(Abstract)

Laughlin, Winston M. A Study of the Effects of Different Fertilizer Mixtures and Certain Minor Elements on the Growth of Mint and on the Yields and Physicochemical Constants of the Oil.

Peppermint was grown on muck soil in the greenhouse, and peppermint and spearmint in field experimental plots, with various soil treatments. Measurements of plant height and observations of symptoms of Verticillium wilt were made at intervals during growth in the greenhouse. When the plants commenced to bloom, both tops and roots were weighed. In the field counts of plants showing symptoms of Verticillium wilt were made and at harvest time the mint was weighed immediately after cutting, cured and distilled. In the laboratory the amount of oil and the following physicochemical constants were determined -- specific gravity, specific optical rotation, and refractive index of both peppermint and spearmint oil, the percentage of esters, menthol, and menthone of peppermint oil, and the percentage of carvone of spearmint oil. All data were subjected to statistical treatment by the analysis of variance.

Large applications of calcium and of calcium and magnesium carbonate depressed root yields of peppermint in the greenhouse.

Copper applied in the greenhouse stimulated early growth but had no effect on yield of plant material or oil.

In the field copper tended to increase oil yields on a decidedly acid soil which had been limed.

The oil production of plants in the greenhouse was increased by iodine applications. These treatments had no effect on the early growth or the yield of plant material. There were no differences in the yield of plant material obtained by the use of six different carriers of iodine. Iodine applications in the field had no influence on the production of foliage or oil.

Applications of boron, cobalt, and silicon were toxic only when the following forms and rates in pounds per acre were used: cobalt sulphate, 160; boric acid, 100; sodium metasilicate, 3200. Lower rates of application of these materials had no significant influence on early growth or yields of plant material in the greenhouse.

Molybdenum, strontium, chromium, magnesium, and zinc had no significant influence on early growth or yields of plant material in the greenhouse when the following forms and rates in pounds per acre were used: sodium molybdate, 48; strontium chloride, 1600; potassium dichromate, 320; magnesium sulphate, 8000; zinc sulphate, 960.

No minor element treatment influenced the incidence of Verticillium wilt symptoms in the greenhouse or in the field. While the use of 2000 pounds per acre of 0-10-20 fertilizer had no influence on the incidence of Verticillium wilt, the plants produced greater foliage and oil in spite of the prevalance of the disease.

Yields of peppermint oil and of spearmint foliage and oil tended to decrease and yields of peppermint foliage tended to increase as the ratio of potash to phosphate in the fertilizer rose above 1:1.

Alphatron, a radioactive material, had no effect on yields of foliage or oil or the incidence of Verticillium wilt symptoms.

In 1947 peppermint grown the previous year depressed peppermint foliage and oil yields. This was not true in 1948. Other crops of the previous year had no influence on yields of foliage or oil. Crops of the previous year had no effect on the yields of either the foliage or the oil content of spearmint.

The physicochemical constants of the oils were not influenced by soil treatments.

The correlation coefficients between yields of peppermint foliage and oil, yields of spearmint foliage and oil, of total menthol and menthone percentages, and of total menthol percentage and specific optical rotation were 0.584, 0.897, -0.971, and 0.777, respectively.

# A STUDY OF THE EFFECTS OF DIFFERENT FERTILIZER MIXTURES AND CERTAIN MINOR ELEMENTS ON THE GROWTH OF MINT AND ON THE YIELDS AND PHYSICOCHEMICAL CONSTANTS OF THE OIL.

by

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## INTRODUCTION

Peppermint (Mentha piperita) is an important crop on the muck* soils of Michigan and Indiana. However, its culture is declining, principally because of decreasing oil yields, part of which is due to the presence of Verticillium wilt. Spearmint (Mentha viridis or Mentha spicata), on the other hand, due to its greater resistance to this same disease, is becoming an increasingly important crop in this area. This study was undertaken to ascertain the effect of various soil treatments upon the growth of peppermint and spearmint, the incidence of Verticillium wilt, the production of oil, and the physicochemical constants of the oil.

## REVIEW OF LITERATURE

Pilz (30) (Austria) reported that peppermint responded to nitrate and potash applications, but showed no response to phosphates. Springer (37) (Germany) found the largest yields of peppermint and peppermint oil associated with the application of nitrates and phosphates while Bauer, Rudorf, and Heeger (4) (Germany) stated that the phosphate content of individual experimental plots was directly proportional to the oil yield. Lutzenberger (26) (Germany) regarded phosphate as having a particularly beneficial effect on peppermint

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* The term "muck soil" is used interchangeably with "peat" in this discussion.

grown on marsh soils. Powers and Jones (33) found on different Oregon peat soils maximum yields were obtained by potash applications. Schlemmer and Springer (36) (Germany) and Kwinichidze and Rozanski (25) (Poland), after extensive field experiments with various fertilizer mixtures, report that the form of the fertilizer applied exerted only a slight (if any) influence on the oil yields. Harmer (17,18), for peppermint on new muck in Michigan, recommends a ratio of phosphate to potash of 2:1, changing to a ratio of 1:1 or 1:2 after the land is cropped a few years. Nitrogen is recommended in the fertilizer mixture only for rather poorly drained soils under abnormally wet conditions. Ellis (11), Harmer (19, 21), and Ellis, Fawcett, Gaylord, and Baldinger (13) regard the yield of peppermint oil as being directly affected by the fertilizer and state that a fertilizer mixture having a ratio of either one part of phosphate to two parts of potash or equal parts of phosphate and potash as the most effective. They report an increase in the proportion of potash frequently results in more hay but less oil. They also found 300 pounds of fertilizer per acre gave as good results as 600 pounds. Powers and Jones (33) on Oregon peat soils, where response is obtained only to potash, regard 320 pounds of 50% potash salts per acre as the maximum amount. Harmer (22) is now advising heavy fertilization (800 to 1000 pounds per acre) as part of a program in the growth of peppermint on a soil infested with the Verticillium wilt organism.

Little has been published concerning the influence of various minor elements on the growth of peppermint. Bode (6), after growing peppermint in nutrient solutions, concluded that probably boron, cobalt, aluminum, zinc, and copper were essential for high oil formation in the plant. Lutzenburger (26) reported manganese and boron increased oil yields on organic soils by increasing the number and size of leaves on the plants.

The pH of the soil producing peppermint has been given considerable thought. Deel and Deel (9) found the maximum oil yield was obtained at pH 5.0. Birkeli (5) has stated the plant prefers a pH from 6.0 to 7.0, with the maximum yield being secured at pH 6.8. Powers (31) in Oregon found good yields could be obtained on soils of pH 4.8 to 7.3 and Harmer (18) in Michigan on soils of pH 4.5 to 8.0. Similarly Ellis (10) has reported good yields of mint hay in Indiana on muck soils varying from pH 5.0 to 8.0, with an optimum range for growth and yield of oil at pH 6.0 to 7.5. Powers (31) gives the optimum pH for spearmint production as 6.0.

The composition of peppermint oil as affected by fertilizer applications has by no means been determined. Ummey (40) in 1896 regarded the chemical composition of the oil as little affected by the soil upon which the crop was grown. Schlemmer and Springer (36) carried out extensive fertilizer treatments with N, P, and K in relation to menthol and ester contents. They found that P and K without N produced oil having the highest ester content while the highest menthol content was obtained with N and K with P absent. Springer (37) has tended to bear this out since he found that the oil from plants receiving P and N with no K contains the least esters. Harmer and Benne (23) found the menthol and ester content of the oil relatively independent of the proportion of phosphate and potash in the fertilizer mixture when both were applied. Powers (32) has found the use of borax in the fertilizer resulted in increased menthol content of the oil. Ellis, Fawcett, Gaylord, and Baldinger (13), after completion of a three year study, have stated that the chemical and physical constants of peppermint oil are not affected by fertilizer except as fertilizer affects the maturity of the plants.

Harmer (20) reported the carvone content of spearmint oil increased with the proportion of phosphate in the fertilizer when both phosphate and potash were applied.

## EXPERIMENTAL

Studies of mint were made in the field or in the greenhouse of the following organic soils:

1. Muck Experimental Farm, Clinton County. Part of a large muck area of approximately 1400 acres of deep muck (pH 5.9 - 6.2). Cropped 7 years. No Verticillium wilt present until summer of 1948.
2. Lapeer County. Part of a large area of deep woody muck (pH 6.7 - 7.2). Cropped around 15 years. Fertilized each year with about 400 pounds per acre of 3-9-18 commercial fertilizer. Verticillium wilt has been present for eight or more years.
3. Calhoun County. Part of an area of around 200 acres of deep muck (pH 4.0). New muck limed in the spring of 1948 with 5 tons per acre of dolomitic limestone bringing the pH to 5.6 when the peppermint was harvested.
4. Clinton County. Part of a large area of well decomposed muck (pH 5.2 - 5.8) high in mineral matter. No peppermint grown because of severity of Verticillium wilt.

## Greenhouse Experiments

### Object

Peppermint was grown in two-gallon glazed clay pots in the greenhouse to study the effect of various treatments upon the growth of the plant and the prevalence of peppermint wilt. In two cases the oil was distilled from the plants in the individual jars of the entire experiment.

### General Procedure

Fertilizers, as well as all other materials applied, were mixed with the entire amount of soil in each pot. These pots were kept at an approximately optimum moisture content by bringing them up to a predetermined weight by the addition of distilled water. Four peppermint plants were transplanted into each jar from a lot which had been grown previously from rhizome cuttings and which were selected for uniformity. During growth, heights of individual plants were recorded. Whenever soil nitrates approached a low value, as revealed by the Spurway (38) Simplex soil test, ammonium nitrate was added in solution at the rate of 100 pounds per acre. Just as the plants commenced to bloom, they were harvested. In most cases the weight of the tops* and roots* of the freshly cut mint** were obtained.

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* Tops throughout this discussion refers to all portions of the plant above the ground while roots refers to all portions below the ground.

** Yields of all harvested mint is reported as weight of freshly cut green mint.

Plate 1 shows the laboratory apparatus used in the distillation of the tops from individual greenhouse pots. This apparatus consists essentially of two five-liter Florence flasks (one serving as a steam generator, the other as a "mint tub"), connecting tubing, a water condenser, and a large separatory funnel as a receiver. The steam inlet is directed to the bottom of the "mint tub".. In addition a Bunsen burner is placed beneath this flask to prevent condensation of steam in the "mint tub" rather than in the condenser.

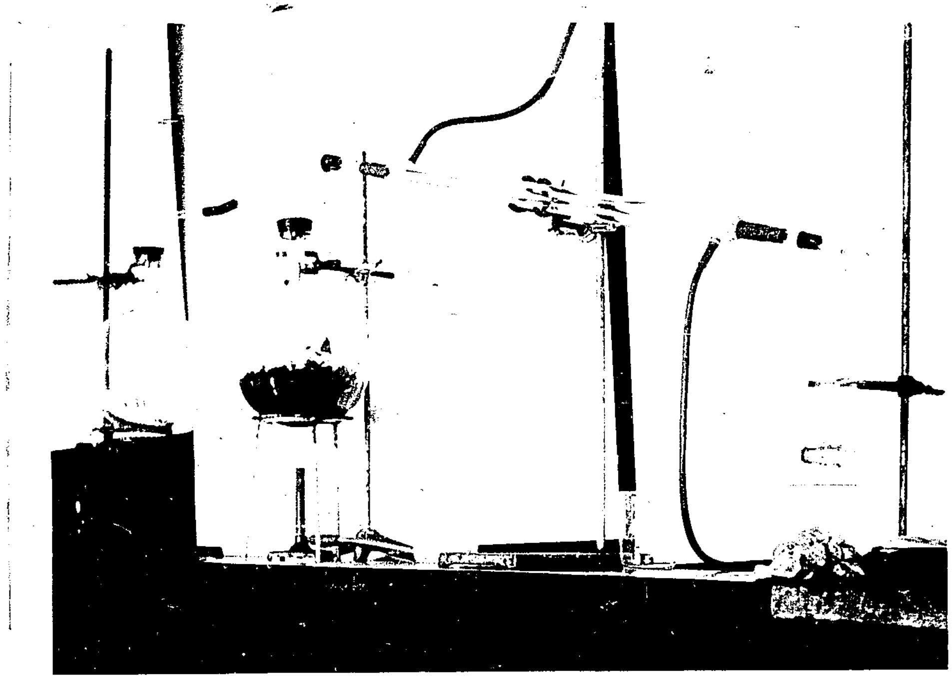


Plate 1. Laboratory apparatus used in distillation of peppermint from individual greenhouse pots.

## Soil Treatments

Fertilizers and Carbonates. The first of these greenhouse experiments involved three replications, with four levels of chemically pure fertilizer and six levels of precipitated calcium and magnesium carbonates applied to a muck (pH 5.2) highly infested with the Verticillium wilt organism from a diseased Clinton County mint field. The carbonates were applied three months before fertilizing and planting the first crop of peppermint. Immediately after harvesting the first crop, which had been treated with a 0-10-20 fertilizer, a second was planted and the same fertilizer treatments repeated with a 0-10-30 mixture.

Crop 1. Table 1 presents the weight of material produced with varying carbonate and 0-10-20 fertilizer treatments, together with the average pH of the soil resulting from each treatment. These data indicate that the yield of tops is not affected by increasing applications of fertilizer nor by carbonates of calcium or both calcium and magnesium. However, the total plant weight, and especially the roots, decrease with the application of carbonates, this decrease being highly significant with the 16-ton-application of calcium carbonate and calcium and magnesium carbonate. The more rapid decrease in root weight with increasing amounts of carbonates is well illustrated by the ratio of tops to roots which markedly increases with the heavier carbonate applications. The pH of 5.2 of the original soil was consistently raised by the application of calcium and of mixed calcium and magnesium carbonate to approximately 7.1 with the 16-ton applications. All plants developed symptoms of Verticillium wilt.

Table 1. Effects of Varying Amounts of 0-10-20 Fertilizer and of Calcium and Magnesium Carbonates on the Weight of Peppermint Plants Produced on Muck Soil in the Greenhouse.

Crop 1.[1]

| Treatment | | | pH[2] | Weight (grams)[3] | | |
|---|---|---|---|---|---|---|
| Fertilizer Lbs./A | $CaCO_3$ T/A[3] | $MgCO_3$ T/A[3] | | Tops | Roots | Total Plant |
| 500 | 0 | 0 | 5.2 | 389 | 140 | 529 |
| 500 | 4 | 0 | 5.8 | 360 | 138 | 498 |
| 500 | 8 | 0 | 6.3 | 345 | 121 | 466 |
| 500 | 16 | 0 | 6.9 | 330 | 106 | 436 |
| 500 | 2 | 2 | 5.9 | 340 | 143 | 483 |
| 500 | 8 | 8 | 7.1 | 333 | 96 | 429 |
| 1000 | 0 | 0 | 5.2 | 383 | 109 | 492 |
| 1000 | 4 | 0 | 5.8 | 344 | 175 | 519 |
| 1000 | 8 | 0 | 6.3 | 373 | 104 | 477 |
| 1000 | 16 | 0 | 6.9 | 376 | 79 | 455 |
| 1000 | 2 | 2 | 5.9 | 369 | 125 | 494 |
| 1000 | 8 | 8 | 7.1 | 311 | 60 | 371 |
| 2000 | 0 | 0 | 5.3 | 392 | 159 | 551 |
| 2000 | 4 | 0 | 5.8 | 393 | 126 | 519 |
| 2000 | 8 | 0 | 6.3 | 350 | 111 | 461 |
| 2000 | 16 | 0 | 7.0 | 364 | 70 | 434 |
| 2000 | 2 | 2 | 5.9 | 367 | 97 | 464 |
| 2000 | 8 | 8 | 7.1 | 388 | 97 | 485 |
| 4000 | 0 | 0 | 5.2 | 441 | 142 | 583 |
| 4000 | 4 | 0 | 5.8 | 399 | 89 | 488 |
| 4000 | 8 | 0 | 6.3 | 383 | 125 | 508 |
| 4000 | 16 | 0 | 7.0 | 375 | 89 | 464 |
| 4000 | 2 | 2 | 5.8 | 385 | 139 | 524 |
| 4000 | 8 | 8 | 7.0 | 331 | 102 | 433 |

1. Harvested June 11, 1948.
2. June 11, 1949.
3. Average of 3 replications.

Analysis of Variance

| Source | DF | Tops SS | Tops MS | Roots SS | Roots MS | Total Plant SS | Total Plant MS |
|---|---|---|---|---|---|---|---|
| Total | 71 | 195295 | | 126164 | | 415970 | |
| Carbonates | 5 | 23577 | 4715 | 29338 | 5868** | 94692 | 18,938* |
| Fertilizers | 3 | 14190 | 4730 | 2515 | 838 | 10831 | 3610 |
| Replication | 2 | 7328 | 3664 | 21046 | 10523 | 6835 | 3418 |
| Carbonates x Fertilizers | 15 | 18552 | 1237 | 22757 | 1517 | 35315 | 2354 |
| Error | 46 | 131648 | 2862 | 50508 | 1098 | 268297 | 5832 |
| L.S.D.[1] | (5%) | | | | 55 | | 126 |
| | (1%) | | | | 73 | | 168 |

* Significant at 5% level.
** Significant at 1% level.

1. Throughout this discussion L.S.D. refers to least significant difference.

Summary

| Treatment | | Average Weight in Grams | | | Ratio Tops to Roots |
|---|---|---|---|---|---|
| $CaCO_3$ T/A | $MgCO_3$ T/A | Tops | Roots | Total Plant | |
| 0 | 0 | 401 | 138 | 539 | 2.9 |
| 4 | 0 | 374 | 132 | 506 | 2.8 |
| 8 | 0 | 363 | 115 | 478 | 3.2 |
| 16 | 0 | 361 | 86 | 447 | 4.2 |
| 2 | 2 | 366 | 126 | 492 | 2.9 |
| 8 | 8 | 341 | 89 | 430 | 3.8 |
| Fertilizer Lbs/A | | | | | |
| 500 | | 350 | 124 | 474 | 2.8 |
| 1000 | | 359 | 109 | 468 | 3.3 |
| 2000 | | 376 | 110 | 486 | 3.4 |
| 4000 | | 386 | 114 | 500 | 3.4 |

Crop 2. Table 2 presents measurements of early plant growth and the weight of material produced with varying carbonate and 0-10-30 fertilizer treatments, together with the average pH of the soil resulting from each treatment. These applications (500, 1000, 2000, and 4000 pounds per acre) of fertilizer were in addition to any residual fertilizer remaining from Crop 1. Although early plant growth tended to increase with the 500 pound application of 0-10-30 fertilizer, there were no significant differences as related to fertilizer or carbonate level. The total weight and the top weight were not affected by fertilizer or carbonate level. However, root growth was inhibited by all fertilizer applications exceeding 500 pounds per acre, particularly with the heaviest lime applications. This would indicate that the fertilizer applied in addition to the residue from the preceding crop produced a toxic effect, possibly due to a high soluble salt content of the soil, or that there was so much nutrient available the roots did not find it necessary to grow in search of it. These combined fertilizer applications for the two crops amounted to 4 to 16 times as much as that recommended in the field. Although root growth tended to be depressed again by the 16 ton application of calcium and of calcium and magnesium carbonate, this decrease was not significant. This decrease may be illustrated by the ratio of tops to roots which rises, as with crop 1, with the heavier carbonate applications. The pH of the soil was approximately the same as that after the first crop was harvested. All plants developed symptoms of Verticillium wilt.

