Crop Profile for Mint in Michigan

Prepared: February, 2001

General Production Information

- Total U.S. acreage in 1998 was approximately 150,000 combined for peppermint and spearmint, which makes up 70% of the world's supply of peppermint and spearmint (10).
- Annual sales of the two oils in 1998 was approximately 12 million pounds, with 9 million pounds for peppermint oil and 3 million for spearmint oil (10).
- 90% of all oil produced in the U.S. is used for chewing gum and toothpaste (1 barrel (400 lb) of mint oil will flavor 5.2 million sticks of gum or 400,000 tubes of toothpaste) (10).
- In 1995 there were 1,400 acres of peppermint and 2,200 acres of spearmint in Michigan (13).
- Peppermint: 35 lb oil/acre, only one cutting per year (10).
- Spearmint: 30 to 60 lb oil/acre/cut, two cuttings per season on mineral soil and one cutting on muck soil: first cut - June 25 to July 12; second cut - Aug. 20th to Sept. 5th (10).
- 10 tons of mint produces 150 lbs oil. 10 acres of mint fills a 55 gal barrel of oil: $4,000 to $6,000 per barrel (Barrels can be stored for 5 to 10 years) (10).
- Production costs: $500 per acre (10).

- There are 10 mint growers in Michigan (10).

- Every barrel of oil is tested for presence of pesticides using a gas chromatogram (10).

Production Regions:
Mint is grown in the Midwest in Indiana, Michigan and Wisconsin north of the 41st parallel (Fort Wayne, IN). Mint needs a midsummer day-length of at least 15 hours for satisfactory yields and oil quality. This day-length cannot be achieved south of the 40th parallel (Indianapolis, IN) (1).

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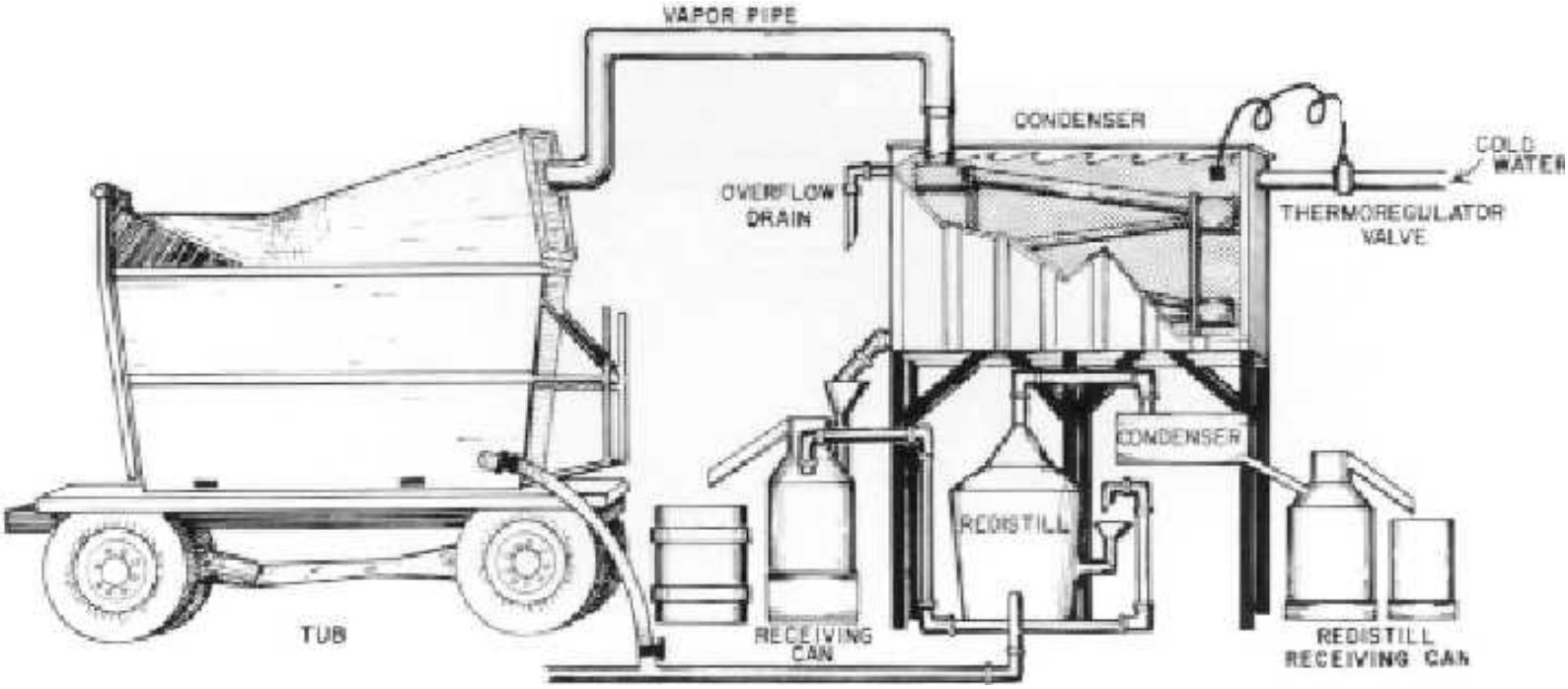
Production Practices:
Mint is a perennial plant that produces no seed. New fields are planted with root stock or underground runners, called stolons, from existing plants. Mint is planted as a row crop, but by the second year the plants spread out with stolons, creating a solid mint field. Every three to five years, the mint fields are rotated with another field crop and then the mint planting cycle begins again. Mint is grown on both muck and mineral soils in Michigan (18).

