OREGON STATE UNIVERSITY EXTENSION SERVICE

Integrated Pest Management Strategic Plan

for Oregon, Washington and Idaho Mint Crops

Summary of a workshop held on March 8, 2019, in Portland, Oregon.

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Process for this Integrated Pest Management Strategic Plan ("IPMSP")

In a proactive effort to identify pest management priorities and lay a foundation for future strategies and increased use of integrated pest management (IPM) in mint production, growers, commodity-group representatives, pest control advisors, processors, university specialists and other technical experts from the mint industry in Oregon, Washington and Idaho formed a work group and assembled this plan. Members of the group met for one day in March 2019, in Portland, Oregon, where they discussed and reached consensus about IPM priorities and opportunities. The plan outlines major pests, current management practices, critical needs, activity timetables and efficacy ratings of various management tools for specific pests in mint production. The result is a strategic plan that addresses many IPM and pest-specific critical needs for the Pacific Northwest mint industry.

A list of top-priority critical needs was created based on a group-voting process at the work group meeting. This was drawn from an assessment of all the needs that appear throughout the document, which were compiled based on input from work group members. A list of broader IPM needs was also compiled to address broader, less pest-specific barriers to IPM adoption. Crop-stage-specific critical needs are also listed, and discussed throughout this publication.

This strategic plan begins with an overview of mint production. The overview is followed by discussion of critical production aspects of this crop, including the basics of IPM in mint production in the Pacific Northwest. Each pest is described briefly, with links provided for more information about the pest's biology and life cycle. Within each major pest grouping (insects, diseases and weeds), individual pests are presented in alphabetical order, not in order of importance. The remainder of the document is an analysis of management practices and challenges organized by crop life stage in an effort to assist the reader in understanding whole-season management practices and constraints. Current management practices are presented using a "Prevention, Avoidance, Monitoring, and Suppression" (PAMS) framework to place practices within a simple IPM classification and to demonstrate areas where additional tools or practices may be needed. For more information, see Appendix F, "Using PAMS Terminology" (page 58).

Trade names for certain pesticides are used throughout this document as an aid for the reader. The use of trade names in this document does not imply endorsement by the work group or any of the organizations represented.

Work group members

In attendance

Travis Boyd, Aromatics, Inc.

Lisa Brain, consultant, Agrimanagement Inc.

Devin Dekker, Buyer, RCB International

Will Jessie, Extension, Oregon State University

Mark Nelson, Buyer, AM Todd

Bryon Quebbeman, consultant

John Reerslev, grower

Steve Salisbury, Mint Industry Research Council

Betsy Verhoeven, Extension, Oregon State University

Darrin Walenta, Extension, Oregon State University

Doug Walsh, IPM Coordinator, Washington State University

Tony Weitz, grower

Others in attendance

Paul Jepson, Oregon State University

Katie Murray, Oregon State University

Isaac Sandlin, Oregon State University

Contributing workgroup members not in attendance

Jeremiah Dung, Extension, Oregon State University

Review of 2002 summary of most critical needs in PNW mint pest management

A similar plan was developed for mint in 2002. The following needs were identified by the 2002 workgroup as "most critical." An update on current progress, reported by the 2019 workgroup, follows each item and is designated by an open box (❑)

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.
  - ❑ Much progress has been made in the areas of herbicides, but research regarding effective crop rotation sequences to mitigate against soil-borne diseases is an ongoing need.
- Develop new pesticides for resistance management.
  - ❑ Progress has been made, yet this remains an ongoing need.
- Develop new, more effective, practical and cost-effective control measures for root-feeding insects and nematodes.
  - ❑ Progress has been made toward more effective controls. Chlorantraniliprole (Coragen) has provided effective alternative control for mint root borer and cutworm pre- or postharvest. Alternative controls for *Symphyla* remains a need.
- Investigate control measures for hard-to-control perennial weeds (such as field bindweed, yellow nutsedge, yellow toadflax).
  - ❑ This is an ongoing problem, and research is still needed for effective bindweed control.
- Investigate ways to reduce pesticide inputs
  - ❑ This is an ongoing need.
- Develop highyielding, disease- and pest-resistant cultivars
  - ❑ The Mint Industry Research Council has a nationwide varietal improvement program, and major advances have been made since 2002 with regard to mint cultivars. However, cultivar improvement remains an ongoing need, and flavor profile is one particular challenge.
- Develop an assay for Verticillium to distinguish between the mint strain and other strains of *V. dahliae*
  - ❑ This work has been done, with protocols available through Oregon State University.
- Develop a replacement for Tough (pyridate).
  - ❑ This is no longer an issue for the industry.

Regulatory

- Register Mocap (ethoprop).
  - ❑ This product is registered.

- Register Prowl (pendimethalin).
  - ❏ This product is registered.
- Maintain workable re-entry intervals (REI's) and pre-harvest intervals (PHI's) during the risk assessment processes.
  - ❏ This remains an ongoing need for various products, including pyridate and propargite (Comite), which have PHI issues that impact usage.

Education

- Continue to educate regulators about interactions between pesticides and predators
  - ❏ This is an ongoing need for education.
- Educate growers concerning new research developments
  - ❏ This is an ongoing need for education.
- Develop and distribute symptom-identification field guides.
  - ❏ The Mint Industry Research Council has developed some bulletins, and Oregon State University has a handbook, but these materials need updating.
- Create list-serve discussions.
  - ❏ This is an ongoing need.
- Develop and disseminate educational materials for growers concerning cultural and biological control (e.g. site selection, crop histories)
  - ❏ This is an ongoing need.
- Educate growers about using new techniques with existing control measures (more conventional pesticides and methodology)
  - ❏ Oregon has a mint pest alert system for two key insect pests (root borer and variegated cutworm) but needs to expand the system for more species. Mint root borer and variegated cutworm models are included in USPest.org.
- Educate the general public on the benefits and safety margin of most agricultural chemicals.
  - ❏ This is an ongoing need.

2019 top-priority critical needs

The following critical needs were voted as the "top-priority" needs by the work group members present at the February meeting. Crop-stage-specific aspects of these needs, as well as additional needs, are listed and discussed throughout the body of the document. Note that the order of appearance within these lists does not reflect an order of importance.

Research topics

- Conduct research to develop improved varieties for wilt resistance.
- Commercialize and make available an efficient method for strain-specific testing for verticillium.

- Develop efficacious alternatives (chemical and nonchemical) for post-emergence broadleaf weed control.
- Investigate the level of resistance to miticides within mite species.
- Increase research on nematodes and effective controls.

Regulatory actions

- Perform efficacy research and testing in preparation for registration of effective alternatives to organophosphate insecticides (chlorpyrifos, acephate, and ethoprop) for control of mint pests.
- Register cost-effective alternatives to miticides with resistance issues.
- Streamline the registration process to fast-track needed registrations.
- Clarify regulations related to single- vs. double-cut mint, and the impacts and implications of these, including the "once per season" application limit and how this relates to double-cut mint, which has more than one harvest during the growing season.

Education

- Educate pest managers on best practices for pyrethroid use, once registered, to avoid negative impacts on beneficial mites.
- Educate pest managers on best practices and crops for rotation.
- Educate pest managers on fertility and nutrient management best practices, including best timing for nitrogen applications.
- Educate pest managers on the importance of using certified disease-free root stock to minimize the spread of diseases, including Verticillium.
- Educate pest managers on the importance of treating mites only as needed in order to best manage resistance.
- Revise and update the Oregon Mint IPM website.

Mint production overview

Mint is a perennial crop, grown mainly for its oil, which is used as a flavoring in chewing gum, dental products, and other confectionery and pharmaceutical products. The United States is the largest producer of peppermint oil and spearmint oil in the world. The Pacific Northwest region of the United States (Oregon, Washington, and Idaho) is the center of U.S. mint production, accounting for about 80% of U.S. peppermint acreage, and 63% of U.S. spearmint acreage. In 2018, the Pacific Northwest harvested 43,500 acres of peppermint, which yielded an average of 104 pounds of oil per acre. Approximately 14,500 acres of spearmint were harvested, yielding an average of 148 pounds of oil per acre.

Table 1: Mint Oil: Harvested acres, oil yield and U.S. ranking, 2018 crop year; data provided by the Mint Industry Research Council.

	Peppermint			Spearmint		
	Harvested acres	**U.S. acreage (%)**	**Oil yield (lb./A)**	**Harvested acres**	**U.S. acreage (%)**	**Oil yield (lb./A)**
Washington	13,000	24%	117	11,400	51%	154
Oregon	13,500	25%	88	1,600	7%	113
Idaho	17,000	31%	106	1,050	5%	139
Pacific Northwest	43,500	80%	104	14,050	63%	148
U.S.	54,000			22,200		

Washington leads the United States in total mint production, with 13,000 acres of peppermint and 11,400 acres of spearmint. Washington accounts for more than half of the U.S. spearmint acreage, producing both native and Scotch spearmint. Mint production in Washington 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 is also grown in Clark County, which is on the west side of the Cascade Mountains.

Idaho ranks second for U.S. mint production and first for peppermint production, with approximately 17,000 acres of peppermint and over 1,000 acres of spearmint in production. Mint production in Idaho is primarily in the southwestern part of the state, with most of the acreage located in Ada, Canyon, Elmore, Gem, Owyhee, Payette, Twin Falls and Washington counties.

Oregon ranks third for U.S. mint production, with approximately 13,500 acres of peppermint, and 1,600 acres of spearmint harvested in 2018. About a quarter of the production occurs in the moist and moderate Willamette Valley on the west side of the Cascade Mountains and the other three quarters 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, Clackamas, Columbia, Lane, Linn, Marion, Polk and Yamhill. Central and eastern Oregon counties that produce mint include Baker, Crook, Deschutes, Harney, Jefferson, Klamath, Lake, Malheur, Morrow, Umatilla, Union and Grant.

All commercially grown mint is dependent upon environmental and physical factors, including temperature, day length and soil type. The long day length north of the 45th parallel 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. Mint requires warm days (85–95° F) and cool nights (55–60° F) for optimum growth. 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.

Most of the mint-growing regions of the Pacific Northwest are semiarid and require irrigation for optimum production. The water requirements for a good mint crop are from 30 to 40 acre-inches per year. 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. Fertilizer is an integral part of mint production, and most mint requires up to 250 pounds per acre of nitrogen fertilizer per acre per season.

The crop is established by transplanting either greenhouse-grown plants in the spring or field-grown roots in the fall. Greenhouse-grown plants are usually planted in the spring, in rows 40 inches apart, with total plant populations of about 10,000 per acre. Over the course of the first summer, stolons spread between rows to create an established stand. The crop is then swathed, chopped and distilled to extract the oil when it begins to bloom in the summer. If planted in the fall, field-grown roots are transplanted in 20-inch rows.