Table 2. Effects of Varying Amounts of 0-10-30 Fertilizers and of Calcium and Magnesium Carbonates on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil in the Greenhouse.

Crop 2.[1]

| Treatment | | | pH[2] | Height (cm.)[3] | Weight (Grams)[4] | | |
|---|---|---|---|---|---|---|---|
| Fertilizer Lbs./A | $CaCO_3$ T/A | $MgCO_3$ T/A | | | Tops | Roots | Total Plant |
| 500 | 0 | 0 | 5.2 | 33 | 103 | 56 | 159 |
| 500 | 4 | 0 | 5.7 | 39 | 114 | 58 | 172 |
| 500 | 8 | 0 | 6.2 | 42 | 123 | 63 | 186 |
| 500 | 16 | 0 | 7.0 | 37 | 125 | 56 | 181 |
| 500 | 2 | 2 | 6.0 | 41 | 120 | 71 | 191 |
| 500 | 8 | 8 | 7.1 | 39 | 125 | 62 | 187 |
| 1000 | 0 | 0 | 5.1 | 37 | 133 | 44 | 177 |
| 1000 | 4 | 0 | 5.7 | 34 | 84 | 38 | 122 |
| 1000 | 8 | 0 | 6.3 | 30 | 124 | 52 | 176 |
| 1000 | 16 | 0 | 7.0 | 27 | 129 | 40 | 169 |
| 1000 | 2 | 2 | 6.0 | 41 | 106 | 48 | 154 |
| 1000 | 8 | 8 | 7.1 | 31 | 115 | 44 | 159 |
| 2000 | 0 | 0 | 5.2 | 28 | 141 | 45 | 186 |
| 2000 | 4 | 0 | 5.7 | 30 | 119 | 49 | 168 |
| 2000 | 8 | 0 | 6.3 | 38 | 139 | 59 | 198 |
| 2000 | 16 | 0 | 7.0 | 37 | 141 | 44 | 185 |
| 2000 | 2 | 2 | 5.9 | 30 | 96 | 39 | 135 |
| 2000 | 8 | 8 | 7.1 | 37 | 120 | 46 | 166 |
| 4000 | 0 | 0 | 5.1 | 33 | 138 | 60 | 198 |
| 4000 | 4 | 0 | 5.7 | 31 | 139 | 63 | 202 |
| 4000 | 8 | 0 | 6.3 | 40 | 131 | 37 | 168 |
| 4000 | 16 | 0 | 7.0 | 38 | 140 | 38 | 178 |
| 4000 | 2 | 2 | 5.7 | 27 | 116 | 34 | 150 |
| 4000 | 8 | 8 | 7.1 | 29 | 100 | 26 | 126 |

1. Harvested October 9, 1948
2. October 9, 1949
3. Average height of plants of 3 replications of 4 plants each. July 29, 1948.
4. Average of 3 replications.

Analysis of Variance

| Source | DF | SS | MS |
|---|---|---|---|
| Total | 71 | 5,364 | |
| Carbonates | 5 | 168 | 34 |
| Fertilizer | 3 | 409 | 136 |
| Replication | 2 | 143 | 72 |
| Carbonates x Fertilizer | 15 | 1,097 | 73 |
| Error | 46 | 3,547 | 77 |

| Source | DF | Tops SS | Tops MS | Roots SS | Roots MS | Total Plant SS | Total Plant MS |
|---|---|---|---|---|---|---|---|
| Total | 71 | 44558 | | 20028 | | 83823 | |
| Carbonates | 5 | 6106 | 1221 | 802 | 160 | 7208 | 1442 |
| Fertilizers | 3 | 1814 | 605 | 3659 | 1220** | 3580 | 1193 |
| Replications | 2 | 1719 | 860 | 1188 | 594 | 997 | 498 |
| Carbonates x Fertilizers | 15 | 8555 | 570 | 4066 | 271 | 20976 | 1398 |
| Error | 46 | 26364 | 573 | 10313 | 224 | 51062 | 1110 |
| L.S.D. (5%) | | | | | 25 | | |
| (1%) | | | | | 33 | | |

** Significant at 1% level

Summary

| Treatment | | Average Weight in Grams | | | Ratio Tops to Roots |
|---|---|---|---|---|---|
| $CaCO_3$ T/A | $MgCO_3$ T/A | Tops | Roots | Total Plant | |
| 0 | 0 | 129 | 51 | 180 | 2.5 |
| 4 | 0 | 114 | 52 | 166 | 2.2 |
| 8 | 0 | 129 | 53 | 182 | 2.4 |
| 16 | 0 | 134 | 45 | 179 | 3.0 |
| 2 | 2 | 110 | 48 | 158 | 2.3 |
| 8 | 8 | 115 | 45 | 160 | 2.6 |
| Fertilizer Lbs/A | | | | | |
| 500 | | 118 | 61 | 179 | 1.9 |
| 1000 | | 115 | 44 | 159 | 2.6 |
| 2000 | | 126 | 47 | 173 | 2.7 |
| 4000 | | 128 | 43 | 171 | 3.0 |

<u>Minor Elements</u>: In all cases each pot was fertilized at the rate of 1000 pounds per acre of a 0-10-20 fertilizer. With the exception of the element in question minute and uniform quantities of the other minor elements were added to each pot by means of a solution. Whenever a potassium salt of an element was used, enough potassium in the form of potassium chloride was added to the various pots so each received the same total amount of potassium, irrespective of treatment. The following minor elements were included in this study: copper, iodine, cobalt, molybdenum, strontium, boron, chromium, magnesium, zinc, and silicon.

<u>Copper</u>.... Three pots containing muck soil of pH 4.7 obtained from northern Indiana received no copper while the remaining three received 100 pounds per acre of copper sulphate. Plates 2 and 3 show the response in early growth to copper sulphate. However, these differences did not continue throughout the growth of the plant. Table 3 presents the oil yield and weight of peppermint plants. Although the data indicate that the application of copper sulphate resulted in a slight decrease in yield of both weight and oil, the decrease was not significant.

Plate 2. The effect of copper sulphate on early growth of peppermint grown in the greenhouse on muck soil. (pH 4.7). The pot on the left received no copper.

Plate 3. The effect of copper sulphate on early growth of peppermint grown in the greenhouse on muck soil. (pH 4.7). The pot on the left received no copper.

Table 3. Effect of 100 pounds per acre of Copper Sulphate on Oil Yield and Weight of Peppermint Plants Produced on Muck Soil (pH 5.1) in the Greenhouse.

| Treatment | Weight (Grams) | | | | Oil (Ml.) | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | Mean | I | II | III | Mean |
| No copper sulphate | 420 | 410 | 445 | 425 | 0.8 | 0.9 | 1.1 | 0.93 |
| Copper sulphate | 408 | 324 | 322 | 351 | 0.8 | 0.7 | 0.8 | 0.77 |

Analysis of Variance

| Source | DF | Tops | | Oil | |
|---|---|---|---|---|---|
| | | SS | MS | SS | MS |
| Total | 5 | 13,609 | | 0.095 | |
| Treatments | 1 | 8,140 | 8,140 | 0.042 | 0.042 |
| Replications | 2 | 2,274 | 1,137 | 0.030 | 0.015 |
| Error | 2 | 3,194 | 1,597 | 0.023 | 0.016 |

Iodine.... The effect of iodine on peppermint growth was more intensively investigated than was that of any other minor element. Potassium iodide was used as the source of the element in most of the studies.

Effect of Potassium Iodide. This first study involved three replications with applications of 0, 5, and 10 pounds of potassium iodide per acre to wilt-infested muck (pH 5.1) from Clinton County. Table 4 presents the oil yield and weight of peppermint plants. Although the weight of tops increased slightly with increasing applications of iodine, this increase was not significant. Oil yield was significantly increased by the application of potassium iodide. All plants showed symptoms of Verticillium wilt.

Since these smaller applications apparently increased the oil yield, larger amounts of potassium iodide were used in another experiment. Four replications of applications of potassium iodide of 0, 5, 10, 20, 40, and 80 pounds per acre to a wilt-infested muck soil (pH 6.8) from Lapeer County were set up. Table 5 presents measurements of early plant growth and of the weight of peppermint plants. These data indicate that iodine had little effect on peppermint growth. All plants developed symptoms of Verticillium wilt.

Table 4. Effect of Potassium Iodide on the Oil Yield and Weight of Peppermint Plants Produced on Muck Soil (pH 5.1) in the Greenhouse.

| Potassium Iodide Lbs./A | Weight (Grams) | | | | Oil (Ml.) | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | Mean | I | II | III | Mean |
| 0 | 278 | 271 | 269 | 273 | 0.35 | 0.30 | 0.30 | 0.32 |
| 5 | 298 | 300 | 280 | 293 | 0.50 | 0.40 | 0.55 | 0.48 |
| 10 | 288 | 287 | 336 | 304 | 0.50 | 0.50 | 0.50 | 0.50 |

Analysis of Variance

| Source | DF | Tops | | Oil | |
|---|---|---|---|---|---|
| | | SS | MS | SS | MS |
| Total | 8 | 3,338 | | 0.075 | |
| Treatments | 2 | 1,482 | 741 | 0.062 | 0.031* |
| Replications | 2 | 134 | 67 | 0.005 | 0.002 |
| Error | 4 | 1,722 | 430 | 0.008 | 0.002 |
| L.S.D. | (5%) | | | | 0.11 |
| | (1%) | | | | 0.17 |

* Significant at 5% level.

Table 5. Effect of Increasing Amounts of Potassium Iodide on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 6.8) in the Greenhouse.

| Lbs./A KI | Height (Cm)[1] Nov.10, 1948 | Height (Cm)[1] Dec. 7, 1948 | Weight (Grams)[2] Tops | Weight (Grams)[2] Roots | Weight (Grams)[2] Total Plant |
|---|---|---|---|---|---|
| 0 | 31 | 68 | 127 | 55 | 182 |
| 5 | 30 | 64 | 95 | 56 | 151 |
| 10 | 32 | 71 | 123 | 58 | 181 |
| 20 | 31 | 69 | 138 | 62 | 200 |
| 40 | 34 | 78 | 128 | 65 | 193 |
| 80 | 32 | 75 | 107 | 60 | 167 |

1. Average height of plants of 4 replications of 4 plants each.
2. Average of 4 replications harvested March 10, 1949.

Analysis of Variance

| Source | DF | Height Nov. 10 SS | Height Nov. 10 MS | Height Dec.7 SS | Height Dec.7 MS | Tops SS | Tops MS | Roots SS | Roots MS | Total Plant SS | Total Plant MS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 23 | 299 | | 1192 | | 14802 | | 2082 | | 18979 | |
| Treatments | 5 | 50 | 10 | 460 | 92 | 5028 | 1006 | 338 | 68 | 6617 | 1323 |
| Replications | 3 | 29 | 10 | 138 | 46 | 1492 | 497 | 269 | 90 | 1610 | 536 |
| Error | 15 | 220 | 15 | 594 | 40 | 8282 | 552 | 1475 | 98 | 10752 | 717 |

Effect of Other Iodine Carriers. In applying potassium iodide to field plots in the spring of 1947, it was noted that occasionally there was considerable volatilization of the iodine when the compound was mixed with enough muck to secure a volume large enough to spread over the required area. Consequently, it seemed desirable to investigate a more stable iodine carrier for such work. Accordingly an experiment, replicated twice, was set up in the greenhouse comparing six different carriers of iodine. Each compound was applied at a rate sufficient to apply five and ten pounds per acre of elemental iodine. Table 6 lists the different iodine carriers used, together with the measurements of early plant growth and the weight of peppermint plants.

Table 6. Effects of Two Rates of Application of Six Different Iodine Carriers on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 6.0) in the Greenhouse.

| Treatment | | Height[1] | Weight (Grams)[2] | | |
|---|---|---|---|---|---|
| Iodine Lbs/A | Carrier | (Cm.) | Tops | Roots | Total Plant |
| 5 | A | 50 | 258 | 176 | 434 |
| 10 | A | 61 | 270 | 194 | 464 |
| 5 | B | 35 | 298 | 160 | 458 |
| 10 | B | 54 | 304 | 205 | 509 |
| 5 | C | 50 | 292 | 178 | 470 |
| 10 | C | 32 | 302 | 135 | 437 |
| 5 | D | 40 | 303 | 159 | 462 |
| 10 | D | 54 | 280 | 188 | 468 |
| 5 | E | 46 | 276 | 170 | 446 |
| 10 | E | 54 | 259 | 167 | 426 |
| 5 | F | 59 | 262 | 214 | 476 |
| 10 | F | 39 | 275 | 160 | 435 |

1. Average height of plants of 3 replications of 4 plants each, June 10, 1948.
2. Average of 2 replications harvested July 24, 1948.

| Carriers | | % Iodine in Carrier |
|---|---|---|
| A - | Thymol iodide | 43.0 |
| B - | Stabilized potassium iodide | 68.1 |
| C - | Fertidine | 18.0 |
| D - | Diphenyl iodonium chloride | 40.0 |
| E - | Bis chlorophenyl iodonium chloride | 32.9 |
| F - | Bis iodo phenyl iodonium iodide | 77.0 |

Analysis of Variance

| Source | DF | Height | | Tops | | Roots | | Total Plant | |
|---|---|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 23 | 3027 | | 13694 | | 15278 | | 25661 | |
| Compounds | 5 | 505 | 101 | 5598 | 1120 | 2704 | 541 | 5056 | 1011 |
| Rates | 1 | 28 | 28 | 0 | 0 | 9 | 9 | 18 | 18 |
| Replications | 1 | 182 | 182 | 2185 | 2185 | 70 | 70 | 1395 | 1395 |
| Compounds x Rates | 5 | 1349 | 270 | 1246 | 249 | 8035 | 1607 | 6692 | 1338 |
| Error | 11 | 963 | 88 | 4665 | 424 | 4460 | 405 | 12500 | 1136 |

No differences in the effect of iodine on the early growth or weight of peppermint plants, when supplied by these different carriers, are indicated by these data.

Boron.... Four replications of boric acid of 0, 50, 100, and 200 pounds per acre to a wilt-infested soil (pH 5.7) from Clinton County were set up. Table 7 presents the measurements of early plant growth and the weight of peppermint plants. There is no indication from these results of any beneficial effect from the boric acid application. In fact the 200 pound application decidedly retarded growth and depressed the yield.

Table 7. Effect of Increasing Amounts of Boric Acid on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 5.7) in the Greenhouse.

| Boric Acid Lbs/A | Height[1] (Cm) | Weight (Grams)[2] | | |
|---|---|---|---|---|
| | | Tops | Roots | Total Plant |
| 0 | 36 | 105 | 60 | 165 |
| 50 | 32 | 104 | 41 | 145 |
| 100 | 34 | 119 | 32 | 152 |
| 200 | 20 | 38 | 8 | 45 |

1. Average Height of plants of 4 replications of 4 plants each August 28, 1948.
2. Average of 4 replications harvested October 27, 1948.

Analysis of Variance

| Source | DF | Height | | Tops | | Roots | | Total Plant | |
|---|---|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 15 | 1020 | | 22918 | | 6844 | | 46054 | |
| Treatments | 3 | 652 | 217* | 16101 | 5367** | 5743 | 1914** | 36399 | 12133** |
| Replications | 3 | 65 | 22 | 968 | 323 | 85 | 28 | 1548 | 516 |
| Error | 9 | 303 | 34 | 5849 | 650 | 1016 | 113 | 8107 | 901 |
| L.S.D. | (5%) | | 10 | | 41 | | 17 | | 48 |
| | (1%) | | 14 | | 59 | | 25 | | 69 |

* Significant at 5% level.
** Significant at 1% level.

The root yield significantly decreased with each increase in application of boric acid. The weight of the total plant also decreased slightly with the higher applications of boric acid but became significantly less with the 200 pound application. Plate 4 shows the depressing effect of boric acid. Plants receiving the 200 pound application of boric acid were decidedly stunted — the outer leaf edges died after turning yellow and then brown. Plate 5 shows this characteristic symptom of boron toxity. A few leaves of plants receiving the 100 pound application also showed this characteristic burning at their edges. All plants irrespective of treatment developed symptoms of Verticillium wilt.

Cobalt.... Four replications of applications of cobalt sulphate of 0, 20, 40, 80, 160, and 320 pounds per acre to a wilt-infested soil (pH 5.5) from Clinton County were set up. Table 8 presents the measurements of early plant growth and the weight of the peppermint plants. It is evident that all applications of cobalt sulphate depressed early growth — the amount of depression increasing with the amount of cobalt applied. This depression was significant July 26, but much less marked by August 3. Plate 6 shows this depressive effect on the early growth of peppermint plants.

Applications of cobalt sulphate up to 160 pounds per acre had no significant effect on the weight produced. However, a 320 pound application depressed yields. This depression was significant when the total plant and the tops are considered. Toward the latter part of August all plants, irrespective of treatment, showed definite Verticillium wilt symptoms.

Plate 4. The effect of boric acid on growth of peppermint grown in the greenhouse on muck soil of pH 5.7. Jars from left to right received 200, 100, 50, and 0 pounds of boric acid per acre.

Plate 5. Boron toxity on peppermint grown on muck soil of pH 5.7 in the greenhouse. 200 pounds per acre of boric acid per acre had been applied.

Table 8. Effect of Increasing Amounts of Cobalt Sulphate on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 5.5) in the Greenhouse.

| Cobalt Sulphate Lbs/A | Height (Cm)[1] | | Weight (Grams)[2] | | |
|---|---|---|---|---|---|
| | July 26 | August 3 | Tops | Roots | Total Plant |
| 0 | 40 | 64 | 181 | 98 | 279 |
| 20 | 35 | 60 | 160 | 62 | 222 |
| 40 | 33 | 58 | 209 | 83 | 292 |
| 80 | 27 | 56 | 206 | 77 | 283 |
| 160 | 24 | 46 | 178 | 74 | 252 |
| 320 | 20 | 40 | 99 | 27 | 126 |

1. Average height of plants of 4 replications of 4 plants each.
2. Average of 4 replications harvested September 23, 1948.

Analysis of Variance

| Source | DF | Height | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | July 26 | | Aug. 3 | | Tops | | Roots | | Total Plant | |
| | | SS | MS | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 23 | 1882 | | 3953 | | 48618 | | 27110 | | 110555 | |
| Treatments | 5 | 1086 | 217** | 1658 | 332 | 32166 | 6433** | 11918 | 2384 | 78110 | 15622** |
| Replications | 3 | 93 | 31 | 142 | 47 | 7281 | 2427 | 1776 | 592 | 7834 | 2611 |
| Error | 15 | 703 | 47 | 2153 | 144 | 9171 | 611 | 13416 | 894 | 24611 | 1641 |
| L.S.D. (5%) | | | 11 | | | | 38 | | | | 62 |
| (1%) | | | 15 | | | | 52 | | | | 85 |

** Significant at 1% level.

Plate 6. The effect of cobalt sulphate on early growth of peppermint plants on muck soil of pH 5.5 in the greenhouse. Jars from left to right received 0, 20, 40, 80, 160, and 320 pounds of cobalt sulphate per acre.

