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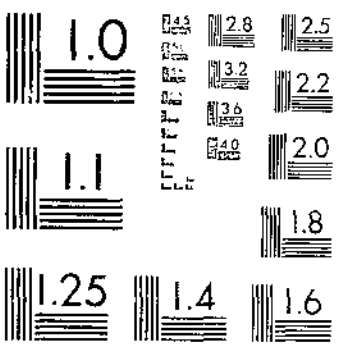

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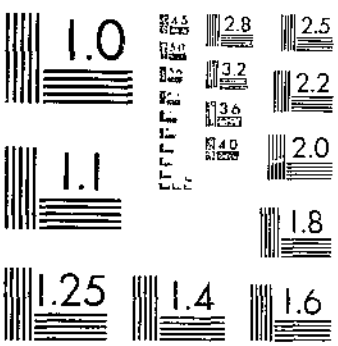

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COMMERCIAL POSSIBILITIES OF JAPANESE MINT IN THE UNITED STATES AS A SOURCE OF NATURAL MENTHOL

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INTRODUCTION

The United States imports annually from Japan large quantities of menthol, an important aromatic chemical used extensively in many medicinal, pharmaceutical, and other preparations. It is obtained in Japan from the volatile oil distilled from Japanese mint (*Mentha arvensis piperascens* Malinvaud), which is widely cultivated in that country where it is one of the important crops. A synthetic menthol is on the market, but the natural product is obtained almost entirely from this mint which is grown commercially almost exclusively in Japan. It follows, therefore, that domestic consuming industries are largely dependent on that country for their requirements of this important natural product.

The cultivation of peppermint and spearmint has long been a specialized industry in certain sections of the United States. The oils obtained from these mints occupy important positions among the volatile oils produced and consumed in this country, and their production has gradually increased as their uses in the manufacture of many products have been extended. The cultivation of these

[1] The writers wish to acknowledge the valuable cooperation of the following: The Vick Chemical Co., Greensboro, N.C., which assisted in defraying the expense of the field work for several years and contributed much of the data from the Southeastern States; Essential Products Co., of California; the Alabama Polytechnic Institute; the Virginia Polytechnic Institute; the schools of pharmacy of the State universities of Florida, North Carolina, and Oklahoma, and the many individuals who contributed samples of oil or data regarding such from various localities. Acknowledgment is also due O. M. Freeman, assistant botanist, Bureau of Plant Industry, who wrote the description of the plant.

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mints has been investigated by the United States Department of Agriculture and the results have been published,[2] but until recent years no serious attention had been given to the possibilities of growing Japanese mint in this country. When it is considered that the several species of mint under cultivation in the world do not differ greatly in their cultural requirements, the possibility of introducing Japanese mint into this country naturally suggests itself. It was with the purpose of thoroughly studying the requirements of this plant, its behavior under conditions prevailing in the mint-growing sections and elsewhere, and its general possibilities as a crop in the United States to furnish a domestic source of natural menthol, that this investigation was undertaken.

The two principal objectives of the investigations of Japanese mint were: (1) To study the general behavior of the plant under various conditions and in various localities to determine the possibilities of its successful culture from the agronomic standpoint; and (2) to collect and interpret data concerning the quality of the oil produced, with special reference to its menthol content, and to note the gradual effect of soil and climate, particularly whether a progressive decline in menthol content would result from continued cultivation of the plant in this country.

The experiments were begun in 1919 by G. A. Russell, who was in direct charge of the investigation up to the time of his resignation from the Department on December 31, 1924, and the data for that period are taken from his unpublished reports.

USES AND IMPORTANCE OF MENTHOL IN THE UNITED STATES

According to available records, it appears that menthol first came on the market for commercial purposes about 1875, and thereafter its uses were rapidly extended, although the consumption continued relatively small for many years. Its value for medicinal and pharmaceutical purposes was officially recognized in this country in 1894, when it was included in the seventh revision of the United States Pharmacopoeia. At the present time it is used extensively for internal and external medicine, and to a less extent in confectionery and perfumery. The increasing use of this product in the United States is indicated in table 1, which shows the quantities imported since 1908. The consumption seems to have become stabilized at around

TABLE 1.—*Quantity of menthol imported into the United States from 1908 to 1931* [1]

Year [2]	Quantity [3]	Year [2]	Quantity [3]	Year [2]	Quantity [3]	Year [2]	Quantity [3]
	Pounds		*Pounds*		*Pounds*		*Pounds*
1908	20,183	1914	127,924	1920	205,911	1926	458,600
1909	23,183	1915	111,020	1921	184,986	1927	359,000
1910	23,051	1916	145,203	1922	182,287	1928	254,000
1911	50,533	1917	172,767	1923	191,176	1929	296,000
1912	51,720	1918	172,460	1924	193,300	1930	308,000
1913	49,896	1919	296,179	1925	293,800	1931	326,100

[1] Figures are from Foreign Commerce and Navigation of the United States, issued by the United States Department of Commerce.

