



Peppermint

(Western Oregon)

J.M. Hart, D.M. Sullivan, M.E. Mellbye, A.G. Hulting, N.W. Christensen, and G.A. Gingrich

Gale Gingrich, © Oregon State University



Summary

Lime	Soil pH between 5.5 and 6.0 is adequate for peppermint production. Before planting, apply lime according to Table 4 when the soil pH is below 6.0. In established stands, apply lime when the soil pH is below 5.5. See pages 9–10.
Nitrogen (N)	Application of no more than 200 to 250 lb N/a is necessary for peppermint under good irrigation water management. Supply approximately 175 lb N/a before mid-May. Do not apply N after late July. Monitor soil nitrate-N on a few typical fields to evaluate trends in soil N availability for the crop (June) and late-season soil nitrate-N accumulation (July and August). See pages 5–7.
Phosphorus (P)	When soil test P is below 40 ppm, apply P according to Table 5. See pages 10–11.
Potassium (K)	When soil test K is below 200 ppm, apply K according to Table 6. See page 11.
Sulfur (S)	Apply 20 to 30 lb S/a in early spring with the first application of N.

The Pacific Northwest produces about 90 percent of the peppermint grown in the United States for oil, rootstock, and dried leaves. Dry peppermint leaves are used for tea and as a culinary herb. Peppermint oil is used to flavor chewing gum, toothpaste, mouthwashes, pharmaceuticals, and confectionary and aromatherapy products. Use for medicinal purposes is growing.

Optimum oil quality and quantity are produced with ample daylight (usually more than 14 hours), warm daytime temperatures (85–95°F), and cool nighttime temperatures (55–60°F).

Peppermint (*Mentha piperita*) is typically produced on deep, well-drained soil in locations with plentiful good-quality irrigation water. Historically, peppermint was grown on soil series such as Chehalis, Cloquato, and Newberg. These deep, well-drained sandy loam and silt loam “bottomland” soils were formed in mixed alluvium deposited by the Willamette River and its tributaries. Currently, peppermint is also grown on well-drained silt loam valley floor terrace soils, such as the Amity, Malabon, Willamette, and Woodburn soil series. See the sidebar “Peppermint production in the U.S.” (page 2) for more information.

Peppermint reproduces vegetatively via “runners” (rhizomes and stolons), which originate from the main rootstock in early to mid-June (Figure 1, page 2). Stolons are stems growing at or just above the soil surface. Rhizomes are stems growing at or just below the soil surface. Both have fewer leaves than do vertical stems and can produce new roots and shoots from buds. Other crops with stolons include bentgrass, strawberries, and some clovers. Kentucky bluegrass and creeping red fescue have rhizomes. New root growth from stolons and rhizomes near the soil surface creates the impression that peppermint is a shallow-rooted crop. In fact, peppermint roots are easily found 2 feet below the surface.

The “aggressive” or “invasive” reproductive nature of peppermint is exploited for establishment. Stands are established by planting stolons or rhizomes in rows. The new plants spread quickly throughout the field; by the second year, rows are no longer distinguishable. Stands

J.M. Hart, Extension soil scientist; D.M. Sullivan, Extension soil scientist; M.E. Mellbye, area Extension agronomist; A.G. Hulting, Extension weed management specialist; N.W. Christensen, professor of soil science emeritus; and G.A. Gingrich, area Extension agronomist emeritus; all of Oregon State University.

remain in production for as few as 3 or as many as 15 years. The average Willamette Valley peppermint field produces oil for 5 to 7 years.

The oil is stored in glands on the leaves. As plants approach bloom, oil concentration increases, and the lower leaves drop from the plant. Oil concentration reaches its peak during bloom. Cutting is recommended at early bloom development stage to minimize leaf loss and maximize oil concentration and quality.

Peppermint is a challenging crop to grow. Timely water and fertilizer applications are essential for optimum yields and quality oil. Nitrogen (N) is the most yield-limiting fertilizer nutrient. Liming to increase soil pH is necessary, as is the addition of phosphorus (P), potassium (K), and sulfur (S).

This guide provides nutrient and lime recommendations for first-year and subsequent-year single-cut peppermint crops in Clackamas, Benton, Lane, Linn, Marion, and Polk counties. For peppermint harvested twice in a growing season, see the sidebar “Double-cut peppermint.”

The average peppermint oil yield in the Willamette Valley is between 90 and 100 lb/a. Recommendations in this guide are adequate to routinely produce a peppermint oil yield greater than 100 lb/a, assuming that disease-free rootstock of an appropriate variety is planted on suitable soils free of verticillium wilt.

Recommendations in this guide are based on research conducted during the past 50 years on both large plots in grower fields and small plots at Oregon State University research facilities in the Willamette Valley. See Appendix A (page 14) for a list of research projects.



Figure 1.—Peppermint is a perennial aromatic herb with erect, square, branched stems. Leaves are arranged on the stem in opposite pairs. Illustration: Kathy Merrifield

Double-cut peppermint

A few western Oregon peppermint fields are harvested twice in a growing season (June and September). This practice is known as “double-cutting.” Cutting twice in a season can increase oil yield by 30 to 40 percent, but oil quality will differ from that of peppermint harvested during early bloom. For information about oil quality, see the sidebar “Peppermint oil quality” (page 8).

No research has been performed for double-cut peppermint in the Willamette Valley. Nitrogen rate is likely to be the primary nutrient management adjustment needed for this harvest system. At the first harvest (mid- to late June), 150 to 175 lb N/a has been accumulated by the crop. If the second harvest produces a similar hay yield, then two applications of 150 to 175 lb N/a will be needed.

Peppermint production in the U.S.

Peppermint production in the United States began in 1812, when stolons from England were planted in Massachusetts. By 1835, production had moved to the midwestern U.S. The soils and climate of Michigan and Indiana were well suited to peppermint culture. These states became the major peppermint-producing area by 1920, with production peaking in 1930.

Verticillium wilt led to a decline in production in the Midwest and an increase in acreage in Washington and Oregon. After 1950, the Pacific Northwest became the largest peppermint- and spearmint-producing area in North America. Currently, the northwestern states of Montana, Idaho, California, Washington, and Oregon produce between 85 and 90 percent of the peppermint oil in the U.S. Oregon’s production is about one-third of the national total.

In Oregon, peppermint production began in 1908 near Eugene. By 1939, 2,200 acres were harvested; by 1960,

acreage had increased to 15,900. Peppermint production reached a peak of 50,000 acres in 1996. About half of Oregon’s mint production was in Marion, Linn, Lane, Benton, and Polk counties.

By 2008, harvested acreage in Oregon had decreased to 21,000 acres. The Willamette Valley continues to grow approximately one-half of Oregon’s peppermint crop. Peppermint is also produced in Columbia County, in the irrigated areas of Morrow and Umatilla counties, in the central Oregon counties of Jefferson, Crook, and Deschutes, and in the Grande Ronde Valley of Union County.

For Willamette Valley farms with irrigation, peppermint oil is a high-value crop. During the peak years of production, 25 to 40 percent of irrigated cropland in the Valley was planted to peppermint. Peppermint pest and weed control practices make it an ideal rotation crop with grass seed, wheat, and sugar beets for seed.

Healthy plants with adequate root systems are required to obtain the greatest return from your fertilizer investment. The nutrient recommendations in this guide assume adequate control of weeds, insects, and diseases. Lack of pest control cannot be overcome by the addition of nutrients.

Common diseases of peppermint are verticillium wilt (*Verticillium dahliae*), powdery mildew (*Erysiphe cichoracearum*), and leaf rust (*Puccinia menthae*). Planting disease-free roots (certified wilt-free if possible) in fields free of verticillium wilt helps assure a productive, healthy stand for several years. See the sidebar “Variety and verticillium wilt” for more information.

Nematodes are serious soil pests that can interact with verticillium wilt to severely weaken mint stands. Sample fields to assay nematodes and control nematodes prior to planting.

Control of weeds is essential for reducing competition with the crop and ensuring oil quality. Common weeds in peppermint fields include annual and perennial grasses, as well as broadleaf weeds such as common groundsel (*Senecio vulgaris*), field bindweed (*Convolvulus arvensis*), Canada thistle (*Cirsium arvense*), common lambsquarters (*Chenopodium album*), annual sowthistle (*Sonchus oleraceus*), pigweed species (*Amaranthus* spp.), nightshade species (*Solanum* spp.), marestail (*Conyza*

canadensis), and prickly lettuce (*Lactuca serriola*). See Appendix C (page 16) for information about the influence of weeds on peppermint oil quality. Specific weed management recommendations are found in the mint chapter of the *PNW Weed Management Handbook* and in OSU Extension publication EM 8774, *Weed Management in Mint*.

