil larvae can continue to feed on mint roots throughout the dormant period if weather is not too cold. Control measures for the larvae, however, occur in spring or fall; adults are treated during the summer months.

DISEASES (Dormancy)

No disease control measures are implemented during dormancy.

WEEDS (Dormancy)

Winter annual weeds and some perennial weeds continue to emerge and grow during the dormant season. Winter annual and biennial weeds common in mint include Western

salsify, downy brome, sowthistle, prickly lettuce, mustard sp., marestail, common groundsel, and chickweed. Fall strip tillage or power harrowing can remove some small weed seedlings, but is not commonly practiced due to the spread of Verticillium wilt. Buctril (bromoxynil), Tough (pyridate), Gramoxone (paraquat), Goal (oxyfluorfen), Sinbar (terbacil), and Stinger (clopyralid) may be applied postemergence to control emerged weeds in dormant mint. Roundup (glyphosate) may be used as a nonselective postemergence treatment to spot treat perennial weed patches in dormant mint.

Herbicides with pre-emergence activity are commonly applied in the fall or late winter during the dormant stage to prevent annual weed flushes after mint emerges in the spring. Herbicides applied during the dormant stage with soil residual activity include Sinbar (terbacil), Goal (oxyfluorfen), Prowl (pendimethalin) which has been allowed under Section 18 in Idaho, Washington, and east of the Cascade Mountains in Oregon, Command (clomazone), Devrinol (napropamide) which is registered for use only in Oregon, Washington, and Idaho, Treflan (trifluralin), and Karmex (diuron) which is registered for use only on peppermint in Oregon, Washington, and Idaho. Devrinol (napropamide) and Treflan (trifluralin) performance is improved when mechanically incorporated, which is seldom practiced in mint due to spread of Verticillium wilt. Command (clomazone), Prowl (pendimethalin), Karmex (diuron), and Goal (oxyflurofen) should be applied at least several weeks prior to mint emergence to reduce injury to mint. Sinbar (terbacil), due to its broad spectrum of weeds controlled and excellent mint tolerance, is the most widely used herbicide in mint production. As a result of its extensive use, Sinbar (terbacil) resistant weed biotypes have increased (pigweed, lambsquarters, kochia, common groundsel) and growers commonly rotate or tank mix with herbicides having different modes of action.

CRITICAL NEEDS FOR MANAGEMENT OF WEEDS IN MINT (Dormancy)

Research:

- Investigate timing of tank mix pre-emerge herbicides application
- Develop new pre-emergence herbicides
- Develop data on Starane (fluroxypyr)

Regulatory:

- Support registration of Valor (flumioxazin) and Spartan (sulfentrazone)

Education:

- None

REFERENCES

1. Weed Management in Mint. February 2001. Oregon State University, Extension Service Publication #EM 8774.

2. A Guide to Nematode Biology and Management in Mint. September 1996. R. Ingham and K. Merrifield. Oregon State University, IPPC Publication #996, 38p.

3. Pesticide Environmental Stewardship Strategy for the US Mint Oil Industry. November 1, 1995. M. Morris and R. Lundy. Mint Industry Research Council. 34p.

4. A Guide to Peppermint Insect and Mite Identification and Management. February 1993. R. Berry and G. Fisher. Oregon State University. Publication #182. 37p.

5. Pests, Pest Control, and Fertilizer Use in Washington Mint. A. Morrell, A. Schreiber, and R. Lundy. WSU Publication #MISC0188. 8p.

6. Using Biological Control in Mint. M. Morris and J. Takeyasu. 8p.

7. Crop Profile for Mint in Montana. May 2002.

8. Crop Profile for Mint in Idaho. July 2000.

9. Crop Profile for Mint in Oregon. 1999.

10. Insect Control Recommendations for Mint Production in Idaho. 1993. C. Barid, H. Homan, and E. Eldredge. UI Publication #CIS 773.

11. Pacific Northwest Insect Management Handbook. 2002. Extension Services of Oregon State University, Washington State University, and the University of Idaho.

12. Pacific Northwest Disease Management Handbook. 2002. Extension Services of Oregon State University, Washington State University, and the University of Idaho.

13. Pacific Northwest Weed Management Handbook. 2002. Extension Services of Oregon State University, Washington State University, and the University of Idaho.