Molybdenum.... Four replications of applications of sodium molybdate of 0, 3, 6, 12, 24 and 48 pounds per acre to a wilt-infested soil (pH 6.8) from Lapeer County were set up. Table 9 presents the measurements of early plant growth and the weight of peppermint plants. These data indicate that the application of sodium molybdate up to 48 pounds per acre had no significant influence upon either the early growth or the weight of peppermint plants. However, there is a suggestion that sodium molybdate may have had a tendency to increase the yield. All plants developed symptoms of Verticillium wilt. The low yields of some individual pots may have been due to severe infestation by red spider and injury from Parathion used in its control. Plate 7 shows typical injury to peppermint by Parathion spray.

Plate 7. Injury to peppermint forty-eight hours after spraying with Parathion. Note the twisting stems and downward bending petioles. (Concentration used -- 1 teaspoon of Parathion per gallon of water.)

Table 9. Effect of Increasing Amounts of Sodium Molybdate on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 6.8) in the Greenhouse.

| Sodium Molybdate Lbs/A | Height (Cm)[1] | | Weight (Grams)[2] | | |
|---|---|---|---|---|---|
| | Nov. 23 | Dec. 28 | Tops | Roots | Total Plant |
| 0 | 15 | 38 | 84 | 28 | 112 |
| 3 | 18 | 41 | 92 | 41 | 133 |
| 6 | 20 | 47 | 86 | 31 | 117 |
| 12 | 16 | 38 | 93 | 32 | 125 |
| 24 | 18 | 41 | 91 | 30 | 121 |
| 48 | 20 | 45 | 95 | 41 | 136 |

1. Average height of 4 replications of 4 plants each.
2. Average of 4 replications harvested March 10, 1949.

Analysis of Variance

| Source | DF | Height | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nov.23 | | Dec.28 | | Tops | | Roots | | Total Plant | |
| | | SS | MS | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 23 | 367 | | 2488 | | 7964 | | 2988 | | 16459 | |
| Treatments | 5 | 80 | 16 | 276 | 55 | 339 | 68 | 661 | 132 | 1685 | 337 |
| Replications | 3 | 82 | 27 | 665 | 222 | 516 | 172 | 519 | 173 | 649 | 216 |
| Error | 15 | 205 | 14 | 1547 | 103 | 7109 | 474 | 1808 | 120 | 14125 | 942 |

Strontium.... Four replications of applications of strontium chloride of 0, 100, 200, 400, 800, and 1600 pounds per acre to a wilt-infested soil (pH 7.0) from Lapeer County were set up. Table 10 presents the measurements of early plant growth and the weight of peppermint plants. It is evident that the application of strontium chloride up to 1600 pounds per acre had no significant influence upon the early growth or weight the plants produced. The low yields of some individual pots may have been due to severe infestation by red spider and injury from Parathion used in its control. All plants showed symptoms of Verticillium wilt.

Chromium.... Four replications of applications of potassium dichromate of 0, 40, 80, 160, and 320 pounds per acre to a wilt-infested soil (pH 6.9) from Lapeer County were set up. Table 11 presents the measurements of early plant growth and the weight of peppermint plants. These data indicate that the application of potassium dichromate up to 320 pounds per acre had no significant influence upon the early growth or the weight produced. All plants developed characteristic symptoms of Verticillium wilt.

Table 10. Effect of Increasing Amounts of Strontium Chloride on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 7.0) in the Greenhouse.

| Strontium Chloride Lbs/A | Height (Cm)[1] | | Weight (Grams)[2] | | |
|---|---|---|---|---|---|
| | Nov.23 | Dec.28 | Tops | Roots | Total Plant |
| 0 | 19 | 37 | 66 | 24 | 90 |
| 100 | 15 | 33 | 87 | 32 | 119 |
| 200 | 16 | 34 | 76 | 28 | 104 |
| 400 | 22 | 47 | 77 | 32 | 109 |
| 800 | 19 | 41 | 84 | 26 | 110 |
| 1600 | 17 | 36 | 91 | 27 | 118 |

1. Average height of plants of 4 replications of 4 plants each.
2. Average of 4 replications harvested March 10, 1949.

Analysis of Variance

| Source | DF | Height | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nov.23 | | Dec.28 | | Tops | | Roots | | Total Plant | |
| | | SS | MS | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 23 | 484 | | 2172 | | 12779 | | 1919 | | 19282 | |
| Treatments | 5 | 136 | 27 | 544 | 109 | 1723 | 345 | 222 | 44 | 2314 | 463 |
| Replications | 3 | 86 | 29 | 675 | 225 | 3710 | 1237 | 1159 | 386 | 8756 | 2919 |
| Error | 15 | 262 | 17 | 953 | 64 | 7346 | 490 | 538 | 36 | 8212 | 547 |

Table 11. Effect of Increasing Amounts of Potassium Dichromate on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 7.0) in the Greenhouse.

| Potassium Dichromate Lbs/A | Height (Cm)[1] Dec.1 | Height (Cm)[1] Jan.4 | Weight (Grams)[2] Tops | Weight (Grams)[2] Roots | Weight (Grams)[2] Total Plant |
|---|---|---|---|---|---|
| 0 | 12 | 29 | 91 | 33 | 124 |
| 40 | 11 | 28 | 110 | 30 | 140 |
| 80 | 10 | 27 | 103 | 31 | 134 |
| 160 | 10 | 26 | 78 | 24 | 102 |
| 320 | 9 | 28 | 98 | 32 | 130 |

1. Average height of plants of 4 replications of 4 plants each.
2. Average of 4 replications harvested March 10, 1949.

Analysis of Variance

| Source | DF | Height | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dec.1 | | Jan.4 | | Tops | | Roots | | Total Plant | |
| | | SS | MS | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 19 | 73 | | 334 | | 6322 | | 1042 | | 10213 | |
| Treatments | 4 | 32 | 8 | 24 | 6 | 2364 | 591 | 160 | 40 | 3333 | 833 |
| Replications | 3 | 3 | 1 | 31 | 10 | 526 | 175 | 203 | 68 | 939 | 313 |
| Error | 12 | 38 | 3 | 279 | 23 | 3432 | 286 | 679 | 57 | 5941 | 495 |

<u>Magnesium</u>.... Four replications of applications of magnesium sulphate of 0, 500, 1000, 2000, 4000, and 8000 pounds per acre to a wilt-infested soil (pH 7.3) from Lapeer County were set up. Table 12 presents the measurements of early plant growth and the weight of peppermint plants. It is indicated that the application of magnesium sulphate up to 8000 pounds per acre had no significant influence upon the early growth or the weight produced. However, there is a tendency of magnesium sulphate up to 2000 pounds per acre to increase the weight of roots while higher applications tend to decrease their weight. All plants developed characteristic symptoms of Verticillium wilt.

<u>Zinc</u>.... Four replications of applications of zinc sulphate of 0, 60, 120, 240, 480, and 960 pounds per acre to a wilt-infested soil (pH 7.3) from Lapeer County were set up. Table 13 presents the measurements of early plant growth and the weight of peppermint plants. These data indicate that the application of zinc sulphate up to 960 pounds per acre had no significant influence on the early growth or weight produced. All plants developed characteristic symptoms of Verticillium wilt.

<u>Silicon</u>.... Four replications of applications of sodium metasilicate of 0, 400, 800, 1600, 3200, and 6400 pounds per acre to a wilt-infested soil of pH 7.3 from Lapeer County were set up. Table 14 presents the measurements of early plant growth and the weight of peppermint plants. It is evident

Table 12. Effect of Increasing Amounts of Magnesium Sulphate on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 7.3) in the Greenhouse.

| Magnesium Sulphate Lbs/A | Height[1] | | Weight (Grams)[2] | | |
|---|---|---|---|---|---|
| | Apr.15 | Apr.20 | Tops | Roots | Total Plant |
| 0 | 37 | 54 | 247 | 71 | 318 |
| 500 | 40 | 58 | 244 | 81 | 325 |
| 1000 | 42 | 61 | 220 | 87 | 307 |
| 2000 | 38 | 56 | 239 | 88 | 327 |
| 4000 | 36 | 53 | 227 | 73 | 300 |
| 8000 | 34 | 50 | 226 | 67 | 293 |

1. Average height of plants of 4 replications of 4 plants each.
2. Average of 4 replications harvested May 31, 1949.

Analysis of Variance

| Source | DF | Height | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr.15 | | Apr.20 | | Tops | | Roots | | Total Plant | |
| | | SS | MS | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 23 | 1031 | | 1964 | | 7637 | | 5463 | | 10720 | |
| Treat-ments | 5 | 147 | 29 | 283 | 57 | 2454 | 491 | 1498 | 300 | 3793 | 759 |
| Replica-tions | 3 | 228 | 76 | 636 | 212 | 187 | 62 | 2186 | 729 | 2405 | 802 |
| Error | 15 | 656 | 44 | 1045 | 70 | 4996 | 333 | 1779 | 119 | 4522 | 301 |

Table 13. Effect of Increasing Amounts of Zinc Sulphate on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 7.3) in the Greenhouse.

| Zinc Sulphate Lbs/A | Height[1] (Cm) Apr.15 | Apr.20 | Weight (Grams)[2] Tops | Roots | Total Plant |
|---|---|---|---|---|---|
| 0 | 32 | 50 | 220 | 80 | 300 |
| 60 | 36 | 53 | 199 | 78 | 277 |
| 120 | 37 | 54 | 185 | 76 | 261 |
| 240 | 39 | 56 | 196 | 90 | 286 |
| 480 | 37 | 52 | 177 | 99 | 276 |
| 960 | 39 | 54 | 206 | 104 | 310 |

1. Average height of plants of 4 replications of 4 plants each.
2. Average of 4 replications harvested May 31, 1949.

Analysis of Variance

| Source | DF | Height Apr.15 SS | MS | Apr.20 SS | MS | Tops SS | MS | Roots SS | MS | Total Plant SS | MS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 23 | 790 | | 1390 | | 13886 | | 10402 | | 24027 | |
| Treatments | 5 | 129 | 26 | 104 | 21 | 4822 | 964 | 2786 | 557 | 6387 | 1277 |
| Replications | 3 | 329 | 110 | 523 | 174 | 1680 | 560 | 2895 | 965 | 2734 | 911 |
| Error | 15 | 332 | 22 | 763 | 51 | 7383 | 492 | 4720 | 315 | 14905 | 994 |

that the application of sodium metasilicate up to 6400 pounds per acre had no significant influence on the early growth of peppermint. However, applications of 6400 pounds per acre significantly depressed the weight of the tops and the total plant while applications up to 3200 pounds per acre had no significant effect upon the material produced. All plants developed characteristic symptoms of Verticillium wilt.

Table 14. Effect of Increasing Amounts of Sodium Metasilicate on the Early Growth and Weight of Peppermint Plants Produced on Muck Soil (pH 7.3) in the Greenhouse.

| Sodium Metasilicate Lbs/A | Height[1] (Cm.) | | Weight (Grams)[2] | | |
|---|---|---|---|---|---|
| | Apr.15 | Apr.20 | Tops | Roots | Total Plant |
| 0 | 32 | 50 | 203 | 99 | 302 |
| 400 | 36 | 51 | 198 | 87 | 284 |
| 800 | 31 | 46 | 212 | 94 | 305 |
| 1600 | 34 | 50 | 216 | 97 | 314 |
| 3200 | 34 | 52 | 230 | 93 | 323 |
| 6400 | 32 | 46 | 150 | 93 | 243 |

1. Average height of plants of 4 replications of 4 plants each.
2. Average of 4 replications harvested May 31, 1949.

Analysis of Variance

| Source | DF | Height | | | | Tops | | Roots | | Total Plant | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr.15 | | Apr.20 | | | | | | | |
| | | SS | MS | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 23 | 736 | | 1633 | | 23994 | | 4289 | | 28965 | |
| Treatments | 5 | 56 | 11 | 116 | 23 | 15302 | 3060** | 333 | 67 | 16583 | 3317* |
| Replications | 3 | 142 | 47 | 438 | 146 | 2402 | 801 | 1772 | 591 | 909 | 303 |
| Error | 15 | 538 | 36 | 1079 | 72 | 6290 | 419 | 2184 | 146 | 11473 | 765 |
| L.S.D. | (5%) | | | | | | 31 | | | | 42 |
| | (1%) | | | | | | 43 | | | | 58 |

* Significant at 5% level.
** Significant at 1% level.

## Field and Laboratory Experiments

### Object

Field plots of peppermint and spearmint were established in four localities to study the effects of various factors on yield of plants, oil production, prevalence of Verticillium wilt, and the physicochemical constants of the oil.

### General Procedure

All plots were handled as nearly as possible as commercial plantings. At harvest the mint was cut, weighed, cured, and steam distilled in a portable still, the picture of which is shown in Plate 8. This still was patterned after a commercial mint still and was designed to operate with steam and water from the boiler and well of a regular grower's still. The herb was distilled for at least five minutes after no odor of oil could be detected in steam emitted from a small hole in the top of the tub when the cork was removed. This time varied from one half to one hour depending on the quantity of steam admitted and the condition of the crop. The more dry the herb, the shorter the time required. The oil was collected by gravity separator over water as is customarily done. At the completion of each distillation, all oil was removed from the separator, together with approximately two gallons of water. This was poured in a large separatory funnel and, after a few minutes, the greater portion of the water was removed. The re-

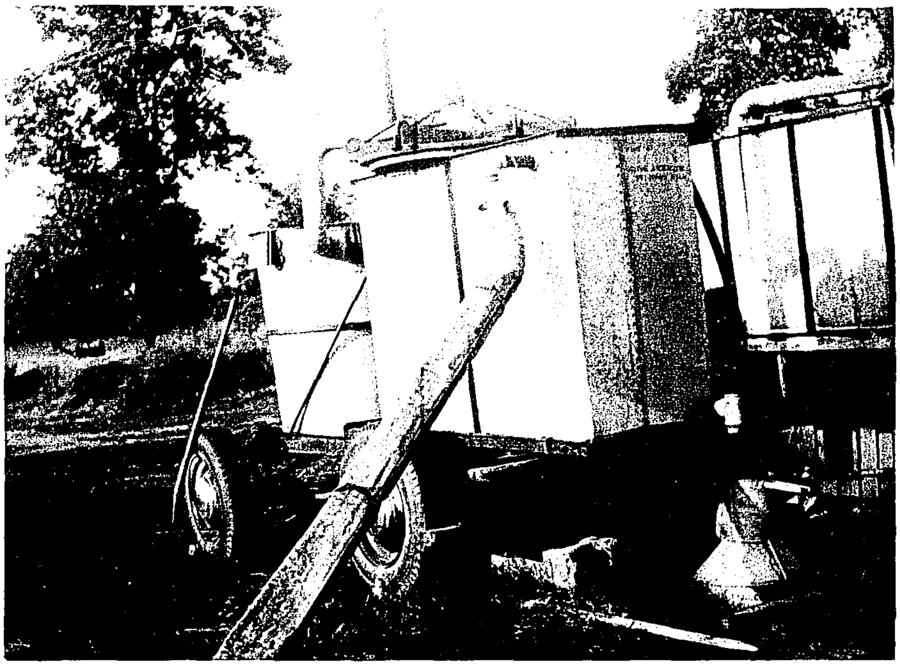


Plate 8. Portable Still Used for Distilling Peppermint and Spearmint Plots.

maining material (oil, water, and sludge) was taken to the laboratory, filtered, and the remainder of the water removed. After weighing the oil from each plot, a four-ounce ground glass stoppered bottle, containing one teaspoon of anhydrous sodium sulphate, was completely filled with a sample of the oil. These samples were then placed in cold storage at approximately a $40^{\circ}$ F. temperature, as recommended by Nelson (28), until the physico-chemical constants were determined.

## Methods Used and Physical Constants and Constituents Determined

Specific Gravity... A 50 gram pycnometer with attached thermometer was used in determining the specific gravity at $25^{\circ}$ C. (25/25°)

Optical Rotation... The specific optical rotation was obtained at $25^{\circ}$ C. by means of a 100 mm. tube and a Franize, Schmidt, and Huensch saccharimeter, using a potassium dichromate solution as a filter for the light source. (This filter gives a light equivalent to that from a sodium laboratory arc.) It was necessary to dilute by one-half with ethyl alcohol each spearmint sample in order to bring it within range of the saccharimeter.

Refractive Index... This constant was determined with an Abbé refractometer at $20^{\circ}$ C.

Esters... The U.S.P. XII method (1) was used and the esters were calculated as menthyl acetate.

Total Menthol... The U.S.P. XII procedure and formula (1) for calculating the percent of menthol were employed.

Menthone... The hydroxylamine hydrochloride method as outlined by Baldinger (3) was used.

Carvone... The U.S.P. XII procedure (1), reading the percentage of carvone directly from the cassia flask, was employed.

## Soil Treatments

<u>Fertilizers</u>... In 1947 and 1948 both peppermint and spearmint were grown on the Muck Experimental Farm in Clinton County, with four different mixtures of phosphate and potash replicated five times on soil with a pH of 6.0 to 6.2. These treatments had been established in the spring of 1942 and applications of 500 pounds per acre of the respective fertilizer had been made each succeeding spring. Both peppermint and spearmint had been grown on these mixtures each year since that time. Each year the plots were reestablished by the transplanting of plants in such a way that each particular plot was set to plants obtained from the growth of mint on that plot the previous year.

<u>Peppermint</u>... In 1947 the peppermint was cut September 4 and 5 and was distilled September 8 and 9. The following year it was harvested August 23 and 24 and was distilled August 25 to 27. Table 15 presents the yield of foliage and oil for both 1947 and 1948. These data indicate that in 1947 the yield of foliage increased significantly as the ratio of potash to phosphate in the fertilizer rose above 1:1. These results differ from those of 1948 when, under different seasonal weather conditions, there were no significant differences in foliage yields. The additional growth expected from higher ratios of potash was probably curtailed by restricted rain-

fall in 1948. Both foliage and oil yields in 1948 were less than those of 1947. Although these data suggest that, in both years, the oil yield decreased with increase in proportion of potash to phosphate in the fertilizer, a statistical analysis combining the data of both 1947 and 1948 shows this decrease was not significant. Table 16 presents the physicochemical constants of the oil produced in 1947 and 1948. These data indicate that none of these constants were influenced by the ratio of phosphate to potash in the fertilizer. The specific gravity of the 1948 oil was slightly greater and the percentage of esters and menthol were less. Such differences would indicate that the 1947 crop had attained a greater degree of maturity than the 1948 crop at harvest time.