Mint can be harvested once or twice, depending on the variety and location. A single harvest is referred to as “single-cut” mint. Some varieties are allowed to regrow through the summer after the first harvest, then harvested again. This practice refers to “double-cut” mint. Most spearmint (particularly native spearmint) and some peppermint acreage is harvested twice, depending on the production region and the needs of mint oil processors.

About a quarter of the acreage in Idaho is double-cut, along with most of the eastern Washington acreage. Fields irrigated with overhead sprinklers are commonly double-cut.

Eastern Oregon acreage is mostly single cut, as is the majority of Willamette Valley acreage.

Integrated Pest Management (IPM) overview in mint production

Commercial mint production in the Pacific Northwest started around 1920, and mint has since served as an economically important perennial crop. As a mint field matures over time, it becomes increasingly susceptible to insects, diseases and weeds, all of which can have negative impacts on oil yield and quality. Pest infestation can build to excessive levels that significantly weaken a mint stand, resulting in economic loss. Complete economic loss can occur if the field has to be removed from production too early in the rotation cycle.

The first step in mint IPM is to prevent the introduction of diseases, insects and weeds into a new field. This can be achieved through planting pest-free rootstock, followed by thorough sanitation of equipment when moving between fields. General crop management practices that emphasize planting disease-free rootstocks, good soil sanitation and tilth, plant vigor, irrigation scheduling and frequent monitoring (scouting) fields for soil moisture, plant health, pests and beneficial arthropods are key for optimizing oil yield.

Agrochemicals are also important tools for effective pest management in mint production. Decision-support tools such as the Oregon mint pest alert system (http://blogs.oregonstate.edu/mintpestalert/); USPest.org and the Integrated Pest Management on Peppermint 3.0 web site (http://uspest.org/mint/) ; and the Pacific Northwest Pest Management Handbooks (https://pnwhandbooks.org/) facilitate judicious use of these compounds when needed. Mint IPM is based on a continuous effort to identify effective pest management options that include cultural, biological, chemical and genetic techniques that enable long-term economic and environmental sustainability.

Numerous insect pests can thrive in mint production fields and pose a year-round threat to crop health. Although some variation in seasonal impacts may occur depending upon the pest species and production area, major spring insect pests in mint include cutworms, armyworms, symphylans and mint stem borer. Summer insect pests include spider mites, cutworms, loopers and mint root borer. Post-harvest or fall active insect pests include mint root borer, symphylans, cutworms and root weevil larvae.

Insecticides remain a key management tool for mint insect pests of economic concern. The recent development and registration more pest-specific and biologically based pesticide compounds has reduced reliance upon broad-spectrum pesticides. Chlorantraniliprole (Coragen) is an example of a new, target-specific insecticide that provides effective control for several larval pests on peppermint (including mint root borer, cutworm, armyworm and looper), and has the added benefit of low toxicity to beneficial insects. This compound also offers a dual-application window, either as a pre- or post-harvest application.

A diverse community of beneficial insects inhabits many mint fields and can have suppressive effects on pest insect populations. Examples of natural enemies include parasitic wasps, syrphid flies, lady beetles, predator mites, lacewings, big-eyed bugs and spiders. However, in-field levels can change in favor of pest populations due to management practices, weather, insecticide applications, etc., and overcome the ability of natural enemies to fully suppress pest populations. In spite of this, natural enemies still play an important role, and IPM programs must strive to protect and enhance populations. Although spider mites can sometimes be a major pest in mint, predator mites naturally occurring in the field can maintain spider mite populations at a low enough level to delay or avoid the need for miticides. Insecticide applications against

other target pests can disrupt natural enemies, leading to an outbreak of secondary pests, including spider mites. In situations where spider mite populations exceed thresholds, pest control compounds are chosen to minimize impact on predator mite populations.

Several diseases in mint are caused by fungal pathogens. Verticillium wilt ( ) is a soil-borne fungal pathogen considered to be the most significant threat to mint production. Over time, disease inoculum in wilt-infected fields can increase to levels that prevent mint growth. The disease survives for years in the soil as microsclerotia, and thus, long rotation cycles out of mint are required to reduce soil inoculum.

Management for verticillium wilt is limited mainly to cultural techniques deployed prior to planting a new stand of mint. However, flaming the field after harvest is used in some production areas to reduce inoculum in post-harvest residue. In fields with a history of verticillium wilt but with at least five years out of mint production, some growers fumigate before planting, and then plant certified-disease free rootstock of an improved cultivar. Soil fumigation provides the added benefit of managing plant-parasitic nematodes. Severely infected fields may require rotation cycles out of mint production for up to 10 years in an effort to reduce soil inoculum levels below economic injury levels. Fields with no history of mint production are ideal candidates for planting with certified disease-free rootstock.

Native spearmint is relatively resistant to verticillium wilt, whereas, Scotch spearmint and Black Mitcham peppermint are susceptible. Only a few improved peppermint cultivars are currently available that exhibit low to moderate levels of resistance to verticillium wilt. New peppermint production fields are often planted with state-certified *Verticillium*-free rootstock produced from certified propagation materials sourced from the Mint Industry Research Council or state-certified field rootstock propagation programs.

Mint fields are highly susceptible to weed infestations, especially during the year of establishment and before the crop canopy closes. Weeds impact both the yield and quality of mint oil with varying levels of impact based on the weed species present and level of infestation. Weeds can also become hosts to insects and diseases that can become economically damaging.

Weed management for new mint fields focuses on crop rotation, cultivation, seed-bed and root-stock preparation, and properly timed herbicide applications. In established stands, weed pressure can increase over time even with the use of herbicides, which requires the investment of additional hand-labor to remove the infestations prior to harvest Problematic annual weeds (common groundsel, pigweed, mayweed and prickly lettuce) and persistent perennial weeds (field bindweed) are difficult to control, and infestation levels build over time if management efforts are not successful.

Successful weed IPM relies on frequent monitoring of fields, early management decisions, and integration of multiple management tactics.

IPM critical needs

The following list of broad IPM needs was compiled based on input from workgroup members. Participants were asked to identify specific needs related to each of the headings in bold. Specific needs appear as bulleted lists below.

Decision and knowledge support

- Review and update existing insect pest scouting guide with key pests.
- Develop smart phone applications to support pest management decision-making.
- Develop ideal crop rotations to precede and follow the mint crop.
- Review and update the fertilizer and pesticide handbooks.
- Utilize existing grower groups and Extension education programs to deliver information.
- Develop economic thresholds for key pests.
- Increase funding for agriculture research.
- Develop a cost-benefit calculator or application to help growers determine how these two relate for a given pest management decision.
- Increase production and dissemination of education materials aimed at growers and crop consultants.
- Update crop enterprise budgets for improved economic analysis.
- Encourage more independent field scouts and consultants to support increased monitoring and education.
- Offer trainings for new chemical sales representatives and field scouts.

Reduced reliance on agrochemicals, and development of alternatives

- Develop effective biopesticides, to include:
  - ❏ Test and demonstrate the efficacy of biopesticide alternatives (including biological nematicides, fungicides and miticides) using replicated trials.
  - ❏ Include economic analyses in results.
  - ❏ Test efficacy of biostimulants.
- Improve no-till options
- Encourage the installation of pollinator and beneficial insect habitat near crops and educate on best practices for pollinator protection.
- Evaluate and document natural enemy benefits and thresholds for key mint pests.
- Develop and register new, more targeted agrochemical modes of action.
- Develop conservation biological control programs for beneficial mites.
- Increase the marketability of resistant varieties.
- Research effective, more selective controls for verticillium wilt.
- Increase funding for independent research relative to research coming from chemical companies.
- Evaluate impact of predator and beneficial insects on insect-pest populations.

Pollinator protection

- Continue to quantify the abundance and diversity of pollinators in mint fields.
- Develop and share communication materials demonstrating pollinator protections involved with mint production.
- Require clearer product labeling that indicates pollinator safety during production.
- Develop a bee safety guide or Best Management Practices for pollinators in mint that addresses currently used and pipeline chemistries.

Water quality

- Perform pesticide-runoff analysis for mint producing areas.
- Promote practices that reduce runoff.
- Continue to improve available irrigation methods .
    - ❑ Continue to encourage more efficient irrigation practices (such as draglines and drip) and water-use efficiency among growers.
- Research on fertilizer-use efficiency and leaching reduction for single- and double-cut mint with respect to quality, and to include seasonal variations in river flows, etc.
- Promote best practices for fertility management: optimize application rates and timing for maximum attainable yield.

Human health and worker protection

- Provide more pesticide safety trainings.
- Clarify and simplify new worker protection standard (WPS) regulations in collaboration with pesticide safety education program.
- Encourage better education of farm laborers.
- Reduce dependency on pesticides.

List of major mint pests

(listed alphabetically)

Insects, mites, slugs

Alfalfa looper (*Autographa californica*)

Aphid (*Ovatus crataegarius*)

Armyworm (*Mamestra configurata*)

Cabbage looper (*Trichoplusia ni*)

Mint cutworm (*Heliothis phloxiphaga*)

Spotted cutworm (*Amathes c-nigrum*)

Variegated cutworm (*Peridroma saucia*)

Garden symphylan (*Scutigerella immaculata*)

Clearwinged grasshopper (*Camnula pellucida*)

Lygus (*Lygus* spp.)

Mint flea beetle (*Longitarsus waterhousei*)

Mint root borer (*Fumibotys fumalis*)

Redbacked cutworm (*Euxoa ochragaster*)

Root weevil (*Otiorhynchus sulcatus*)

Slug (*Deroceras reticulatum*)

Spider mite (*Tetranychus urticae*)

Thrips (*Frankliniella* spp.)

Wireworm (*Limonius* spp.)

Pathogens and nematodes

Black stem rot (*Phoma strasseri*)

Leaf blight (*Cephalosporium* sp.)

Needle Nematodes (*Longidorus elongatus*)

Pin Nematodes (*Paratylenchus* spp.)

Root-knot Nematodes (*Meloidogyne hapla*)

Root-lesion Nematodes (*Pratylenchus penetrans*)

Phoma (*Phoma* sp.)

Powdery mildew (*Golovinomyces biocellatus*)

Stolon decay and canker (*Rhizoctonia solani*)

Verticillium wilt (*Verticillium dahlia*)

Rust (*Puccinia menthae*)

Weeds

Barnyard grass (*Echinochloa crus-galli*)

Little bittercress (*Cardamine oligosperma*)

Annual bluegrass (*Poa annua*)

Wild buckwheat (*Polygonum convolvulus*)

Canada thistle (*Cirsium arvense*)

Catchweed bedstraw (*Galium aparine*)

Common chickweed (*Stellaria media*)

Common dandelion (*Taraxacum officinale*)

Cheatgrass (*Bromus tectorum*)

Field bindweed (*Convolvulus arvensis*)

Filaree (*Erodium* spp.)