The oil is stored in glands on the underside of the peppermint and spearmint leaves. The plant reacts to sun and day length, by producing oil; thus very long sunny days will produce a higher yield crop. On average the Midwest produces about 35-70 lbs of mint oil per acre while the Northwest produces an average of 30 to 60 lbs of mint oil per acre (18).

Mint is one of the more difficult plants to grow because of its susceptibility to disease, insects, and weeds, all of which can harm the plant, alter the quality of the oil, and reduce the yield (18).

Once the grower has successfully battled inclement weather, disease, weeds and insects, the mature crop is ready to be harvested and distilled into oil. The harvesting season for mint is mid-June to late September, depending on the crop and the growing region (18).

Oil Distillation Process



Once the mint is harvested and laid to dry for about 3 days, a mechanical forage chopper picks up the dried mint and it is blown into the mint tub. The mint is taken to the distillery where the oil is extracted from the leaves by steam distillation. Boilers provide the pressurized steam connected to a pressurized line which forces steam through tubes that line the bottom of the mint tub. As the steam is released through tiny holes in the tubes, it rises through the hay (dried mint) and the mint oil is vaporized. The oil and steam vapors then pass through an outgoing vapor line at the top of the tub. From here the vapors are piped to water-cooled condensers where they return to a liquid state. In the separator, the oil rises to the top and is drawn into 55-gallon drums, while the water is drained from the bottom of the separator (10).

Mechanical Forage Chopper Distillery Receiving Can

Mint tubs attached to Vapor Pipe

After the oil has been extracted, some mint growers compost the hay and spread it on the field at a later time or place the mint hay directly onto other fields. A mint farmer in Michigan, Tom Irrer, however spreads the hay back onto the field immediately following mint oil extraction. Many mint growers do not replace mint hay back onto the mint field at all, rather they put it onto another field. The photo below is from Tom Irrer's farm where the mint tub is brought directly out into the field and the hay dumped into the mechanical spreader. The hay is still steaming, but does not seem to have any affect on the following years crop (20).

Mechanical Spreader

Commercial mint is cultivated for the flavorful oils produced in glands on the underside of the leaves. The bulk -about 90%- of commercially grown mint is used for flavoring two categories of consumer products: chewing gum and toothpaste. The remainder of these oils is used as flavoring agents in a variety of confectionery, pharmaceutical, and liqueur flavoring trades (20).

In the Midwest, mint production is gradually switching from organic to mineral soils. The addition of herbicides, nitrogen fertilizers and irrigation has negated most of the advantages of muck soils for mint production. As our muck soils become "minted out" from prolonged growing of mint and as no new muck land will be cleared, mint production on muck-land is bound to decrease. Fortunately the adoption of western mineral soil mint production techniques allows Midwest mint growers to remain competitive (20).

Insect Pests

Mint Flea Beetle, *Longitarsus ferrugineus*

Life Cycle: Female flea beetles lay eggs in the soil near the crowns of plants sometime in late July to early August, and continue laying eggs until late fall. The eggs do not hatch in the fall, but remain dormant in the soil until late April or early May. After hatching, the young larvae feed first on the fine hair roots and then tunnel into stolons and underground parts of the stem, where they continue to feed, for about 4 to 5 weeks (1).

Damage: Damage on underground parts is easily visible as distinct tracks or tunnel marks. In June, the larvae stop feeding and pupate in the soil with adults emerging 3 to 4 weeks later. The larval damage is far more serious for mint production than adult feeding. In addition to interfering with water and nutrient uptake, the feeding damage provides entrance for plant pathogens and produces generalized stress on the plants. As with other stress factors on mint, aboveground symptoms include stunting, perhaps some wilting under extremely dry conditions, and a general reddish-purple discoloration of new growth. This reddish discoloration is not, however, restricted to flea beetle feeding, nor does spearmint characteristically show this reddish coloration (1).

General Control Information: Larval control is currently impractical, therefore the adult stage must be controlled in order to minimize damage (1).

Cultural Controls: Crop rotation generally reduces buildup of populations of mint flea beetle. Also, if volunteer mint populations on roadsides, ditch banks and other areas are kept low, flea beetle populations are less likely to build up and move into nearby fields (1).

Biological Controls: No information available.

Chemical Controls: Timing is critical. Insecticides are applied when adults have emerged from the soil, but when a minimum number of eggs have been laid. This timing generally falls between mid/late July to mid August. Applications are made in late afternoon or evening to reach the adults when they are most actively feeding (1).