Numerous insects and invertebrate pests attack peppermint, including the two-spotted spider mite (*Tetranychus urticae*), root borers (*Fumibotys fumalis*), several cutworms and armyworms, alfalfa looper (*Autographa californica*), cabbage looper (*Trichoplusia ni*), grasshoppers (*Camnula pellucida*), multiple slug species, symphylans (*Scutigera immaculata*), and flea beetles (*Longitarsus waterhousei*). For more information about insect management in peppermint, see the *PNW Insect Management Handbook* or PNW 182, *A Guide to Peppermint Insect and Mite Identification*.

Understanding peppermint growth

The growth pattern for crops such as wheat and grass grown for seed resembles an elongated “S” with three segments or “phases.” The first phase is the “tail” of the “S” as growth slowly begins. The second phase is rapid

Variety and verticillium wilt

Profitable peppermint production and stand longevity require that disease-free rootstock of an appropriate variety be planted in fields free of verticillium wilt. The traditional variety, Black Mitcham (Figure 2), is susceptible to verticillium wilt. When a wilt-free field is not assured (due to a history of mint production), an alternative variety such as Redefined Murray will produce more peppermint hay and have less verticillium wilt infection than Black Mitcham (Table 1).



Figure 2. Newer varieties (background) produce higher yields in verticillium-infested fields than does the traditional variety Black Mitcham (weedy plot in foreground). Photo: Mark Mellbye

Table 1.—Influence of verticillium wilt on Willamette Valley peppermint production, by variety and field history.^a

Variety	Noninfested soil			Soil infested with verticillium wilt		
	Wilt infection (%)	Ground cover (%)	Wet hay yield (lb/a)	Wilt infection (%)	Ground cover (%)	Wet hay yield (lb/a)
Black Mitcham	0.4	99	30,100	67	50	5,300
Redefined Murray	0.1	100	37,500	20	95	19,900
M-83-7	0.1	100	38,900	27	95	19,000

^aData collected during the fourth production year, 1999. Fields were part of a variety trial conducted at the Botany and Plant Pathology Farm, Corvallis, OR, 1996–2000.

growth, with the crop sometimes seeming to change daily. The third phase is characterized by flower and seed development, in addition to movement of nutrients from leaves into the developing seed or fruit. Little nutrient accumulation occurs during Phase 3. When both nutrient accumulation and growth stop, the line becomes flat.

Peppermint grown for oil production does not fit this three-phase growth model, as the crop is harvested during bloom. Thus, the peppermint growth pattern has only two segments:

- Slow early growth from late February to late April or early May
- Rapid linear development from early or mid-May to harvest

Figure 3 illustrates the linear, steady growth of late spring and summer. Total harvested dry biomass ranges from 8,000 to 10,000 lb/a. The maximum biomass accumulation rate of 75 to 125 lb dry matter/a/day occurs in late June to mid-July (Figure 4).

Peppermint hay at harvest contains 175 to 225 lb N/a (Figure 3). The maximum N uptake rate of 2 to 3 lb/a/day occurs in May to early June, 30 to 40 days before peak biomass accumulation. By the end of June, the N uptake rate falls to less than 0.5 lb/a/day (Figure 4).

The rapid growth of peppermint during May and early June creates sufficient leaves for a full canopy, which intercepts all sunlight. From the time the canopy “closes” until harvest, new leaf growth is accompanied by loss of

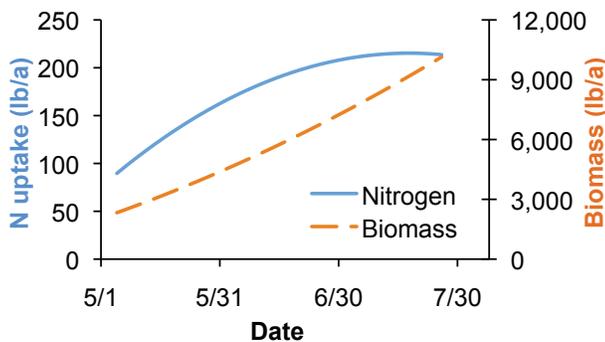


Figure 3.—Cumulative nitrogen uptake and biomass accumulation for peppermint.

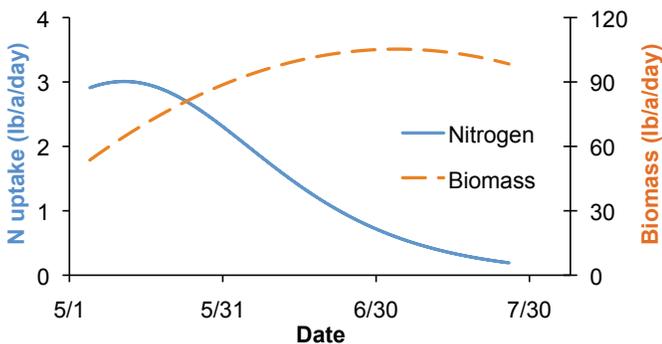


Figure 4.—Rate of nitrogen uptake and biomass accumulation for peppermint.

lower leaves. Sometimes, peppermint will lodge, “turn,” and grow new stem and leaf material.

Residue remaining in the field after leaves and stems are removed for oil distillation represents a significant portion of peppermint dry matter production. This material is between 1,000 and 1,500 lb/a and contains 40 lb N/a, 4 lb P/a, and 15 lb K/a. Peppermint roots from the top 8 inches of soil weigh about 2,500 lb/a and contain 50 lb N/a, 10 lb P/a, and 30 lb K/a.

After harvest, peppermint is irrigated and begins to grow new leaves and stems. This postharvest growth produces 1,000 to 2,000 lb dry matter/a, which contains 40 to 50 lb N/a, 4 to 5 lb P/a, and 30 to 40 lb K/a.

Oil weight represents from 0.5 to 2 percent of dry matter. Oil yield is determined by the quantity of leaves on the plant. Oil concentration in the upper 15 inches of a plant (stems and leaves) is 1.3 percent, while oil concentration from the entire plant is slightly less than 1 percent.

Collecting soil samples

Before planting peppermint, collect soil samples to plow depth. A sample should contain a minimum of 20 cores and represent no more than 40 acres. Request sample analyses for pH, SMP buffer (preplant only), phosphorus, potassium, calcium, and magnesium.

Nutrient stratification commonly occurs in peppermint fields from top-dress fertilizer application without tillage. For this reason, we recommend collecting soil samples from two depths on established fields: (1) the surface 2 inches of soil, and (2) the 2- to 6-inch layer of soil.

Additional information on nutrient and soil pH stratification can be found in OSU Extension publication EM 9014-E, “Evaluating Soil Nutrients and pH by Depth in Situations of Limited or No Tillage in Western Oregon.” See also the sidebar “Sampling depth for P and K” (page 10).

If peppermint is not growing well in some parts of a field, collect plant samples from both “good” and “bad” areas.



Figure 5.—Soil sampling in an established peppermint field. Photo: Mark Mellbye

Nitrogen (N)

Peppermint hay at harvest contains 175 to 225 lb N/a. Nitrogen is the nutrient most likely to limit growth and yield of peppermint. Application of 200 to 250 lb N/a is adequate for peppermint that is not excessively irrigated (Figure 6). Nitrogen can be supplied through irrigation water or to the soil early in the growing season.

Growers typically apply some N in late March or early April. Research has not been performed to confirm the need for N application at this time. Nitrogen rate and timing research in 1970 and 1971 indicated that oil yield was maximized with application of approximately 175 lb N/a before mid-May. This recommendation was confirmed by research in 1996 and 1997. N applied after late July or early August is likely to remain in the soil and be lost to leaching with winter rain.

Yearly variation in early-season growth controls N accumulation by peppermint. As shown in Figure 7, early-season peppermint biomass (hay) production from the same field was substantially less in 1996 (a cool spring) than in 1997 (a warm spring). Figure 8 shows N uptake from this field in 1996 and 1997. By early June 1996, the amount of N in the peppermint crop was about 50 lb/a. In 1997, the N in the crop was double this amount, 100 lb/a. Adjust N timing based on spring weather conditions.

Nitrogen management recommendations are summarized in the sidebar “Nitrogen management summary.” Additional information is provided in the sidebars “Nitrogen leaching below the root zone,” “Nitrogen monitoring,” and “Peppermint oil quality” (pages 6–8).