Flixweed (*Descurainia Sophia*)

Green foxtail (*Setaria viridis*)

Common groundsel (*Senecio vulgaris*)

Horseweed (*Conyza canadensis*)

Prostrate knotweed (*Polygonum arenastrum*)

Kochia (*Bassia scoparia*)

Common lambsquarters (*Chenopodium album*)

Black nightshade (*Solanum americanum*)

Hairy nightshade (*Solanum physalifolium*)

Yellow nutsedge (*Cyperus esculentus*)

Pineappleweed (*Chamomilla suaveolens*)

Powell amaranth (*Amaranthus powellii*)

Prickly lettuce (*Lactuca serriola*)

Puncturevine (*Tribulus terrestris*)

Quackgrass (*Elymus repens*)

Rattail fescue (*Vulpia myuros*)

Red orach (*Atriplex hortensis*)

Redroot pigweed (*Amaranthus retroflexus*)

Russian thistle (*Salsola* ssp.)

Italian ryegrass (*Lolium multiflorum*)

Common salsify (*Tragopogon porrifolius*)

Shepherd's-purse (*Capsella bursa-pastoris*)

Red sorrel (*Rumex acetosella*)

Annual sowthistle (*Sonchus oleraceus*)

Tumble mustard (*Sisymbrium altissimum*)

Witchgrass (*Panicum capillare*)

Invasive and emerging pests

Bladder campion (*Silene vulgaris*)

Nightflowering catchfly (*Silene noctiflora*)

Cinquefoil (*Potentilla supina*)

Mint stem borer (*Pseudobaris nigrina*)

Mint pest management timing by crop stage

Preplant through planting

Nematodes, symphylans, verticillium wilt, weeds

First year dormancy

Cutworms, weeds

Established crop dormancy

Cutworms, weeds

Vegetative growth through harvest

Aphids, caterpillars, cutworms, loopers, mites, mildew, root borer, root weevil, nematodes, symphylans, rust, weeds

Post-harvest (single-cut mint/second cutting for double-cut mint)

Armyworms, cutworms, root borer, nematodes, symphylans, weeds

Between cuttings (double-cut only; post first harvest)

Weeds

Major mint pest descriptions

Insects, mites, and slugs

Aphid (*Ovatus crataegarius*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-aphid. Wingless forms of aphid are apple green to yellow-green. Winged forms have a dark brown head and thorax. Large populations can stunt and distort stems and leaves, make plants more susceptible to water stress, and secrete honeydew, which can lead to sunburned leaves or result in leaves covered with black, sooty mold.

Armyworm and cutworm

Bertha armyworm (*Mamestra configurata*)

Mint cutworm (*Heliothis phloxiphaga*)

Spotted cutworm (*Amathes c-nigrum*)

Variegated cutworm (*Peridroma saucia*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-armyworm-cutworm

Variegated cutworm larvae are brownish, with white marks on each dorsal (top) abdominal segment. Bertha armyworm larvae are highly variable, from uniform pale green to black with fine longitudinal yellow lines. Mint cutworm are large, yellow, tan or green larvae with black spots over the body, similar to corn earworm. Spotted cutworm larvae vary in color, but most are dark brown to black, with distinct markings on the back. Damage is similar to that of the variegated cutworm and alfalfa looper, but this insect is seldom a problem of economic importance on mint. Larval feeding on leaves in late June, July, and August can reduce oil yield.

Garden symphylan (*Scutigerella immaculata*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-garden-symphylan

Garden symphylans are small (less than a quarter inch), white, centipede-like animals that feed on the hairs and tissue of roots and underground stems. Heavy feeding causes plant stunting, poor stem elongation and small, chlorotic leaves. This insect is a very serious pest of many crops in western Oregon where there is a long history of only partially successful control methods.

Populations build rapidly in spring and summer, and usually decline from late summer through fall as soil temperatures rise and moisture content drops. Populations build again in the fall with rains, and can cause damage to roots in mild winters.

Clearwinged grasshopper (*Camnula pellucida*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-grasshopper

Grasshoppers feed on leaves throughout spring and summer. Leaf loss can be significant in years with warm, dry conditions in the spring.

Looper

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-alfalfa-looper-cabbage-looper

Alfalfa looper (*Autographa californica*)

Cabbage looper (*Trichoplusia ni*)

Looper larvae are pale green with white lines on backs and sides. Larvae have three pairs of abdominal prolegs, whereas cutworms and armyworms have five pairs. Larvae move in a "looping" manner. The adult looper is a gray-brown moth with U-shaped spot on forewings.

In the Willamette Valley, damage during the early season (May and early June) may appear serious. However, the plant almost always repairs the damage by harvest. This generation can be heavily parasitized by natural enemies, which reduces potential for late-season damage from this pest.

Mint flea beetle (*Longitarsus waterhousei*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-mint-flea-beetle

The main damage is by the flea beetle larvae, which feed on and severely damage roots in late April, May and June. However, the small, pale brown to brownish-yellow adult flea beetles feed on mint foliage, producing "shot-holed" leaves.

Because of the potential for damage, they usually are treated when detected (early July).

Mint root borer (*Fumibotys fumalis*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-mint-root-borer

This pest is present and can severely reduce stands in most mint-producing areas. Larvae are white with a brown head. They feed inside mint rhizomes and on mint roots, from late July through September and early October in some years.

This pest overwinters in the soil around mint roots as a prepupa in a cocoon, pupates in the spring, and emerges as a moth in June and July. There is one generation per year.

Mint stem borer (*Pseudobaris nigrina*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-mint-stem-borer

Mint stem borer is a small white grub, 0.08 to 0.16-inch-long, with a brown head and no legs. Damage is caused to the main root, leading to injury or death to the central stalk, which usually breaks off. It is found in eastern Oregon and Idaho. This pest can infest mint rootstock for export. It is also suspected by some as a possible disease vector.

Redbacked cutworm (*Euxoa ochragaster*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-redbacked-cutworm

Redbacked cutworm is a key pest of mint east of the Cascades. As mint begins to send up aerial growth in the spring, larvae feed underground by day, clipping off new spring shoots at or below ground level. At night, larvae feed above the soil surface. In some years, damage to mint during May and early June in central Oregon has been severe enough to result in extensive stand loss. It can be a worse problem in sandier, noncompacted soils.

Root weevil

Black vine weevil (*Otiorhynchus sulcatus*)

Strawberry root weevil (*O. ovatus*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-root-weevil

Root weevil larvae are legless white grubs with tan heads. They overwinter from two to eight inches deep in the soil. Adults are generally black, but may be brown or chocolate brown. Larvae feed on mint roots, and adults feed on foliage.

Slug

European black slug (*Arion ater*)

Gray garden slug (*Deroceras reticulatum*)

Great gray garden slug (*Limax maximus*)

Marsh slug (*Deroceras laeve*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-slug

Slugs are an occasional mint pest, mainly a problem in the Willamette Valley region of Oregon. Slug damage can be distinguished from that of cutworms and other pests by the presence of slime trails and their small sausage-shaped feces on the damaged plants as well as on the soil surface around damaged plants. Underground feeding on roots and tubers is characterized by shallow (0.12 inch) to deep (0.5 inch), smooth-sided pits that are usually less than 0.5 inch in diameter. Leaf damage is typified by removal of plant tissue between veins.

The most economically damaging species in Oregon is the “gray field slug” or gray garden slug (*Deroceras reticulatum*).

Spider mite (*Tetranychus urticae*)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-spider-mite

Spider mite adults are small, eight-legged, spiderlike animals associated with webbing and round eggs on the underside of leaves. They are pale green, yellowish to reddish, with two large, dark spots on each side of their bodies. They suck plant juices, causing leaves to yellow, dry, and fall under heavy infestations. They reduce oil yield and likely have negative impacts to quality. Predator mite populations can help maintain low infestation levels until populations grow too high based on conditions favorable to spider mites. Frequent field monitoring is critical.

Thrips (*Frankliniella* spp.)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-thrips

Thrips are a sporadic pest in mint. They are small yellowish insects less than 1 mm long. Feeding on undersides of leaves injures cells. Damage appears as stippling, silvering and or yellowing of leaves. Generally, thrips are a localized problem in drought-stressed areas of fields or portions of fields adjacent to a crop just harvested. They are seldom a problem requiring treatment.

Wireworm (*Limonius* spp.)

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-wireworm

Wireworms are brown, jointed, wiry, yellow to brown larvae of click beetles that feed on roots and underground stems of mint plants. Wireworms are a problem mainly when mint is planted into soil that is already infested. They do not become a problem in well managed and well-watered, established mint.

Diseases and nematodes

Black stem rot

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-black-stem-rot

Black stem rot is caused by a fungus, *Phoma strasseri*, which is most active during cool, wet weather. Dark-brown or black cankers form on stems, usually at the junction of lateral branches. Cankers may girdle the stem, causing plant parts above the infection to wilt and die.

Leaf blight

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-leaf-blight

Leaf blight is caused by a fungus, *Cephalosporium* sp. It infects leaves through wounds such as those from rust pustules, insects, or machinery.

Irregularly shaped black spots rapidly coalesce and eventually kill leaves. Infection can move down the leaf petiole into the stem. Infection develops rapidly in cool, wet weather and causes severe leaf drop, especially if hot, dry weather follows cool, wet weather.

Nematodes, Needle (*Longidorus elongatus*)

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-nematode-needle

Longidorus elongatus is one of several nematodes that live in soil and cause plant decline by affecting the root system. Needle nematodes are frequently found in the Willamette Valley of Oregon, though seldom in high numbers. Needle nematodes are migratory ectoparasites found only in soil.

Above ground symptoms are similar to those of root-lesion nematode infections, but roots do not show lesions. The field may have open patches of severely depressed, red-green plants with short, weak root systems. On or near the roots it may be possible to see the nematodes, which look like slender, coiled threads about 0.25-inch-long and as thick as a spider web.

Nematode, Pin (*Paratylenchus* spp.)

For more information, see: http://uspest.org/mint/pinnemaid.htm

Pin nematodes (*Paratylenchus* spp.) are the smalles plant parastic nematodes that attack plants. Adult females found in mint average 0.4 mm (0.016 inch). Pin nematodes are migratory ectoparasites. Pin nematodes easily detect and move towards plant roots, with the majority found around the root within 30 minutes of hatching.

Nematode, Root-knot (*Meloidogyne hapla*)

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-nematode-root-knot

Root-knot nematodes live in soil and cause plant decline by affecting the root system. Galls form on roots; however, infection does not appear to cause yield loss under field conditions.

Nematode, root-lesion (*Pratylenchus penetrans*)

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-nematode-root-lesion

As with root-knot nematodes, root-lesion nematodes live in soil and cause plant decline by affecting the root system. Root-lesion nematodes are migratory endoparasites; part of the population is in soil and part in the roots most of the time. In peppermint, populations are relatively low through winter, peak in May, decline through late spring and early summer, then increase rapidly as summer progresses. Populations are highest generally just after harvest, then decline rapidly.