Table 15. Effects of Different Ratios of Phosphate to Potash on the Yield of Peppermint Foliage and Oil Grown in 1947 and 1948 on Muck Soil (pH 6.1) in Clinton County.[1]

| Fertilizer 500 lbs. per acre | Foliage Tons per acre | | | Oil Lbs. per acre | | |
|---|---|---|---|---|---|---|
| | 1947 | 1948 | 1947 and 1948 | 1947 | 1948 | 1947 and 1948 |
| 0-20-10 | 10.6 | 8.7 | 9.7 | 23.8 | 23.1 | 23.4 |
| 0-10-10 | 9.9 | 8.7 | 9.3 | 24.6 | 21.0 | 22.8 |
| 0-10-20 | 11.1 | 8.6 | 9.8 | 22.0 | 20.4 | 21.2 |
| 0-10-30 | 12.0 | 8.4 | 10.2 | 19.1 | 20.0 | 19.6 |

1. Averages of 5 replications.

Analysis of Variance

| Source | DF | 1947 Foliage SS | 1947 Foliage MS | 1947 Oil SS | 1947 Oil MS | 1948 Foliage SS | 1948 Foliage MS | 1948 Oil SS | 1948 Oil MS | DF | 1947 - 1948 Foliage SS | 1947 - 1948 Foliage MS | 1947 - 1948 Oil SS | 1947 - 1948 Oil MS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 19 | 26.3 | | 349 | | 20.7 | | 228 | | 39 | 99.2 | | 592.5 | |
| Treatments | 3 | 12.6 | 3.9** | 87 | 29 | 0.3 | 0.1 | 29 | 10 | 3 | 4.1 | 1.4 | 90.5 | 30.5 |
| Replications | 4 | 12.1 | 3.0 | 116 | 29 | 9.6 | 2.4 | 81 | 20 | 4 | 15.3 | 3.8 | 106.6 | 26.6 |
| Years | | | | | | | | | | 1 | 52.2 | 52.2 | 15.5 | 15.5 |
| Treat x Years | | | | | | | | | | 3 | 7.8 | 2.6 | 25.3 | 8.4 |
| Error | | 2.6 | 0.2 | 146 | 12 | 10.8 | 0.9 | 118 | 10 | 28 | 19.8 | 0.7 | 354.6 | 12.7 |
| L.S.D. (5%) | | | 0.7 | | | | | | | | | | | |
| (1%) | | | 0.9 | | | | | | | | | | | |

** Significant at 1% level.

Table 16. Effects of Different Ratios of Phosphate to Potash on the Physicochemical Constants of Peppermint Oil Produced in 1947 and 1948 on Muck Soil (pH 6.1) in Clinton County.[1]

| Fertilizer 500 lbs per acre | Specific Gravity | | | Specific Optical Rotation | | | Refractive Index | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1947 | 1948 | 1947 & 1948 | 1947 | 1948 | 1947 & 1948 | 1947 | 1948 | 1947 & 1948 |
| 0-20-10 | .9025 | .9027 | .9026 | -29.6 | -24.1 | -26.8 | 1.4619 | 1.4606 | 1.4613 |
| 0-10-10 | .9025 | .9029 | .9027 | -29.5 | -23.6 | -26.5 | 1.4619 | 1.4608 | 1.4614 |
| 0-10-20 | .9022 | .9026 | .9024 | -29.7 | -24.3 | -27.0 | 1.4619 | 1.4607 | 1.4613 |
| 0-10-30 | .9025 | .9033 | .9029 | -29.8 | -24.0 | -26.9 | 1.4620 | 1.4607 | 1.4613 |

| Fertilizer 500 lbs per acre | % Esters | | | % Total Menthol | | | % Menthone | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1947 | 1948 | 1947 & 1948 | 1947 | 1948 | 1947 & 1948 | 1947 | 1948 | 1947 & 1948 |
| 0-20-10 | 9.34 | 4.69 | 7.02 | 60.40 | 49.41 | 54.91 | 21.3 | 31.9 | 26.60 |
| 0-10-10 | 9.36 | 4.66 | 7.01 | 60.00 | 49.60 | 54.80 | 21.3 | 32.1 | 26.70 |
| 0-10-20 | 9.39 | 4.89 | 7.14 | 59.68 | 49.74 | 54.71 | 21.3 | 31.6 | 26.47 |
| 0-10-30 | 9.48 | 4.69 | 7.08 | 59.66 | 50.35 | 55.00 | 21.6 | 32.1 | 26.86 |

1. Average of 5 replications.

Analysis of Variance

| Source | DF | Specific Gravity 1947 SS x10⁻⁷ | 1947 MS x10⁻⁷ | 1948 SS x10⁻⁷ | 1948 MS x10⁻⁷ | DF | 1947 & 1948 SS x10⁻⁸ | 1947 & 1948 MS x10⁻⁸ |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 40 | | 57 | | 39 | 1151 | |
| Treatments | 3 | 9 | 3 | 14 | 4 | 3 | 133 | 44 |
| Replications | 4 | 15 | 4 | 5 | 1 | 4 | 131 | 33 |
| Years | | | | | | 1 | 186 | 186 |
| Treat x Years | | | | | | 3 | 36 | 6 |
| Error | 12 | 16 | 1 | 38 | 3 | 28 | 665 | 24 |

| Source | DF | Specific Optical Rotation 1947 SS | 1947 MS | 1948 SS | 1948 MS | DF | 1947 & 1948 SS | 1947 & 1948 MS |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 10.1 | | 14.0 | | 39 | 344.5 | |
| Treatments | 3 | 0.3 | 0.1 | 1.2 | 0.4 | 3 | 1.2 | 0.4 |
| Replications | 4 | 6.6 | 1.6 | 10.8 | 2.7 | 4 | 9.3 | 2.3 |
| Years | | | | | | 1 | 320.4 | 320.4 |
| Treat x Years | | | | | | 3 | 0.3 | 0.1 |
| Error | 12 | 3.2 | 0.3 | 2.0 | 0.2 | 28 | 13.3 | 0.5 |

| Source | DF | Refractive Index 1947 SS x10⁻⁸ | 1947 MS x10⁻⁸ | 1948 SS x10⁻⁷ | 1948 MS x10⁻⁷ | DF | 1947 & 1948 SS x10⁻⁸ | 1947 & 1948 MS x10⁻⁸ |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 29 | | 98 | | 39 | 1783 | |
| Treatments | 3 | 0 | 0 | 1 | 0 | 3 | 3 | 1 |
| Replications | 4 | 9 | 2 | 20 | 5 | 4 | 82 | 20 |
| Years | | | | | | 1 | 1475 | 1475 |
| Treat x Years | | | | | | 3 | 8 | 3 |
| Error | 12 | 20 | 2 | 77 | 6 | 28 | 215 | 8 |

| Source | DF | Esters 1947 SS | 1947 MS | 1948 SS | 1948 MS | DF | 1947 & 1948 SS | 1947 & 1948 MS |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 8.70 | | 3.5 | | 39 | 229.5 | |
| Treatments | 3 | 0.05 | 0.02 | 0.2 | 0.1 | 3 | 0.1 | 0.0 |
| Replications | 4 | 7.47 | 1.87 | 2.4 | 0.6 | 4 | 4.0 | 1.0 |
| Years | | | | | | 1 | 217.3 | 217.3 |
| Treat x Years | | | | | | 3 | 0.1 | 0.0 |
| Error | 12 | 1.18 | 0.10 | 0.9 | 0.1 | 28 | 8.0 | 0.3 |

| Source | DF | Total Menthol 1947 SS | 1947 MS | 1948 SS | 1948 MS | DF | 1947 & 1948 SS | 1947 & 1948 MS |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 43.6 | | 93 | | 39 | 1168.3 | |
| Treatments | 3 | 1.8 | 0.6 | 2 | 1 | 3 | 0.5 | 0.2 |
| Replications | 4 | 25.4 | 6.4 | 71 | 18 | 4 | 66.0 | 16.5 |
| Years | | | | | | 1 | 1031.6 | 1031.6 |
| Treat x Years | | | | | | 3 | 3.8 | 1.3 |
| Error | 12 | 16.4 | 1.4 | 20 | 2 | 28 | 66.4 | 2.4 |

| Source | DF | Menthone 1947 SS | 1947 MS | 1948 SS | 1948 MS | DF | 1947 & 1948 SS | 1947 & 1948 MS |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 27.4 | | 79.4 | | 39 | 1220.8 | |
| Treatments | 3 | 0.3 | 0.1 | 0.8 | 0.3 | 3 | 0.8 | 0.3 |
| Replications | 4 | 13.2 | 3.3 | 62.3 | 15.6 | 4 | 24.2 | 6.0 |
| Years | | | | | | 1 | 1114.1 | 1114.1 |
| Treat x Years | | | | | | 3 | 0.3 | 0.1 |
| Error | 12 | 13.9 | 1.2 | 16.3 | 1.4 | 28 | 81.4 | 2.9 |

<u>Spearmint</u>... In 1947 the spearmint was cut August 25 to 27 and was distilled August 28 to September 2. The following year it was harvested August 16 to 18 and was distilled August 19 to 21. Table 17 presents the yield of foliage and oil for both 1947 and 1948. In both years foliage and oil yields decreased as the amount of potash in the fertilizer increased. This decrease was not significant in 1948. However, the 1947 and the 1947 and 1948 data combined indicate that the ratio of phosphate to potash of 2:1 produced significantly more foliage that the other ratios and the decrease in oil yields was significant when the ratio exceeded 1:1. As with the peppermint both foliage and oil yields in 1948 were less than those of 1947 which was undoubtedly due to restricted rainfall. Table 18 presents the physicochemical constants of the oil produced in 1947 and 1948. These data indicate that none of these constants were influenced by the ratio of phosphate to potash in the fertilizer. The specific gravity and refractive index of the oil were slightly greater and the specific optical rotation and the percentage of carvone slightly less in 1947 than in 1948. Such differences are undoubtedly due to differences in the maturity of the crop at harvest.

Table 17. Effects of Different Ratios of Phosphate to Potash on the Yield of Spearmint Foliage and Oil Grown in 1947 and 1948 on Muck Soil (pH 6.1) in Clinton County.[1]

| Fertilizer 500 lbs. per acre | Foliage Tons per acre 1947 | 1948 | 1947 and 1948 | Oil Lbs per acre 1947 | 1948 | 1947 and 1948 |
|---|---|---|---|---|---|---|
| 0-20-10 | 11.3 | 5.0 | 8.1 | 35.0 | 26.2 | 30.6 |
| 0-10-10 | 9.9 | 4.4 | 7.2 | 33.7 | 20.7 | 27.2 |
| 0-10-20 | 9.7 | 4.3 | 7.0 | 27.6 | 18.2 | 22.9 |
| 0-10-30 | 9.4 | 4.0 | 6.7 | 26.1 | 18.8 | 22.4 |

1. Averages of 5 replications

Analysis of Variance

| Source | DF | 1947 Foliage SS | 1947 Foliage MS | 1947 Oil SS | 1947 Oil MS | 1948 Foliage SS | 1948 Foliage MS | 1948 Oil SS | 1948 Oil MS | DF | 1947 - 48 Foliage SS | 1947 - 48 Foliage MS | 1947 - 48 Oil SS | 1947 - 48 Oil MS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 19 | 29 | | 1794 | | 12.6 | | 556 | | 39 | 363.1 | | 3274 | |
| Treatments | 3 | 10 | 3* | 293 | 98** | 3.0 | 1.0 | 200 | 67 | 3 | 11.8 | 3.9** | 449 | 150* |
| Replications | 4 | 10 | 2 | 1307 | 327 | 4.3 | 1.1 | 102 | 25 | 4 | 11.9 | 3.0 | 804 | 201 |
| Years | | | | | | | | | | 1 | 321.5 | 321.5 | 924 | 924 |
| Treat x Years | | | | | | | | | | 3 | 1.1 | 0.4 | 44 | 15 |
| Error | 12 | 9 | 1 | 194 | 16 | 5.3 | 0.4 | 254 | 21 | 28 | 16.8 | 0.6 | 1053 | 38 |
| L.S.D. | (5%) | | 1.3 | | 5.6 | | | | | | | 0.8 | | 5.7 |
| | (1%) | | 1.8 | | 7.8 | | | | | | | 1.0 | | 7.7 |

* Significant at 5% level
** Significant at 1% level

Table 18. Effects of Different Ratios of Phosphate to Potash on the Physicochemical Constants of Spearmint Oil Produced in 1947 and 1948 on Muck Soil (pH 6.2) in Clinton County.[1]

| Fertilizer 500 lbs. per acre | Specific Gravity | | | Specific Optical Rotation | | |
|---|---|---|---|---|---|---|
| | 1947 | 1948 | 1947 and 1948 | 1947 | 1948 | 1947 and 1948 |
| 0-20-10 | .9277 | .9277 | .9277 | -56.6 | -57.8 | -57.2 |
| 0-10-10 | .9282 | .9273 | .9277 | -56.4 | -58.0 | -57.2 |
| 0-10-20 | .9287 | .9281 | .9284 | -56.9 | -58.2 | -57.6 |
| 0-10-30 | .9280 | .9277 | .9278 | -55.9 | -57.6 | -56.7 |
| **Fertilizer 500 lbs. per acre** | **Refractive Index** | | | **% Carvone** | | |
| | 1947 | 1948 | 1947 and 1948 | 1947 | 1948 | 1947 and 1948 |
| 0-20-10 | 1.4888 | 1.4886 | 1.4887 | 67.4 | 68.4 | 67.9 |
| 0-10-10 | 1.4891 | 1.4887 | 1.4889 | 67.8 | 67.9 | 67.8 |
| 0-10-20 | 1.4891 | 1.4891 | 1.4891 | 67.9 | 68.4 | 68.1 |
| 0-10-30 | 1.4892 | 1.4887 | 1.4890 | 66.7 | 68.1 | 67.4 |

1. Averages of 5 replications.

Analysis of Variance

| Source | DF | Specific Gravity 1947 SS $\times 10^{-6}$ | 1947 MS $\times 10^{-6}$ | 1948 SS $\times 10^{-7}$ | 1948 MS $\times 10^{-7}$ | DF | 1947 and 1948 SS $\times 10^{-7}$ | 1947 and 1948 MS $\times 10^{-7}$ |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 36 | | 225 | | 39 | 611 | |
| Treatments | 3 | 3 | 1 | 16 | 5 | 3 | 32 | 11 |
| Replications | 4 | 12 | 3 | 69 | 17 | 4 | 114 | 29 |
| Years | | | | | | 1 | 21 | 21 |
| Treat x Years | | | | | | 3 | 11 | 37 |
| Error | 12 | 21 | 2 | 140 | 12 | 28 | 433 | 15 |

## Specific Optical Rotation

| Source | DF | 1947 SS | 1947 MS | 1948 SS | 1948 MS | DF | 1947 and 1948 SS | 1947 and 1948 MS |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 20 | | 6.0 | | 39 | 48.4 | |
| Treatments | 3 | 3 | 1 | 0.9 | 0.3 | 3 | 3.3 | 1.1 |
| Replications | 4 | 5 | 1 | 1.4 | 0.4 | 4 | 0.8 | 0.2 |
| Years | | | | | | 1 | 21.6 | 21.6 |
| Treat x Years | | | | | | 3 | 0.6 | 0.2 |
| Error | 12 | 12 | 1 | 3.7 | 0.3 | 28 | 22.1 | 0.8 |

## Refractive Index

| Source | DF | 1947 SS $x10^{-8}$ | 1947 MS $x10^{-8}$ | 1948 SS $x10^{-8}$ | 1948 MS $x10^{-8}$ | DF | 1947 and 1948 SS $x10^{-8}$ | 1947 and 1948 MS $x10^{-9}$ |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 189 | | 204 | | 39 | 441 | |
| Treatments | 3 | 47 | 16 | 46 | 15 | 3 | 89 | 297 |
| Replications | 4 | 2 | 0 | 2 | 0 | 4 | 1 | 2 |
| Years | | | | | | 1 | 50 | 500 |
| Treat x Years | | | | | | 3 | 12 | 40 |
| Error | 12 | 140 | 12 | 156 | 13 | 28 | 289 | 103 |

## C arvone

| Source | DF | 1947 SS | 1947 MS | 1948 SS | 1948 MS | DF | 1947 and 1948 SS | 1947 and 1948 MS |
|---|---|---|---|---|---|---|---|---|
| Total | 19 | 75 | | 20.2 | | 39 | 101.3 | |
| Treatments | 3 | 4 | 1 | 0.6 | 0.2 | 3 | 2.6 | 0.8 |
| Replications | 4 | 44 | 11 | 7.4 | 1.8 | 4 | 41.1 | 10.3 |
| Years | | | | | | 1 | 5.7 | 5.7 |
| Treat x Years | | | | | | 3 | 2.5 | 0.8 |
| Error | 12 | 27 | 2 | 12.2 | 1.0 | 28 | 49.4 | 1.8 |

Heavy Fertilization.... In 1948 there was included with the minor element treatments on peppermint in Lapeer County one treatment of a ton of 0-10-20 fertilizer per acre in addition to the original fertilization of 400 pounds per acre of a 3-9-18. These data are found in detail in Tables 26 and 27. Table 19 presents the average wilt count, yields of foliage and oil, and physicochemical constants of the oil of the heavily fertilized plots with the averages of all the other plots. Although practically as many of the plants receiving the heavy rate of fertilization were infected with Verticillium wilt as with the lower rate, the former were infected to a much less degree and made a markedly greater growth, as shown by these data. Yields of plants and oil were significantly increased by the application of 2000 pounds per acre of 0-10-20. None of the physicochemical constants were significantly influenced. However, these data suggest that the percentages of both the esters and the total menthol were decreased by the large application of fertilizers.

Minor Elements.... In 1947 and 1948 six sets of plots were established to which were added various minor elements. Salts of these elements were mixed with enough muck to secure a volume large enough to broadcast uniformly by hand over the entire plot area and then carefully cultivated into the soil. Whenever a potassium salt of an element was added, enough potassium chloride was added to the other plots so each received the same amount of potassium.

Table 19. Comparison of Wilt Count, Yield of Peppermint Plants and Oil, and Physicochemical Constants of Plots Receiving a Large Fertilizer Application with Other Plots in Lapeer County.

| Additional fertilizer applied | No. plants showing wilt symptoms | Foliage T/A | Oil Lbs/A | Specific Gravity |
|---|---|---|---|---|
| 2000 Lbs/A[1] 0-10-20 | 29 | 5.3 | 25.3 | .9041 |
| None [2] | 31 | 4.1 | 19.1 | .9045 |

| Additional fertilizer applied | Specific Optical Rotation | Refractive Index | % Esters | % Menthol | % Menthone |
|---|---|---|---|---|---|
| 2000 Lbs/A[1] | -29.6 | 1.4619 | 8.57 | 67.49 | 12.5 |
| None [2] | -29.7 | 1.4620 | 9.48 | 68.91 | 12.2 |

1. Averages of 4 plots.
2. Averages of 28 plots.

## Experiment 1

Treatments.... Seven minor elements were applied June 29, 1947 to muck soil of pH 6.2 on the Muck Experimental Farm in Clinton County. The form of application and the amounts used appear below, while the combination of minor elements, applied in triplicate, are given in Table 20.