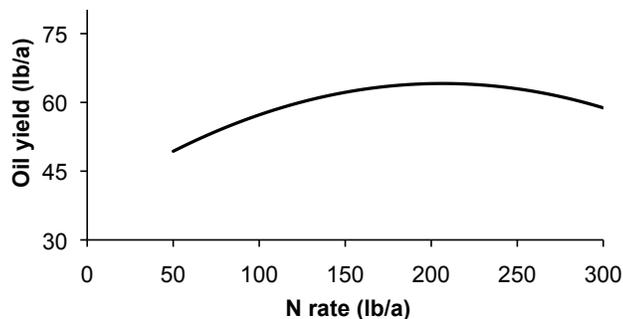


Figure 6.—Peppermint oil yield and nitrogen rate from a Benton County peppermint field, 1971.

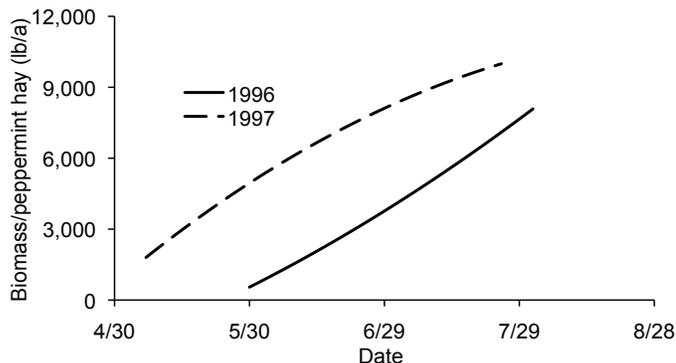


Figure 7.—Peppermint hay or biomass production in a Lane County peppermint field, 1996 and 1997.

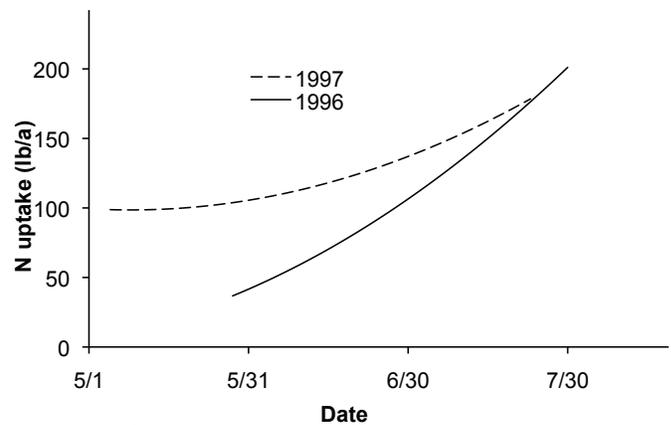


Figure 8.—Cumulative N uptake in a Lane County peppermint field, 1996 and 1997.

Nitrogen management summary

- Apply N fertilizer at a rate that produces adequate yield and minimizes nitrate accumulation in soil in August.
- Apply no more than 200 to 250 lb N/a/yr. This application rate supplies adequate N under current management practices.
- Irrigate to meet crop evaporative demand. Use irrigation scheduling and monitoring tools to maintain adequate, but not excessive, soil moisture.
- Target N management and irrigation management toward productive portions of the field. Crop growth on gravel bars may be poor when the rest of the field has optimum N and irrigation water applied.
- Maintain the sprinkler irrigation system to apply water uniformly.
- Schedule N fertilizer applications to precede crop need.
- Apply N fertilizer at two or more application dates (split application). Split N application is of greatest benefit on sandy soils that have low water-holding capacity.
- Eliminate late-season N fertilizer applications. Nitrogen fertilizer applications 3 weeks to a month before harvest are not effective in increasing crop yield or oil quality.
- Do not apply slow- or controlled-release N fertilizers during late June or early July, because some of the N will be released too late for crop uptake.
- Monitor trends in soil nitrate-N on a few typical fields to evaluate soil N availability for the crop (June) and excess soil nitrate-N accumulation in late season (July and August). See page 7.

Nitrogen leaching below the root zone

Small-plot lysimeters and field-scale, replicated research plots were used to estimate N leaching. Both approaches reached the conclusion that with existing management practices, typical nitrate-N leaching losses approach 100 lb N/a/yr.

This research demonstrated that opportunities exist to improve crop utilization of N, thereby decreasing the amount of N leached. Crop efficiency at using N is a function of N fertilizer management practices and the distribution and timing of irrigation water application.

Monitoring with small-plot lysimeters

The lysimeter is a catch basin placed under an undisturbed soil profile. Water drains from the soil profile into the lysimeter, providing an accurate estimate of the N quantity leached per unit area, as well as the nitrate concentration in the leachate. Measurement of a small area (10 square feet) is the major limitation of lysimeters.

Nitrate leaching from five farmer-managed Lane County peppermint fields receiving an average of 250 lb N/a/yr was monitored (1993–1998). Leachate volume at a depth of 3 to 4 feet, nitrate concentration, and lysimeter water collection efficiency were used to estimate annual N loss via leaching.

An average of 82 lb N/a/yr was leached, with an average leachate nitrate-N concentration of 12 mg/L (ppm). Individual field averages for N loss ranged from 40 to 120 lb N/a/yr. Field averages for leachate-N concentration were 6, 8, 11, 17, and 23 ppm (mg/L).

This study demonstrated that nitrate-N leaching losses under peppermint can be a concern for groundwater quality. Nitrate-N concentrations in excess of 10 mg/L are considered unsafe in drinking water.

Monitoring agronomic field trials

Replicated plots that are large enough to be fertilized and harvested using grower equipment (1.5 acre) offer an opportunity to compare the effects of fertilization practices on oil yield, crop N uptake, and soil nitrate-N concentrations. This method can provide a field-scale estimate meaningful to growers.

Soil samples for nitrate-N analysis are collected in 1-foot depth increments to a depth of 5 feet. Soil profile nitrate-N is measured in the spring and fall to determine soil nitrate-N concentrations. Loss of soil nitrate-N over the winter is attributed to leaching below the root zone.

This method has the following limitations:

- Samples are usually taken only when tractor-mounted sampling equipment can be used without damaging the crop, usually in the spring and after harvest.
- N leaching loss is calculated as the difference between fall and spring concentrations. This method is less reliable than a direct measurement.

- Nitrate-N concentration in leachate is not measured, but rather is estimated from weather data and soil water-holding capacity.

Large-scale N rate experiments were conducted in 1996 and 1997 to compare applications of 230 lb N/a and 320 lb N/a on a Lane County and Marion County farm. Fertilizer application was split into three or four applications, with most of the N applied by mid-June. The high N rate treatment received the extra N fertilizer (90 lb N/a) in mid-June. Oil yield (average 97 lb/a) and crop N uptake (average 202 lb/a) were not affected by N fertilizer rate (4 site-years).

Postharvest soil nitrate-N (0- to 5-foot depth) increased when the N fertilizer rate increased from 230 to 320 lb/a (Figure 9). The top 2 feet of soil contained most of the unused N. Most of the nitrate-N present in the entire 0- to 5-foot sample was gone by the next spring (March), with leaching the most likely mechanism for nitrate loss. Soil nitrate-N decreased by more than 100 lb N/a between late August and early April.

Conclusions

- Oil yields did not benefit from N fertilizer rates in excess of 230 lb N/a.
- Over-winter nitrate-N loss exceeded 100 lb N/a/yr using moderate N fertilizer rates (230 lb N/a).
- Monitoring of nitrate-N in the top foot of soil was a good indicator of soil profile nitrate-N. In late summer, 45 percent of the nitrate in a 5-foot soil profile was present in the top foot (0 to 12 inches), 20 percent in the second foot (12 to 24 inches), and only 35 percent in the lower profile (24 to 60 inches).
- Monitoring for soil ammonium-N increased cost, but did not provide useful information.

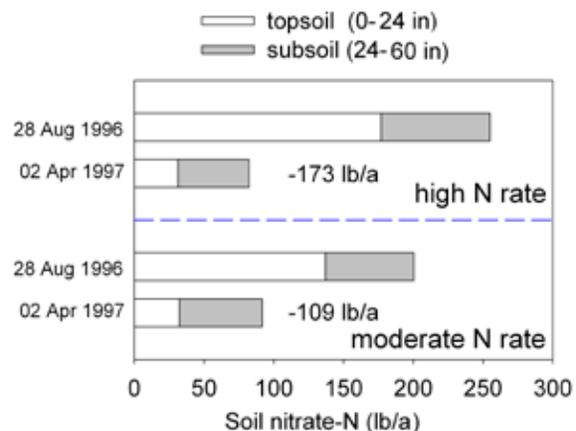


Figure 9.—Effect of nitrogen fertilizer rate on soil nitrate-N remaining in late summer (August 28) and the following spring (April 2). High N fertilizer rate = 320 lb N/a; moderate N fertilizer rate = 230 lb N/a. Source: Christensen et al. (2003)

Nitrogen monitoring

The goal of N management is to support crop needs, while minimizing the amount of soil nitrate-N remaining after harvest. Soil and plant tissue monitoring can provide useful information about N fertilizer practices.