This nematode is the most frequent cause of open patches in a field with severely depressed, red-green plants with short, weak root systems. Roots and rhizomes have small reddish-brown lesions, which may blend together if the infestation is heavy.

This nematode's most important role is in increasing the incidence and severity of Verticillium wilt on both peppermint and Scotch spearmint. It also can reduce winter hardiness on both mint types.

Powdery mildew

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-powdery-mildew

Powdery mildew is caused by a fungus, *Golovinomyces biocellatus* (syn = *Erysiphebiocellata*, formerly *Erysiphe cichoracearum*; anamorph *Oidium erysiphoides)*, which overwinters on mint, mint stubble, and many wild hosts. A gray, powdery fungus grows on leaves, then leaves yellow and drop.

It is seldom serious enough on peppermint to warrant control measures, and does not impact native spearmint; however, it is very destructive on Scotch spearmint (grown in Washington) and has caused problems in Idaho peppermint. Interactions with some herbicides increase susceptibility to this disease.

Rust

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-spearmint-mentha-spp-rust

Rust is caused by a fungus, *Puccinia menthae*, which overwinters on mint stubble and on wild and escaped mint. Eleven races have been identified in the Pacific Northwest. Peppermint rust is found frequently in western but not in central Oregon, while rust is a major disease on Scotch spearmint in central Oregon. Rust is found on native spearmint and Scotch spearmint in south-central Washington; however, it is not observed on peppermint due to high summer temperatures. It usually doesn't reach economic treatment thresholds.

Rust causes brown, circular pustules on the leaves' undersides followed by leaf yellowing and defoliation. A yellow spore stage (urediniospores) leads to reddish blisters on young shoots in spring, and a black spore stage (teliospores) occurs on stems and regrowth in fall. Swollen shoots with elongated, chlorotic internodes are associated with systemic infection.

Spotted wilt

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-spotted-wilt

The *Impatiens necrotic spot virus* (INSV) and the *Tomato spotted wilt virus* (TSWV) infect many economically important plants, including both dicots and monocots, and have been found in mint. A number of weedy hosts have been identified and include Lamb's-quarters (*Chenopodium album*), Chickweed (*Stellaria media*), Shepherd's purse (*Capsella bursa-pastoris*), and Purslane (*Portulaca oleraceae*). TSWV and INSV are transmitted by at least five species of thrips. The onion thrips and the flower thrips are known to be in the Pacific Northwest. The INSV is associated with the most severe

symptoms in mint. New mint plantings show the worst symptoms, but they fade or disappear in later years.

Symptoms appear first on terminals and move progressively toward the plant base. Yellow leaf areas soon become necrotic, eventually killing leaves, followed by death of the entire aboveground portion of the plant. Early disease stages may be mistaken for powdery mildew. In the field, the underground portion of the plant regrows in the fall. Losses caused by this virus are unknown.

Stolon decay and canker

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-stolon-decay-canker

Stolon decay and canker is caused by several fungi that live in soil. Stolon decay is associated with *Fusarium solani*. Stem and stolon canker are caused by *Rhizoctonia solani*. Roots, runners, and rhizomes will have brown or black, progressively-rotting areas. Stands may be greatly reduced.

Verticillium wilt

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/peppermint-mentha-spp-verticillium-wilt

Verticillium wilt is a critical disease, and the main driver of mint disease management. It is caused by a fungus, *Verticillium dahliae*, which lives in the soil and in diseased plants. Once established in soil it is almost impossible to eradicate because of the presence of microsclerotia, which germinate and infect roots. The fungus grows throughout the vascular system and up into mint stems. After diseased plant parts die, microsclerotia form and can survive in the soil for several years. The pathogen is spread with infected rhizomes used for planting, and in contaminated surface irrigation water. Co-infection of *V. dahlia* and the root lesion nematode, *Pratylenchus penetrans*, increases disease incidence and severity.

The VCG 2B strain of *V. dahliae* is most aggressive and prevalent in mint. This strain infects potato but symptoms and damage on potato are very mild or do not occur. The VCG 4A and VCG 4B strains, which are frequently obtained from potato, infect mint but symptoms and damage on mint are mild or not evident.

Native spearmint is relatively resistant, but Scotch spearmint and Black Mitcham peppermint are susceptible. Redefined Murray Mitcham is moderately resistant, but this cultivar is not as vigorous as Black Mitcham in the Columbia Basin. Grasses including corn and related crops do not sustain the population, but fallow or grass rotations alone may take many years to effectively reduce soil populations below economic levels.

Infection causes upper leaves to twist and curl, bunching at the top of the plant. Infected plants are stunted, and foliage turns yellowish to red or bronze. Lower leaves die first, then the whole above-ground part of the plant. With flowering or other stresses, stems or plants may die too rapidly for these symptoms to be readily observed while they are occurring.

Weeds

One major limiting factor to a profitable mint crop is the development of dense weed populations, especially those weeds that affect the quality of the mint oil. Weeds have a significant impact on the organoleptic (i.e. flavor profile) quality of mint oil, ultimately reducing the value and marketability of the oil.

Newly established mint grows slowly and is susceptible to weed competition. Competition is most severe in mint during the first and second year of the stand before the canopy closes over. Even after canopy closure, winter annual and perennial weeds

can be major problems. It is important to reduce weed populations before the crop is planted because the herbicide options for newly established mint are limited.

Oil quality problems are more serious with broadleaf weeds than with grasses. Oil quality problems are most severe when pigweed, common groundsel, mayweed chamomile, prickly lettuce, and salsify are present. In addition to contaminating the oil, weeds also reduce the yield of mint crops. Weeds can also become a source of disease and insect pests if not managed effectively.

With the use of rotation crops, weeds must be eliminated before they go to seed to prevent the buildup of weed seed in the soil. Planting an annual crop such as grain or sudangrass for two seasons preceding the establishment of a mint field is a good strategy, because herbicides registered for use in these crops effectively control the broadleaf weeds that are most troublesome in mint.

Seedbed preparation activities before planting will eliminate many annual weeds, as will an application of herbicide before planting. Perennial weeds can be controlled by crop rotation, by fallowing in conjunction with repeated cultivations, or by herbicide applications.

The primary method of weed management after the mint crop is established is the use of herbicides. Because of the narrow planting arrangement of this crop, and the rapid spread of plants by stolons, close cultivation is generally not practiced after the first year.

Hand weeding, though costly, is also frequently necessary before harvest to eliminate mature broadleaf weeds such as mayweed chamomile, pigweed, or prickly lettuce that have escaped herbicide treatments, in order to prevent oil contaminants.

Mint pest management activities by crop stage

Preplant through planting

Mint can be planted in both spring and fall in the Pacific Northwest. Exact planting time varies based on region, soil moisture and temperature. Spring planting can take place anywhere between late February and April. Fall planting often takes place after the third week of September, through October. In Washington, mint is most commonly planted in the spring. In Idaho and western and northeastern Oregon, planting takes place primarily in the fall. Fall planted crops can be more challenging, depending on water availability and weather. Use of certified mint rootstock reduces the risk of introducing diseases, weeds or insects that may be associated with contaminated planting material.

Mint is planted in rows and can be harvested the first season, but at a lower yield than in 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.

Mint is often rotated with other crops, with the field returning to mint after three or more years. Rotation aids in the control of nematodes, diseases and weeds prior to planting. Longer rotations between mint stands is a strategy often used to mitigate against disease inoculum buildup in the soil of fields where problems have existed previously. 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. Irrigation method (furrow vs. sprinkler) will impact subsequent pest management practices. Irrigation can also impact pesticide efficacy.

Planting is a critical time for evaluation of field history and soil to understand Verticillium wilt pressure. Current soil testing methods only provide a coarse estimate of Verticillium wilt pressure because commercial tests cannot distinguish between, or specifically identify, the strains that infect mint.

Soil fumigation takes place during this crop stage, but does not take place once the crop is planted. In the Willamette Valley, fumigation is not as common, while in northeastern Oregon, 20% tpo40% of acres are estimated to be fumigated. In Washington, approximately 40% to 50% of acres are fumigated.

Field activities and pest management decisions that occur during preplant through planting

- Soil preparation: formation of beds, furrows or rills in surface-irrigated fields
- Soil testing for pH and overall soil fertility
- Preirrigation
- Fertilizer and lime applications

PAMS[1] practice	Pre-plant through planting pest management activities	Target pest(s)
Prevention	Ensure healthy rootstock, including certified stock	Verticillium wilt, nematodes
Avoidance	Use rotation crops – wheat, alfalfa, annual cereals	Nematodes and soil borne diseases, broadleaf weeds; limits access to primary and alternative crop hosts
	Follow potatoes or onions to take advantage of soil fumigation used for these crops	Nematodes, symphylans, Verticillium wilt
	Field selection based on disease history	Verticillium wilt
Monitoring	Soil testing; pre-plant nematode testing	Verticillium wilt, nematodes
Suppression	Soil-applied insecticides/fumigants: ▪ Ethoprop (Mocap): used pre-plant in the fall in the Willamette Valley region for nematodes and symphylans ▪ Metam sodium, metam potassium (Vapam, K-pam) ▪ 1,3 dichloropropene (Telone): used for nematode control; not effective against wilt. Generally, one application is made in spring or fall depending on pest pressure, but not used every year or in every place. Note: sandy soils do not fumigate well; poor efficacy is achieved in some areas	▪ Verticillium wilt, nematodes
	Biological nematicides (used by some growers): ▪ MeloCon WG (Paecilomyces lilacinus strain 251) ▪ Majestene (Burkholderia spp. strain A396) ▪ NemOMEX (Saponins of Quillaja Saponaria)	Nematodes
	Herbicides: ▪ 2,4 D: used in the fall after previous years' crop Glyphosate (Roundup): used in the fall after previous years' crop Terbacil (Sinbar): used just after planting Sulfentrazone (Spartan) (post-planting)	Perennial weeds
	Biofumigants including mustards: used in both conventional and organic fields	Perennial weeds, nematodes, Verticillium wilt

[1] See Appendix "Using PAMS Terminology," page 58

Critical needs for pest management during preplant through planting

Research topics

- Commercialize and make more widely available the current method for strain-specific testing for Verticillium. Explore opportunities to partner with potato producers on this effort to commercialize tests that can differentiate between strains that infect mint and potato.
- Identify effective control options for major mint pests, including possible biological control options and the use of biofumigants.
- Data collection and synthesis regarding best rotations (crops and lengths of rotation) for reduction in Verticillium in mint..
- Research the use of biofumigants in rotation with mint: efficacy and best practices.