Malathion, Methomyl (1)

Alternative Controls: No information available.

Mint Bud Mite, *Floridotarsonemus* sp.

Mint bud mite has recently been associated with the condition known as "squirrelly disease" only on peppermint. The mite is spread by infested planting stock, and damage increases in older stands (4).

Life Cycle: The bud mite is small and difficult to identify without a magnifying glass. Bud mites overwinter primarily in the egg and immature stages in dormant mint left in the field as well as in and around plowed under material. Mature bud mites do not begin appearing in mint fields until late into the summer, generally around harvest time. They remain in the most terminal part of the plant (bud). Once the bud begins to bloom, mites move down the plant or down onto the surface of rhizomes (runners) at the soil surface. Information on the life cycle of mint bud mites is still being researched, therefore information on the life cycle is not complete. However, it is known that there are several generations per year (4, 15).

Damage: Bud mites most likely inject chemicals into the plant at the most terminal portion of the plant (bud) which disrupt growth and development. They do the most damage to the new leaves, which is where the majority of the oil is located. Yield losses can be as great as 80% or more. Oil quality is also affected with the oil having chemical profiles characteristic of immature hay (3). Unfortunately since there is no great loss in hay weight, yield loss may not be detected until oil has been extracted, in other words, until it is too late (15).

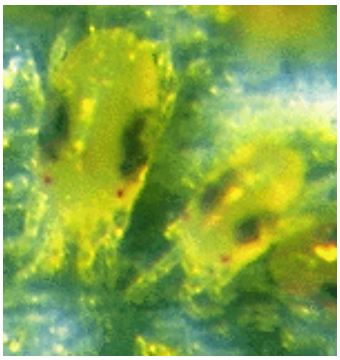
Visible damage includes stunting and distortion of the upper plant late in the season. Generally, visible symptoms are difficult to detect and once they are detected it is too late to save the crop from yield loss (15).

Management: Effective control requires intensive and careful scouting early in the season. The presence of the mite is limited to the buds on the plant terminals and requires some magnification to be seen. Cultural controls include crop rotations of four years or less, and fall plowing. Fall plowing is very important to reduce populations the following year by destroying their overwintering sites. Mint farms located on muck soils are at a disadvantage for continued bud mite infestation since they do not fall plow (4, 15).

Other important cultural controls include using rootstock from mite-free areas. Since bud mites move down onto the rhizomes, it is very important to scout a field before gathering rootstock for another field (15).

Chemical controls include Kelthane and Omite. However, volatile pesticides need to be used with caution, since processing may lead to pesticide contaminated oil. Therefore, since Kelthane is a volatile pesticide, it is limited to a single application, generally applied early in the season, followed by an application of Omite (which is not volatile) (15).

Two-spotted Spider Mite, *Tetranychus urticae*



Two spotted spider mites are only occasionally pests in mint, but in hot, dry years may be quite severe in some fields (1).

Life Cycle: Spider mites are tiny (0.5 mm, the size of a period on this page). Adult mites are pale yellow and have 2 dark spots on the body. Mites overwinter in mint fields in soil and in debris as females. In the spring, these females begin laying eggs on undersides of leaves. Eggs hatch in 4 to 5 days and the resulting larvae mature in 1 to 3 weeks depending on temperatures. With this rapid development, many generations of mites may be completed in a single season and numbers can reach damaging levels under ideal conditions (1).

Damage: Spider mites in low to moderate populations are generally found on the undersides of leaves and feed by sucking out cell contents. As chlorophyll is removed, the plant takes on a mottled appearance, and eventually bronzing and browning occurs. Heavy infestation results in leaf drop and reduced plant vigor. When mite buildup is heavy, it is often possible to see silken webbing on leaves and stems (1).

General Control Information: Injury to mint plants occurs when populations of spider mites reach five per leaf. Feeding injury caused by densities greater than five mites per leaf increases water stress, reduces photosynthesis, and alters terpene metabolism, resulting in elevated levels of menthol and neomenthol and decreased levels of pulegone. Peppermint leaf phenolics reduce spider mite fecundity and increase developmental time (6).

The mites may be almost impossible to see without examining the leaf surfaces with a hand lens or microscope. One way to detect mites is to hold a white piece of paper under the leaf or plant and strike the plant sharply. The mites will be dislodged and can be observed crawling about on the paper. The economic threshold for spider mites is an average of 5 mites per leaf before action needs to be taken (1).

Cultural Controls: No information available.

Biological Controls: Predatory mites can control mite populations in mint fields (6).

Chemical Controls: Kelthane, Meta-systox, malathion (1).

Alternative Controls: No information available.

Cutworms, *Peridroma saucia*

While several species of caterpillars, called cutworms, can be found in peppermint and spearmint, the most serious of these in the Midwest is the variegated cutworm (1).