Table 20. Effects of Various Minor Elements on the Yield of Peppermint Foliage and Oil Grown in 1947 on Muck Soil (pH 6.1) in Clinton County.

| Treatment | Foliage Tons per acre | | | | Oil Lbs. per acre | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | Mean | I | II | III | Mean |
| Nothing | 10.8 | 7.7 | 8.3 | 8.9 | 39.4* | 24.8 | 22.8 | 29.0 |
| Zn | 11.1 | 8.2 | 7.5 | 8.9 | 37.9* | 25.1 | 22.3 | 28.4 |
| Cu | 10.0 | 10.6 | 7.4 | 9.3 | 34.0* | 34.8 | 23.1 | 30.6 |
| Cu, Zn | 9.4 | 10.8 | 7.6 | 9.3 | 35.4* | 37.2 | 25.6 | 32.7 |
| Cu, Zn, $I_1$ | 9.7 | 10.8 | 9.1 | 9.9 | 34.1* | 35.9 | 29.0 | 33.0 |
| Cu, Zn, $I_2$ | 9.7 | 10.1 | 6.5 | 8.8 | 34.3* | 34.7 | 22.2 | 30.4 |
| Cu, Zn, $I_1$, Cr | 10.0 | 8.8 | 9.9 | 9.6 | 35.0* | 32.3 | 24.6 | 30.6 |
| Cu, Zn, $I_1$, Si | 8.9 | 8.7 | 9.2 | 8.9 | 35.2* | 32.8 | 25.6 | 31.2 |
| Cu, Zn, $I_1$, Br | 8.7 | 10.5 | 9.2 | 9.5 | 33.2 | 30.8 | 24.8 | 29.6 |
| Cu, Zn, $I_1$, F | 8.8 | 10.5 | 8.6 | 9.3 | 30.1 | 32.9 | 23.9 | 29.0 |

* These plots were cut three days after the other plots because an exceedingly heavy rain stopped harvesting operations.

Analysis of Variance

| Source | DF | Foliage | | Oil | |
|---|---|---|---|---|---|
| | | SS | MS | SS | MS |
| Total | 29 | 41.0 | | 845 | |
| Treatments | 9 | 3.2 | 0.4 | 64 | 7 |
| Replications | 2 | 12.3 | 6.2 | 590 | 295 |
| Error | 18 | 25.5 | 1.4 | 191 | 11 |

| Element | Lbs. per acre of compound applied | Form applied |
|---|---|---|
| Zinc | 50 | Zinc sulphate |
| Copper | 50 | Copper sulphate |
| Iodine 1 | 3 | Potassium iodide |
| Iodine 2 | 6 | " " |
| Silicon | 100 | Sodium metasilicate |
| Bromine | 3 | Potassium bromide |
| Fluorine | 1 | Sodium fluoride |
| Chromium | 50 | Potassium dichromate |

Peppermint plants were transplanted ~~in~~ June 27 and June 28. 250 pounds of 0-10-20 commercial fertilizer was applied as a sidedressing July 8. The crop was cut September 8 - 13 and was distilled September 13 - 16.

<u>Yields</u>.... Table 20 presents the yield of foliage and oil. These date indicate that none of these minor elements influenced the yield of the foliage or the oil.

<u>Physicochemical Constants</u>.... Table 21 presents the physicochemical constants of the oil produced. It is evident that these minor elements did not influence these constants.

Table 21. Effects of Various Minor Elements on the Physicochemical C onstants of Peppermint Oil Produced in 1947 on Muck Soil (pH 6.2) in Clinton County.

| Treatment | Specific Gravity | | | | Optical Rotation | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | Mean | I | II | III | Mean |
| Nothing | 0.9024* | 0.9036 | 0.9037 | 0.9032 | -21.9* | -24.1 | -24.3 | -23.4 |
| Zn | 0.9021* | 0.9033 | 0.9034 | 0.9029 | -22.0* | -24.3 | -24.3 | -23.5 |
| Cu | 0.9022* | 0.9035 | 0.9036 | 0.9031 | -21.5* | -23.7 | -25.3 | -23.5 |
| Cu, Zn | 0.9022* | 0.9036 | 0.9040 | 0.9033 | -22.0* | -24.4 | -24.9 | -23.8 |
| Cu, Zn, $I_1$ | 0.9027* | 0.9035 | 0.9041 | 0.9034 | -20.9* | -24.2 | -24.6 | -23.2 |
| Cu, Zn, $I_2$ | 0.9023* | 0.9033 | 0.9034 | 0.9030 | -21.9* | -24.2 | -24.5 | -23.5 |
| Cu, Zn, $I_1$, Cr | 0.9024* | 0.9032 | 0.9031 | 0.9029 | -21.1* | -24.4 | -24.4 | -23.3 |
| Cu, Zn, $I_1$, Si | 0.9027* | 0.9030 | 0.9031 | 0.9029 | -22.0* | -24.4 | -24.4 | -23.6 |
| Cu, Zn, $I_1$, Br | 0.9036 | 0.9038 | 0.9034 | 0.9036 | -24.0 | -24.2 | -24.0 | -24.1 |
| Cu, Zn, $I_1$, F | 0.9032 | 0.9038 | 0.9036 | 0.9035 | -24.2 | -24.4 | -23.7 | -24.1 |

* Plots from which this oil was produced were cut three days after the other plots because an exceedingly heavy rain stopped harvesting operations.

Table 21. Continued

| Treatment | Refractive Index | | | | % Esters | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | Mean | I | II | III | Mean |
| Nothing | 1.4612* | 1.4609 | 1.4605 | 1.4609 | 4.93* | 8.91 | 8.58 | 7.47 |
| Zn | 1.4608* | 1.4608 | 1.4606 | 1.4607 | 4.77* | 8.88 | 8.80 | 7.48 |
| Cu | 1.4604* | 1.4610 | 1.4608 | 1.4607 | 4.47* | 6.62 | 9.20 | 6.76 |
| Cu, Zn | 1.4605* | 1.4612 | 1.4606 | 1.4608 | 4.52* | 7.08 | 9.32 | 6.97 |
| Cu, Zn, $I_1$ | 1.4605* | 1.4609 | 1.4607 | 1.4607 | 4.51* | 7.31 | 8.83 | 6.88 |
| Cu, Zn, $I_2$ | 1.4601* | 1.4609 | 1.4608 | 1.4606 | 4.82* | 7.00 | 8.92 | 6.91 |
| Cu, Zn, $I_1$, Cr | 1.4604* | 1.4611 | 1.4599 | 1.4605 | 4.66* | 7.15 | 8.90 | 6.90 |
| Cu, Zn, $I_1$, Si | 1.4607* | 1.4610 | 1.4604 | 1.4607 | 4.96* | 7.34 | 8.36 | 6.89 |
| Cu$\frac{1}{2}$ Zn, $I_1$, Br | 1.4611 | 1.4607 | 1.4605 | 1.4608 | 7.06 | 9.00 | 8.26 | 8.11 |
| Cu, Zn, $I_1$, F | 1.4611 | 1.4607 | 1.4605 | 1.4608 | 7.24 | 9.05 | 8.11 | 8.13 |

* Plots from which this oil was produced were cut three days after the other plots because an exceedingly heavy rain stopped harvesting operations.

Table 21. Continued

| Treatment | % Total Menthol | | | | % Menthone | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | Mean | I | II | III | Mean |
| Nothing | 50.62* | 55.42 | 54.92 | 53.65 | 28.6* | 27.7 | 29.1 | 28.5 |
| Zn | 50.57* | 55.74 | 56.20 | 54.17 | 30.4* | 27.0 | 28.2 | 28.5 |
| Cu | 49.61* | 56.40 | 55.74 | 53.92 | 31.6* | 25.6 | 27.1 | 28.1 |
| Cu, Zn | 49.72* | 56.55 | 55.87 | 54.05 | 31.0* | 24.6 | 26.2 | 27.3 |
| Cu, Zn, $I_1$ | 49.07* | 57.08 | 56.44 | 54.20 | 33.9* | 25.5 | 26.9 | 28.8 |
| Cu, Zn, $I_2$ | 50.47* | 57.39 | 54.80 | 54.22 | 31.1* | 24.4 | 27.6 | 27.7 |
| Cu, Zn, $I_1$, Cr | 49.33* | 57.43 | 54.16 | 53.64 | 31.9* | 24.7 | 28.0 | 28.2 |
| Cu, Zn, $I_1$, Si | 51.34* | 57.32 | 53.62 | 54.09 | 30.1* | 24.7 | 29.2 | 28.0 |
| Cu, Zn, $I_1$, Br | 60.86 | 55.36 | 53.43 | 56.55 | 24.6 | 27.6 | 29.2 | 27.1 |
| Cu, Zn, $I_1$, F | 58.10 | 55.90 | 53.98 | 55.99 | 25.1 | 26.9 | 29.2 | 27.1 |

* Plots from which this oil was produced were cut three days after the other plots because an exceedingly heavy rain stopped harvesting operations.

Analysis of Variance

| Source | DF | Specific Gravity | | Optical Rotation | | Refractive Index | |
|---|---|---|---|---|---|---|---|
| | | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ | SS | MS | SS $\times 10^{-8}$ | MS $\times 10^{-8}$ |
| Total | 29 | 94 | | 45.1 | | 270 | |
| Treatments | 9 | 20 | 2 | 2.3 | 0.2 | 20 | 2 |
| Replications | 2 | 56 | 28 | 32.0 | 16.0 | 67 | 34 |
| Error | 18 | 18 | 1 | 10.8 | 0.6 | 183 | 10 |

| Source | DF | Ester | | Menthol | | Menthone | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Total | 29 | 87.6 | | 270 | | 184 | |
| Treatments | 9 | 7.3 | 0.8 | 26 | 3 | 10 | 1 |
| Replications | 2 | 67.5 | 33.8 | 104 | 52 | 79 | 40 |
| Error | 18 | 12.8 | 0.7 | 140 | 8 | 95 | 5 |

Table 22. Effects of Various Minor Elements on the Yield of Peppermint Foliage and Oil Grown in 1948 on Muck Soil (pH 6.0) in Clinton County.[1]

| Treatment | Foliage T/A | Oil Lbs./A |
|---|---|---|
| Cu | 5.4 | 21.2 |
| Cu, Zn | 5.5 | 22.9 |
| Cu, Zn, Mo | 5.4 | 20.0 |
| Cu, Zn, $I_1$ | 5.7 | 24.4 |
| Cu, Zn, $I_2$ | 5.3 | 21.4 |
| Cu, Zn, Br | 5.6 | 22.6 |
| Cu, Zn, F | 5.6 | 23.2 |
| Cu, Zn, Cr | 6.9 | 28.1 |
| Cu, Zn, Si | 6.1 | 25.8 |

1. Averages of 3 replications.

Analysis of Variance

| Source | DF | Foliage | | Oil | |
|---|---|---|---|---|---|
| | | SS | MS | SS | MS |
| Total | 26 | 38.0 | | 662 | |
| Treatments | 8 | 6.2 | 0.8 | 152 | 19 |
| Replications | 2 | 1.2 | 0.6 | 44 | 22 |
| Error | 16 | 30.6 | 1.9 | 466 | 29 |

## Experiment 2

Treatments... Eight minor elements were applied June 17, 1948 to muck soil of pH 6.0 on the Muck Experimental Farm in Clinton County. The form of application and the amounts used appear below, while the combination of minor elements, applied in triplicate, are given in Table 22. Peppermint plants were transplanted June 10. 250 pounds per acre of 0-10-20 commercial fertilizer was applied as sidedressing June 24. The crop was cut August 30 and 31 and was distilled September 1 to 3.

| Element | Lbs. per acre of compound applied | Form Applied |
|---|---|---|
| Zinc | 50 | Zinc sulphate |
| Copper | 50 | Copper sulphate |
| Iodine 1 | 3 | Potassium iodide |
| Iodine 2 | 6 | Potassium iodide |
| Silicon | 100 | Sodium metasilicate |
| Bromine | 3 | Potassium bromide |
| Fluorine | 1 | Sodium fluoride |
| Chromium | 50 | Sodium dichromate |
| Molybdenum | 3 | Ammonium molybdate |

Yields.... Table 22 presents the yield of foliage and oil. There is no indication from these results that the applications of the minor elements influenced the yields of foliage or oil.

Physicochemical Constants.... Table 23 presents the physicochemical constants of the oil produced. It indicates that these constants were not significantly influenced by the minor elements used. There is, however, a suggestion that the percentage of ester and total menthol was increased and that that percentage of menthone was decreased by the application of iodine.

Table 23. Effects of Various Minor Elements on the Physicochemical Constants of Peppermint Oil Grown in 1948 on Muck Soil (pH 6.0) in Clinton County.[1]

| Treatment | Specific Gravity | Specific Optical Rotation | Refractive Index | % Esters | % Total Menthol | % Menthone |
|---|---|---|---|---|---|---|
| Cu | .9039 | -22.5 | 1.4618 | 6.03 | 52.83 | 25.9 |
| Cu, Zn | .9039 | -22.2 | 1.4619 | 5.52 | 52.23 | 26.9 |
| Cu, Zn, Mo | .9036 | -22.4 | 1.4617 | 5.60 | 51.76 | 27.1 |
| Cu, Zn, $I_1$ | .9042 | -22.8 | 1.4616 | 6.03 | 55.48 | 25.2 |
| Cu, Zn, $I_2$ | .9041 | -23.1 | 1.4617 | 6.17 | 54.15 | 25.2 |
| Cu, Zn, Br | .9035 | -22.6 | 1.4615 | 5.48 | 54.07 | 26.9 |
| Cu, Zn, F | .9047 | -22.5 | 1.4616 | 5.84 | 53.72 | 26.6 |
| Cu, Zn, Cr | .9035 | -22.8 | 1.4614 | 5.63 | 53.87 | 25.8 |
| Cu, Zn, Si | .9040 | -22.1 | 1.4617 | 5.49 | 52.34 | 27.3 |

1. Averages of 3 replications.

Analysis of Variance

| Source | DF | Specific Gravity SS x $10^{-7}$ | Specific Gravity MS x $10^{-7}$ | Optical Rot. SS | Optical Rot. MS | Ref. Index SS x $10^{-8}$ | Ref. Index MS x $10^{-8}$ |
|---|---|---|---|---|---|---|---|
| Total | 26 | 110 | | 14.4 | | 247 | |
| Treatments | 8 | 36 | 4 | 2.6 | 0.3 | 53 | 7 |
| Replications | 2 | 26 | 13 | 4.8 | 2.4 | 2 | 1 |
| Error | 16 | 48 | 3 | 7.0 | 0.4 | 192 | 12 |

| Source | DF | Ester SS | Ester MS | Menthol SS | Menthol MS | Menthone SS | Menthone MS |
|---|---|---|---|---|---|---|---|
| Total | 26 | 2.96 | | 224 | | 66 | |
| Treatments | 8 | 1.70 | 0.21 | 34 | 4 | 17 | 2 |
| Replications | 2 | 0.01 | 0.00 | 66 | 33 | 13 | 6 |
| Error | 16 | 1.25 | 0.08 | 124 | 8 | 36 | 2 |

## Experiment 3

Treatments.... Five minor elements were applied June 19, 1947 to muck soil of pH 6.9 in Lapeer County. The form of application and the amounts used appear below, while the combination of minor elements, applied in duplicate, are given in Table 24.

| Element | Lbs. per acre of compound applied | Form Applied |
|---|---|---|
| Copper | 50 | Copper sulphate |
| Zinc | 25 | Zinc sulphate |
| Iodine 1 | 3 | Potassium iodide |
| Iodine 2 | 6 | Potassium iodide |
| Strontium | 50 | Strontium chloride |
| Silicon | 50 | Sodium metasilicate |

These treatments were applied to meadow mint two years old. 450 pounds of 3-12-12 commercial fertilizer had been applied in May. The crop was cut August 21 to 23 and was distilled August 23 and 24.

Yields.... Table 24 presents the yield of foliage and oil. These data indicate that these yields were not influenced by the minor elements.

Physicochemical Constants.... Table 25 presents the physicochemical constants of the oil produced. It is evident that these constants were not influenced by the minor elements used.

Table 24. Effects of Various Minor Elements on the Yield of Peppermint Foliage and Oil Grown in 1947 on Muck Soil (pH 6.9) in Lapeer County.[1]

| Treatment | Foliage T/A | Oil Lbs./A |
|---|---|---|
| Nothing | 5.2 | 27.2 |
| Cu | 5.2 | 29.8 |
| Cu, Zn | 5.8 | 32.3 |
| Cu, Zn, $I_1$ | 6.0 | 31.2 |
| Cu, Zn, $I_2$ | 6.4 | 34.8 |
| Cu, Zn, $I_1$, Sr | 6.8 | 34.7 |
| Cu, Zn, $I_1$, Si | 6.5 | 34.0 |

1. Averages of 2 replications

Analysis of Variance

| Source | DF | Foliage | | Oil | |
|---|---|---|---|---|---|
| | | SS | MS | SS | MS |
| Total | 13 | 13.3 | | 225 | |
| Treatments | 6 | 5.0 | 0.8 | 94 | 16 |
| Replications | 1 | 4.5 | 4.5 | 100 | 100 |
| Error | 6 | 3.8 | 0.6 | 31 | 5 |

Table 25. Effects of Various Minor Elements on the Physico-chemical Constants of Peppermint Oil Produced in 1947 on Muck Soil (pH 6.9) in Lapeer County.[1]

| Treatment | Specific Gravity | Specific Optical Rotation | Refractive Index | % Esters | % Total Menthol | % Menthone |
|---|---|---|---|---|---|---|
| Nothing | .9008 | -29.2 | 1.4624 | 6.56 | 55.18 | 23.0 |
| Cu | .9010 | -28.8 | 1.4633 | 6.50 | 56.56 | 24.0 |
| Cu, Zn | .9007 | -29.2 | 1.4626 | 6.29 | 55.60 | 23.0 |
| Cu, Zn, $I_1$ | .9005 | -29.1 | 1.4628 | 6.20 | 54.56 | 22.8 |
| Cu, Zn, $I_2$ | .9005 | -29.0 | 1.4621 | 5.76 | 54.38 | 25.0 |
| Cu, Zn, $I_1$, Sr | .9003 | -28.9 | 1.4623 | 5.76 | 54.26 | 24.7 |
| Cu, Zn, $I_1$, Si | .9002 | -29.4 | 1.4626 | 5.99 | 54.20 | 23.6 |

1. Averages of 2 replications.

Analysis of Variance

| Source | DF | Specific Gr. | | Op. Rot. | | Ref. Index | |
|---|---|---|---|---|---|---|---|
| | | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ | SS | MS | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ |
| Total | 13 | 19 | | 2.83 | | 24 | |
| Treatments | 6 | 10 | 2 | 0.54 | 0.09 | 18 | 3 |
| Replications | 1 | 1 | 1 | 0.04 | 0.04 | 1 | 1 |
| Error | 6 | 8 | 1 | 2.25 | 0.38 | 5 | 1 |

| Source | DF | Ester | | Menthol | | Menthone | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Total | 13 | 3.0 | | 14.0 | | 12.7 | |
| Treatments | 6 | 1.3 | 0.2 | 9.2 | 1.5 | 8.9 | 1.5 |
| Replications | 1 | 0.7 | 0.7 | 1.7 | 1.7 | 0.0 | 0.0 |
| Error | 6 | 1.0 | 0.2 | 3.1 | 0.5 | 3.8 | 0.6 |

## Experiment 4

Treatments.... The following seven treatments and one control, all replicated four times, were applied May 18, 1948 to muck soil of pH 6.8 in Lapeer County. The form of application and the amounts used appear below.

| Element | Lbs. per acre of compound applied | Form applied |
|---|---|---|
| Molybdenum 1 | 6 | Ammonium molybdate |
| Molybdenum 2 | 3 | Ammonium molybdate |
| Iodine 1 | 6 | Potassium iodide |
| Iodine 2 | 10.7* | Thymol iodide |
| Cobalt | 20 | Cobalt sulphate |
| Strontium | 100 | Strontium chloride |
| | 2000 | 0-10-20 fertilizer |

* Supplies an amount of iodine equivalent to that supplied by the potassium iodide.