Regulatory actions

- None at this time

Education

- Educate farm managers regarding the importance of using certified, disease-free rootstock.
- Educate farm managers regarding best practices for rotations, once understood through data synthesis, including ideal crops and the avoidance of crops that are hosts for Verticillium wilt.

First year dormancy

In Washington, there is not much dormancy after planting due to the spring planting time. In the Willamette Valley, northeastern Oregon, Columbia Basin, and Idaho, mint is planted in the fall and winter, from October/November through February/March, so has a dormant period before growth begins.

The planting year (first year) dormancy period differs from the established crop dormancy in that the lack of growth and spread between rows from rhizomes leaves more bare soil in the first year. Typically, fall-planted mint is assumed to be dormant at the time of planting, and does not actively grow (above ground) until the following spring. Rhizomes are planted into the fields, but there is no visible vegetation at this time. Dormancy occurs until there is visible growth above the soil surface.

Field activities and pest management decisions that may occur during first year dormancy

Harrowing beds

Cultivation (at emergence)

Reservoir tillage (trade name is “Dammer Diking): forming or cleaning of furrows or rills for surface irrigation.

Flaming for weeds

PAMS practice	First year dormancy pest management activities	Target pest(s)
Prevention		
Avoidance		
Monitoring	Scouting	Cutworm
Suppression	Herbicide applications: First (establishment) year, dormant (pre-emergence): ▪ Clomazone (Command) (spring application) ▪ Pendimethalin (Prowl) ▪ Terbacil (Sinbar) (Note: some herbicide products cannot be used during establishment year dormancy but can be used during dormancy after establishment)	Burn down for soil residual weeds
	Removal of winter annual weeds (hand-hoeing if necessary)	Weed management
	In the Willamette Valley, growers use: ▪ Clomazone (Command) ▪ Flumioxazin (Chateau): cannot be used if crop is not completely dormant ▪ Oxyfluorfen (Goal) ▪ Paraquat (Gramoxone) ▪ Sulfentrazone (Spartan) ▪ Terbacil (Sinbar)	
	Flaming	Weeds

Critical needs for pest management during first year dormancy

Research topics

None at this time

Regulatory actions

None at this time

Education

None at this time

Established crop dormancy

Established year dormancy takes place between October and March, when plants have gone dormant and are no longer actively growing. This takes place every year of the established crop, which may remain in production for up to five to six years.

Field activities and pest management decisions that may occur during established crop dormancy

- Cultivation (at emergence)
- Reservoir tillage ("Dammer Diking" trade name): forming or cleaning of furrows or rills for surface irrigation
- Soil testing for pH/fertility levels

PAMS practice	Established crop dormancy pest management activities	Target pest(s)
Prevention		
Avoidance	Ensure good weed control	Winter annuals; perennial weeds; growers also attribute good weed control as helping with cutworm management
	Mow regrowth from the previous year, which can provide new shoots and encourage cutworm feeding	Cutworms
Monitoring	Scouting	Cutworm, weeds
Suppression	Flaming weeds	Winter annuals
	Insecticide application: Chlorpyrifos (Lorsban)	Cutworm
	Established crop, dormant (pre-emergence) herbicide applications: ▪ Carfentrazone -ethyl (Aim) ▪ Clomazone (Command) ▪ Flumioxazin (Chateau) ▪ Oxyfluorfen (Goal) ▪ Paraquat (Gramoxone) ▪ Pendimethalin (Prowl) ▪ Pyroxasulfone (Zidua) ▪ Sulfentrazone (Spartan) ▪ Terbacil (Sinbar) Note: different mixes and higher concentrations are used during established year dormancy based on establishment of perennial weeds	Burn down herbicides for established and newly germinated weeds; pre-emergent herbicides for fall/winter germinating weeds
	In the Willamette Valley, growers use: ▪ Flumioxazin (Chateau): cannot be used if crop is not completely dormant ▪ Oxyfluorfen (Goal) ▪ Paraquat (Gramoxone) ▪ Terbacil (Sinbar)	

Critical needs for pest management during established crop dormancy

Research topics

- Develop improved methods of scouting for cutworms to enable earlier detection at lower pest levels and when larvae are in early instar stages and control is more effective.
- Identify and test new and alternative products for early season insect control that can serve as replacements for chlorpyrifos and ethoprop.
- Develop new pre-emergent soil active herbicides as alternative options to terbacil.

Regulatory actions

- Obtain registrations for new and alternative products for early season insect control that can serve as alternatives and replacements to chlorpyrifos and ethoprop.
- Maintain current registrations for chlorpyrifos and ethoprop for as long as possible and until there are effective alternatives in place.

Education

- Educate growers and farm managers regarding the importance of effective weed control programs during dormancy, which also help with cutworm management.
- Educate farm managers on the importance of eliminating weed seed banks in established crops.

Vegetative growth to harvest

Vegetative growth takes place at different timings depending on the planting time, region and program. For double-cut mint, vegetative growth spans from March or April to early June or mid-July, when the first cutting would take place, then again (following a short postharvest phase of 2–3 weeks) after the first cutting. Second cutting usually occurs in September.

For single-cut mint, vegetative growth generally begins at the same time as double-cut mint, in March or April depending on the spring, with rapid linear growth in May and June until harvest, which is generally in late July or early August.

Note: see https://catalog.extension.oregonstate.edu/em9018 for biomass curves for WV single-cut mint.

During this period of active vegetative growth, many insects, mites, diseases and weeds need to be controlled. At this time, fields are scouted for pests, irrigation continues, fertilizers are applied and pest control measures are implemented as needed. Hand-hoeing is sometimes needed in fields where weeds have escaped other control measures.

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. The mint field continues to be irrigated and fertilized between cuts to encourage vigorous regrowth.

Field activities and pest management decisions that may occur during vegetative growth.

- Irrigation
- Fertilizer —applied via spreader, or applied with irrigation water both in overhead or surface irrigation systems
- Cleaning out corrugates/furrows

PAMS practice	Vegetative growth pest management activities	Target pest(s)
Prevention	No effective tactics available	
Avoidance	Preserve natural predators (big-eyed bugs [*Geocoris* spp.], damsel bugs, spiders, lacewing, lady beetles, and predatory mites)	Mites
Monitoring	Scouting	Weeds (grasses), mites, root weevil, cutworms, other insects
	Utilization of OSU mint pest alerts	Mint Root Borer, Variegated Cutworms, Alfalfa/Cabbage Loopers
	Petiole sampling/testing	

PAMS practice	Vegetative growth pest management activities	Target pest(s)
Suppression	Hand rogueing	Weeds
	Ladybeetle release	Aphids
	Release of predator mites	Spider mites
	Insecticide applications: ▪ Chlorpyrifos (Lorsban) ▪ Oxamyl (Vydate)	Nematodes, symphylans, cutworms
	▪ *Bacillus thuringiensis* products (varied efficacy)	Caterpillars, worms
	▪ Acephate (Orthene) ▪ Thiamethoxam (Actara)	Root weevil
	▪ Chlorantraniliprole (Coragen): needs to be followed by irrigation or precipitation to achieve optimal response	Cutworm, mint root borer
	Miticide applications: ▪ Abamectin ▪ Bifenazate (Acramite) ▪ Etoxazole (Zeal) ▪ Hexythiazox (Onager) ▪ Propargite (Comite)	mites
	Fungicide/biofungicide applications: ▪ *Bacillus amyloliquefaciens* strain D747 (Double Nickel 55) ▪ Copper products (Instill) ▪ Hydrogen dioxide, peroxyacetic acid (OxiDate) ▪ Sulfur	Mildew
	▪ Azoxystrobin (Quadris) ▪ *Bacillus amyloliquefaciens* strain D747 (Double Nickel 55) ▪ Propiconazole ▪ Pyraclostrobin (Headline) ▪ *Reynoutria sachalinensis* (Regalia) Note: in the Willamette Valley, rust requires preventative control every 2–3 weeks until harvest	Preventative sprays for mildew, rust
	Herbicide applications: ▪ Bentazon (Basagran) ▪ Bromoxynil (Buctril) ▪ Quizalofop p-Ethyl (Assure II) ▪ Clethodim (Select Max) ▪ Clopyralid (Stinger) ▪ MCPB sodium salts (Thistrol) ▪ Pyridate (Tough) ▪ Sethoxydim (Poast) ▪ Terbacil (Sinbar)	Emerged annual and perennial weeds
	B**iological Nematicide applications:** ▪ *Paecilomyces lilacinus* strain 251 (MeloCon WG) ▪ *Burkholderi*a spp. strain A396 (Majestene)	

Critical needs for pest management during vegetative growth

Research topics

- Investigate the level of resistance to miticides, such as hexythiazox (Onager), both within and between species.
- Investigate adjacent host crops as potential sources for mites, including sweet corn, hops, and hemp.
- Research possible new mite species (such as Pacific mite) that are not effectively controlled by current products (such as hexythiazox).
- Develop more effective organic-approved tools for mint pest management.
- Research to improve post-emergent broadleaf weed control, including the development of alternative products and best practices for rotation.
- Conduct efficacy testing for existing post-emergent broadleaf weed control products to identify potential new modes of action.
- Research effective management programs for stem borer, including effective management tools, economic and action thresholds, treatment timing, and possible interactions with Verticillium wilt .
- Continue research on nematodes and effective control options.
- Research the potential for using entomopathogenic nematodes for mint root borer control on a commercial scale; the tools currently exist, but these are cost-prohibitive and difficult to scale up to commercial scale.
- Conduct research to determine levels of herbicide resistance in problem weed infestations, particularly with groundsel, pigweed complex (resistance noted to terbacil; prostrate pigweed showing resistance), and annual bluegrass.
- Develop effective management tools for major weed challenges including prickly lettuce, bindweed, catchweed bedstraw and sharppoint fluvellin.
- Demonstrate and quantify the impact of weeds on mint oil quality and market value.
- Research and identify lower risk and effective replacement products for acephate (current alternatives include lambda-cyhalothrin and chlorpyrifos; lower risk alternatives needed).
- Research cutworm resistance to acephate, and develop alternatives to acephate that will also manage thrips and grasshoppers (note: chlorantraniliprole is an effective alternative for cutworm, but not effective against thrips or grasshoppers).
- Identify effective fungicides against powdery mildew and rust.
- Research effective, reduced-risk alternatives to chlorpyrifos.
- Research best practices for use of beneficial predators to control mint pests.
- Investigate the interaction between nitrogen management and pest presence, and whether high nitrogen rates may increase pest pressure.
- Research the efficacy of using of drop tubes on irrigation pivots and impacts on mildew and rust levels.
- Identify effective controls for late-season armyworm management (need a short PHI).
- Research the efficacy of Double Nickel (*Bacillus amyloliquefaciens* strain D747) for use on mint pests including Verticillium wilt as well as nematodes.