Early-season soil sampling or tissue monitoring (May to mid-June) is generally not helpful in predicting N fertilizer need. Monitoring from mid-June to harvest can assist in (1) determining the need for additional N application in June or July and (2) developing a database to assist in evaluating your N fertilizer management. Following harvest, review N monitoring data and crop production records to evaluate your N management program and identify opportunities for improvement.

Rather than sampling many fields a single time, we recommend choosing a few “typical” fields to monitor weekly or biweekly from June through harvest. Choose 1-acre areas in productive portions of the field. Select areas with typical management practices, avoiding gravel bars and other atypical areas. You can also collect soil moisture data from the same areas for irrigation scheduling.

We recommend monitoring both soil and stem nitrate, as these two measurements reflect complementary aspects of N management.

The *soil nitrate-N test* measures N currently available for plant growth. Trends in soil nitrate indicate whether plant-available N is being lost (via plant uptake or leaching) or accumulated (from fertilizer, mineralization of soil organic matter, or irrigation water).

The *stem nitrate test* is a measurement of nitrate as it enters the plant but before it reaches the leaves. Therefore, it is a direct assessment of N supply as “seen” by the plant. Monitoring of other nutrients via stem sampling may also help assess plant nutrition.

Although both tests provide useful information, we consider soil nitrate-N to be a better indicator of crop N status than stem nitrate-N. Soil nitrate-N is a direct measurement of current plant-available N supply. The stem nitrate test indirectly measures soil N effects on plant tissue N concentration. As an indirect measurement, stem nitrate test results can be confounded by environmental factors that affect plant metabolism. When limited resources are available to support monitoring activities, soil nitrate-N is the preferred measurement.

Sampling method

Soil nitrate-N: Collect at least 15 cores to a depth of 1 foot using a soil probe. Combine cores in a sturdy plastic or plastic-lined bag and submit the composite sample to the lab for analysis. Keep the sample cool and ship to the lab via next-day delivery. If sample results are not needed immediately, samples can be frozen and shipped later.

Stem nitrate-N: Choose stems that receive adequate sunlight and have typical internode length. Do not sample shaded stems from deep within the plant canopy (near the ground) or upright, purplish stems that are budding or flowering on top of the canopy. Collect a composite sample of 30 stems by cutting stems 6 inches below the shoot tip. It takes 30 stems to get sufficient dry matter for lab analysis because stems are mostly water. Remove the leaves from stems and discard. Send the top 6 inches of stems (minus leaves) to the lab. Keep the sample cool and ship to the lab via next-day delivery.

Research was conducted in Lane County production fields to evaluate the effects of sampling protocol on stem nitrate-N values (Smesrud and Selker 1998). Results showed that the sampling protocol outlined above should provide a reproducible stem nitrate value within 10 to 15 percent of the true mean value. Sampling time of day did not have a major effect on results.

Interpretive values

Trends in soil and stem nitrate values during the growing season are of greater value for evaluating N management than are single test values. Use the information below as a starting point for interpreting monitoring data.

Soil nitrate-N: Soil test nitrate-N is usually expressed in lb/a. A soil containing 20 ppm nitrate-N (0- to 1-foot depth) contains approximately 70 lb nitrate-N/a. During June, when soil nitrate-N values in the 0- to 1-foot depth fall below 20 ppm, plants may respond to N application.

Research has not been conducted to determine the minimum level of nitrate-N needed in July and August for optimum crop growth and oil yield. Because the N uptake rate declines in July, soil nitrate-N can be lower than 20 ppm at harvest without compromising oil yield.

Stem nitrate-N: Replicated field trials to identify deficient, adequate, and excess stem nitrate-N values have not been conducted in the Willamette Valley. Guidelines from other growing regions may not be helpful under local conditions. Stem nitrate-N values greater than 6,000 to 8,000 ppm (mg/kg) likely indicate adequate N supply in early season. Sufficient values may decline to 2,000 to 4,000 ppm near harvest.

When N is applied frequently via sprinkler irrigation, and plants are growing rapidly, stem nitrate-N may not increase following N application. When most of the N fertilizer is applied early (June), stem nitrate-N values may be high in June and decline rapidly as the crop matures. Both trends in stem nitrate-N during the growing season may indicate sufficient N for peppermint grown in the Willamette Valley.

Peppermint oil quality

A peppermint plant synthesizes oil in glands on its leaves. Oil quality is determined by the balance of several oil constituents. Many factors influence the composition of distilled oil, including stage of maturity at harvest; environmental conditions throughout the growing season and at harvest; crop management, including nutrient source and time of application; postharvest handling techniques; and the presence of weeds in the field. The effects of N and S application and crop maturity are discussed in this section.

The quality of mint oil is determined by laboratory chemical analysis and by organoleptic evaluation (aroma testing by trained oil quality analysts). As shown in Table 2, superior peppermint oil contains high quantities of menthol, moderate amounts of menthone, and low levels of pulegone and menthofuran. Menthol is the component that creates peppermint's characteristic cool, refreshing sensation.

Nighttime temperatures below 55 to 60°F during the growing season favor production of menthone and menthol. Warm nighttime temperatures allow conversion of these compounds to pulegone and menthofuran, thus reducing oil quality.

Table 2.—Acceptable composition of peppermint oil from a single-cut production system in western Oregon.

Oil component ^a	Range (%)
Limonene	Below 1.8
Eucalyptol	4.0–5.5
Menthone	15–25
Menthol	39–45
Menthyl acetate	5–6
Menthofuran	Below 2.5
Pulegone	Below 2.0
Piperitone	0.4–0.9

^aDetermined by gas chromatography.

Nitrogen and maturity

The influence of N rate and peppermint maturity on oil composition was measured near Corvallis in 1970 and 1971. N rates were 50 to 300 lb/a, and peppermint was harvested at bud, 50 percent bloom, or full bloom. Results are shown in Table 3 and Appendix B (page 15).

Based on results of this research, we recommend application of 200 to 250 lb N/a and harvest at 10 percent bloom. This combination of N rate and harvest time should yield an acceptable balance of oil constituents. Since not all fields can be cut at one time, typical harvest for a grower would probably begin with less than 10 percent bloom and be completed with slightly greater than 10 percent bloom.

Effects of S application

S fertilizer is generally applied to the soil early in the growing season (March–April) in the form of sulfate-S (SO₄) at a rate of 20 to 30 lb S/a. In addition to the sulfate form, S is commonly sold in the elemental form. Elemental S should not be used as a source of current-season S for peppermint or most other crops because it is not available for crop uptake until bacteria oxidize it to the sulfate form. This change usually does not occur rapidly enough to supply plant-available sulfate-S.

Elemental S is sometimes applied to peppermint as a fungicide. This use of S shortly before harvest can reduce oil quality. The effects of sulfate-S and elemental S on oil quality were compared in commercial field-grown peppermint. These studies confirmed that sulfate-S does not influence peppermint oil quality. However, elemental S, if improperly applied, can decrease peppermint oil quality. To reduce potential oil quality degradation, apply the lowest effective rate of elemental S needed for disease control in conjunction with the longest possible preharvest interval. Consult the Oregon State University online *PNW Plant Disease Management Handbook* for current recommendations.

Table 3.—Peppermint oil quality change with maturity and N rate.

Peppermint oil component	Influence of N rate	Suggested N rate (lb/a)	Influence of maturity
Terpene hydrocarbons	Little	NA	Decrease
Menthone	Increase	200–250	Decrease
Menthol	Decrease	200–250	Increase
Menthyl acetate	Little	NA	Increase
Menthofuran	Decrease	200	Increase
Oil yield	Increase	200–250	Increase
Oil yield and quality	—	200–250	—

Lime, calcium, and magnesium

Importance of soil pH

Soil pH indicates the chemical condition roots will experience. As soil pH decreases (soil becomes more acidic), solubility of iron, zinc, manganese, and aluminum increases. If soil is too acidic, the concentration of aluminum can reach levels that inhibit root growth. Soil pH analysis indicates whether soils are too acidic and whether lime is needed to raise soil pH. Lime rate is estimated with another test, the SMP buffer test.

A soil pH between 5.5 and 6.0 is adequate for peppermint production. The most important preplant nutrient management activity is to ensure a soil pH of at least 6.0. This will ensure that soil pH remains adequate for several years.

Preplant lime application

Sample and test soil for pH, SMP buffer lime requirement, and calcium (Ca) well before planting, because lime should be mixed into the field before planting.