Peppermint rootstalks were deeply planted May 7. Four hundred pounds per acre of 3-9-18 commercial fertilizer was applied broadcast. Counts of plants showing symptoms of Verticillium wilt were made August 26. The plots were cut September 10 and 11 and distilled September 13 and 14.

Wilt Counts and Yields.... Table 26 shows the number of plants showing symptoms of Verticillium wilt and the yield of foliage and oil. It is evident that none of the treatments influenced the number of infected plants. Although as many of the plants which received the heavy rate of fertilizer were infected as with the lower rate, the former were infected to a much less degree and made a markedly greater growth. None of the minor elements influenced plant or oil yields. The effect of the heavy fertilizer application is discussed on page 54 .

Physicochemical Constants.... Table 27 presents the physicochemical constants of the oil produced. There is no indication from these results that these constants were influenced by the minor elements used. The influence of the heavy application of fertilizer is discussed on page 54 .

## Experiment 5

Treatments.... The following seven treatments and one control, all replicated twice, were applied June 9, 1948 to muck soil of pH 4.0 in Calhoun County. The form of application and the amounts used appear below.

| Element | Lbs. per acre applied | Form Applied |
|---|---|---|
| Manganese | 100 | Manganese sulphate |
| Copper 1 | 76* | Black copper oxide |
| Copper 2 | 100 | Copper sulphate |
| Zinc | 50 | Zinc sulphate |
| Boron | 50 | Boric acid |
| Molybdenum | 6 | Ammonium molybdate |

* Supplies an amount of copper equivalent to that supplied by the copper sulphate.

Table 26. Effects of Various Minor Elements and Applications of a Large Amount of Fertilizer on the Number of Plants Showing Symptoms of Verticillium Wilt and on the Yield of Peppermint Foliage and Oil Grown in 1948 on Muck Soil (pH 6.8) in Lapeer County.[1]

| Treatment | No. Plants showing wilt symptoms | Foliage T/A | Oil Lbs/A |
|---|---|---|---|
| Nothing | 31 | 4.0 | 20.3 |
| $Mo_1$ | 31 | 4.0 | 17.7 |
| $Mo_2$ | 31 | 4.0 | 18.4 |
| $Mo_2$, $I_1$ | 26 | 4.2 | 20.4 |
| $Mo_2$, $I_2$ | 32 | 4.2 | 20.0 |
| $Mo_2$, $I_1$, Co | 32 | 4.0 | 18.4 |
| $Mo_2$, $I_1$, 0-10-20 | 29 | 5.3 | 25.3 |
| $Mo_2$, Sr | 32 | 4.2 | 18.6 |

1. Averages of 4 replications.

Analysis of Variance

| Source | DF | Infected Plants SS | Infected Plants MS | Foliage SS | Foliage MS | Oil SS | Oil MS |
|---|---|---|---|---|---|---|---|
| Total | 31 | 3914 | | 10.0 | | 292 | |
| Treatments | 7 | 143 | 20 | 5.8 | 0.8** | 160 | 23** |
| Replications | 3 | 550 | 183 | 1.0 | 0.3 | 4 | 1 |
| Error | 21 | 3221 | 153 | 3.2 | 0.2 | 127 | 6 |
| L.S.D. (5%) | | | | | 0.6 | | 3.7 |
| (1%) | | | | | 0.8 | | 5.0 |

** Significant at 1% level.

Table 27. Effects of Various Minor Elements and Applications of a Large Amount of Fertilizer on the Physicochemical Constants of Peppermint Oil Produced in 1948 on Muck Soil (pH 6.8) in Lapeer County.[1]

| Treatment | Specific Gravity | Specific Optical Rotation | Refractive Index | % Esters | % Total Menthol | % Menthone |
|---|---|---|---|---|---|---|
| Nothing | .9045 | -29.6 | 1.4621 | 9.58 | 68.60 | 11.8 |
| $Mo_1$ | .9046 | -29.6 | 1.4620 | 9.26 | 69.24 | 12.7 |
| $Mo_2$ | .9043 | -29.6 | 1.4620 | 9.55 | 68.56 | 12.5 |
| $Mo_2$, $I_1$ | .9044 | -29.7 | 1.4622 | 9.33 | 68.92 | 12.3 |
| $Mo_2$, $I_2$ | .9048 | -29.9 | 1.4620 | 9.56 | 69.52 | 12.0 |
| $Mo_2$, $I_1$, Co | .9046 | -29.9 | 1.4620 | 9.62 | 69.10 | 11.8 |
| $Mo_2$, $I_1$, 0-10-20 | .9041 | -29.6 | 1.4619 | 8.57 | 67.49 | 12.5 |
| $Mo_2$, Sr | .9044 | -29.8 | 1.4618 | 9.44 | 68.44 | 12.1 |

1. Averages of 4 replications.

Analysis of Variance

| Source | DF | Specific Gr. | | Op. Rot | | Ref. Index | |
|---|---|---|---|---|---|---|---|
| | | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ | SS | MS | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ |
| Total | 31 | 34 | | 12.3 | | 22 | |
| Treatments | 7 | 12 | 2 | 0.7 | 0.1 | 2 | 3 |
| Replications | 3 | 4 | 1 | 3.8 | 1.3 | 9 | 30 |
| Error | 21 | 18 | 1 | 7.8 | 0.4 | 11 | 5 |

| Source | DF | Ester | | Menthol | | Menthone | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Total | 31 | 9.09 | | 56.0 | | 104.7 | |
| Treatments | 7 | 3.15 | 0.45 | 10.9 | 1.6 | 3.3 | 0.5 |
| Replications | 3 | 0.23 | 0.08 | 27.8 | 9.3 | 20.3 | 6.8 |
| Error | 21 | 5.71 | 2.72 | 17.3 | 0.8 | 81.1 | 3.9 |

Peppermint rootstalks were planted in May. Five tons per acre of a finely pulverized dolomitic limestone was applied June 2. 700 pounds per acre of 3-9-18 commercial fertilizer was applied broadcast June 9. The plots were cut September 1 and distilled September 3. Plants from duplicate treatments were combined for distilling.

<u>Yields of Plants and Oil</u>.... Table 28 presents the yield of foliage and oil. These data indicate that none of the minor elements influenced yields of foliage. There is, however, an indication that the oil yield was increased by copper, boron, and molybdenum whereas zinc tended to decrease it.

<u>Physicochemical Constants</u>.... Table 29 presents the physicochemical constants of the oil produced. These data suggest that boron and molybdenum decreased the specific gravity, optical rotation, and percentage of esters and total menthol and increased the percent of menthone. It also suggests that manganese, copper, and zinc increased the optical rotation and percentage of esters and of total menthol and decreased the percentage of menthone.

Table 28. Effects of Various Minor Elements on the Yield of Peppermint Foliage and Oil Grown in 1948 on Muck Soil (pH 4.0 Brought up to pH 5.6 with Lime) in Calhoun County.

| Treatment | Foliage[1] | Oil Lbs/A |
|---|---|---|
| Nothing | 3.1 | 13.2 |
| Mn | 3.2 | 12.6 |
| Mn, $Cn_1$ | 3.0 | 16.8 |
| Mn, $Cu_2$ | 3.0 | 15.5 |
| Mn, $Cu_2$, Zn | 3.2 | 13.1 |
| Mn, $Cu_2$, Zn, B | 3.0 | 16.3 |
| Mn, $Cu_2$, Zn, B, Mo | 3.0 | 19.6 |
| $Cu_2$ | 2.8 | 15.8 |

1. Average of 2 replications.

Analysis of Variance of Foliage

| Source | DF | SS | MS |
|---|---|---|---|
| Total | 15 | 1.8 | |
| Treatments | 7 | 0.2 | 0.0 |
| Replications | 1 | 0.7 | 0.7 |
| Error | 7 | 0.9 | 0.1 |

Table 29. Effects of Various Minor Elements on the Physicochemical Constants of Peppermint Oil Produced in 1948 on Muck Soil (pH 4.0 Brought up to pH 5.6 with Lime) in Calhoun County.

| Treatment | Specific Gravity | Optical Rotation | Refractive Index | % Esters | % Total Menthol | % Menthone |
|---|---|---|---|---|---|---|
| Nothing | .9048 | -25.5 | 1.4626 | 7.62 | 56.43 | 21.7 |
| Mn | .9046 | -27.0 | 1.4628 | 8.35 | 57.51 | 20.1 |
| Mn, $Cu_1$ | .9040 | -27.6 | 1.4628 | 8.36 | 58.20 | 18.7 |
| Mn, $Cu_2$ | .9037 | -28.9 | 1.4636 | 8.37 | 58.71 | 16.9 |
| Mn, $Cu_2$, Zn | .9045 | -28.2 | 1.4637 | 8.44 | 57.19 | 18.3 |
| Mn, $Cu_2$, Zn, B | .9032 | -27.6 | 1.4632 | 7.39 | 57.57 | 19.5 |
| Mn, $Cu_2$, Zn, B, Mo | .9029 | -27.6 | 1.4634 | 6.88 | 54.79 | 20.0 |
| $Cu_2$ | .9036 | -27.8 | 1.4632 | 8.06 | 56.80 | 17.8 |

Radioactive Material (Alphatron)

This experiment was designed to study the effect of alphatron upon the incidence of wilt symptoms, and foliage and oil yields of peppermint. June 28, 1948 there was established in Lapeer County a set of twelve plots with three treatments involving a commercial radioactive material (alphatron) supplied by the United States Department of Agriculture. This material was said by the manufacturer to have an alpha ray disintegration rate of eight million per pound per second, largely from actinium. Dolomitic limestone was the carrier material and constituted more than 99% of its weight. These plots adjoined the minor element treatments, hence, the peppermint was planted and handled in the same manner as those plots. (See page 69). The treatments were as follows.

| | Pounds per acre | Material |
|---|---|---|
| Check | 20 | Dolomite |
| Alphatron 2 | 10 each | Dolomite and radioactive material |
| Alphatron 4 | 20 | Radioactive material |

Wilt Count and Foliage and Oil Yields.... Counts of plants showing symptoms of Verticillium wilt were made September 11. Table 30 shows the number of infected plants and the foliage and oil yields. It is evident that alphatron had no significant effect upon the incidence of symptoms of the disease or upon peppermint foliage or oil yields.

Physicochemical Constants.... Table 31 presents the physicochemical constants of the oil produced. These data show alphatron applications had no effect on these constants.

Table 30. Effect of Alphatron on the Number of Plants Showing Verticillium Wilt Symptoms and on the Yield of Peppermint Foliage and Oil Grown in 1948 on Muck Soil (pH 7.0) in Lapeer County.[1]

| Treatment | No. Plants with Wilt Symptoms | Foliage T/A | Oil Lbs/A |
|---|---|---|---|
| Check | 32 | 3.7 | 18.3 |
| Alphatron 2 | 26 | 4.0 | 20.4 |
| Alphatron 4 | 31 | 3.8 | 21.2 |

1. Averages of 4 replications.

Analysis of Variance

| Source | DF | Wilt | | Foliage | | Oil | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Total | 11 | 2345 | | 2.5 | | 41 | |
| Treatments | 2 | 64 | 32 | 1.0 | 0.5 | 18 | 9 |
| Replications | 3 | 379 | 126 | 0.1 | 0.0 | 4 | 1 |
| Error | 6 | 1902 | 317 | 1.5 | 0.2 | 19 | 3 |

Table 31. Effect of Alphatron on the Physicochemical Constants of Peppermint Oil Grown in 1948 on Muck Soil (pH 7.0) in Lapeer County.

| Treatment | Specific Gravity | Optical Rotation | Refractive Index | % Esters | % Total Menthol | % Menthone |
|---|---|---|---|---|---|---|
| Check | .9040 | -29.6 | 1.4618 | 9.34 | 67.20 | 12.61 |
| Alphatron 2 | .9040 | -29.4 | 1.4618 | 9.23 | 67.26 | 12.36 |
| Alphatron 4 | .9039 | -29.6 | 1.4618 | 9.42 | 67.16 | 12.31 |

Analysis of Variance

| Source | DF | Specific Gravity | | Optical Rotation | | Refractive Index | |
|---|---|---|---|---|---|---|---|
| | | SS $\times 10^{-8}$ | MS $\times 10^{-8}$ | SS | MS | SS $\times 10^{-8}$ | MS $\times 10^{-9}$ |
| Total | 11 | 54 | | 3.95 | | 5 | |
| Treatments | 2 | 5 | 2 | 0.05 | 0.02 | 1 | 5 |
| Replications | 3 | 14 | 5 | 1.20 | 0.40 | 1 | 5 |
| Error | 6 | 35 | 6 | 2.70 | 0.45 | 3 | 5 |

| Source | DF | Ester | | Menthol | | Menthone | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Total | 11 | 1.53 | | 18.38 | | 6.5 | |
| Treatments | 2 | 0.07 | 0.04 | 0.02 | 0.01 | 0.2 | 0.1 |
| Replications | 3 | 0.21 | 0.07 | 8.53 | 2.84 | 0.6 | 0.2 |
| Error | 6 | 1.25 | 0.21 | 9.83 | 1.64 | 5.7 | 1.0 |

## Crop Rotation

This experiment was designed to study the influence of preceding crops on the growth of peppermint and spearmint. It was established in 1946 on soil of pH 5.9 on the Muck Experimental Farm in Clinton County. Crops were planted in an east and west direction in 1947 and north and south in 1948 in order to cross the previous year's treatments. All crops received 1000 pounds per acre of an 0-15-30 commercial fertilizer which was applied with a grain drill each spring.

Peppermint.... In 1947 peppermint plants were transplanted June 10. The plots were cut September 2 and 3 and were distilled September 5 and 6. In 1948 they were transplanted June 20. At weekly intervals throughout August counts were made of those plants having symptoms of Verticillium wilt. This was the first season this disease had been observed in this area. The plots were cut August 20 and distilled August 23 and 24. Table 32 presents the yield of foliage and oil secured in both 1947 and 1948. These data indicate that the 1946 peppermint crop significantly depressed foliage and oil yields in 1947. But peppermint grown in 1947 had no influence on the 1948 peppermint. No other crop significantly influenced the amount of foliage or oil produced. Yields of both foliage and oil in 1948 were much lower than in 1947 because of restricted moisture. Tables 33 and 34 present the physicochemical constants of the oil produced in 1947 and 1948 respectively. Both years these constants were not significantly influenced by the previous year's crop. However, the data of 1948 suggested that the percentage of menthol and the specific optical rotation is increased and that the percentage of menthone is decreased by a previous crop of peppermint. Table 35 presents the number of plants showing wilt symptoms in 1948. These data strongly suggest a more heavy infestation of the disease on those plots which produced [redacted]mint in 1947 and also a more rapid increase in the number of plants showing symptoms of Verticillium wilt. However, this is not borne out statistically.

Spearmint.... Spearmint plants in 1947 were transplanted June 13. August 16 and September 2 the plots were cut and were distilled August 18 to 19 and September 4. In 1947 the plants were transplanted June 17, cut September 16 and distilled September 18. Table 36 presents the yield of foliage and oil for both 1947 and 1948. Foliage and oil yields were not significantly influenced by the previous crop in either 1947 or 1948. However, there is a suggestion that peppermint grown in 1946 depressed the foliage

Table 32. Effect of Crop of Previous Year on the Yield of Peppermint Foliage and Oil Grown in 1947 and 1948 on Muck Soil (pH 5.9) in Clinton County.[1]

| 1946 Crop | 1947 Foliage T/A | 1947 Oil Lbs/A | 1947 Crop | 1948 Foliage T/A | 1948 Oil Lbs/A |
|---|---|---|---|---|---|
| Onions | 13.0 | 41.0 | Spearmint | 7.1 | 26.9 |
| Head Lettuce | 12.8 | 35.8 | Celery | 8.2 | 27.1 |
| Spinach and Cabbage | 11.9 | 35.4 | Potatoes | 8.2 | 23.5 |
| Peppermint | 10.6 | 30.6 | Peppermint | 8.2 | 27.6 |
| Celery | 12.4 | 39.4 | Sugar Beets | 8.2 | 27.8 |
| Sugar Beets | 12.4 | 39.4 | Head Lettuce | 8.4 | 24.8 |
| Table Beets | 12.2 | 37.8 | Spinach | 9.0 | 29.0 |
| Potatoes | 12.9 | 42.4 | Onions | 9.2 | 33.1 |

1. Average of 2 replications.

Analysis of Variance

| Source | DF | 1947 | | | | 1948 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Foliage | | Oil | | Foliage | | Oil | |
| | | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 15 | 11.6 | | 401 | | 12.9 | | 171.6 | |
| Crops | 7 | 8.3 | 1.2* | 194 | 28* | 5.9 | 0.8 | 115.6 | 16.5 |
| Replications | 1 | 1.9 | 1.9 | 170 | 170 | 3.8 | 3.8 | 0.1 | 0.1 |
| Error | 7 | 1.4 | 0.2 | 37 | 5 | 3.2 | 0.5 | 55.9 | 8.0 |
| L.S.D. | (5%) | | 1.1 | | 5.4 | | | | |
| | (1%) | | 1.6 | | 8.0 | | | | |

* Significant at 5% level.