Regulatory actions

- To combat resistance developing to currently effective miticides, register cost-effective alternatives to hexythiazox (Onager); current alternatives are expensive.
- Register lower-risk and effective replacement products for acephate once identified (current alternatives include lambda-cyhalothrin and chlorpyrifos; lower-risk alternatives needed).
- Register fluoxypyr (Starane) for use in mint.
- Streamline the pesticide registration process to reduce time lags and be able to address emerging issues related to resistance or risk reduction.
- Register cyantraniliprole as an alternative to chlorpyrifos, acephate, and chlorantraniliprole.
- Encourage manufacturers to produce entomopathogenic nematodes for mint root borer control on a scale that supports commercial production.

Education

- Educate farm managers on the importance of treating mites only as needed to best manage resistance; encourage the use of predator mites to treat mite outbreaks and reduce reliance on miticides.
- Educate farm managers on best practices for pyrethroid use, once registered, to avoid mite flareups.
- Develop and support more training programs to promote and increase the number of independent consultants.
- Educate farm managers on possible effective alternatives to acephate and why this is important.
- Educate farm managers on best practices for nutrient management, including guidance on ideal timing of nitrogen applications for enhancing fertility.
- Educate farm managers on importance of using drop tubes on pivots to avoid overhead sprinkling and support better disease management.

Postharvest

This section applies to the post-harvest period following single-cut mint, as well as the postharvest period following the second cutting of double-cut mint. The following section, “Between cuttings,” addresses post-harvest issues following the first cutting of double-cut mint.

The timeframe for this stage ranges from early to mid-August through October, and into winter dormancy.

Field activities and pest management decisions that may occur during post-harvest

- Irrigation
- Flaming weeds

PAMS practice	Post-harvest pest management activities	Target pest(s)
Prevention		
Avoidance	Add mint crop residue back to fields to increase soil nutrients and maintain healthy plants	Healthy plants better avoid pest outbreaks
Monitoring	Visual scouting	Weeds, cutworms, armyworms
	Soil/rhizome sampling	Mint root borer, cutworms
	Testing for nematodes after harvest, while soil temperatures are still warm	Nematodes
Suppression	Hand weeding/hoeing	General weed control
	Flaming	Weeds
	Insecticide applications:	
	▪ Chlorpyrifos (Lorsban): used in Idaho and eastern Oregon; used with overhead irrigation only; not effective in furrow-irrigated fields	Root borer, spring cutworms
	▪ Chlorantraniliprole (Coragen): not as effective in furrow irrigated fields	Root borer
	▪ Acephate (Orthene): 2-week PHI limits use during this timeframe	Late season armyworm
	Nematicides: ▪ Ethoprop (Mocap) ▪ Oxamyl (Vydate)	Nematodes, root borer, symphylans
	▪ *Paecilomyces lilacinus* strain 251 (MeloCon WG): used by some growers	Nematodes
	Herbicide applications:	
	▪ Clethodim (Select Max) ▪ Terbacil (Sinbar) (not used with Buctril)	General weed control
	Bromoxynil (Buctril)	Groundsel

Critical needs for pest management during post-harvest

Research topics

- Research the efficacy of chlorantraniliprole (Coragen) for control of spring cutworms.
- Research the efficacy of Indoxacarb (Avaunt) for control of loopers and cutworms.
- Identify additional effective controls for root borer in furrow-irrigated fields.
- Clarify last pre-harvest application date for avoiding clopyralid detections in crop residue.

Regulatory actions

- Clarify regulations related to single- vs. double-cut mint, and the impacts and implications, including the “once per season” application limit and how this relates to double-cut mint, which has more than one harvest.

Education

- Educate farm managers regarding the use of clopyralid and its persistence in crop residue, which will impact waste that might be sold to composters.
- Educate farm managers on feed restrictions for mint used for cattle feed.

Between cuttings

This stage takes place in double-cut mint, and comprises the period after the first cutting and before the second cutting. The timeframe for this stage ranges from mid-June to mid-July (timing of first cutting) through mid-August. Commonly, there are 14–21 days of "post-harvest" between the first and second cuttings, and before vegetative growth begins. This stage covers that "post-harvest" stage after the first cutting, and before vegetative growth begins.

When the canopy is opened up by the first cutting, weeds can quickly become a problem. So good weed control is a primary activity during this stage.

Field activities and pest management decisions that may occur between cuttings

- Reclean furrows
- Irrigation management
- Fertilizer
- Weed surveys/herbicide applications

PAMS practice	Between cuttings pest management activities	Target pest(s)
Prevention		
Avoidance		
Monitoring	Scouting	Weeds
Suppression	Herbicide applications: ▪ Clethodim (Select) ▪ Pyridate (Tough) ▪ Quizalofop (Assure II) ▪ Sulfentrazone (Spartan) ▪ Terbacil (Sinbar)	General weed control

Critical needs for pest management between cuttings

Research topics

- Conduct more soil-active herbicide research and efficacy trials to identify new registrations that minimize crop injury.

Regulatory actions

- Clarify regulations related to single- vs. double-cut mint, and the impacts and implications, including the “once per season” application limit and how this relates to double cut mint, which has more than one harvest.

Education

- None at this time.

Invasive and emerging pests

Insects and mites

Mint Stem borer

For more information, see: https://pnwhandbooks.org/insect/agronomic/mint/mint-mint-stem-borer.

Mint stem borer is currently not a threshold pest, but the problem can intensify when Verticillium wilt is also an issue. This pest should be monitored as there are currently no registered insecticides for control.

Weeds

Emerging weed issues that need monitoring include bladder campion (*Silene vulgaris*), night flowering catch fly (*Silene noctiflora*), and sulfur cinquefoil *(Potentilla supina)*.

Also, Terbacil resistant pigweeds are an established problem, including redroot pigweed, prostrate pigweed, and palmer amaranth.

Critical needs for invasive and emerging pests

Ongoing monitoring for emerging weeds

References

Jepson, P.C., Murray, K., Bach, O., Bonilla, M.A., Neumeister, L. (2020). Selection of pesticides to reduce human and environmental health risks: a global guideline and minimum pesticides list. Lancet Planetary Health 4: e56-53. Available online at: https://doi.org/10.1016/S2542-5196(19)30266-9

Pacific Northwest Weed Management Handbook. 2018. Oregon State University, Washington State University, and the University of Idaho. https://pnwhandbooks.org/weed

Pacific Northwest Plant Disease Management Handbook. 2018. Oregon State University, Washington State University, and the University of Idaho. https://pnwhandbooks.org/plantdisease

Pacific Northwest Insect Management Handbook. 2018. Oregon State University, Washington State University, and the University of Idaho. https://pnwhandbooks.org/insect

Pest Management Strategic Plan for Pacific Northwest Mint Production. 2002. https://ipmdata.ipmcenters.org/documents/pmsps/PNWMintPMSP.pdf

UC IPM Pest Management Guidelines: http://ipm.ucanr.edu/PMG/r61700111.html

Appendices

Seasonal activity tables for mint

(Oregon, east of Cascades)

Field activities (other than pest management)												
Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Soil preparation								x	x	x	x	x
Soil analysis		x	x					x	x	x		
Planting			x	x						x	x	
Fertilization				x	x	x	x					
Irrigation				x	x	x	x	x	x			
Harvest							x	x	x			
Pest management activities												
Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Fungicide application							x					
Fumigation preplant			x	x				x	x	x		
Scouting		x	x	x	x	x	x	x	x	x	x	
Herbicide, dormancy	x	x	x								x	x
Hand rogueing weeds					x	x	x					
Herbicide, postemergent					x	x	x		x	x		
Herbicide, postharvest									x	x	x	
Insecticide application			x	x	x	x	x	x	x	x		
Miticide application					x	x	x	x				
Nematicide application				x	x							

Seasonal pest management activities for mint

(Oregon, east of Cascades)

Notes: X = times when pest-management strategies are applied to control these pests, not all times when pest is present.

Insects	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Alfalfa looper					X	X						
Aphid					X	X						
Armyworm			X	X			X					
Cabbage looper				X	X							
Cutworm						X	X	X				
Grasshopper					X							
Mint root borer							X	X	X			
Mint stem borer					X	X						
Root weevil						X						
Spider mite					X	X	X	X				
Pathogens	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Nematodes (needle, pin, Root-knot, Root-lesion)				X				X	X	X		
Powdery mildew						X						
Verticillium wilt				X				X	X	X	X	
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual grasses	X	X	X		X	X	X					X
Perennial grasses								X	X			
Annual broadleaves	X	X	X			X	X				X	X
Perennial broadleaves								X	X			

Seasonal activity tables for mint

(Idaho)

Field activities (other than pest management)												
Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Cultivation (first year)				X	X							
Fertilization				X	X	X	X	X	X			
Irrigation				X	X	X	X	X	X			
Soil analysis			X	X						X	X	
Soil preparation		X	X	X						X	X	
Planting		X	X	X						X	X	
Plant tissue analysis					X	X	X					
Corrugate (rill)		X	X					X	X			
Harvest						X	X	X	X			

Pest management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Fungicide application					X	X	X					
Fumigation (preplant)		X	X	X				X	X	X		
Scouting/monitoring		X	X	X	X	X	X	X	X	X	X	
Herbicide, dormancy	X	X										X
Hand rogueing weeds						X	X					
Herbicide, post-emergence				X	X	X	X	X				
Herbicide, between cuttings							X					
Herbicide, post-harvest single cut								X	X	X		
Insecticide				X	X	X	X	X	X			
Miticide					X	X	X	X				
Nematicide			X	X						X		

APPENDIX D

Seasonal pest management activities for mint

(Idaho)

Notes: X = times when pest-management strategies are applied to control these pests, not all times when pest is present.

Insects	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Alfalfa/Cabbage looper						X	X					
Aphid						X	X					
Cutworm/Armyworm			X	X		X	X	X	X			
Grasshopper					X	X	X	X				
Mint flea beetle								X				
Mint root borer							X	X	X			
Mint stem borer				X	X	X						
Strawberry root weevil						X						
Spider mite					X	X	X	X				
Wireworm				X	X							
Pathogens	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Black stem rot						X	X					
Nematodes (needle, Root-knot, Root-lesion)			X	X						X	X	
Powdery mildew						X	X	X				
Verticillium wilt			X							X	X	
Rust						X						
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual grasses		X	X				X				X	X
Perennial grasses					X	X	X	X				
Annual broadleaves	X	X	X	X	X	X					X	X
Perennial broadleaves					X	X				X		

Seasonal activity tables for mint

(Central WA and Columbia Basin OR)

Field activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Soil sampling	X	X								X	X	
Soil Prep/tillage		X	X	X								
Planting		X	X							X	X	
Irrigation			X	X	X	X	X	X	X	X		
Fertilization				X		X	X					
Hoeing				X	X	X	X					
Petiole sampling					X	X	X	X				
Irrigation monitoring				X	X	X	X	X	X			
Harvest						X	X	X	X	X		

Pest management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Pest scouting			X	X	X	X	X	X	X	X		
Nematode sampling						X	X		X	X		
Miticide application					X	X	X	X				
Nematicide application			X	X					X	X		
Insecticide application				X	X	X	X	X				
Fungicide application				X	X	X	X	X				
Fumigation										X	X	X
Herbicide, pre-emergent		X	X			X	X					
Herbicide, vegetative growth				X	X		X	X				

Seasonal pest management activities for mint

(Central WA and Columbia Basin OR)

Notes: X = times when pest-management strategies are applied to control these pests, not all times when pest is present.