Soil pH naturally varies through the year by as much as 0.3 to 0.5 unit. It is lowest in late August and September, before the fall rains begin, and highest in February or March, when the soil is wettest. Sample soils for pH at the same time each year to avoid confusion caused by seasonal fluctuation.

The Shoemaker-McLean-Pratt (SMP) buffer or lime requirement test (LR) estimates the amount of lime needed to raise soil pH. Preplant lime application rates can be estimated from Table 4. A lime application is effective for several years. See OSU Extension Service publication FS 52-E, *Fertilizer and Lime Materials*, for more information about liming materials.

When more than 3 to 4 t lime/a is recommended, mix in half the lime before or during plowing and incorporate the remainder with tillage after plowing. This strategy also can be used with lower lime application rates.

Table 4.—Preplant lime rate recommendations for western Oregon using the SMP buffer.

SMP buffer test result ^a	Apply this amount of lime ^b (t/a)
Below 5.2	5–6
5.2–5.6	4–5
5.6–5.9	3–4
5.9–6.1	2–3
6.1–6.5	1–2
Over 6.5	None

^aLime recommendations are based on the SMP buffer test only. If other buffer tests are used, recommendations may differ. Note that the SMP buffer does *not* equal soil pH. Liming rates cannot be determined based solely on soil pH.

^bLime rate is based on 100-score lime.

Topdress lime application

Ammoniacal N fertilizers (e.g., urea) readily reduce soil pH in the surface layer on the lighter textured soils where mint is grown. When ammoniacal N is topdressed, surface soil pH decreases about 0.1 pH unit/yr for every 100 lb N/a applied. Since more than 200 lb N/a is typically applied annually to peppermint, the soil pH could decrease 0.5 unit in as few as 3 years, especially on a sandy soil such as the Newberg series.

This reduction in soil pH could lead to the need for lime topdressing, but topdressed lime creates soil pH stratification, since lime has limited mobility. Lime increases soil pH only in the surface layer of soil (Figure 10). If soil pH falls below 5.0, topdressed lime will produce a suitable soil pH only at the surface. Soil pH even slightly below the surface can remain too low to maintain adequate crop growth.

The stratification in soil pH from N fertilizer or lime application is reason to collect soil samples from two depths, 0 to 2 inches and 2 to 6 inches. Apply lime via topdressing when the soil pH in the surface 2 inches is 5.5 or below. Monitor soil pH in the 2- to 6-inch depth. If it falls below 5.5, peppermint oil yield will likely decline. The only solution to increasing soil pH below the surface 2 inches is to mix lime into the soil. Incorporating lime into the soil may necessitate removing the peppermint stand.

Soil pH increase following topdressed lime application depends on lime rate, soil type, crop, and management. Normally, topdress lime application rates are 1 or 2 t/a. In some situations, this lime rate increases soil pH to a depth of 1 or possibly 2 inches in the first year after application. Below this depth, soil pH is unlikely to change. Changes in soil pH after the first year are uncommon.

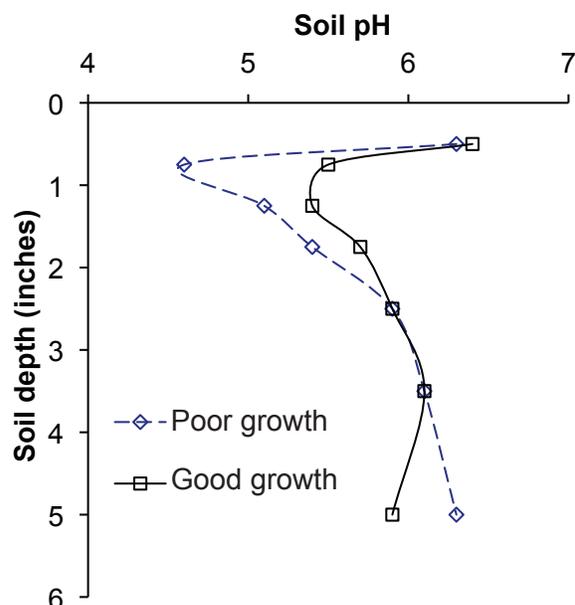


Figure 10.—Soil pH at varying depths from areas of good and poor growth in a Benton County peppermint field.

On established fields, topdress lime as soon after harvest as possible so that it can react before spring N fertilizer is applied. Surface application of lime can cause volatilization losses from topdressed ammoniacal N materials such as urea. The chance of volatile N loss is greatest when urea remains on the surface of a recently limed field for more than a day. The chance of N loss through volatilization is reduced when lime reacts through the winter or through several applications of irrigation water. During the season following a topdress lime application, irrigating immediately following N application is prudent.

Calcium (Ca) and magnesium (Mg)

In addition to soil pH, review extractable Ca before planting peppermint. If extractable Ca is less than 8 meq/100 g soil (1,600 ppm), add 1 t lime/a even if soil pH is above 5.5.

Peppermint oil yield increase from application of Mg has not been documented in western Oregon. Nonetheless, we advise adding Mg if soil test Mg is below 120 ppm or 1 meq/100 g soil. Magnesium can be supplied from 1 t dolomitic lime/a or by applying 30 to 50 lb Mg/a from

potassium-magnesium sulfate (approximate analysis 22 percent K₂O, 11 percent Mg, 22 percent S), marketed as Sul-Po-Mag or K-Mag.

Phosphorus (P)

Between 30 and 40 lb P/a is removed in peppermint hay. Unlike N, limited P application research has been conducted. In the few Oregon and Washington research trials using P rates, a benefit from P application was rarely measured. A 1967 survey of 60 fields found “high” tissue P with no apparent relationship between P concentration and oil yield.

P application did not increase oil yield in Montana fields with low soil test P (Olsen or bicarbonate extractable P of 5 ppm). These results led to speculation that established mint fields become infected with mycorrhizae, a fungus that aids plants in P uptake.

Determine P need from soil test results and use Table 5 (page 11) to estimate P rate. Apply P in fall to established stands when soil test P is below 30 ppm. When soil test P is between 30 and 40 ppm or for maintenance application, P can be applied in either spring or fall. See the sidebar “Sampling depth for P and K” for more information.

Sampling depth for P and K

Comparisons between soil test values from the surface 2 inches and the soil below can help you make cost-effective nutrient management decisions. The examples here use a sample from the 2- to 10-inch depth. This depth is not recommended; it is used only as an example.

In Figure 11, P soil test values in the 0- to 2-inch sample increased as stand age increased. In the 2- to 10-inch sample, however, they remained constant. Based on the P soil test value from the 2- to 10-inch sample, a P application would be recommended. However, the sample from the 0- to 2-inch depth shows that additional P is not needed, since peppermint roots readily use P from the surface 2 inches of soil. By sampling soil from multiple depths, this grower could reduce or eliminate P fertilizer application.

Figure 12 shows declining K soil test values in all sample depths. Two important points are seen:

- Peppermint uses nutrients from at least the surface foot of soil.
- A single sample from the surface 2 inches is not adequate for understanding soil test K depletion.

Note: The peppermint stand represented in Figures 11 and 12 was about twice the age of most fields. The age, fertilizer application history, and consistent collection of soil samples provide an excellent example of soil test changes that can occur in peppermint fields.

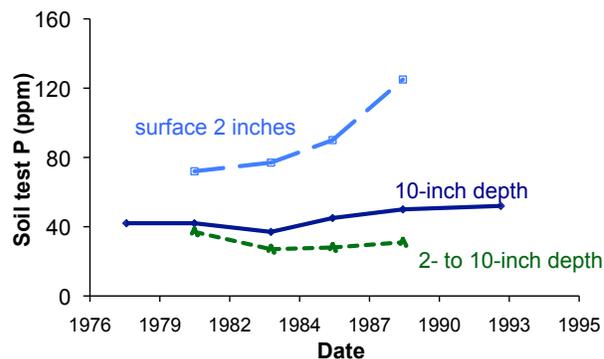


Figure 11.—Soil test phosphorus for three soil sample depths during the life of a peppermint stand, Polk County, OR.

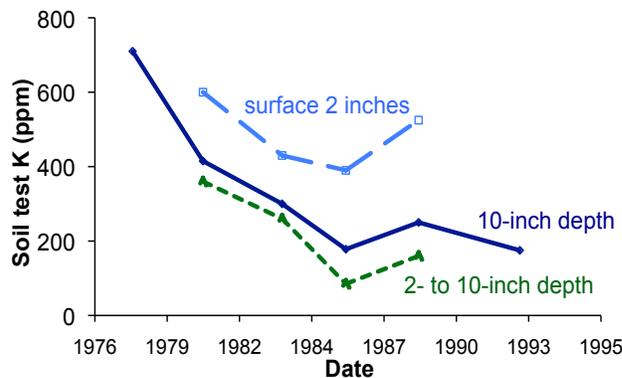


Figure 12.—Soil test potassium for three soil sample depths during the life of a peppermint stand, Polk County, OR.