Life Cycle: This species has 3 to 5 generations per year and attacks a number of crops including mint. The moths of this caterpillar fly at night, laying eggs in bunches throughout the field. Thus caterpillars are found infesting circular areas throughout the field. When infestations become more serious, these patches run together giving the appearance of a uniform infestation. The first generation of larvae usually appears in fields about late May to early June. After completing development, these larvae pupate in the soil with a second group of moths appearing and larvae showing up in July. A third generation may be present from the middle to the end of August (1).

Damage: The larvae feed on all portions of the plant, but are usually found under the canopy rather than on the top of the plants. It is not uncommon, however, to find larvae feeding on the terminal buds. The mature variegated cutworm larva is about 2 inches and varies from pale gray to dull brown. Larvae are marked with distinctive pale cream to yellow spots down the middle of the back (1).

General Control Information: Cutworms must be controlled before they become more than 3/4 of an inch in length. Treatment is justified if there are an average of 1.3 larvae/ft^2 (1).

Cultural Controls: Scouting is an important practice when assessing cutworm damage and infestation. Scouting takes place from mid-June through just prior to first harvest. Growers may sometimes harvest earlier to avoid further crop injury (5).

Biological Controls: There are naturally occurring predators and parasites that play an important role in suppressing cutworm populations on most mint-growing farms (5).

Chemical Controls: Orthene, Lannate (5).

Alternative Controls: A sex pheromone is commercially available and can be used to detect and monitor adult males of the variegated cutworm in the spring. Trapping males provides valuable early season information to growers concerning the potential need to control cutworm larvae during June and July. Sticky traps baited with this lure can be set in fields in late April and monitored weekly or biweekly through June. The real value of pheromone traps lies in the fact that they signal when to begin inspecting fields for larvae, thereby greatly improving timing of an insecticide application, if one is necessary (5).

Mint Aphid, *Ovatus crataegarius*

Mint aphid is a sporadic problem on both peppermint and spearmint in Michigan (19).

Symptoms: These small soft bodied insects feed on plants by sucking the plant sap. They are typically found on the undersides of leaves. When aphid numbers are great enough, the plant's leaves may curl or the entire plant may be stunted. In severe cases, plants may die. Aphids are also vectors of diseases that can be more damaging than the aphid feeding itself (19).

Methods of Transmission: Mint aphids overwinter around the bases of plants, on roots, beneath plant debris and in cracks

and crevices in the soil. Females give live birth to mobile nymphs in the spring. A single generation may be completed in 7 to 10 days and as many as 12 to 15 generations may be produced in a year (19).

Conditions Favoring Disease: The higher the temperatures, the faster the rates of development and higher the population densities (19).

Insecticide Profiles

Acephate (Organophosphate)

Formulations: Orthene 75S.
Pests Controlled: Cutworms and aphids.
Acres of Crop Treated: No information available.
Application Rate: 1 1/3 lb (11).
Types of Application: Ground (foliar) (12).
Timing: Applications are made before worms are 3/4 inch long for best results (11) or when eggs or insects first appear and one repeat application is made if necessary to maintain control (15).
PHI: 14 days (11).
REI: 24 hours (12).
IPM Concerns: No information available.
Efficacy Issues: Animals cannot be grazed on treated areas (15).

Dicofol (Chlorinated hydrocarbon)

Formulations: Kelthane MF.
Pests Controlled: Mites.
Acres of Crop Treated: No information available.
Application Rate: 1 3/4 to 2 1/2 pt (rate based on broadcast application, must recalculate if applying banded) (15).
Types of Application: Ground (broadcast and banded) (12).
Timing: Applications are made when mites first become active and only one application per season is permitted (15).
PHI: 30 days (11).
REI: 12 hours (12).
IPM Concerns: Resistance to miticides is common and has been shown for dicofol, although resistance is unstable (meaning that susceptibility to dicofol can return). Therefore it is a good idea to rotate with miticides with other modes of action (15).
Efficacy Issues: No information available.

Malathion (Organophosphate)

Formulations: Malathion 57EC.
Pests Controlled: Mint flea beetle, two spotted spider mite and grasshoppers (11).
Acres of Crop Treated: No information available.
Application Rate: 0.78 lbs ai/A (13).
Types of Application: Chemigation (12).
Timing: Applications are made prior to egg-laying activity if needed to control adult stage, which reduces root-damaging populations of larvae the following year (mint flea beetle) (11).
PHI: 7 days (11).
REI: 12 hours (12).
IPM Concerns: No information available.
Efficacy Issues: Three applications, 7 to 10 days apart, are sometimes needed to control severe infestations of mint flea beetle (11).

Methomyl (Carbamate)

Formulations: Lannate SP or LV.
Pests Controlled: Cutworms, mint flea beetles and aphids.
Acres of Crop Treated: No information available.
Application Rate: SP: 3/4 to 1 lb or LV: 3 pt (11).
Types of Application: Shield sprayers and air assisted sprayers (12).
Timing: For cutworm control, it is best to apply before worms are 3/4 inch long. For mint flea beetle control see Malathion (11).
PHI: 14 days (11).
REI: 48 hours (12).
IPM Concerns: Lannate is used along side an IPM program since resistance has been already found (12).
Efficacy Issues: Three applications, 7 to 10 days apart, are sometimes needed to control severe infestations of mint flea beetle. (11). No more than 4 applications per season per crop should be made as well as no more than 1.8 lb ai/A/season (12).
Restricted Use Pesticide.