Insects	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Aphid						x		x	x			
Armyworm								X				
Cutworm			X	X								
Grasshopper						X	X	X				
Mint root borer									X	X		
Spider mite				X	X	X	X	X				
Pathogens	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Black stem rot/phoma				X	X	X	X	X	X			
Nematodes (needle, pin, Root-knot, Root-lesion)			X	X					X	X		
Powdery mildew				X	X	X	X	X				
Rust					X	X	X					
Rhizoctonia								X	X			
Fusarium								X	X			
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual grasses				X	X	X	X	X	X			
Perennial grasses	X	X	X	X	X	X						
Annual broadleaves				X	X	X	X	X	X			
Perennial broadleaves	X	X	X	X	X	X	X	X	X			

Seasonal activity tables for mint

(Western OR and WA)

Field activities (other than pest management)												
Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Fertilization/lime application				X	X	X			X			
Irrigation					X	X	X	X	X	X		
Planting			X	X					X			
Soil sampling (nutrients)			X					X				
Soil sampling (pests)			X	X	X	X	X	X				
Harvest								X				
Rolling mint						X						
Pest management activities												
Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Herbicide application	X			X	X				X			X
Insecticide application			X	X	X	X	X	X	X			
Pest scouting			X	X	X	X	X	X	X	X		
Nematode sampling						X	X		X	X		
Miticide application					X	X	X	X				
Nematicide application			X	X								
Fungicide application				X	X	X	X	X				

Seasonal pest management activities for mint

(Western OR and WA)

Notes: X = times when pest-management strategies are applied to control these pests, not all times when pest is present.

Insects	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Alfalfa looper							X					
Aphid				X	X	X	X	X				
Cabbage looper							X					
Cutworm							X	X				
Garden symphylan			X						X			
Mint root borer									X			
Root weevil						X						
Spider mite					X	X	X					
Pathogens	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Nematodes (needle, pin, Root-knot, Root-lesion)			X						X			
Rust				X	X	X	X					
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual grasses	X			X	X				X			
Perennial grasses	X			X	X				X			
Annual broadleaves	X			X	X				X			
Perennial broadleaves	X			X	X				X			

Mint pesticide risk management

The letters below represent four categories of nontarget risk potentially affected by pesticide use. If a letter is used, it indicates that mitigation is needed at commonly used application rates in order to reduce risk. Risks were calculated using the risk assessment tool IPM PRiME. This table does not substitute for any mitigations required by the product label. For more information see Appendix X "Pesticide Risk Classification".
A= Risks to aquatics: invertebrates and fish
T= Risks to terrestrial wildlife: birds and mammals
P= Risks to pollinators: risk of hive loss
B= Risks to bystanders: e.g., a child standing at the edge of the field
"ND" means no data is available for this product.
"–" means that risks are not anticipated for this product based on the categories of risk analyzed
HHP = Any product highlighted in yellow is classified as a "highly hazardous pesticide" (HHP) by the World Health Organization and the Food and Agriculture Organization of the United Nations. These products may pose significant risks to human health or the environment, and risk reduction measures may not be effective in mitigating these risks.

	Risks requiring mitigation	Pre-plant	Vegetative Growth	Between cuttings	Dormancy	Target pests	Comments
Pesticides	**Average number of applications per crop stage, if used**						
Insecticides and fumigants							
1,3 dichloropropene (Telone II, Telone C-17)	A, T, P, B	1				Nematodes	
Abamectin (ABBA, Agri-Mek)	A, P		1			Mites	
Acephate (Orthene)	T, P		1			Caterpillars	
Beauveria bassiana (Mycotrol ES)	_						Not widely used
Bifenazate (Acramite 4SC)	_		1			Mites	
Bt (*Bacillus thuringiensis*)	_		3			Caterpillars	Mostly organic
Burkholderia spp. (Venerate XC)	ND					Mites, caterpillars	Not widely used
Chlorantraniliprole (Coragen)	-				1	Mint root borer	* Used either preharvest in July or postharvest in Sept/Oct
Chlorantraniliprole/thiamethoxam (Voliam Flexi)	A, P						NU

	Risks requiring mitigation	Pre-plant	Vegetative Growth	Between cuttings	Dormancy	Target pests	Comments
Pesticides	**Average number of applications per crop stage, if used**						
Chlorpyrifos (Lorsban Advanced)	A, T, P, B		1		1	Mint root borer	In fall/after harvest. Used for cutworm in early spring
Dicofol (Dicofol 4E)	T, B						Not widely used
Ethoprop (Mocap EC or 15G)	HHP				1		Nematodes, mint root borer, symphylan
Etoxazole (Zeal)	A		1			Mites	
Fenpyroximate (FujiMite 5EC)	A, T		1			Mites	
Flonicamid (Beleaf 50SG)	-						Not widely used
Grandevo (*Chromobacterium subtsugae*)	ND						Not widely used
GS-omega/kappa/*Bacillus thuringiensis* (Spear-C Biological Insecticide)	ND						Not widely used
Hexythiazox (Onager Optek)	-		1			Mites	
Indoxacarb (Avaunt)	P						Not widely used
Iron phosphate + spinosad (Bug-N-Sluggo)	P		1			Snails, slugs	Willamette Valley only
Malathion (Gowan Malathion 8)	P		1				
Metaldehyde	-		1				Willamette Valley only
Metam potassium	A, T	1					
Metam sodium (Vapam)	A, T	1					After harvest
Methomyl (Lannate SP)	HHP						Not widely used
Methoxyfenozide (Intrepid 2F)	-						Not widely used
Neem oil or azadirachtin (Neemix 4.5 IGR, Certis)	-						Not widely used

Pesticides	Risks requiring mitigation	Pre-plant	Vegetative Growth	Between cuttings	Dormancy	Target pests	Comments
	Average number of applications per crop stage, if used						
Oxamyl (Vydate L)	HHP		1		1	Nematodes	
Oxydemeton-methyl (MSR Spray Concentrate)	HHP						Not widely used
Parasitic nematodes (BioNem-C, Becker Underwood)	ND						Not widely used
Propargite (Omite 6E, Comite)	T		1			Mites	
Pyrethrins	P						Not widely used
Spinetoram (Radiant SC)	P						Not widely used
Spinosad (Success, Entrust SC)	P						Not widely used
Tebufenozide (Confirm 2F)	-		1			caterpillars	
Thiamethoxam (Actara)	A, P		2				Not widely used; expensive
Fungicides							
Azoxystrobin (Quadris Flowable)	A		3			Mildew	
Azoxystrobin + propiconazole (Quilt, Quilt Xcel)	A		3			Mildew	
Bacillus amyloliquefaciens strain D747 (Double Nickel LC)	ND					Mildew	Efficacy unknown; not widely used
Bacillus subtilis (Serenade MAX)	-					Mildew	
Chlorothalonil (Equis)	A, T		0				OR label; not registered in WA or ID
JMS Stylet Oil	ND						
Myclobutanil (Rally 40WSP)	T					Mildew	
Potassium bicarbonate (Kaligreen)	-					Mildew	
Propiconazole (Tilt, Bumper, Propimax EC)	-		3			Mildew	
Pyraclastrobin (Headline)	A					Mildew	

Pesticides	Risks requiring mitigation	Pre-plant	Vegetative Growth	Between cuttings	Dormancy	Target pests	Comments
	Average number of applications per crop stage, if used						
Reynoutria sachalinensis (Regalia)	-						
Sulfur products	-					Mildew	
Herbicides							
Bentazon (Basagran)	-		1				Usually establishment year only
Bromoxynil (Buctril)	-		1	1	1		Usually establishment year only
Carfentrazone (Aim)	-				1		Willamette Valley only
Clethodim (Select Max)	-		1				Used when needed
Clomazone (Command)	-				1		Used mainly in WA
Clopyralid (Stinger)	-						Used when needed but not every year
Diuron (Karmex/Direx)	T				1		Not used in WA
Flumioxazin (Chateau)	HHP				1		Not widely used in WA. Used in other areas almost every year.
MCPB (Thistrol)	-		1				Only used on bindweed patches, not entire fields
Napropramide (Devrinol)	T						

Pesticides	Risks requiring mitigation	Pre-plant	Vegetative Growth	Between cuttings	Dormancy	Target pests	Comments
	Average number of applications per crop stage, if used						
Oxyfluorfen (Goal)	A, T				1		Used some in Willamette Valley, but not in other areas
Paraquat (Gramoxone Inteon, Firestorm)	HHP				1		Used almost every year in all areas
Pendimethalin (Prowl H20)	T				1		Used in WA and ID only
Pyridate (Tough)	-			1			Used when needed; between double cuts only pending EPA Section 3 application determination
Quizalafop (Assure II)	-		1				Used rarely but when needed
Sethoxydim (Poast)	-		1				Used rarely but when needed
Sulfentrazone (Spartan)	T				1		Not widely used (all regions)
Terbacil (Sinbar)	-	1+	1	1	1		
Trifluralin (Treflan)	T	1					Not often used

Efficacy ratings for PATHOGEN and NEMATODE management tools in mint

Rating scale: E = excellent (90–100% control); **G** = good (80–90% control); **F** = fair (70–80% control); **P** = poor (< 70% control); **?** = efficacy unknown in management system—more research needed.

Management tools	Leaf Blight	Black stem rot	Needle nematode	Root-rot nematode	Root-lesion nematode	Powdery Mildew	Spotted wilt	Stolon canker and decay	Verticillium wilt	Rust	Comments
Fungicides and fumigants											
1,3 dichloropropene (Telone II, Telone C-17)			F	F	F						
Azoxystrobin (Quadris Flowable)						G				G	
Azoxystrobin + propiconazole (Quilt, Quilt Xcel)						G				G	
Bacillus amyloliquefaciens strain D747 (Double Nickel LC)											Not widely used
Bacillus subtilis (Serenade MAX)											Not widely used
Chlorothalonil (Equis)											Not widely used
JMS Stylet Oil											Not widely used
Metam sodium (Vapam HL)			G	G	G				G		
Myclobutanil (Rally 40WSP)						G				G	
Potassium bicarbonate (Kaligreen)											Not widely used
Potassium N-methyldythiocarbamate (K-pam)											Not widely used
Propiconazole (Tilt, Bumper, Propimax EC)						G				G	
Pyraclastrobin (Headline)						G				G	
Reynoutria sachalinensis (Regalia)											Not widely used
Sulfur products						G					
Unregistered/new chemistries											
Fluopyram (Vellum)			?	?	?						Registration pending. Efficacy research underway.