14. Crop Production Summary, 2001. Agricultural Statistics Board, NASS, USDA. (http://usda.mannlib.cornell.edu/reports/nassr/field/pcp-bban/cropan02.pdf)

Seasonal Pest Occurrence for PNW Mint:

Western Oregon and Western Washington

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Aphids					-------	-------	-------					
Cutworms						-------	-------					
Grasshoppers							-------	-------				
Loopers							-------					
Mint root borer						-------	-------	-------	-------	-------		
Root weevils	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Spidermites				-------	-------	-------	-------	-------				
Symphylans			-------	-------	-------	-------	-------	-------	-------	-------		
DISEASES												
Black stem rot			-------	-------	-------	-------	-------	-------	-------			
Powdery mildew					-------	-------	-------	-------				
Rust				-------	-------	-------	-------	-------				
Spotted wilt			-------	-------	-------	-------	-------	-------	-------			
Stolon canker		-------	-------	-------	-------	-------	-------	-------	-------	-------		
Stolon decay		-------	-------	-------	-------	-------	-------	-------	-------	-------		
Verticillium wilt	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
WEEDS												
Annual Grasses:												
Barnyardgrass						-------	-------		-------			
Crabgrass								-------	-------	-------		
Green foxtail					-------	-------	-------					
Yellow foxtail					-------	-------	-------					
Perennial Grasses:												
Bermudagrass						-------	-------					
Quackgrass					-------	-------	-------	-------				
Annual Broadleafs:												
Common groundsel	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Common lambsquarter					-------	-------	-------					
Common mallow					-------	-------	-------	-------				
Mustards	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Nightshade sp.					-------	-------	-------					
Pigweed sp.				-------	-------	-------	-------	-------	-------			
Prickly lettuce	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Salsify	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Sowthistle	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Perennial Broadleafs:												
Canada thistle	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Dandelion	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Field bindweed				-------	-------	-------	-------	-------	-------	-------		
Yellow nutsedge					-------	-------	-------	-------				
NEMATODES												
Mint (needle) nematode			-------	-------	-------	-------	-------	-------	-------	-------		
Root-knot nematode			-------	-------	-------	-------	-------	-------	-------	-------		
Root-lesion nematode			-------	-------	-------	-------	-------	-------	-------	-------		
OTHER												
Slugs	-------	-------	-------	-------						-------	-------	-------

Seasonal Pest Occurrence in PNW Mint:

Idaho, California, Eastern Washington and Eastern Oregon

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Aphids				-------	-------	-------	-------	-------				
Cutworms		-------	-------	-------	-------	-------	-------	-------				
Grasshoppers					-------	-------	-------	-------	-------			
Loopers						-------	-------	-------				
Mint root borer							-------	-------	-------	-------		
Mint stem borer					-------	-------	-------	-------				
Root weevils	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Spidermites				-------	-------	-------	-------	-------	-------			
Wireworms				-------	-------							
DISEASES												
Powdery mildew					-------	-------						
Rust (native spearmint only)			-------	-------								
Spotted wilt			-------	-------	-------	-------	-------	-------	-------	-------		
Verticillium wilt	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
WEEDS												
Annual Grasses:												
Barnyardgrass				-------	-------	-------	-------	-------	-------			
Crabgrass					-------	-------	-------	-------	-------			
Downy brome	-------	-------	-------	-------					-------	-------	-------	-------
Green foxtail				-------	-------	-------	-------	-------	-------			
Yellow foxtail				-------	-------	-------	-------	-------	-------			
Perennial Grasses:												
Bermudagrass					-------	-------	-------	-------	-------			
Quackgrass				-------	-------	-------	-------	-------	-------	-------		
Annual Broadleafs:												
Common groundsel	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Common lambsquarter			-------	-------	-------	-------	-------	-------	-------	-------		
Common mallow	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Kochia			-------	-------	-------	-------	-------	-------	-------	-------		
Marestail	-------	-------	-------	-------	-------						-------	-------
Mustards	-------	-------	-------	-------	-------						-------	-------
Nightshade sp.					-------	-------	-------	-------	-------			
Pigweed sp.				-------	-------	-------	-------	-------	-------			
Prickly lettuce	-------	-------	-------	-------	-------					-------	-------	-------
Russian thistle			-------	-------	-------	-------	-------	-------	-------	-------		
Salsify	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Sowthistle	-------	-------	-------	-------	-------				-------	-------	-------	-------
Perennial Broadleafs:												
Canada thistle				-------	-------	-------	-------	-------	-------	-------		
Dandelion				-------	-------	-------	-------	-------	-------	-------		
Field bindweed				-------	-------	-------	-------	-------	-------	-------	-------	
Yellow nutsedge					-------	-------	-------	-------	-------			
NEMATODES												
Mint (needle) nematode	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Root-knot nematode	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Root-lesion nematode	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