Nematodes

Lesion nematode, *Pratylenchus penetrans*

All plant-parasitic nematodes are microscopic animals. To determine if nematodes are present, it is necessary to collect soil and roots from suspected areas and submit the samples to a nematode diagnostic laboratory for analysis. Nematodes typically appear in clumps in fields. Therefore, in the absence of diseased plants to use for guidance, it is necessary to collect multiple soil cores to increase the chances of sampling within the nematode "hot spots (17)."

Damage: Lesion nematodes feed within plant roots. They are migratory in their feeding behavior destroying cortical cells within roots. Therefore, lesion nematode-infested plants have reduced root systems. These plants are often stunted and yields are reduced. Lesion nematodes will predispose mint to invasion by *Verticillium dahliae*. This is a very common soil fungus that causes wilt. Mint is very susceptible to Verticillium wilt (17).

Life Cycle: Lesion nematodes overwinter in roots and soil. Females typically lays eggs within roots and all life stages are parasitic. Lesion nematodes can complete their life cycles in about 30 days under optimal conditions (17).

Management: It is imperative that the nematodes present in any given field are identified before implementing any management strategies or tactics. Chemical control is not used if the cause of any problem has not been properly diagnosed (17).

Cultural Controls: Fields are planted with nematode-free roots whenever possible especially on fumigated sites. Lesion nematode population densities will reach high levels if infested roots are grown in fumigated soils presumably due to the elimination of competing organisms (17).

Lesion nematodes feed on virtually all species of cultivated plants although some species are more susceptible to these pathogens than others. Therefore, crop rotation is not effective for control of these nematodes (17).

Mint varieties are typically resistant to *Verticillium*. However, feeding by lesion nematodes alters the physiology of these plants so they may become susceptible to the fungus (17).

Biological Controls: Results with biological control agents have been very erratic to date (17).

Chemical Controls: Soil fumigation is very effective for control of lesion nematodes and will also provide good control of *V. dahliae*. Fall fumigation is preferred over treating in the spring. Soil fumigation is expensive. It is important mint producers realize they may not recover the cost of fumigation in the first year. However, fumigated sites should remain more productive for at least 3-5 more years than untreated sites (17).

The nonfumigant nematicide, Vydate L, is registered for use on mint in Michigan. This material provides good control on lesion nematodes (17).

False Root-lesion Nematode, *Pratylenchoides crenicauda*

Damage and Life Cycle: Very similar to lesion nematodes although these nematodes may not interact with *V. dahliae* (17).

Management: False root-lesion nematodes have only been recovered from peppermint or spearmint fields in Michigan. Mint is not the only host plant, but these nematodes apparently do not have a large number of hosts. Therefore, rotation to virtually all other crops will reduce population densities of false root-lesion nematodes *(17)*.

Northern Root-knot Nematode, *Meloidogyne hapla*

The presence of galls on roots is positive diagnosis of a root-knot nematode problem. However, collection of soil and root samples is still recommended to further assess the population densities of these organisms (17).

Damage: The northern root-knot nematode feeds within plant roots. They establish their feeding sites within cells programmed to become vascular tissue. Therefore, they disrupt the xylem and phloem within roots. Infested plants will have dysfunctional root systems. These plants will not be able to compete well for water and soil nutrients. Plants will be stunted and may wilt during hot periods of the day. Yields will be reduced (17).

Unlike most nematodes, feeding by root-knot nematodes produces characteristic symptoms on roots called galls. Galls are small swellings that house the nematodes. Within a single gall, one to many root-knot nematodes can be found (17).

Life Cycle: The northern root-knot nematode overwinters as eggs within the soil or possibly as juveniles or adults within roots. Females can produce up to several hundred eggs in a gelatinous material. These nematodes can complete a life cycle in about a month (17).

Management: Diagnosis of root-knot nematodes within soil is often a function of the time of the year samples are collected. Because these nematodes overwinter as eggs (it is not possible to identify nematodes to genus using eggs), it is recommended samples are collected before soil temperatures fall below 50° F (17).

Cultural Controls: Corn and small grains are not hosts to the northern root-knot nematode. Growing these crops will result in declines in population densities of these organisms. The length of the rotation is dependent on the numbers of root-knot nematodes present in any given location and the susceptibility of the future crop (17).

Biological Controls: There are reports of successful use of biological control agents against root-knot nematodes. However, these have not been successfully implemented in Michigan (17).

Chemical Controls: Soil fumigation will provide effective control. Nonfumigant nematicides are not nearly as effective (17).