Efficacy ratings for INSECT management tools in mint

Rating scale: E = excellent (90–100% control); **G** = good (80–90% control); **F** = fair (70–80% control); **P** = poor (< 70% control); **?** = efficacy unknown, more research needed

Management tools	Alfalfa Looper	Aphid	Armyworm	Cranefly	Cabbage looper	Cutworm	Garden symphylan	Grasshopper	Mint flea beetle	Mint root borer	Mint stem borer	Painted lady	Redback cutworm	Root weevil	Slug	Spider mite	Thrips	Wireworm	Comments
Insecticides																			
Abamectin (ABBA, Agri-Mek 0.15EC)																G			
Acephate (Orthene)	G		G		G	G							G						
Beauveria bassiana (Mycotrol ES)																			Not widely used
bifenazate (Acramite 4SC)																G			
Bt (*Bacillus thuringiensis*)			F		F	F							F						
Burkholderia spp. (Venerate XC)																			Not widely used
Chlorantraniliprole (Coragen)	G		G		G	G				G									
Chlorantraniliprole/thiamethoxam (Voliam Flexi)	G	G	G		G	G				G									Expensive
Chlorpyrifos (Lorsban Advanced)	G	G	G		G	G				G			G						
Dicofol (Dicofol 4E)																			Not widely used
Ethoprop (Mocap EC or 15G)										F									
Etoxazole (Zeal)																G			
Fenpyroximate (FujiMite 5EC)																G			
Flonicamid (Beleaf 50SG)		G																	
Grandevo (Chromobacterium subtsugae)																			Not widely used
GS-omega/kappa/Bacillus thuringiensis (Spear-C Biological Insecticide)																			Not widely used
Hexythiazox (Onager Optek)																G			

Management tools	Alfalfa Looper	Aphid	Armyworm	Cranefly	Cabbage looper	Cutworm	Garden symphylan	Grasshopper	Mint flea beetle	Mint root borer	Mint stem borer	Painted lady	Redback cutworm	Root weevil	Slug	Spider mite	Thrips	Wireworm	Comments
Indoxacarb (Avaunt)																			Not widely used
Iron phosphate + spinosad (Bug-N-Sluggo)																			Not widely used
Malathion (Gowan Malathion 8)								G											
Metaldehyde																			Not widely used
Metam sodium (Vapam)																			Not widely used
Methomyl (Lannate SP)																			Not widely used
Methoxyfenozide (Intrepid 2F)																			Not widely used
Neem oil or azadirachtin (Neemix 4.5 IGR, Certis)																			Not widely used
Oxamyl (Vydate L)																			Not widely used
Oxydemeton-methyl (MSR Spray Concentrate)		G																	
Parasitic nematodes (BioNem-C, Becker Underwood)																			Not widely used
Propargite (Omite 6E, Comite)																G			
Pyrethrins																			Not widely used
Spinetoram (Radiant SC)																			Not widely used
Spinosad (Success, Entrust SC)																			Not widely used
Tebufenozide (Confirm 2F)																			NOT WIDELY USED
Unregistered/new chemistries																			
Lambda-cyhalotrhin (Warrior)			E			E													Registration pending
Spiromesifen (Oberon)																G			Registration pending
Cyantraniliprole (Verimark)										?	?								Efficacy research being conducted

Efficacy ratings for WEED management tools in mint

Rating scale: E = excellent (90–100% control); **G** = good (80–90% control); **F** = fair (70–80% control); **P** = poor (<70% control); **?** = efficacy unknown—more research needed

Note**:** Weed size or stage of growth is an important consideration with most postemergence herbicides.

In "Type" column, Pre = soil-active against pre-emerged weeds; Post = foliar-active against emerged weeds.

Management tools	Pre/ Post	Annual grasses	Perennial grasses	Annual broadleaves	Perennial broadleaves			Comments
Bentazon (Basagran)	Post			F	P			Tank mixes help
Bromoxynil (Buctril)	Post			G	F			Timing/temperature dependent; applied through chemigation
Carfentrazone (Aim)	Pre			P-G	P			
Clethodim (Select Max)	Post	G	F					
Clomazone (Command)	Pre	G	P	F	P			Susceptible to off-target movement
Clopyralid (Stinger)	Post			E*	G*			*Depends on the weed
Diuron (Karmex/Direx)	Pre	P		F-P	P			
Flumioxazin (Chateau)	Pre			E				Dry weather can reduce efficacy
MCPB (Thistrol)	Post				G			Bindweed only
Napropramide (Devrinol)								Not widely used
Oxyfluorfen (Goal)	Pre			G				Not used much outside the Willamette Valley; rainfall or overhead irrigation required to activate chemical
Paraquat (Gramoxone Inteon, Firestorm)	Pre	E		E				
Pendimethalin (Prowl H20)	Pre	F		G				
Pyridate (Tough)	Post			E	F			
Quizalafop (Assure II)	Post	E	F					
Sethoxydim (Poast)	Post	G	F					Rainfall or overhead irrigation required to activate chemical
Sulfentrazone (Spartan)	Pre/ Post			E	P			

Management tools	Pre/ Post	Annual grasses	Perennial grasses	Annual broadleaves	Perennial broadleaves			Comments
Terbacil (Sinbar)	Pre/ Post	G	F	G	P			
Trifluralin (Treflan)	Pre	F	P	P	P			Must be soil incorporated
Vapam	Pre	F	F	F	F			
Unregistered/new chemistries								
Sharpen	Pre			E				
Zidua	Pre	G	G	G				

Pesticide risk classification

Paul Jepson & Katie Murray, Oregon State University

The pesticide risk analysis is based on work by the Oregon IPM Center that forms the basis for a number of 3rd party certification standards for IPM (Jepson *et al.* 2020). We analyzed more than 650 pesticides, identifying those that were hazardous to human health, and those that posed manageable risks to aquatic life, wildlife, pollinators and bystanders. The analysis is intended to provide guidance that is supplementary to the pesticide label, which is the primary source of risk-management information and mandatory practices.

Risk to aquatic life

Pesticides qualified for this risk category if risks to one or more of the following risk models exhibited 10% or greater risk of an adverse outcome at a typical application rate: aquatic algae, aquatic invertebrates, or fish (reproduction).

Risk to terrestrial wildlife

Pesticides qualified for this risk category if risks to one or more of the following risk models exhibited 10 percent or greater risk of an adverse outcome at a typical application rate: avian reproduction, avian acute, or small mammal risk.

Risk to pollinators

Pesticides were selected based on a widely used hazard quotient (HQ) resulting of pesticide application rate in gallons of active ingredient per hectare, and contact LD50 for the honey bee (*Apis mellifera*). Values of the hazard quotient less than 50 have been validated as low risk in the European Union, and monitoring indicates that products with a hazard quotient greater than 2,500 are associated with a high risk of hive loss. The hazard quotient value (350 or greater) used by the Oregon IPM Center corresponds to a 15% risk of hive loss. The quotient includes a correction for systemic pesticides, where risks to bees are amplified.

Inhalation risk

Inhalation risk to bystanders was calculated using the ipmPRiME model for inhalation toxicity (Jepson et al., 2014), calculated on the basis of child exposure and susceptibility. This index is protective for workers who may enter fields during or after application, and also bystanders.

Using PAMS terminology

This system of terminology for IPM was developed for use by U.S. Federal agencies seeking to support adoption of IPM by farmers. The table below summarizes common tactics used in agricultural IPM using a Prevention, Avoidance, Monitoring, Suppression (PAMS) classification. We also define (in ***italics***) the ecological purpose that lies behind a particular practice. The PAMS tables throughout the text provide a simple basis for surveying practices that are used at different crop growth stages in terms of their contribution to a comprehensive IPM program.

P PREVENTION

Prevent introduction to the farm
- Pest-free seeds, transplants

Prevent reservoirs on the farm
- Sanitation procedures
- Eliminate alternative hosts
- Eliminate favorable sites in and off crop

Prevent pest spread between fields on the farm
- Cleaning equipment between fields

Prevent pests developing within fields on the farm
- Irrigation scheduling to prevent disease development
- Prevent weed reproduction
- Prevent pest-susceptible perennial crops by avoiding high-risk locations

A AVOIDANCE

Avoid host crops for the pest
- Crop rotation

Avoid pest-susceptible crops
- Choose genetically resistant cultivars
- Choose cultivars with growth and harvest dates that avoid the pest
- Place annual crops away from high-risk sites for pest development (even parts of a field)

Avoid crop being the most attractive host
- Trap cropping
- Use of pheromones
- Use crop nutrition to promote rapid crop development

Avoid making the crop excessively nutritious
- Use nutrition to promote rapid crop development
- Avoid excessive nutrients that benefit the pest

Avoid practices that increase the potential for pest losses
- Narrow row spacing
- Optimized in-row plant populations
- No-till or strip till

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M MONITORING

Collect pests
- Scouting and survey approaches
- Traps

Identify pests
- Use of identification guides, diagnostic tools and diagnostic laboratories

Identify periods or locations of high pest risk
- Use weather-based pest-development and risk models
- Use soil and plant nutrient testing

Determine status and trends in pest risks and classify pest severity
- Maintain pest records over time for each field

Minimize pest risks over time
- Plan an appropriate PAMS IPM strategy, based upon pest status and trends

Determine interventions based upon risks and economics
- Use of decision-support tools, economic thresholds

S SUPPRESSION

CULTURAL

Outcompete the pest with other plants
- Cover crops

Suppress pest growth
- Mulches

Suppress pest with chemicals from crops or other plantings
- Bio-fumigant crops

PHYSICAL

Physically injure pest or disrupt pest growth
- Cultivation
- Flaming
- Exclusion devices
- Mowing
- Temperature management

Physically remove pests
- Mass trapping
- Hand weeding

BIOLOGICAL

Suppress pest reproduction
- Pheromones

Increase pest mortality from predators, parasites, and pathogens
- Conservation biological control
- Inundative release and classical biological control
- Use of pest antagonists

CHEMICAL

Use of least-risk, highest-efficacy pesticides
- Use economic thresholds to determine that pesticide use is economically justified
- Use pesticides as a last resort, as part of a PAMS IPM strategy

For more information see:

Jepson, P.C., Murray, K., Bach, O., Bonilla, M.A., Neumeister, L. (2020). Selection of pesticides to reduce human and environmental health risks: a global guideline and minimum pesticides list. Lancet Planetary Health 4: e56-53. https://doi.org/10.1016/S2542-5196(19)30266-9

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