Seasonal Pest Occurrence for PNW Mint: *Montana*

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Aphids				-------	-------	-------	-------	-------	-------	-------		
Cutworms			-------	-------	-------	-------	-------	-------	-------			
Grasshoppers				-------	-------	-------	-------	-------	-------			
Loopers				-------	-------	-------	-------	-------	-------			
Mint flea beetle				-------	-------	-------	-------	-------	-------			
Mint root borer	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Root weevils	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Spidermites				-------	-------	-------	-------	-------	-------	-------		
Symphylans	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Wireworms	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
DISEASES												
Powdery mildew					-------	-------	-------	-------	-------			
Rust				-------	-------	-------	-------	-------	-------	-------		
Spotted wilt				-------	-------	-------	-------	-------	-------	-------		
Verticillium wilt	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
WEEDS												
Annual Grasses:												
Annual bluegrass			-------	-------	-------	-------						
Downey brome	-------	-------	-------	-------	-------	-------	-------				-------	-------
Rattail fescue			-------	-------	-------	-------	-------	-------	-------			
Wild oats			-------	-------	-------	-------	-------	-------	-------			
Perennial Grasses:												
Quackgrass		-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	
Annual Broadleafs:												
Bedstraw	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Common groundsel			-------	-------	-------	-------	-------	-------	-------	-------	-------	
Common lambsquarter				-------	-------	-------	-------	-------				
Henbit	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mustards	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Pigweed sp.			-------	-------	-------	-------	-------	-------	-------			
Prickly lettuce			-------	-------	-------	-------	-------	-------	-------			
Prostrate knotweed			-------	-------	-------	-------	-------	-------	-------			
Wild pansy			-------	-------	-------	-------	-------	-------	-------			
Perennial Broadleafs:												
Canada thistle	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Horsetail			-------	-------	-------	-------	-------	-------	-------	-------		
Dandelion			-------	-------	-------	-------	-------	-------	-------	-------		
White cockle	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Yellow toadflax			-------	-------	-------	-------	-------	-------	-------	-------		
NEMATODES												
Mint (needle) nematode			-------	-------	-------	-------	-------	-------	-------	-------		
Root-knot nematode			-------	-------	-------	-------	-------	-------	-------	-------		
Root-lesion nematode			-------	-------	-------	-------	-------	-------	-------	-------		

Cultural and Pest Management Activities for PNW Mint:
Western Oregon and Western Washington

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fertilization				-------	-------	-------	-------					
Fungicide application				-------	-------	-------	-------					
Harvest					-------	-------	-------					
Herbicide application	-------			-------	-------	-------			-------			-------
Insecticide application			-------	-------		-------	-------		-------			
Irrigation					-------	-------	-------	-------	-------	-------		
Miticide application					-------	-------	-------					
Nematicide application			-------	-------					-------			
Plant nutrient analysis					-------	-------						
Planting				-------	-------					-------		
Scout/monitor for pests			-------	-------	-------	-------	-------	-------				
Soil fumigation									-------			
Soil prep. for planting				-------					-------			
Soil sample for pests			-------					-------				
Soil sample for nutrients								-------	-------	-------		

Cultural and Pest Management Activities for PNW Mint:
Idaho, California, Eastern Washington and Eastern Oregon

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Cultivation (first year mint)				-------	-------							
Fertilization			-------	-------	-------	-------	-------	-------	-------	-------		
Fungicide application					-------	-------						
Hand hoe				-------	-------	-------	-------					
Harvest						-------	-------	-------	-------			
Herbicide application	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Insecticide application			-------	-------	-------	-------	-------	-------	-------	-------		
Irrigation				-------	-------	-------	-------	-------	-------	-------		
Miticide application					-------	-------	-------	-------				
Nematicide application			-------	-------					-------	-------		
Plant nutrient analysis					-------	-------	-------	-------				
Planting		-------	-------	-------	-------					-------	-------	
Re-establish rows/furrows			-------	-------							-------	-------
Scout/monitor for pests			-------	-------	-------	-------	-------	-------	-------	-------		
Soil fumigation			-------	-------					-------	-------		
Soil prep		-------	-------	-------						-------	-------	
Soil sample for pests			-------	-------				-------	-------	-------		
Soil sample for nutrients		-------	-------	-------				-------	-------	-------		
Tillage (for root borer)		-------	-------							-------	-------	