Table 5.—Fertilizer phosphorus (P) rate recommendations for western Oregon using the Bray P1 soil test. Use this table for preplant soil sample from 0 to 6 inches and 0 to 2 inches in established stands.

Soil test P ^a (ppm)	Apply this amount of P ₂ O ₅ (lb/a)
Below 20	100–150
20–30	60–100
30–40	0–6
Over 40	None

^aBray P1 soil test method.

Potassium (K)

Potassium is the second most likely nutrient (after N) to limit peppermint hay and oil yield. Harvest of 4 to 5 t/a of peppermint hay removes 250 to 350 lb K/a (Figure 13). Many soils on which peppermint is produced are sandy and relatively low in organic matter. The combination of sandy, low-organic-matter soil and K use by peppermint can rapidly deplete soil test K.

Conversely, annual topdress of K fertilizer will create stratification in soil test values. The surface 2 inches of soil can easily have a soil test K value double the amount found in a sample from 2 to 6 inches. See the sidebar “Sampling depth for P and K” (page 10) for more information.

The stratification from K fertilizer application is reason to collect soil samples from two depths, 0 to 2 inches and 2 to 6 inches. Apply K to soil with less than 200 ppm ammonium extractable K in the surface 2 inches of soil.

Monitor soil test K in the 2- to 6-inch depth. When it declines, increase the annual K application rate. When the soil test value from this sampling depth is above 200 ppm and increasing, the annual K rate can be decreased. If the soil test K value from this depth does not change, K supply is adequate and your current fertilizer program can be maintained.

Determine K need from soil test results and use Table 6 to estimate K rate. Apply K in fall to established stands when soil test K is below 200 ppm. For maintenance application (when soil test K is above 200 ppm), K can be applied in either spring or fall.

Table 6.—Fertilizer potassium (K) rate recommendations using the ammonium acetate extractant. Use this table for preplant soil sample from 0 to 6 inches and 0 to 2 inches in established stands.

Soil test K ^a (ppm)	Apply this amount of K ₂ O (lb/a)
Below 100	120–200
100–200	60–120
Over 200	None

^aAmmonium acetate extract method.



Figure 13.—Mint hay harvest removes large quantities of potassium from the field, potentially depleting soil test K. Photo: Gale Gingrich

Sulfur (S)

Crops grown in western Oregon require addition of S, usually 15 to 30 lb/a. The amount and frequency of application depends on soil S supply and on crop removal. Sulfur content of peppermint hay varies and is influenced by N fertilizer application, S application, and the amount of biomass produced. From 1995 through 1997, a range of 6 to 40 lb S/a was measured in hay harvested from seven peppermint fields, with an average of 20 lb S/a.

Apply 20 to 30 lb S/a in early spring with the first application of N. Plants use S as sulfate (SO₄-S). Fertilizer materials such as ammonium sulfate, ammonium phosphate sulfate (16-20-0-14S), Sul-po-mag, urea-sul, and potassium sulfate (0-0-50) supply sulfate-S. See the sidebar “Peppermint oil quality” (page 8) for more information about how various forms of S influence oil quality.

Micronutrients—Zinc (Zn), copper (Cu), boron (B), manganese (Mn), and iron (Fe)

The need for application of Zn, Cu, B, Mn, or Fe has not been demonstrated for peppermint in western Oregon.

For more information

Evaluating Soil Nutrients and pH by Depth in Situations of Limited or No Tillage in Western Oregon,

EM 9014-E. <http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/19024/em9014.pdf>

Fertilizer and Lime Materials, FS 52-E. <http://extension.oregonstate.edu/catalog/html/fg/fg52-e/>

A Guide to Peppermint Insect and Mite Identification, PNW 182. <http://ir.library.oregonstate.edu/jspui/handle/1957/18341>

PNW Insect Management Handbook. <http://uspest.org/pnw/insects>

PNW Plant Disease Management Handbook. <http://plant-disease.ippc.orst.edu/>

PNW Weed Management Handbook. <http://uspest.org/pnw/weeds>

Weed Management in Mint, EM 8774. Available from OSU Crop Science, 541-737-8868.

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Conference Proceedings, Vol. 5, pp. 71–76. March 6–7, 2003, Salt Lake City, UT.

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Appendix A

Nutrient-related research in western Oregon peppermint

- **1955:** N, P, K, S, and Mg were applied to a field near Jefferson in Marion County. Highest yield was achieved with an N rate of 150 lb/a. No other nutrient application increased yield, as soil test levels of other nutrients were adequate or high.
- **1967:** A survey to determine the nutrient status of peppermint fields yielded the following results:
 - Micronutrient concentrations in plant tissue were relatively high. The highest tissue Mn concentration was associated with lower oil production.
 - The highest N concentration was associated with rank, stemmy growth and decreased oil production.
 - Tissue P concentration was high, and no apparent association existed between P concentration and oil production.
 - The majority of the oil is produced in the top 15 inches of the plant.
- **1968–1971:** Experiments in grower fields in Benton, Lane, Linn, and Josephine counties evaluated peppermint hay production and oil yield response to application of N, P, K, and lime. Yield of peppermint hay increased with increasing N rate up to 250 lb N/a, but decreased with higher N rates. Delayed N application decreased hay yield. P application did not increase tissue P concentration or oil concentration (percent oil extracted). In contrast, K application increased tissue K concentration but not oil concentration. Peppermint stem nutrient concentration was evaluated as a management tool for monitoring nutrient status during the season.
- **1980:** Protocols for peppermint stem sampling were assessed at the University of Idaho Parma Research Center. Subsequent stem nitrate monitoring projects at OSU were based on the sampling protocols at Idaho.
- **1985 and 1986:** Liquid fertilizer material was evaluated as a substitute for rust control by propane flaming in Benton, Lane, and Linn counties. Common liquid fertilizer materials such as urea-ammonium nitrate (solution 32) did not adequately defoliate peppermint. Treatments with a mixture of urea (15 percent N) and 49 percent sulfuric acid produced oil yield equal to treatments that received propane flaming.
- **1993–1998:** A long-term project evaluated N leaching loss from vegetable and mint fields in Lane County, as well as the use of stem nitrate-N as a tool for monitoring crop N status.
- **1995 and 1996:** Biomass and nutrient accumulation were measured in four grower fields. Rust was controlled chemically in two fields and by flaming in the other two fields. Biomass accumulation in all fields



Figure 14.—Research in 2005 measured effects of peppermint residue application on plant-available nitrogen and soil nitrogen mineralization (see Appendix C, page 17). Photo: Gale Gingrich

- was relatively linear from late May to harvest, with 8,000 to 11,000 lb hay/a produced. Nitrogen uptake was 200 to 250 lb/a, and K uptake was 275 to 375 lb/a. Peak N uptake of 2 to 3 lb/a/day occurred in mid-June and was followed by peak biomass production of 100 lb/a/day in late July.
- **1997 and 1998:** A large-scale N rate evaluation was performed on a grower field near Junction City and on a second farm near Gervais. This effort confirmed earlier work suggesting that peppermint requires about 200 lb N/a. Addition of more than 300 lb N/a did not increase hay or oil yield. The higher N rates increased residual soil $\text{NO}_3\text{-N}$ after harvest.
 - **1998:** The influence of S source and rate on oil quality was evaluated. Excess $\text{SO}_4\text{-S}$ posed no threat to oil quality, while elemental S applied to foliage may render peppermint oil unacceptable to buyers.
 - **1996–2000 and 2001–2004:** Variety trials were conducted on fields infected with verticillium wilt at the Botany and Plant Pathology Farm near Corvallis. Results demonstrated that new experimental lines had improved wilt and rust tolerance, but lacked suitable oil quality.
 - **2003 and 2004:** Plant-available N release from applied peppermint residue was evaluated at the North Willamette Research and Extension Center, Aurora (Figure 14). Peppermint residue was applied in spring 2003, and N fertilizer equivalency was evaluated for sweet corn crops grown in 2003 and 2004. Incubation of soil from the NWREC trial was also performed.
 - **2005:** Mint stockpiles or “slugs” (after distillation) were sampled at four Willamette Valley farms from August through October. Laboratory incubation was performed to determine plant-available N release from peppermint residues.

Appendix B

Effects of N application and maturity at harvest on oil quality

An overview of the influence of N application and maturity on peppermint oil quality is provided on page 8. Changes in oil component concentrations with N application rate and maturity at harvest are shown here.