Table 33. Effect of Crop of Previous Year on the Physico-chemical Constants of Peppermint Oil Produced in 1947 on Muck Soil (pH 5.9) in Clinton County.[1]

| 1946 Crop | Specific Gravity | Optical Rotation | Refractive Index | % Esters | % Total Menthol | % Menthone |
|---|---|---|---|---|---|---|
| Onions | .9011 | -25.0 | 1.4606 | 5.51 | 47.78 | 33.8 |
| Head Lettuce | .9010 | -25.5 | 1.4610 | 5.42 | 49.02 | 33.8 |
| Spinach and Cabbage | .9014 | -27.0 | 1.4615 | 5.75 | 51.48 | 29.4 |
| Peppermint | .9015 | -26.8 | 1.4618 | 5.64 | 53.28 | 29.2 |
| Celery | .9014 | -25.2 | 1.4614 | 5.35 | 49.20 | 32.3 |
| Sugar Beets | .9012 | -26.0 | 1.4613 | 5.52 | 51.28 | 30.6 |
| Table Beets | .9012 | -26.4 | 1.4614 | 5.36 | 52.14 | 28.6 |
| Potatoes | .9012 | -25.8 | 1.4613 | 5.50 | 51.44 | 31.6 |

1. Average of 2 replications.

Analysis of Variance

| Source | DF | Specific Gravity | | Optical Rotation | | Refractive Index | |
|---|---|---|---|---|---|---|---|
| | | SS $\times 10^{-8}$ | MS $\times 10^{-8}$ | SS | MS | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ |
| Total | 15 | 194 | | 12.5 | | 28 | |
| Crops | 7 | 31 | 4 | 6.9 | 1.0 | 21 | 3 |
| Replications | 1 | 144 | 144 | 3.8 | 3.8 | 1 | 1 |
| Error | 7 | 19 | 3 | 1.8 | 0.3 | 6 | 1 |

| Source | DF | Ester | | Menthol | | Menthone | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Total | 15 | 1.83 | | 68.0 | | 97.9 | |
| Crops | 7 | 0.26 | 0.04 | 47.7 | 6.8 | 57.9 | 8.3 |
| Replications | 1 | 1.06 | 1.06 | 1.2 | 1.2 | 0.3 | 0.3 |
| Error | 7 | 0.51 | 0.07 | 19.1 | 2.7 | 39.7 | 5.7 |

Table 34. Effect of Crop of Previous Year on the Physico-chemical Constants of Peppermint Oil Produced in 1948 on Muck Soil (pH 5.9) in Clinton County.[1]

| 1947 Crop | Specific Gravity | Optical Rotation | Refractive Index | % Esters | % Total Menthol | % Menthone |
|---|---|---|---|---|---|---|
| Spearmint | .9003 | -24.6 | 1.4602 | 4.18 | 44.32 | 36.0 |
| Celery | .9004 | -24.4 | 1.4604 | 4.02 | 44.02 | 36.7 |
| Potatoes | .9010 | -24.8 | 1.4604 | 4.14 | 44.58 | 35.8 |
| Peppermint | .9010 | -25.0 | 1.4604 | 4.27 | 45.16 | 34.8 |
| Sugar Beets | .9014 | -24.2 | 1.4606 | 3.98 | 43.98 | 36.2 |
| Head Lettuce | .9014 | -24.2 | 1.4601 | 4.16 | 44.38 | 36.8 |
| Spinach | .9018 | -24.3 | 1.4604 | 4.29 | 43.67 | 36.6 |
| Onions | .9010 | -24.6 | 1.4602 | 4.12 | 44.37 | 36.7 |

1. Average of 2 replications.

Analysis of Variance

| Source | DF | Specific Gravity | | Optical Rotation | | Refractive Index | |
|---|---|---|---|---|---|---|---|
| | | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ | SS | MS | SS $\times 10^{-8}$ | MS $\times 10^{-8}$ |
| Total | 15 | 79 | | 5.6 | | 101 | |
| Crops | 7 | 35 | 5 | 1.2 | 0.2 | 27 | 4 |
| Replications | 1 | 25 | 25 | 1.2 | 1.2 | 9 | 9 |
| Error | 7 | 19 | 3 | 3.2 | 0.5 | 65 | 9 |

| Source | DF | Esters | | Menthol | | Menthone | |
|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS |
| Total | 15 | 1.08 | | 13.1 | | 19.9 | |
| Crops | 7 | 0.17 | 0.02 | 2.8 | 0.4 | 6.2 | 0.9 |
| Replications | 1 | 0.17 | 0.17 | 0.9 | 0.9 | 0.6 | 0.6 |
| Error | 7 | 0.74 | 0.10 | 9.4 | 1.3 | 13.1 | 1.9 |

Table 35. Effect of Crop of Previous Year on Number of Peppermint Plants Showing Symptoms of Verticillium Wilt in 1948. Clinton County. [1]

| 1947 Crop | No. Plants Showing Verticillium Wilt Symptoms | | | |
|---|---|---|---|---|
| | Aug. 5 | Aug. 10 | Aug. 16 | Aug. 20 |
| Spearmint | 17 | 32 | 46 | 50 |
| Celery | 1 | 2 | 6 | 6 |
| Potatoes | 4 | 9 | 11 | 14 |
| Peppermint | 12 | 26 | 36 | 50 |
| Sugar Beets | 2 | 2 | 2 | 3 |
| Head Lettuce | 0 | 1 | 1 | 2 |
| Spinach | 1 | 2 | 2 | 2 |
| Onions | 2 | 2 | 3 | 3 |

1. Average of 2 replications

Analysis of Variance

| Source | DF | Aug. 5 | | Aug. 10 | | Aug. 16 | | Aug. 20 | |
|---|---|---|---|---|---|---|---|---|---|
| | | SS | MS | SS | MS | SS | MS | SS | MS |
| Total | 15 | 789 | | 3826 | | 8093 | | 10652 | |
| Crops | 7 | 548 | 78 | 2120 | 303 | 4283 | 612 | 6335 | 905 |
| Replications | 1 | 81 | 81 | 541 | 541 | 1260 | 1260 | 1560 | 1560 |
| Error | 7 | 160 | 23 | 1165 | 166 | 2550 | 364 | 2757 | 394 |

and oil yield, and onions the oil yield of spearmint in 1947. The yields of both foliage and oil in 1948 were considerably less than those of 1947 as a result of restricted moisture. Tables 37 and 38 present the physicochemical constants of the oil produced in 1947 and 1948 respectively. It is evident from these data that the previous crop had no significant influence upon the constants of the oil produced in either year. However, in 1947 it is suggested that peppermint grown in 1946 decreased the optical rotation, refractive index, and percentage of carvone. In 1948 oil having the lowest percentage of carvone was obtained from plots which grew peppermint and sugar beets in 1947. In 1948 the specific gravity, refractive index, and percentage of carvone were lower and the optical rotation greater than that of the 1947 oil. Such differences are undoubtedly due to the relatively greater maturity of the plant when harvested in 1947 as compared to that of 1948.

Table 36. Effect of Crop of Previous Year on the Yield of Spearmint Foliage and Oil Grown in 1947 and 1948 on Muck Soil (pH 5.9) in Clinton County.[1]

| 1946 Crop | 1947 Foliage T/A | 1947 Oil Lbs/A | 1947 Crop | 1948 Foliage T/A | 1948 Oil Lbs/A |
|---|---|---|---|---|---|
| Onions | 12.1 | 32.5 | Spearmint | 4.6 | 12.0 |
| Head Lettuce | 11.2 | 39.4 | Celery | 4.4 | 16.4 |
| Spinach and Cabbage | 11.0 | 38.8 | Potatoes | 5.4 | 19.0 |
| Peppermint | 9.4 | 39.0 | Peppermint | 5.1 | 18.2 |
| Celery | 11.1 | 40.1 | Sugar Beets | 3.9 | 10.8 |
| Sugar Beets | 10.2 | 40.6 | Head Lettuce | 4.6 | 15.6 |
| Table Beets | 11.0 | 41.4 | Spinach | 4.2 | 13.7 |
| Potatoes | 10.9 | 42.4 | Onions | 4.2 | 15.5 |

1. Averages of 2 replications

Analysis of Variance

| Source | DF | 1947 Foliage SS | 1947 Foliage MS | 1947 Oil SS | 1947 Oil MS | 1948 Foliage SS | 1948 Foliage MS | 1948 Oil SS | 1948 Oil MS |
|---|---|---|---|---|---|---|---|---|---|
| Total | 15 | 23.5 | | 206 | | 11.7 | | 284 | |
| Crops | 7 | 8.7 | 1.2 | 127 | 18 | 2.1 | 0.3 | 112 | 16 |
| Replications | 1 | 9.6 | 9.6 | 14 | 14 | 6.1 | 6.1 | 82 | 82 |
| Error | 7 | 5.2 | 0.7 | 65 | 9 | 3.5 | 0.5 | 90 | 13 |

Table 37. Effect of Crop of Previous Year on the Physico-chemical Constants of Spearmint Oil Produced in 1947 on Muck Soil (pH 5.9) in Clinton County.[1]

| 1946 Crop | Specific Gravity | Optical Rotation | Refractive Index | % Carvone |
|---|---|---|---|---|
| Onions | .9295 | -56.4 | 1.4900 | 69.3 |
| Head Lettuce | .9290 | -57.2 | 1.4897 | 69.3 |
| Spinach and Cabbage | .9276 | -57.0 | 1.4896 | 68.7 |
| Peppermint | .9284 | -55.7 | 1.4892 | 68.2 |
| Celery | .9298 | -56.6 | 1.4896 | 69.2 |
| Sugar Beets | .9286 | -56.5 | 1.4896 | 69.4 |
| Table Beets | .9293 | -57.0 | 1.4898 | 69.6 |
| Potatoes | .9280 | -56.9 | 1.4894 | 68.8 |

1. Averages of 2 replications

Analysis of Variance

| Source | DF | Specific Gravity | | Optical Rotation | | Refractive Index | |
|---|---|---|---|---|---|---|---|
| | | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ | SS | MS | SS $\times 10^{-7}$ | MS $\times 10^{-7}$ |
| Total | 15 | 226 | | 9.4 | | 44 | |
| Crops | 7 | 81 | 12 | 3.3 | 0.5 | 8 | 1 |
| Replications | 1 | 98 | 98 | 4.2 | 4.2 | 14 | 14 |
| Error | 7 | 47 | 7 | 1.9 | 0.3 | 22 | 3 |

| Source | DF | Carvone | |
|---|---|---|---|
| | | SS | MS |
| Total | 15 | 9.4 | |
| Crops | 7 | 3.0 | 0.4 |
| Replications | 1 | 2.9 | 2.9 |
| Error | 7 | 3.5 | 0.5 |

Table 38. Effect of Crop of Previous Year on the Physico-chemical Constants of Spearmint Oil in 1948 on Muck Soil (pH 5.9) in Clinton County.[1]

| 1947 Crop | Specific Gravity | Optical Rotation | Refractive Index | % Carvone |
|---|---|---|---|---|
| Spearmint | .9266 | -58.0 | 1.4882 | 66.5 |
| Celery | .9262 | -58.0 | 1.4884 | 66.2 |
| Potatoes | .9245 | -58.8 | 1.4880 | 65.7 |
| Peppermint | .9259 | -58.4 | 1.4882 | 65.6 |
| Sugar Beets | .9244 | -58.4 | 1.4884 | 65.6 |
| Head Lettuce | .9254 | -58.8 | 1.4882 | 67.2 |
| Spinach | .9273 | -58.5 | 1.4884 | 68.0 |
| Onions | .9264 | -58.2 | 1.4886 | 66.9 |

1. Averages of 2 replications.

Analysis of Variance

| Source | DF | Spec.Grav. | | Op.Rot. | | Refractive Index | |
|---|---|---|---|---|---|---|---|
| | | SS $x10^{-6}$ | MS $x10^{-6}$ | SS | MS | SS $x10^{-7}$ | MS $x10^{-7}$ |
| Total | 15 | 51 | | 3.97 | | 30 | |
| Crops | 7 | 15 | 2 | 1.52 | 0.22 | 5 | 1 |
| Replications | 1 | 1 | 1 | 0.02 | 0.02 | 1 | 1 |
| Error | 7 | 35 | 5 | 2.43 | 0.35 | 24 | 3 |

| Source | Carvone SS | Carvone MS |
|---|---|---|
| Total | 36.13 | |
| Crops | 10.30 | 1.47 |
| Replications | 0.01 | 0.01 |
| Error | 25.82 | 3.69 |

## DISCUSSION

The peppermint, and possibly also the spearmint industry in Michigan and Indiana, is seriously threatened by the inroads of Verticillium wilt, a disease which remains in the soil for an undetermined number of years once the crop is infected. It is this situation that resulted in the establishment by the Beech-Nut Packing Company of the fellowship under which the study reported in the preceding pages was conducted. It is unfortunate that, with the exception of the results obtained from heavy fertilization, the results from the various soil treatments were largely negative. It is hoped that, from the observations made and largely reported herein, further studies may be inaugurated which will bring relief to the growers of mint whose fields are affected by Verticillium wilt.

Certain of the results obtained in this study deserve further discussion.

The decrease in root growth (Table 1) exhibited by the first crop of peppermint grown in the greenhouse with the heavy applications (16 tons per acre) of carbonates was not repeated with the second crop (Table 2). It is possible that this depression of the first crop was the result of the phosphate being rendered unavailable by the calcium and magnesium. Such a depression was not repeated with the second crop as refertilization supplied more phosphorus, all of which was not rendered unavailable.

From the time of harvest of the first crop to the harvest of the second crop, the soil pH of the individual pots remained approximately constant. Consequently, this depressed root growth of the first crop may be a result of the presence of an excess of calcium and magnesium which in turn rendered manganese or some other nutrient unavailable.

The depression of root growth with fertilizer applications exceeding 500 pounds per acre in greenhouse pots with the second peppermint crop (Table 21) may indicate this plant has comparatively low fertilizer requirements. This would be in accordance with statements made by Ellis (10, 11) and Powers and Jones (33) to the effect that response to increasing amounts of fertilizers decreases or disappears when 300 to 350 pounds per acre are applied in the field. On the other hand, this assumption would be at variance with the data of Table 26 where an average yield increase of over 25% of foliage and oil was obtained in the field with the addition of 2000 pounds per acre more fertilizer.

The early response of peppermint in the greenhouse to copper sulphate applications to the soil (Plates 2 and 3) and the increase in oil production in the field (Table 28) is in agreement with Bode (6) who regards copper as essential for high oil formation in the plant.

The increase in number and size of leaves on peppermint plants reported by Lutzenburger (26) with boron applications to organic soils was not observed.

The increase in yields of peppermint foliage and decrease in the oil yields with an increase of potash in relation to phosphate in the fertilizer (Table 15) is in complete agreement with both Harmer (17, 18) and Ellis (10, 11). Yields of spearmint oil follow a similar pattern, but foliage yields also decrease with the increase in the proportion of potash (Table 17).

In order to bring out more clearly certain physical relationships which are not evident in the individual sets of results a series of charts were prepared. Figure 1 shows the relationship of the weight of peppermint harvested and the number of pounds of oil produced in the field. Using 236 sets of measurements a correlation coefficient of 0.584 was obtained. The relatively wide scatter of points demonstrates that in 1947 and 1948 there was not a good relationship between the amount of foliage harvested and the amount of oil distilled from peppermint.

Figure 2 presents a similar relationship between the weight of spearmint harvested and the oil produced. A corelationship coefficient of 0.897 was obtained with 121 pairs of measurements. This is a considerably better relationship than with the peppermint. However if more measurements had been obtained with the spearmint such a correlation coefficient would be more significant.

FIGURE I RELATION OF YIELDS OF PEPPERMINT TO OIL CONTENT 1947-1948

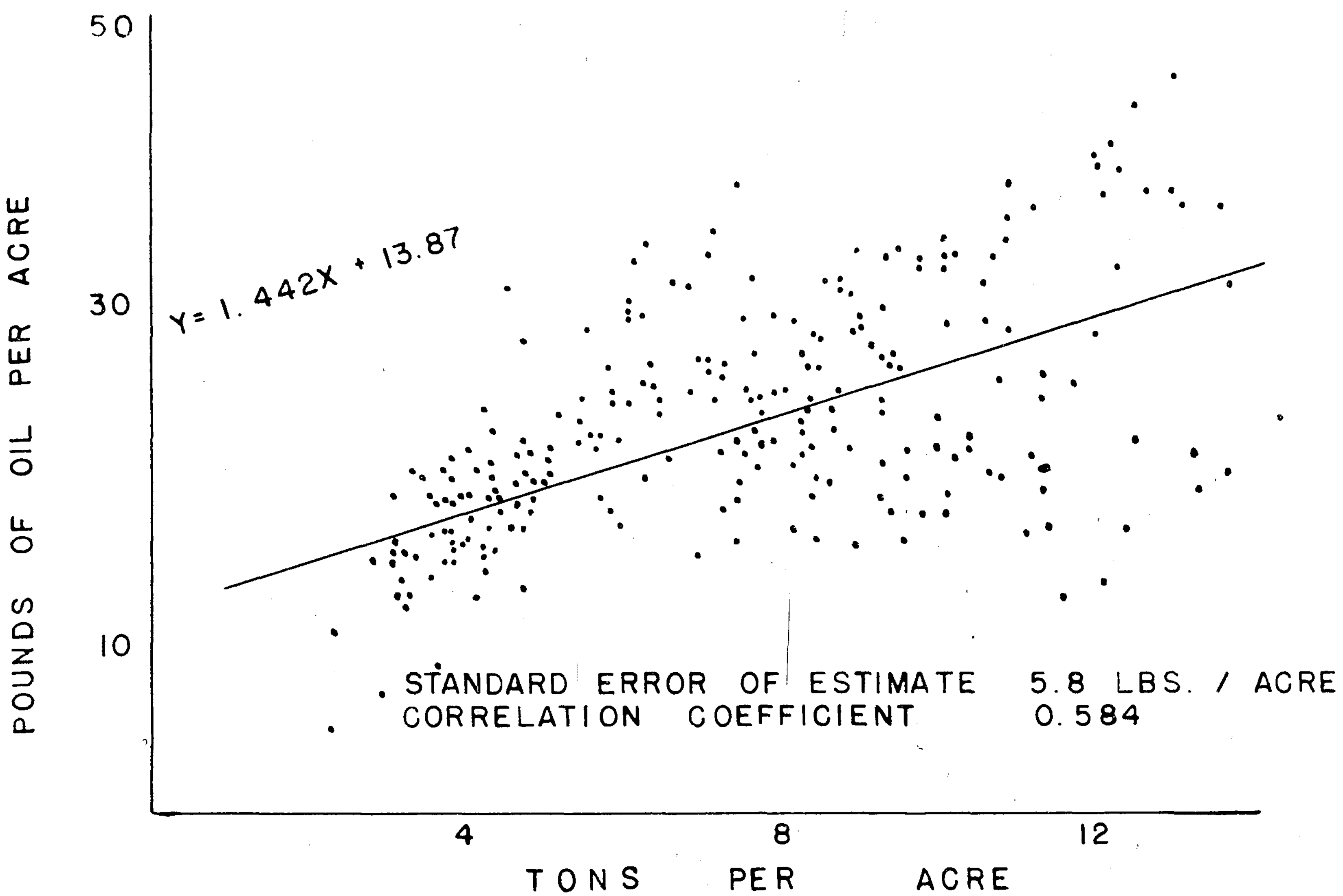
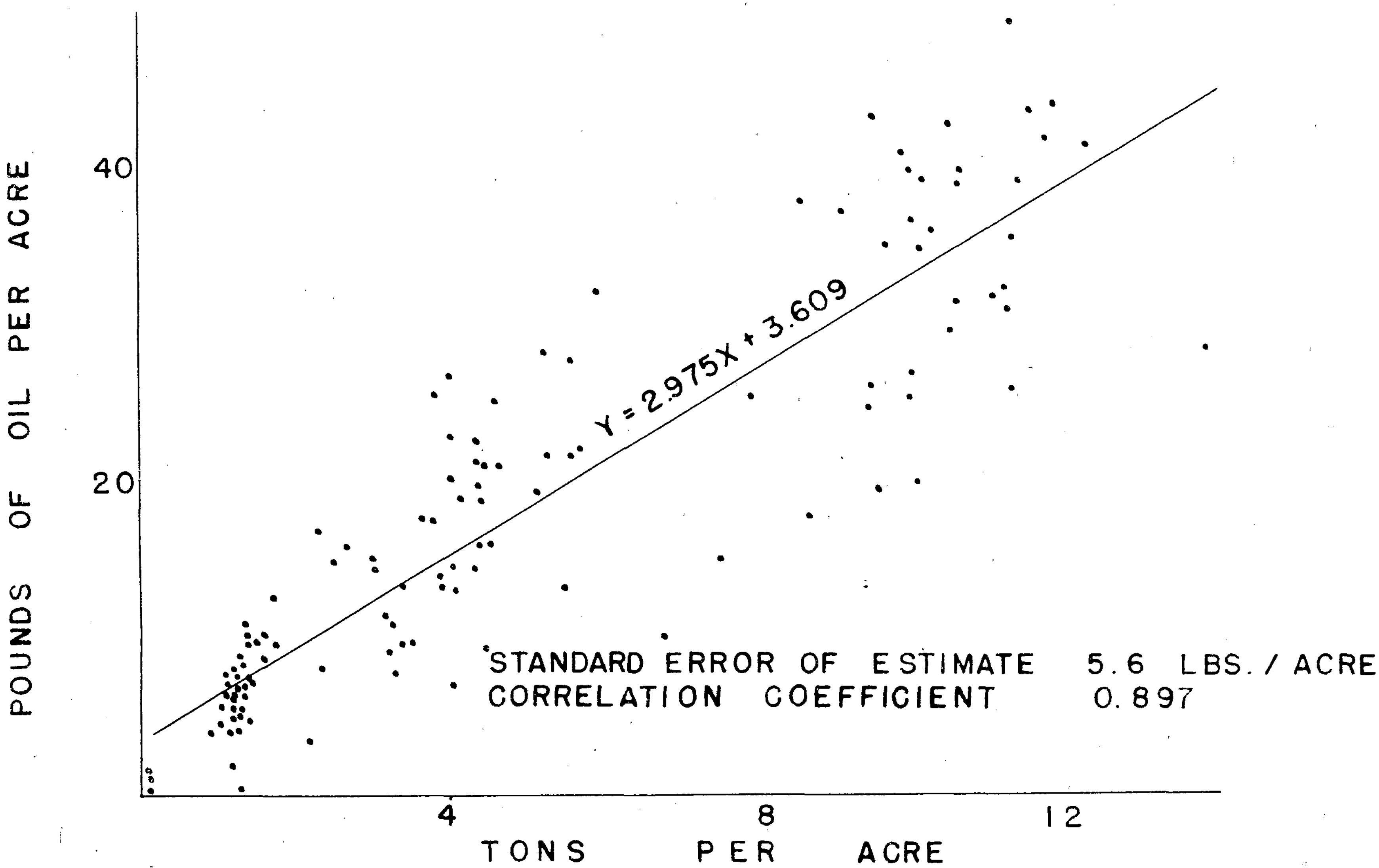