Cultural and Pest Management Activities for PNW Mint: *Montana*

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fertilization				-------	-------							
Fungicide application				-------	-------							
Harvest							-------		-------			
Herbicide application				-------	-------				-------	-------		
Insecticide application				-------	-------	-------	-------	-------	-------			
Irrigation				-------	-------	-------	-------	-------	-------			
Miticide application				-------	-------	-------	-------					
Nematicide application				-------	-------				-------			
Plant nutrient analysis				-------	-------	-------	-------	-------				
Planting				-------	-------					-------	-------	
Scout/monitor for pests				-------	-------	-------	-------	-------	-------			
Soil fumigation			-------									
Soil prep. for planting				-------	-------					-------	-------	
Soil sample for pests			-------	-------	-------				-------	-------		
Soil sample for nutrients			-------	-------	-------				-------	-------		

Efficacy of Management Tools for Insects and Mites in PNW Mint

This table is a compilation of information concerning the efficacy of various compounds and practices on mint insect and mite pests. They are not an indication of registration for specific pests although we have indicated their general registration on mint. The tables do compare the relative efficacy of available and potential products for each pest thereby indicating where research and registration efforts are needed.

Management Tools	Aph	C/L	GH	MFB	MRB	MSB	RW	SM	Sym	WW	Comments
Registered Materials:											
Acephate (Orthene)	E	E	E	NU	NU	G	G-P	NU	NU	NU	Adult RW only; species dependent; night application only.
Chlorpyrifos (Lorsban)	NU	E	NU	NU	E-P	NU	NU	NU	F-P	NU	MRB efficacy depends on irrigation
Dicofol (Kelthane)	NU	NU	NU	NU	NU	NU	NU	E	NU	NU	Miticide
Hexythiozox (Onager)	NU	NU	NU	NU	NU	NU	NU	E	NU	NU	Ovacide only; won't get mite control later in the season as more eggs are laid.
Malathion	G	NU	G-E	E	NU	NU	NU	NU	NU	NU	MFB adults only
Methomyl (Lannate)	NU	G	NU	G	NU	NU	NU	NU	NU	NU	MFB adults only
Oxydemeton-methyl (MSR)	G	NU	NU	NU	NU	NU	NU	NU	NU	NU	
Potassium salts of fatty acids (M-Pede)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	
Propargite (Comite)	NU	NU	NU	NU	NU	NU	NU	E	NU	NU	Miticide
Tebufenozide (Confirm)	NU	E and ?	NU	NU	NU	NU	NU	NU	NU	NU	E for foliar cutworms and loopers; ? for soil cutworms
Dichloropropene (Telone II)	NU	NU	NU	NU	NU	NU	NU	NU	F	?	Rarely used for symphs
Sodium methyldithiocarbamate (Vapam)	NU	NU	NU	NU	NU	NU	NU	NU	?	?	
New Chemistries/IR-4:											
Beauveria bassiana (Mycotrol)	?	?	?	?	?	?	?	?	?	?	
Bifenazate (Acramite)	NU	NU	NU	NU	NU	NU	NU	E	NU	NU	
Cryolite Bait	NU	NU	NU	NU	NU	NU	G-P	NU	NU	NU	SRW not labeled. Registration pending
Cyhexatin (Plictran)	NU	NU	NU	NU	NU	NU	NU	E-G	NU	NU	

Rating System

E = excellent (90-100% control)
G = good (80-90% control)
F = fair (70-80% control)
P = poor (<70% control)
? = efficacy unknown; more research needed
NU = not used for this pest
* = used but not a stand-alone product

Insects/Mites

Aph. = Aphids (*Ovatus cratagarius* and other species in the Aphidae family.
C/L = Cutworms and Loopers (Family: Noctuidae)
GH = Grasshoppers (*Melonopus* spp.)
MFB = Mint flea beetle (*Longitarsus ferrugineus*)
MRB = Mint root borer (*Fumibotys famalis*)
MSB = Mint stem borer (*Pseudobaris nigrina*)
RW = Root weevils (*Otiorhychus* spp.)
SM = Spidermites (Family: Tetranychidae)
Sym. = Symphlans (*Scutigerella immaculate*)
WW = Wireworms (*Ctenicera* sp. and *Limonus* sp.)

Efficacy of Management Tools for Insects and Mites in PNW Mint, continued.