As N rate increased, oil quality changed as follows:

- Menthone concentration increased (Figure 15).
- Menthol concentration decreased (Figure 16).
- Menthyl acetate concentration increased slightly with N rate from 50 to 200 lb N/a (Figure 17).
- Menthofuran concentration decreased (Figure 18).
Because menthofuran increases with maturity, N indirectly influences menthofuran concentration by delaying maturity.

As maturity at harvest increased, oil quality changed as follows:

- Menthone concentration decreased (Figure 15).
- Menthol concentration increased (Figure 16).
- Menthyl acetate concentration increased sharply (Figure 17).
- Menthofuran concentration increased (Figure 18).

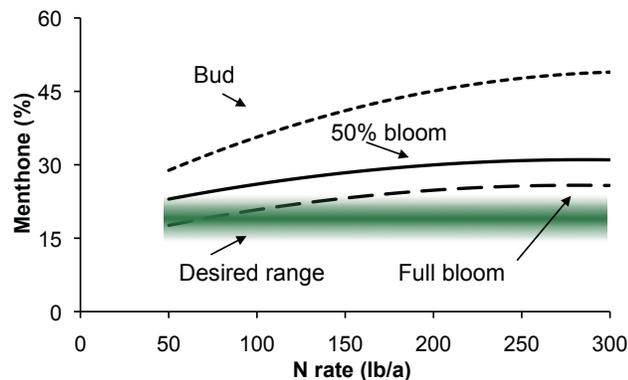


Figure 15.—Menthone concentration of peppermint oil increases with N rate and decreases with maturity.

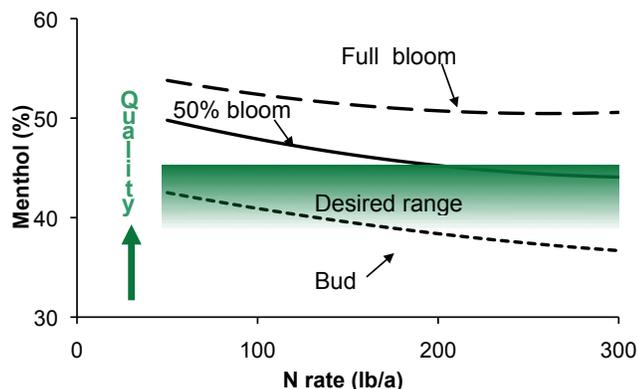


Figure 16.—Menthol concentration of peppermint oil decreases with N application and increases with maturity.

Peppermint maturity at harvest increased oil yield (Figure 19).

Peppermint hay produced with 200 lb N/a and harvested at bud development state produced oil with 4.5 percent menthyl acetate, below the desirable concentration. A similar N rate and harvest at 10 percent bloom should increase menthyl acetate concentration to an acceptable level. Harvesting at this stage provided acceptable levels of menthone and menthol, as long as N rates were less than 300 lb/a. Although menthyl acetate and menthone concentrations remained acceptable at 50 percent bloom, harvesting at this stage is not recommended, as menthofuran concentration increases to an unacceptable level after 10 percent bloom.

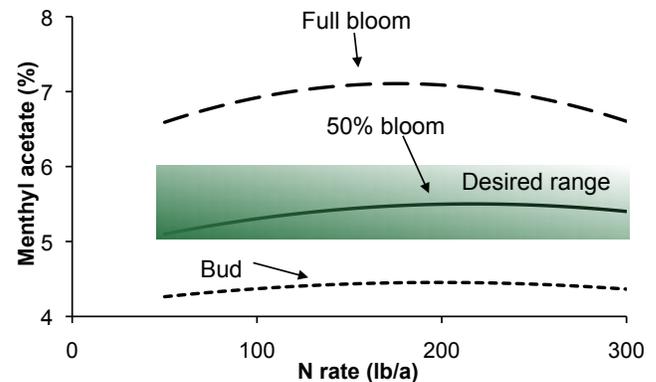


Figure 17.—Menthyl acetate concentration of peppermint oil increases with maturity and is changed little by N rate.

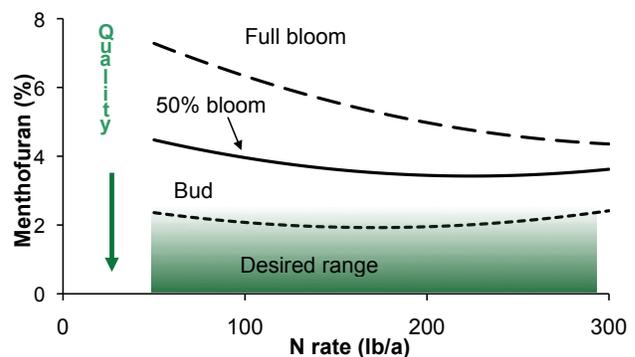


Figure 18.—Menthofuran concentration of peppermint oil increases with maturity and decreases with N application rate when harvested at 50 percent bloom or later.

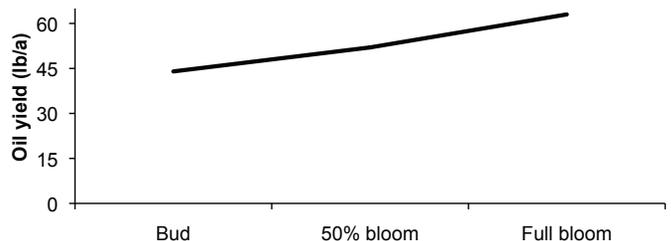


Figure 19.—Peppermint oil yield increases with maturity.

Appendix C

Effects of weeds on peppermint oil quality

The presence of weeds in the field influences peppermint oil yield and quality. Weeds reduce peppermint biomass through competition for resources, including sunlight, water, and nutrients. As weed biomass increases, a generally linear decrease in both peppermint hay and oil yield is expected (Figure 20). Weeds also can reduce the life of the peppermint stand by forcing growers to rotate to other crops in an effort to contain problem weed populations.

Weeds present at peppermint harvest can also impart undesirable color and odor to peppermint oil. Peppermint oil odor is one quality parameter. Oil quality based on aroma testing is termed organoleptic evaluation. The presence of weeds in harvested peppermint can decrease the positive organoleptic ratings and reduce the commercial value of the oil. For example, some weeds, such as marestail, contain components that distill with the mint oil, resulting in off odors and flavors that reduce oil quality. In extreme cases, oil may be commercially unacceptable.

Broadleaf weed species reduce oil quality more than do grass weed species. Unfortunately, broadleaf weed species are often more difficult to manage in peppermint than are grass weed species. Perennial broadleaf weeds, including Canada thistle and field bindweed, can be especially difficult to manage, since their life cycle is similar to that of peppermint.

A trial conducted in Wisconsin quantified the impact on oil quality of three weed species growing at a range of densities in peppermint (Figure 21). As the weed biomass increased relative to harvested peppermint biomass, oil quality decreased. The three weed species varied in their impact on oil quality. For example, at similar biomass levels (greater than 2.5 percent of harvested biomass), the broadleaf weed species (redroot pigweed and common lambsquarters) decreased oil quality more than did barnyardgrass, a grass species.

Management of both grass and broadleaf weeds is critical for peppermint yield and oil quality. Nonetheless, costs of weed management must be weighed against potential gains in oil yield and quality. These costs include direct herbicide and application costs, indirect costs (including peppermint injury and potential stand loss resulting from some herbicide applications), and development of herbicide-resistant weed populations due to overuse of certain herbicides. Individual growers should make weed management decisions on a field-by-field basis. Weigh all potential benefits and costs associated with the particular operation and cropping systems.

Some weeds may warrant greater weed management efforts than others. Broadleaf weeds such as common groundsel and the pigweed species may require special

consideration because of their impact on oil quality. Other species, including those that are wind dispersed and those that are rapidly developing resistance to commonly applied herbicides (e.g., marestail and prickly lettuce), may become increasingly difficult to control in the future. Some weed species (e.g., wild garlic, volunteer garlic, and volunteer onion) must always be managed to limit their impact on oil quality. Conversely, low-density and sporadic populations of grass weed species may not warrant the cost of chemical management, given their lower impact on oil quality.

An understanding of the biology and ecology of weed species can help growers time weed management practices to achieve maximum control. Specific weed management recommendations are found in the mint chapter of the *PNW Weed Management Handbook* and in OSU Extension publication EM 8774, *Weed Management in Mint*.