Common Needle Nematode, *Longidorus elongatus*

Damage: Needle nematodes feed outside of plant roots. They possess extremely long stylets that they use to penetrate plant cells. They usually feed near root tips, often killing them. Lateral roots often emerge from these tips and they also may be fed upon by these nematodes. These nematodes are very damaging. Infected plants will be severely stunted and yields can be drastically reduced (17).

Life Cycle: Needle nematodes overwinter as adults deep in the soil. In the spring they migrate into root zones at which time they do the majority of their feeding and reproduce. These nematodes produce very few offspring but they live long lives. Adults may live for several years and it may take a year or more for them to complete a generation (17).

Management: Needle nematode problems can be difficult to diagnose. These nematodes move vertically in the soil in response to soil temperatures and moisture levels. The best time to sample for these nematodes is in the spring (until June 15) or the fall (later than Sept. 15). During the summer, these nematodes typically migrate to depths of 3-4 feet in the soil *(17)*.

Cultural Controls: Crop rotation is recommended for control of the common needle nematode. However, these nematodes will maintain themselves on a wide variety of plants (grasses are hosts) and some other plants grown in rotation with mint are very susceptible to these pathogens (onions and celery). The adults live for very long periods, so effective rotation may not be practical in many situations (17).

Chemical Controls: Soil fumigation will provide effective control of needle nematodes. However, if soil is fumigated when it is still warm (>70^0F), it is possible some of these nematodes will not be killed due to the depth they are resting. Nonfumigant nematicides do not provide effective control of needle nematodes (17).

Pin Nematodes, *Paratylenchus* sp.

Damage and Life Cycle: Pin nematodes typically feed as ectoparasites on plant roots (although one species of pin nematode known to parasitize mint does enter roots). Their stylets are much shorter than those of needle nematodes, so they typically are far less damaging. Feeding by pin nematodes can result in stunted, unthrifty plants (17).

Management: Collect soil for diagnosis of pin nematode problems. Fumigant and nonfumigant nematicides will provide excellent control of these nematodes. Crop rotation will reduce population densities of pin nematodes in many situations. Most crops are not susceptible to pin nematodes but carrots and celery should be avoided. These nematodes will maintain themselves quite well on small grains and corn (17).

Nematicide Profiles

1,3 Dichloropropene

Formulations: Telone II and Telone C17
Pests Controlled: Nematodes and *Verticillium* wilt.
Acres of Crop Treated: No information available.
Application Rate: 25 to 30 gal/A (73 to 83 fl oz/1000 ft/outlet) (15).
Types of Application: Soil fumigant (preplant), broadcast treated (15).
Timing: In the spring or preferably in the fall (15).
PHI: No information available.
REI: 5 days (15).
IPM Concerns: No information available.
Efficacy Issues: For best results soil temperature should be between 40 and 80 degrees F and soil moisture should go down 12 inches from the soil surface (15).

Metam Sodium (Thiocarbamate)

Formulations: Vapam HL.
Pests Controlled: Suppression of *Verticillium* wilt.
Acres of Crop Treated: No information available.
Application Rate: 37.5 to 75 gal/A (23).
Types of Application: Chemigation, soil injected, rotary tiller or power mulcher, or drip irrigation (23).
Timing: Fumigation takes place when soil temperatures are between 40 and 90 degrees F and when soil moisture is 50 to 80% field capacity. Before applying product to the area to be treated, fields are thoroughly cultivated followed by irrigation to moisten soil (23).
PHI: No information available.
REI: 48 hours (23).
IPM Concerns: No information available.
Efficacy Issues: Efficacy based on contact of gaseous phase with respiring pest (23).

Oxamyl (Carbamate)

Formulations: Vydate L
Pests Controlled: Nematodes.
Acres of Crop Treated: No information available.
Application Rate: ½ to 1 ½ gal/A by ground (23).
Types of Application: Ground, air or low pressure sprinkler system (23).
Timing: Applications are made as mint breaks winter dormancy and begins active root growth. A second application may be made 3 to 4 weeks later or to regrowth that occurs in the fall (23).
PHI: 21 days (23).
REI: 48 hours (23).
IPM Concerns: Toxic to aquatic animals and birds (23).
Efficacy Issues: Use lower rates on coarse textured soils and muck soils. Use higher rates on fine textured soils. Applications to heavy soils does not increase yields (23).

Diseases

Verticillium Wilt, *Verticillium dahliae*

Verticillium wilt is the most serious and destructive plant disease faced by mint growers. It is a disease of many crops grown in the state although isolates from mint are most aggressive on mint and other isolates are crop specific as well (3).

Symptoms: Symptoms of *Verticillium* wilt include stunted, erect plants as a result of shortened internodes. Leaves become yellow and eventually reddish, and opposite leaves bend towards each other into a crescent shape because of asymmetric growth. Yellowed leaves tend to fall off. Immediate losses from wilt occur when stands become thinned out as individual plants are killed. Chronic, non-lethal infections result in stunting of the plants, a reduction of the total leaf area, defoliation of the plants, and reduced oil production because of debilitating effects of the disease on the bud. Severity and yield losses depend on the level of inoculum in the soil, weather conditions and cultivar susceptibility. Spearmint is less susceptible than peppermint. Native spearmint is least susceptible (3).