FIGURE 2 RELATION OF YIELDS OF SPEARMINT TO OIL CONTENT
1947 - 1948



Maku (27) reports that in preliminary experiments the addition of a minute quantity of radium to the soil in flower pots stimulated the growth of peppermint. The radioactive mineral (alphatron) applied to the soil in Lapeer County produced no such stimulation.

Studies regarding the effect of peppermint and spearmint on succeeding crops and the effect of other crops upon peppermint and spearmint have scarcely been started. The results presented here for 1947 and 1948 show evidence that a number of factors are involved and that peppermint and spearmint do not react in the same manner. Odland and Smith (29) postulate that some particular crop may produce a deleterious or beneficial effect upon a succeeding crop by producing, among other factors, changes in the soil microflora, or root excretions.

Only with the heavy application of fertilizer in Lapeer County was there any indication of differences in the physicochemical constants of peppermint oil as a result of soil treatments and this was not statistically significant. This large amount of fertilizer resulted in a depression of the percentage of esters and total menthol. This depression may readily be linked up with the increased growth and vigor of the peppermint which undoubtedly retarded its maturity. Such an assumption is in agreement with the statement of Ellis, Fawcett, Gaylord, and Baldinger (13) that the physicochemical constants of peppermint oil are not affected by fertilizer, except as fertilizer affects the maturity of the plants.

In 1947 and still more so in 1948, the specific optical rotation and the percentage of esters and total menthol increased while the percentage of menthone decreased throughout the distilling season, or with increased maturity of the plant. Table 39 illustrates this point. These data also show greater changes in these physicochemical constants in 1947 than in 1948. This is undoubtedly a result of the different seasons. 1947 was unusually wet and cool throughout the growing season while 1948 was unusually dry and warm throughout the growing season.

Table 39. Certain Physicochemical Constants of Oil Distilled at the Beginning and End of the Season in 1947 and 1948.

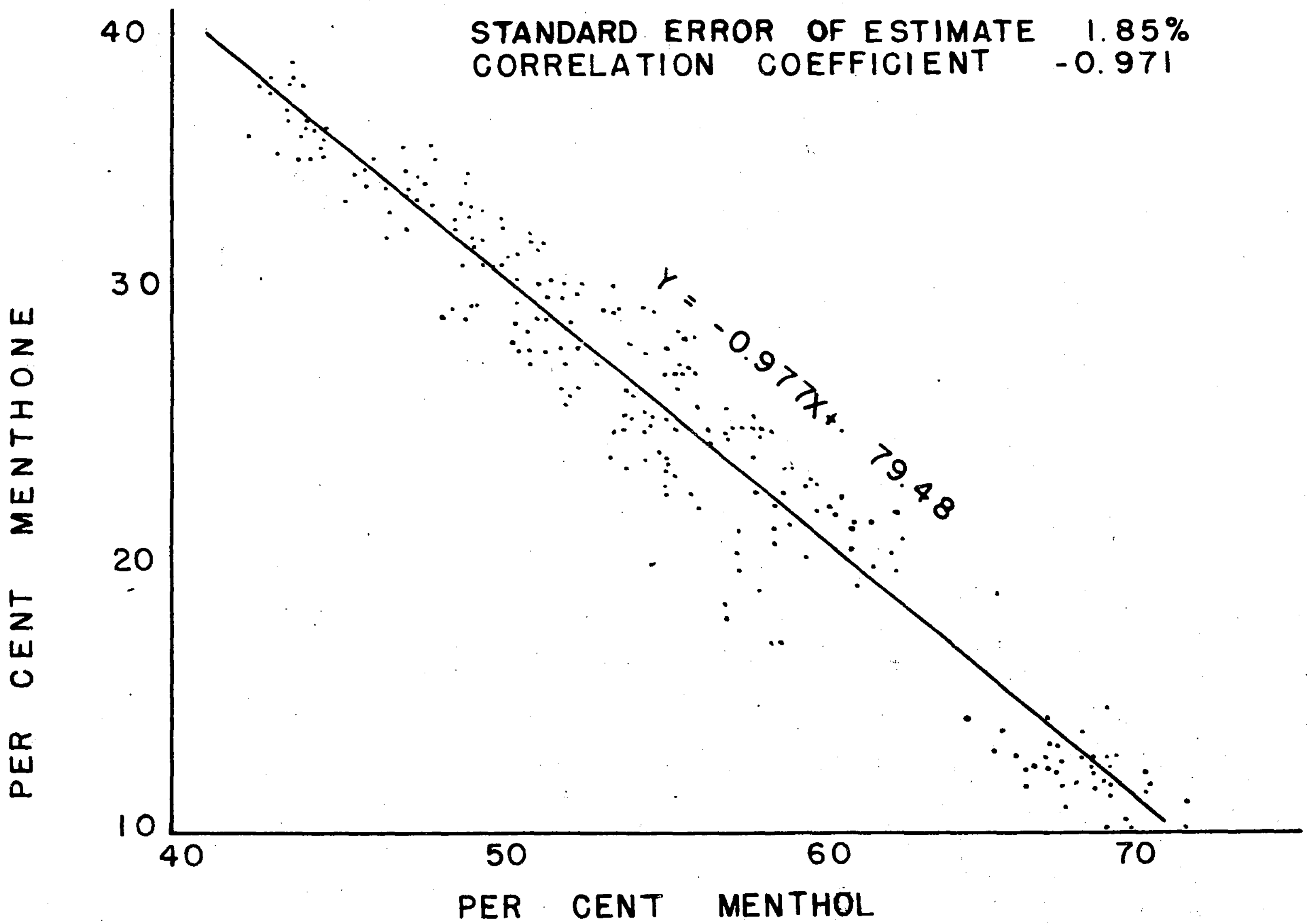
| Time of season | Specific Opt. Rotation | | % Esters | | % Menthol | | % Menthone | |
|---|---|---|---|---|---|---|---|---|
| | 1947 | 1948 | 1947 | 1948 | 1947 | 1948 | 1947 | 1948 |
| Beginning | -23.6 | -23.1 | 5.7 | 4.9 | 50.7 | 48.2 | 31.2 | 31.8 |
| End | -26.0 | -29.5 | 7.3 | 9.3 | 54.5 | 67.2 | 28.0 | 12.4 |

Guenther (16), Bullis, Price, and Kirk (7), Ellis (12), and Rabak (34) also report a rise in the percentage of esters and menthol as the season progresses. Ellis and Gaylord (14) have observed such an increase in the menthol content. Strazewicz (39), on the other hand, reports a decrease of esters in the oil with maturity, particularly with increased insolation and temperature. Chiris (8) also found an increase in the percentage of menthol with the age of the plants, but found the specific optical rotation value decreased. Bullis, Price and Kirk (7) discovered the specific optical rotation of the oil to be higher in the early and late season samples than in the midseason lots. Baldinger (3) and Rutovskii and Tavin (35) have noted that the menthol content of the plant increases during growth whereas the menthone content decreases. The relation between the percent of menthol and menthone is clearly demonstrated in the peppermint samples obtained in this study in 1947 and 1948 (Figure 3). Of 239 samples determined there is a correlation coefficient of -0.971 which is excellent.

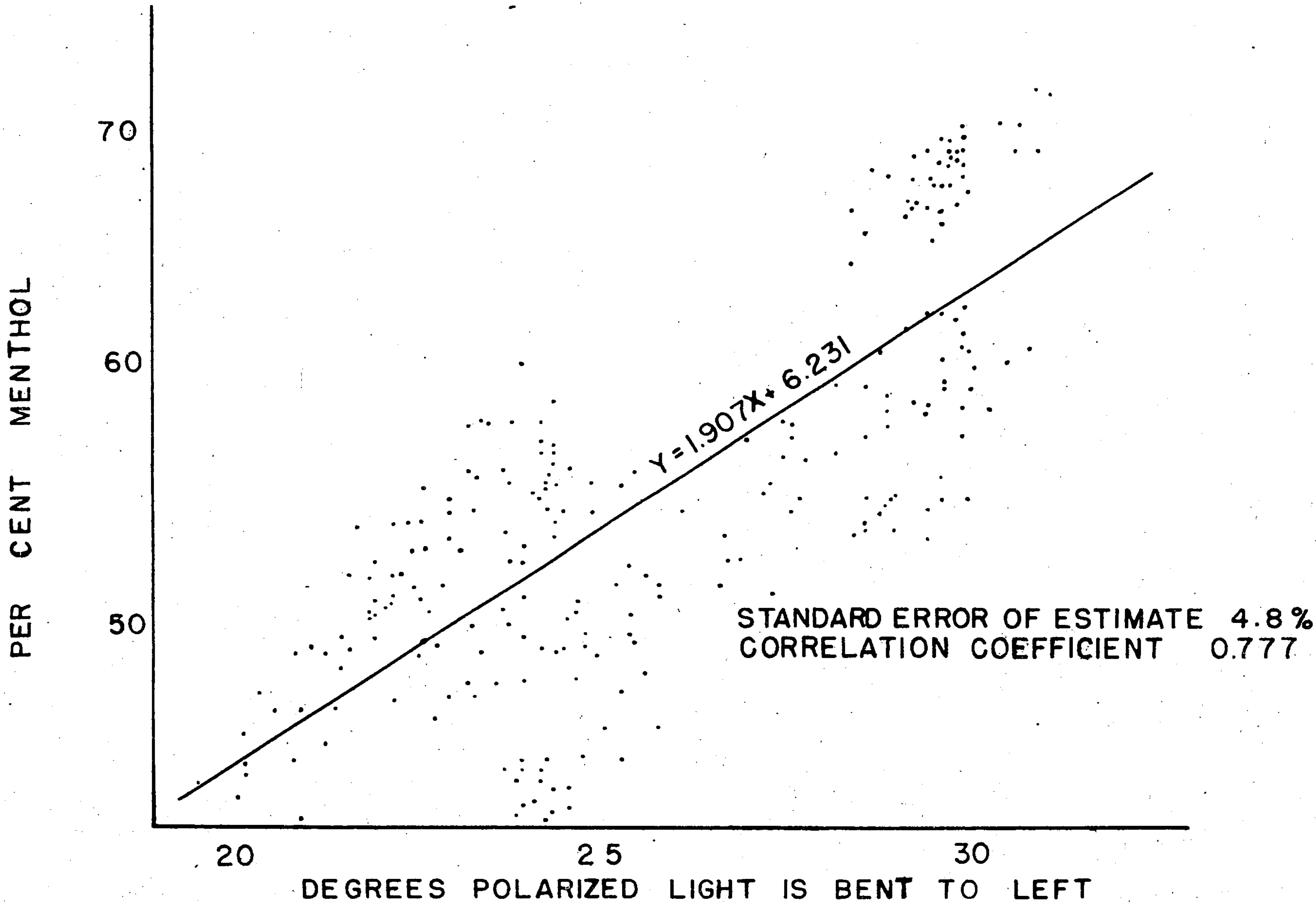
The increase of the percentage of menthol at the expense of the percent of menthone has led Gorden (15) and Wood and Osol (41) to the assumption that, under the influence of sunlight during plant growth up to the time of full bloom, menthol is slowly formed from menthone. Bacon, Jenison, and Kremers (2) suggest that menthol is synthesized from menthone which in turn is produced from pulegone.

Table 31 indicates that, in 1947, there was a decrease in specific gravity, specific optical rotation, refractive index, and percentage of esters and total menthol and an increase in the percentage of menthone three days after a very heavy rain. The rain was followed by an abundance of sunshine with a relatively high temperature. This indicates a

# FIGURE 3 RELATION OF MENTHONE AND MENTHOL PERCENTAGES IN PEPPERMINT OIL 1947-1948



PEPPERMINT OIL TO PER CENT MENTHOL IN THE OIL
1947 - 1948



decided change in the physicochemical constants which at first thought would tend to disprove the theory of the formation of menthol from menthone as the plant matures. However, these changes can be explained as follows. Previous to this rain the plants had ceased growing and producing oil. With a sudden abundance of moisture and favorable conditions, growth was rapidly resumed with the formation of more oil. This oil of recent formation would naturally have different physicochemical constants from that already present and its presence would then alter the proportion of the total constituents which in turn would alter the physical constants. This theory may be supported by the fact that the plots distilled after the rain had up to 10 pounds per acre more oil than those distilled prior to the rain.

The relation between the percentage of total menthol and the number of degrees polarized light is rotated to the left is presented in Figure 4. 239 pairs of measurements gave a correlation coefficient of 0.777 which shows a fair relationship.

Henderson (24) regards the amount of volatile oil in peppermint as an elusive factor which depends upon the climatic conditions at the moment the herb is cut. Peppermint oil is composed of a mixture of various organic compounds which are, of course, produced by photosynthetic activity. Thus with variations in environment, particularly sunlight, one would expect changes in the properties and percentages of these constituents. This factor, together with the fact that the oil content and composition vary with the maturity of the plant, also undoubtedly accounts for the conglomeration of results obtained throughout the mint producing sections of the world with various fertilizer treatments.

## SUMMARY

Peppermint was grown on muck soil in the greenhouse and peppermint and spearmint in field experimental plots to ascertain the effect of various soil treatments upon the growth, incidence of Verticillium wilt, oil production, and the physicochemcial constants of the oil.

This investigation has shown that:

1. In the case of peppermint grown in the greenhouse:

   a. The yield of the first crop of roots was depressed by heavy applications of calcium and of calcium and magnesium carbonates.

   b. Application of copper in the form of copper sulphate stimulated early plant growth, but had no effect upon yield of plant material or oil.

   c. Application of iodine in the form of potassium iodide had no effect upon yield of plant material or oil.

   d. Six different carriers of iodine produced no differences in the yield of plant material.

   e. Applications of boron, cobalt, and silicon were toxic only when the following forms and rates in pounds per acre were used: cobalt sulphate, 160; boric acid, 100; sodium metasilicate, 3200.

f. Applications of iodine, molybdenum, strontium, chromium, magnesium, and zinc were not toxic in the following forms and rates in pounds per acre: potassium iodide, 80; sodium molybdate, 48; strontium chloride, 1600; potassium dichromate, 320; magnesium sulphate, 8000; and zinc sulphate, 6400.

g. None of the minor elements used had any influence upon the incidence of Verticillium wilt symptoms.

2. In the case of peppermint in the field:

a. Yields of foliage tended to increase as the ratio of potash to phosphate in the fertilizer rose above a ratio of 1:1.

b. Oil yields tended to decrease as the ratio of potash to phosphate in the fertilizer rose above a ratio of 1:1.

c. Copper compounds added to acid soil which had been heavily limed tended to increase oil yields slightly.

d. Other minor elements used including zinc, iodine, chromium, silicon, bromine, fluorine, molybdenum, strontium, cobalt, manganese, and boron, did not influence yields of plants or oil.

e. Two thousand pounds per acre of 0-10-20 fertilizer produced markedly higher plant and oil yields.

f. No fertilizer or minor element treatment influenced the incidence of plants showing Verticillium wilt symptoms; however, well-fertilized plants produced larger yields of foliage and oil in spite of the prevalence of Verticillium wilt.

g. In 1947 yields of peppermint plants and oil on soil which had grown peppermint the previous year were depressed, but this was not true in 1948.

h. Alphatron, a radioactive material, when added to the soil had no effect on plant and oil yields or the incidence of Verticillium wilt.

i. The physicochemical constants were not affected by soil treatments.

3. With spearmint in the field that:

a. Plant and oil yields tended to decrease as the proportion of potash in the fertilizer was increased.

b. No minor element treatment influenced plant or oil yields.

c. Crops of the previous year had no effect on plant or oil yields.

d. The physicochemical constants were not affected by soil treatments.

4. The correlation coefficients between peppermint foliage and oil yields, spearmint foliage and oil yields, total menthol and menthone percentages, total menthol percentage and specific optical rotation were 0.584, 0.897, -0.971, and 0.777 respectively.

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