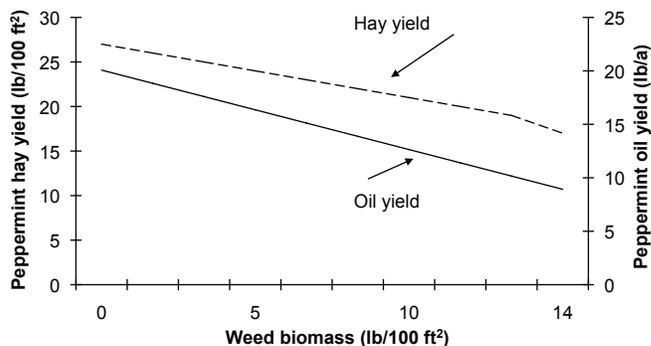


Figure 20.—Characteristic yield loss for peppermint grown in competition with a mixed population of grass and broadleaf weed species.

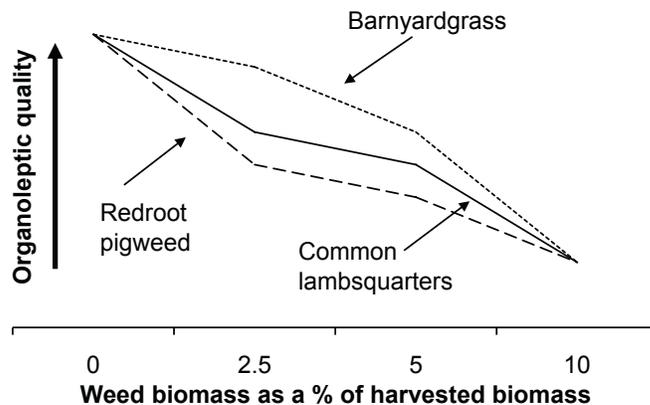


Figure 21.—Influence of weed biomass on organoleptic rating. Source: Adapted from Schmitt (1996).

Appendix D

Plant-available N release from peppermint residue

Peppermint residue consists of the cooked leaves and stems of the peppermint plant after high-temperature distillation to extract oil. This residue has value as a soil amendment. It is often applied to fallow fields in the fall or sold as a soil amendment to gardeners. Research was conducted to determine the plant-available N (PAN) supplied by peppermint residue.

Peppermint residue N concentration

Willamette Valley peppermint residue stockpiles (also called “slugs” or peppermint hay) were sampled following harvest. Three replicates of peppermint slugs from four farms (24 samples) were collected during August and October 2005 (Table 7). Both N concentration and C:N ratio were relatively consistent in all samples, despite differences in storage time in the field (1 to 8 weeks), moisture, and observed fungal growth in the piles.

Short-term effects on PAN

Laboratory incubation with moist soil at 72°F simulated the rapid decomposition that occurs when peppermint residue is tilled into moist soil (Figure 22). The laboratory residue incorporation rate was roughly equivalent to a field application rate of 1 to 2 inches of residue tilled into a 6-inch soil depth (roughly 100 wet ton peppermint residue/a).

Peppermint residue lost about one-third of its organic matter via decomposition during the first 30 days of lab incubation. During this period, soil nitrate-N was immobilized (reduced) by microbial activity (Figure 23). This effect is typical of plant materials with relatively low total N (1.3 to 2.2 percent N, dry wt basis) and high C:N ratios (above 15).

Consumption of nitrate-N by microbes was temporary, however. After 30 days, decomposition slowed, and soil N was converted to nitrate-N at about the same rate in both peppermint-amended and unamended soil (Figure 23).

These results suggest that peppermint residue can be incorporated into soil in the fall without risk of nitrate leaching to groundwater, as the initial decomposition process will consume soil nitrate-N.

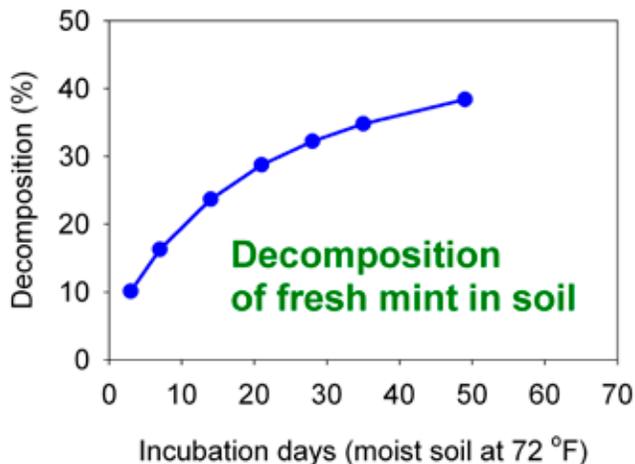


Figure 22.—Decomposition of peppermint residue in laboratory incubation. Soil was a Chehalis silty clay loam, 25 percent gravimetric moisture. Source: Shizato (2006).

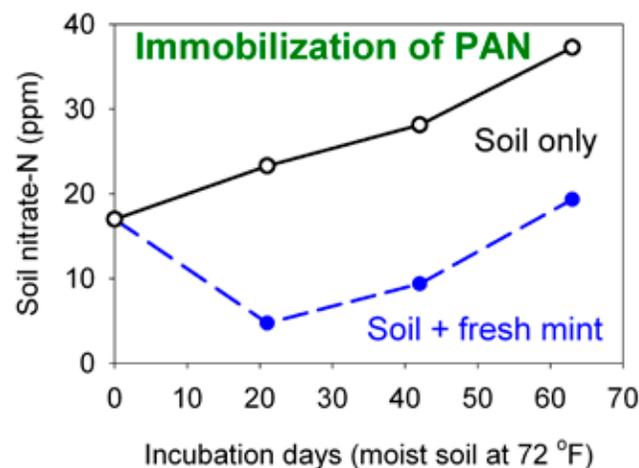


Figure 23.—Immobilization of plant-available N during initial decomposition of peppermint residue in laboratory incubation. Soil was a Chehalis silty clay loam, 25 percent gravimetric moisture. Source: Shizato (2006).

Table 7.—Peppermint residue characteristics.^a

	Dry matter (% of wet weight)	Carbon (C) (% in dry matter)	Total nitrogen (N) (% in dry matter)	C:N ratio
Range	37–65	39–42	1.3–2.2	17–32
Average	50	40	1.8	22

^aOn-farm stockpiles at four Willamette Valley farms collected August and October, 2005. Source: Peppermint hay samples collected by John P.G. McQueen. Incubation data reported in Shizato (2005).

N fertilizer replacement value of peppermint residue

The N fertilizer replacement value of peppermint residue for a sweet corn crop was determined in field trials at the North Willamette Experiment Station in 2003 and 2004. Peppermint residue from the 2002 harvest was incorporated before planting sweet corn in May 2003. Residue was applied at a rate of 9 dry ton/a and supplied 620 lb total N/a. The N fertilizer replacement value of peppermint residue (relative to urea) was 40 lb N/a in 2003 and 30 lb N/a in 2004 (Kusonwiriawong 2005).

Effects on long-term soil N mineralization rate

After 2 years of sweet corn production, soil from the 0- to 6-inch depth was sampled in May 2005 and incubated in the laboratory (Figure 24). The incubation demonstrated the following:

- The rate of PAN release was consistent (linear) under lab conditions (moist soil, 72°F) for a long incubation period.
- A one-time peppermint application (spring 2003), performed 2 years before soil sampling (spring 2005), roughly doubled the soil N mineralization rate. (The rate increased from 0.35 to 0.6 ppm N/day.)

Because of long-term effects on N mineralization, peppermint residues should be applied evenly at a moderate application rate. Do not apply peppermint residues to the same fields every year.

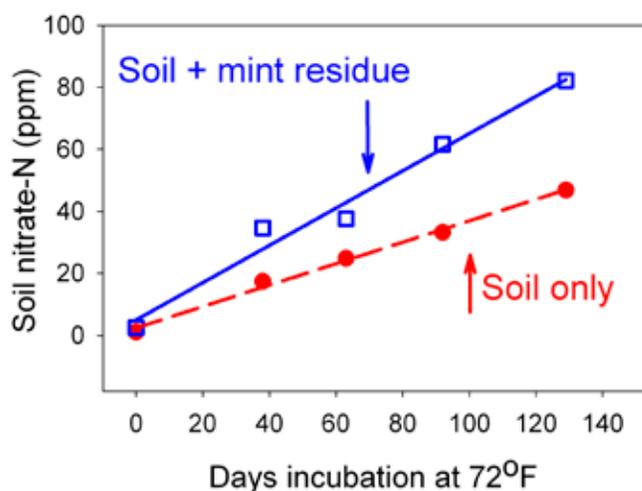


Figure 24.—Peppermint residue effect on long-term soil N mineralization rate. Peppermint residue was applied in spring 2003, and soil incubation data were collected from a spring 2005 soil sample. Soil was a Willamette silt loam, 25 percent gravimetric moisture, NWREC, Aurora, OR. Source: Sullivan and Beldin (unpublished data).

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