Methods of Transmission: The fungus is soil-borne and can survive in the soil indefinitely once microsclerotia numbers build up in the soil. Infection occurs through natural openings and wounds on roots (3).

Conditions Favoring Disease: Severity and yield losses depend on the level of fungus in the soil, weather conditions, and variety susceptibility (4).

Management: Crop rotation is only effective if it has been done from the beginning, before the pathogen is well established. It is good to rotate with a non-susceptible crop every 3-4 years. Onions, corn and soybeans are good crops to rotate with mint to reduce the likelihood of buildup of verticillate propagules in the soil (3).

Mint Rust, ***Puccinia menthae***

Symptoms: The symptoms include light-yellow, blister-like lesions on young shoots in the spring, and brownish-red spots surrounded by a yellow halo on the leaves later in the season. Rusted leaves fall off and defoliation can be severe. When rust infects young shoots, the shoots are usually twisted and break off at the infection point (3).

Methods of Transmission: Later in the season the leaf spots become dark brown and the overwintering spores are produced. Plantings with moderate to severe rust infection are weakened and winter survival is reduced (3).

Conditions Favoring Disease: Cool wet springs favor infestation of mint rust as well as mineral soils rather than on muck soils. It is very important to harvest mint before rust overtakes the crop (3).

Management: It is important to plow the mint beds to bury overwintering spores. Elimination of volunteer mint plants will also reduce available rust inoculum (3). Preventing establishment of the disease early in the spring most effectively controls mint rust. Carefully plowing the fields in the fall to bury crop debris prevents or delays infections. When the mint is 3 to 4 inches tall, 1 lb/acre of Rally can be applied, followed by a second application 14 days later. The timing of these treatments is essential for control. If delayed, control will be less effective (4).

Fungicide Profiles

Myclobutanil (Conazole)

Formulations: Rally WP.
Pests Controlled: Mint rust and powdery mildew (15).
Acres of Crop Treated: No information available.
Application Rate: 0.125 lb ai/A or 5 oz product/A (15).
Types of Application: Ground (15).
Timing: Applications are made every 14 to 21 days beginning in the early spring when plants break dormancy (15).
PHI: 30 days (15).
REI: 24 hours (15).
IPM Concerns: No information available.
Efficacy Issues: Other crops cannot be planted within 30 days of last spray (15).

1,3 Dichloropropene: See nematicide profiles

Weeds

Weeds are the key pest of mint in Michigan. Excessive weed populations compete with mint to reduce yields, and contribute off-flavors and color to the mint oil at harvest, resulting in lowered oil quality. Some weeds may contain volatile compounds, which are extracted along with the mint oil during the distillation process. Up to a 40% yield loss may be realized as a result of weed pressure by pigweed, lambsquarters, and foxtail species. In addition to yield losses, certain weed species such as pigweed can reduce the marketability of the oil. Quality reduction is more difficult to quantify since quality loss is more subjective and determined by the processors (3).

Annual broadleaf weeds are troublesome in mint fields. Pigweed species are a severe problem in both peppermint and spearmint. One hundred percent of the farmers surveyed have problems with pigweed. All of the registered herbicides for broadleaf weed control in mint have some limitations, which result in pigweed being a major pest. Common lambsquarters represents a problem in 90% of the peppermint and spearmint fields. Both pigweed and common lambsquarters (as well as other annual broadleaf weeds) are controlled as early as possible, before they are 2 inches tall (3).

Annual grasses also pose a problem in mint fields. Giant foxtail and large crabgrass are the most problematic annual grass weeds in Michigan. Annual grasses must be treated postemergence, in this case, before they are 1-inch tall (3).

Perennial weeds are generally considered to be a major problem. Once established, they are extremely hard to control. Crop rotation is used to control perennial weeds before planting mint. Perennial weeds are removed by hand or spot spraying of herbicides for severe infestations (3). There are two perennial weeds that affect mint production in Michigan, field bindweed and Canadian thistle.

The most common cultural practice used in Michigan mint production to reduce weed competition is a three year mint rotation followed by three years in another crop, often vegetables or field crops. Disking or dragging, in the spring was also used as a form of mechanical weed control but is not commonly used now. During the first year mint doesn't compete well with weeds. Good chemical or mechanical weed control is necessary (3).

Herbicide Profiles

Bentazone

Formulations: Basagran 4L (11).
Pests Controlled: Emerged broadleaves and sedges (does not control grasses) (11, 15).
Acres of Crop Treated: 50% (13).
Application Rate: 1 lb a.i./A (21).
Types of Application: Ground (broadcast, banded or spot sprayed) (14, 15).
Timing: Postemergence when weeds are small (21).
PHI: No information available.
REI: 12 hours (14).
IPM Concerns: No information available.
Efficacy Issues: For best control, applications are made about 10 days apart, applied when soil moisture is high and temperatures are warm. Weeds must be relatively small and actively growing for good results (1). It should not be applied to newly planted mint and may cause crop injury if temperatures exceed 70° F immediately following application (11).