Management Tools	Aph	C/L	GH	MFB	MRB	MSB	RW	SM	Sym	WW	Comments
Ethoprop (Mocap)	NU	NU	NU	NU	G	NU	NU	NU	G	NU	Section 18 in Western OR only. Registration pending
Fenpyroximate (Sequel)	NU	NU	NU	NU	NU	NU	NU	?	NU	NU	
Methoxyfenozide (Intrepid)	NU	E	NU	NU	P	NU	NU	NU	NU	NU	E for foliar cutworms; not used for soil cutworms
Pyridaben (Pyramite, Sanmite)	NU	NU	NU	NU	NU	NU	NU	?	NU	NU	
Spinosad (Success)	NU	G-F	E-F	NU	P	NU	NU	NU	NU	NU	Ratings for foliar cutworms only. Registration pending
Thiamethoxam (Actara, Platium)	E	NU	G	?	P	NU	G-F	NU	NU	NU	Need maximum rate. Adult RW. Registration pending.
Cultural/Non-Chemical:											
Baited traps	NU	?	?	?	?	?	?	NU	NU	?	
Crop rotation	G	?	?	?	G	G	G	G	?	G-P	
Flaming	NU	NU	NU	NU	NU	NU	NU	E	NU	NU	
Pheromone confusion	?	?	?	?	?	?	?	?	?	?	
Resistant varieties	?	?	?	?	?	?	?	?	?	?	
Sanitation	NU	NU	NU	F	F	F	F	NU	NU	NU	Important for keeping out new pests.
Biological:											
Bacilliust thuringiensis (Bt)	NU	P	NU	NU	NU	NU	NU	NU	NU	NU	For larval stage of Lep insects only
Beneficial mites	NU	NU	NU	NU	NU	NU	NU	E-P	NU	NU	Used for mite control.
Beneficial arthropods	E	E	P	?	*	?	*	?	*	*	Conserve natural population of beneficial arthropods. E for loopers only.
Beneficial nematodes	NU	E	NU	E	E	?	E	NU	NU	?	E for soil cutworms only. Nematodes not commercially available.

Rating System

E = excellent (90-100% control)
G = good (80-90% control)
F = fair (70-80% control)
P = poor (<70% control)
? = efficacy unknown; more research needed
NU = not used for this pest
* = used but not a stand-alone product

Insects/Mites

Aph. = Aphids (*Ovatus cratagarius* and other species in the Aphidae family.
C/L = Cutworms and Loopers (Family: Noctuidae)
GH = Grasshoppers (*Melonopus* spp.)
MFB = Mint flea beetle (*Longitarsus ferrugineus*)
MRB = Mint root borer (*Fumibotys famalis*)
MSB = Mint stem borer (*Pseudobaris nigrina*)
RW = Root weevils (*Otiorhychus* spp.)
SM = Spidermites (Family: Tetranychidae)
Sym. = Symphlans (*Scutigerella immaculate*)
WW = Wireworms (*Ctenicera* sp. and *Limonus* sp.)

Efficacy of Management Tools for Diseases in PNW Mint

This table is a compilation of information concerning the efficacy of various compounds and practices on mint diseases. They are not an indication of registration for specific pests although we have indicated their general registration on mint. The tables do compare the relative efficacy of available and potential products for each pest, thereby indicating where research and registration efforts are needed.

Management Tools	BSR	PM	Rust	SW	SC	SD	VW	Comments
Registered Materials:								
Azoxystrobin (Quadris)	NU	E	E	NU	NU-?	NU-?	NU	
Chlorothalonil (Bravo)	NU	*	F	NU	NU-?	NU-?	NU	
Myclobutanil (Rally)	NU	E	G-E	NU	NU-?	NU-?	NU	
Oils	NU	NU	NU	NU	NU-?	NU-?	NU	
Propiconazole (Orbit/Tilt)	NU	E	G	NU	NU-?	NU-?	NU	
Sulfur	NU	F-G	NU	NU	NU-?	NU-?	NU	
Potassium Bicarbonate (Kaligreen)	NU	P-F	NU	NU	NU-?	NU-?	NU	
New Chemistries/IR-4:								
Cyprodinil+Fludioxonil (Switch)	?	?	?	NU	NU-?	NU-?	NU-?	
Prohexadim calcium (Apogee)	?	?	?	NU	NU-?	NU-?	NU-?	
Cultural/Non-Chemical:								
Crop rotation	?	NU	NU	NU	NU-?	NU-?	P	
Flaming	?	NU	G	NU	NU-?	NU-?	F-G	Flaming suppresses buildup of inoculum entering soil
Insect control	?	NU	NU	?	NU-?	NU-?	NU	
Irrigation management	?	NU	See Comment	NU	NU-?	NU-?	NU	Integrate irrigation practices with fungicides; avoid over irrigation
Nematode control	?	NU	NU	NU	NU-?	NU-?	F	
Tillage	?	NU	NU	NU	NU-?	NU-?	F	Tillage increases spread of wilt. Reduced tillage reduces rate of wilt increase over life of stand
Weed control	?	NU	NU	NU	NU-?	NU-?	NU	
Biological:								
None								

Rating System
E = excellent (90-100% control)
G = good (80-90% control)
G = good (80-90% control)
F = fair (70-80% control)
P = poor (<70% control)
? = efficacy unknown; more research needed
NU = not used for this pest
* = used but not a stand-alone product

Disease
BSR = Black stem rot
PM = Powdery mildew
R = Rust
SW = Spotted wilt

SC = Stolon canker
SD = Stolon decay
VW = Verticillium wilt

Causal Organism
Phoma strasseri
Erysiphe cichoracearum
Puccinia menthae
Impatiens necrotic-spot virus (INSV)
Tomato spotted wilt virus (TSWV)
Rhizoctonia solani
Fusarium solani
Verticillium dahliae

Efficacy of Management Tools for Weeds in PNW Mint						
This table is a compilation of information concerning the efficacy of various compounds and practices on mint weed pests. They are not an indication of registration for specific pests although we have indicated their general registration on mints. The tables do compare the relative efficacy of available and potential products for each pest thereby indicating where research and registration efforts are needed.						
Management Tools	**Type**	**Annual Grasses**	**Perennial Grasses**	**Annual Broadleaves**	**Perennial Broadleaves**	**Comments**
Registered Materials:						
Bentazon (Basagran)	Post	NU	NU	G-E	F	Poor in cool temperatures; costly; weeds should be small when treating; good crop safety; Canadian thistle and yellow nutsedge suppression with two applications, fair on pigweed.
Bromoxynil (Buctril)	Post	NU	NU	G-E	NU	Crop injury potential; worker safety issues; weeds must be very small (<1"); cost effective; resistance in groundsel; kills predatory mites.
Clethodim (Select)	Post	E	G	NU	NU	Gets annual bluegrass; cost effective.
Clomazone (Command)	Pre	G-E	NU	G	NU	Crop injury concerns; drift concerns; carryover concerns (plantback); good on lambsquarter, fair to good on kochia, excellent on annual grasses; Dormant use only.
Clopyralid (Stinger)	Post	NU	NU	G-E	E	Good on many composite species, including Canada thistle, prickly lettuce, and salsify, legumes, solanaceous weeds; expensive; plantback restrictions on legumes and potatoes; residues in spent hay; good on prickly lettuce and salsify.
Diuron (Karmex)	Pre	G	NU	G-E	NU	Marginal crop safety in Western Oregon; inexpensive; only registered on established mint; Dormant use only
Glyphosate (Round-up)	Post	E	E	E	E	Preplant broadcast controls annual weeds emerged and volunteer grain; spot treat and ropewick only or broadcast preplant.Dormant use only or spot treat <10% of acreage.
Napropamide (Devrinol)	Pre	F-G	NU	F-G	NU	Costly; misses mustards, nightshades, kochia, Russian Thistle; some injury potential; Dormant use only.
Oxyfluorfen (Goal, Galigan)	Pre	F-G	NU	G-E	NU	Good on groundsel, winter annuals; crop safety issues; good in combination with Karmex or Gramoxone; Dormant use only.
Paraquat (Gramoxone Extra)	Post	F	NU	E	NU	Inexpensive; worker safety issues; no residual activity; Dormant use only.
Pendimethalin (Prowl)	Pre	G-E	NU	G	NU	Not used west of Cascades due to crop safety; poor on groundsel, mustards, many winter annuals; Dormant use only. Sec 18 in OR, WA, ID.

Efficacy rating symbols:

E=Excellent (90-100% control), **G**=Good (80-90% control), **F**=Fair (70-80% control), **P**=Poor (<70% control), **NU**=not used for this pest

Efficacy of Management Tools for Weeds in PNW Mint, continued.

Management Tools	Type	Annual Grasses	Perennial Grasses	Annual Broadleaves	Perennial Broadleaves	Comments
Pyridate (Tough)	Post	NU	NU	E	NU	Poor on most mustard species, good on pigweed, kochia, lambsquarter, Russian thistle; good in combination with Sinbar; No manufacturer, so may not be available
Quizalofop-ethyl (Assure II)	Post	E	G-E	NU	NU	Misses annual bluegrass, fine fescues
Sethoxydim (Poast)	Post	F-G	P-F	NU	NU	Misses annual bluegrass, fine fescues, and downy brome; fair on perennial grasses (quackgrass and Bermuda grass); costly.
Terbacil (Sinbar)	Pre and Post	G	NU	E	F	Weed resistance (pigweed, lambsquarter, groundsel, kochia); plantback issues (persistence); used either pre or post; good in tank mixes; misses field bindweed.
Trifluralin (Treflan)	Pre	G-E	NU	G	NU	Inexpensive; mechanical incorporation improves efficacy; misses mustard and nightshades; can chemigate; Dormant use only.
New Chemistries/IR-4:						
Flumioxazin (Valor)	Pre	F-G	NU	E	NU	Dormant use only; some crop injury potential
Fluroxypyr (Starane)	Post	NU	NU	G-E	NU	Crop injury potential; pre or post to mint, always post to weeds; good on composites, solanaceous-nightshades and bedstraw.
Sulfentrazone (Spartan)	Pre	F-G	NU	E	NU	Dormant use only. Registration pending
Cultural/Non-Chemical:						
Crop rotation						Allows use of herbicides not registered in mint (e.g. bindweed control)
Flaming		P	P	P-F	P	
Hand hoe		G-E	P	G-E	P	Expensive
Strip tillage in fall		NU	NU	P-F	NU	Winter annual weeds only
Weeder geese		F-G	P-F	NU	NU	
Biological:						
None						