Clopyralid (Picolinic acid)

Formulations: Stinger 3L.
Pests Controlled: Emerged broadleaves (controls composites (Canada thistle, dandelion), legumes, smartweeds, nightshade, plantain and some other weeds).

Acres of Crop Treated: 20 - 30% (13).
Application Rate: 0.19 to 0.375 lb ai/A (21).
Types of Application: Ground (broadcast or banded) (14).
Timing: Applications are made postemergence to actively growing small weeds (15).
PHI: 45 days (15).
REI: 12 hours (14).
IPM Concerns: Kills composites that may be resistant to photosynthesis inhibitor herbicides (14).
Efficacy Issues: Addition of a non-ionic surfactant of at least 80% ai at a rate of 1 pint/100 gal of spray solution increases control (15).

Glyphosate (Organophosphorous)

Formulations: Roundup Ultra.
Pests Controlled: Annual and perennial weeds (15).
Acres of Crop Treated: 9% (13).
Application Rate: 1.0 to 3.0 lb ai/A (21).
Types of Application: Ground (broadcast, hand held and high volume spray equipment) (14, 15).
Timing: Spot applications. Further applications may be made in the same area at 30 day intervals (15).
PHI: 7 days (15).
REI: 4 hours (15).
IPM Concerns: No information available.
Efficacy Issues: Mint sprayed will be killed (21).

Oxyfluorfen (Nitrophenyl ether)

Formulations: Goal 2XL
Pests Controlled: Germinating broadleaf weeds and annual grasses (15).
Acres of Crop Treated: 28% (13).
Application Rate: 0.5 lb ai/A (21).
Types of Application: Ground (no chemigation) (14).
Timing: Pre-emergence before the new mint growth emerges to avoid crop injury (21).
PHI: No information available.
REI: 24 hours (14).
IPM Concerns: Highly toxic to aquatic invertebrates, aquatic plants, wildlife and fish (15).
Efficacy Issues: Indiana, Michigan, and Wisconsin only. May cause temporary stunting of mint plants (11). No more than one application can be made per season (14).

Quizalofop (Aryloxyphenoxypropionate)

Formulations: Assure II 0.88E
Pests Controlled: Emerged annual and perennial grasses (15).
Acres of Crop Treated: 56% (13).
Application Rate: 0.04 to 0.07 (21).
Types of Application: Ground (14).
Timing: Postemergence (actively growing grasses) or preplant burndown for small foxtails, barnyard grass, volunteer corn and wild proso millet (15).
PHI: 30 days (15).
REI: 12 hours (14).
IPM Concerns: Resistance has been documented, so it is a good idea to rotate herbicides with different modes of action into a spray program (15).
Efficacy Issues: Apply in 10 to 40 gal/A water. Use high rate on perennial grass. Include 1% COC or 0.25% NIS/A (15).

Sethoxydim (Cyclohexandione)

Formulations: Poast 1.5E.
Pests Controlled: Emerged grass weeds (21).
Acres of Crop Treated: 31% (13).
Application Rate: 0.19 to 0.28 lb a.i./A (21).
Types of Application: Ground and aerial (14).
Timing: Postemergence (actively growing grasses), cannot apply preplant or preemergence (15).
PHI: 20 days (15).
REI: 12 hours (14).
IPM Concerns: No information available.
Efficacy Issues: No more than two applications should be made per season. Include 1qt COC per acre. Maximum of 5 pt per season (21).

Terbacil (Uracil)

Formulations: Sinbar 80W.
Pests Controlled: Germinating annuals (21).
Acres of Crop Treated: 50% (13).
Application Rate: 0.4 to 1.6 lb ai/A (21).
Types of Application: Ground (14).
Timing: Terbacil can be applied as either a preemergent (apply in spring before mint emerges) or postemergent spray after weeds emerge (1).
PHI: 60 days (11).
REI: 12 hours (14).
IPM Concerns: Terbacil has a very long residual life in soil. While this makes season-long weed control possible with only one application of material, it can also cause toxicity and damage in other crops following mint (1). The loss of this product would have a serious negative impact on Michigan mint production as there is currently no suitable herbicide to replace it (11).
Efficacy Issues: For best results, terbacil must be applied before weeds are more than one-inch tall and followed by at least 1/2 inch of rainfall or irrigation within 10 days (1).

Bromoxynil ()

Formulations: Buctril 2E.
Pests Controlled: Emerged broadleaves (21).
Acres of Crop Treated: No information available.
Application Rate: 0.25 lb ai/A (21).
Types of Application:
Timing: Applications are made during dry weather with temperatures below 70° F (21).
PHI: 70 days (21).
REI:
IPM Concerns:
Efficacy Issues: Effective on small weeds, although may cause temporary stunting and leaf chlorosis of mint (21).

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