Efficacy rating symbols:

E=Excellent (90-100% control), **G**=Good (80-90% control), **F**=Fair (70-80% control), **P**=Poor (<70% control), **NU**=not used for this pest

Efficacy of Management Tools for Nematodes in PNW Mint

This table is a compilation of information concerning the efficacy of various compounds and practices on mint nematode pests. They are not an indication of registration for specific pests although we have indicated their general registration on mint. The tables do compare the relative efficacy of available and potential products for each pest thereby indicating where research and registration efforts are needed.

Management Tools	Nematodes			Slugs	Comments
	Mint (needle)	Root-knot	Root-lesion		
Registered Materials:					
Dichloropropene (Telone II)	G-E	G-E	G-E	NU	Pre-plant soil fumigant
Dichloropropene + chloropicrin (Telone C-17)	G-E	G-E	G-E	NU	Pre-plant soil fumigant
Metaldehyde	NU	NU	NU	G-E	Molluskicide
Oxamyl (Vydate)	?	?	F-G	NU	
Sodium methyldithiocarbamate (Vapam)	G-E	G-E	G-E	NU	Pre-plant soil fumigant
Sodium tetrathiocarbonate (Nemasol-42)	?	?	?	NU	Soil fumigant; pre-plant or via irrigation
New Chemistries/IR-4:					
Iodomethane (Midas)	?	?	?	?	Pre-plant soil fumigant
Cultural/Non-Chemical:					
Crop rotation	P	P	P	P	
Flaming	NU	NU	NU	P	
Irrigation management	NU	NU	NU	NU	
Nematode control	NU	NU	NU	NU	
Resistant varieties	NU	NU	NU	NU	
Sanitation	P-G	P-G	P-G	P	
Weed control	NU	NU	NU	NU	
Biological:					
None					

Rating System

E = excellent (90-100% control)
G = good (80-90% control)
F = fair (70-80% control)
P = poor (<70% control)
? = efficacy unknown; more research needed
NU = not used for this pest

Nematodes:

Mint (needle) nematode = *Longidorus elongates*
Root-knot nematode = *Meloidogyne hapla*
Root-lesion nematode = *Pratylenchus penetrans*

Toxicity ratings for Beneficials in PNW Mint

	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	Comments
Registered Material:												
Insecticides/Miticides:												
Acephate (Orthene)	ND	ND	H	H	ND	H	ND	M	M	M	M	
Chlorpyrifos (Lorsban)	M	M	ND	M	M	M	ND	ND	H	ND	ND	
Dicofol (Kelthane)	M	M	L	L	M	M		L	H	H	H	
Hexythiozox (Onager)												ND for all
Malathion	M	M	M	H	M	H	M	M	M	H	M	
Methomyl (Lannate)	H	H	ND	H	H	H	ND	H	M	H	H	
Oxydemeton-methyl (MSR)	ND	M	M	H	M	H	ND	H	ND	H	ND	
Potass. salts/fatty acids (M-Pede)												Possibly toxic to foliar beneficials
Propargite (Omite, Comite)	L	L	L	ND	M	M	ND	ND	ND	ND	ND	
Tebufenozide (Confirm)	O	O	O	O	O	O	ND	O	O	O	O	
Fungicides:												
Azoxystrobin (Quadris)												ND for all
Chlorothalonil (Bravo)												ND for all
Myclobutanil (Rally)												ND for all
Oils												ND for all
Propiconazole (Orbit)												ND for all
Sulfur	L	ND	M	M	H	L	ND	L	ND	M	M	
Potass.Bicarbonate (Kaligreen)												ND for all
Herbicides:												ND for all
Bentazon (Basagran)												ND for all
Bromoxynil (Buctril)												ND for all
Clethodim (Select, Prism)												ND for all
Clomazone (Command)												ND for all
Clopyralid (Stinger)												ND for all

Ratings:
O = Non-toxic
L = Slightly toxic
M = Moderately toxic
H = Highly toxic
ND = No Data

Key to Beneficials:
BEB = Bigeyed bug (*Geocoris pallens*)
DB = Damsel bug (*Nabis alternatus*)
LW = Lacewings (*Chrysopa* spp.)
LB = Lady beetles (*Hippodamia convergens*)
MPB = Minute pirate bugs (*Orius* spp.)
PM = Predatory mites (*Acari: Phytoseiidae*)
PN = Parasitic nematodes
PW = Parasitic wasps (Ichneumonidae and Braconidae)
S = Spiders (Arachnida: Araneae)
SF = Syrphid flies
TF = Tachnid flies

Toxicity ratings for Beneficials in PNW Mint, continued.

	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	Comments
Diuron (Karmex)	ND	O	ND	M	O	M	ND	L	ND	ND	ND	
Glyphosate (Round-up)	M	ND	ND	ND	ND	H	ND	L	ND	ND	ND	
Napropamide (Devrinol)												ND for all
Oxyfluorfen (Goal,Galigan)												ND for all
Paraquat (Gramoxone Extra)	ND	ND	ND	ND	ND	H	ND	ND	ND	ND	ND	
Pendimethalin (Prowl)												ND for all
Pyridate (Tough)												ND for all
Quizalofop-ethyl (Assure II)												ND for all
Sethoxydim (Poast)												ND for all
Terbacil (Sinbar)												ND for all
Trifluralin (Treflan)												ND for all
Soil Fumigants:												
Oxamyl (Vydate)												ND for all
Sodium Tetrathiocarbonate (Nemasol-42)												ND for all
Dichloropropene (Telone II)												ND for all
Dichloropropene + chloropicrin (Telone C-17)												ND for all
New Chemistries/IR-4:												
Insecticides/Miticides:												
Beauveria bassiana (Mycotrol)												ND for all
Bifenazate (Acramite)	ND	ND	ND	M	L	M	ND	ND	ND	M	ND	
Cryolite Bait												ND for all
Cyhexatin (Plictran)												ND for all
Ethoprop (Mocap)												ND for all
Fenpyroximate (Sequel)												ND for all

Ratings:
O = Non-toxic
L = Slightly toxic
M = Moderately toxic
H = Highly toxic
ND = No Data

Key to Beneficials:
BEB = Bigeyed bug (*Geocoris pallens*)
DB = Damsel bug (*Nabis alternatus*)
LW = Lacewings (*Chrysopa* spp.)
LB = Lady beetles (*Hippodamia convergens*)
MPB = Minute pirate bugs (*Orius* spp.)
PM = Predatory mites (*Acari: Phytoseiidae*)
PN = Parasitic nematodes
PW = Parasitic wasps (Ichneumonidae and Braconidae)
S = Spiders (Arachnida: Araneae)
SF = Syrphid flies
TF = Tachnid flies

Toxicity ratings for Beneficials in PNW Mint, continued.

	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	Comments
Methoxyfenozide (Intrepid)	L	L	L	L	L	L	ND	L	L	L	L	
Pyridaben (Pyramite, Sanmite)												ND for all; Toxic to bees
Spinosad (Success)	M	M	M	M	M	M	ND	M	M	M	M	
Thiamethoxam (Actara, Platium)	L	L	L	L	L	L	ND	L	L	L	L	
Fungicides:												
Cyprodinil+Fludioxonil (Switch)												ND for all
Prohexadim calcium (Apogee)												ND for all
Herbicides:												
Sulfentrazone (Spartan)												ND for all
Flumioxazin (Valor)												ND for all
Fluroxypyr (Starane)												ND for all
Soil fumigant:												
Iodomethane (Midas)												ND for all
Cultural/Non-Chemical:												
Baited traps												Neutral
Crop rotation												Variable ecological impacts on polyphagous natural enemies
Flaming	H	H	H	H	H	H	H	H	H	H	H	Temporary hazard to soil surface and foliage-born fauna
Hand hoe												Neutral
Harrowing in spring												Short term impact on soil surface fauna
Irrigation management												Neutral
Pheromone confusion												Neutral

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Toxicity ratings for Beneficials in PNW Mint, continued.

	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	Comments
Resistant varieties												Neutral
Sanitation												Largely neutral
Strip tillage in fall												Beneficial for habitat and prey for polyphagous species
Weed control												May impact habitat/alternative prey for some species
Weeder geese												Neutral
Biological:												
Bacillius Thuringiensis (Bt)	O	O	ND	ND	O	ND	ND	ND	O	ND	ND	

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