[2] Fiscal years up to and including 1918; thereafter calendar years. The imports for the 6-month period from July 1 to Dec. 31, 1918, are omitted.

[3] From 1908 to 1923, inclusive, the quantities given represent imports for consumption; from 1924 to 1931, general imports.

[2] SIEVERS, A. F., PEPPERMINT AND SPEARMINT AS FARM CROPS. U.S. Dept. Agr. Farmers' Bul. 1555, 28 p., illus. 1929.

300,000 pounds annually. Although the consumption, as indicated by the imports, shows a reasonably steady upward trend up to about 1926, the value of this commodity has fluctuated greatly, as is readily apparent from figure 1, in which the price quotations as given in trade journals are shown at 3-month intervals from 1913 to 1931.

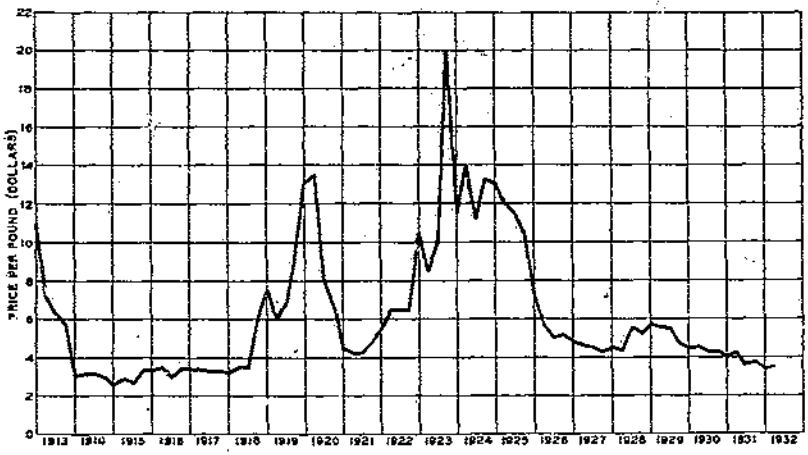

FIGURE 1.—Fluctuations in menthol-price quotations for the period 1913 to 1931.

It will be seen from the price curve (fig. 1) that there have been two periods during which the market value of menthol increased greatly. In the postwar period it reached $13 a pound, which was followed by a rapid decline to nearly the previous level. In 1923 occurred the earthquake in Japan which severely affected menthol prices immediately, forcing them up to as high as $20 a pound. The general effect of this disaster on the menthol market was felt during 1924 and 1925, during which period the price level held well above $10 a pound. The following year there began a gradual decline, and during the last 5 years the price level has been consistently low.

The fact that natural menthol is obtained so largely from Japan, and the severe effect on the market value of the commodity caused by any situation that interferes with either its production or its importation, emphasizes the extent to which the industries that require it are dependent on that country. In the future the extent to which synthetic menthol will replace the natural product, especially when the normal supply of the latter is inadequate, will be an important factor. It may well be assumed that the availability of the synthetic product for some purposes will have a steadying effect on the market and a tendency to cause the maintenance of a lower price level.

BOTANICAL DIFFERENCES BETWEEN THE JAPANESE MINT AND PEPPERMINT

The Japanese mint (*Mentha arvensis piperascens*), in its general behavior, its cultural requirements, its rootstock whereby it multiplies, and in other respects, bears much resemblance to peppermint (*M. piperita* L.). However, the two plants differ greatly in some

important features, as is shown in figures 2 and 3, and when seen side by side are easily distinguished from one another. In the following paragraph O. M. Freeman, assistant botanist, Bureau of

FIGURE 2.—Flowering top of Japanese mint (*Mentha arvensis piperascens*).

Plant Industry, has indicated the chief differences between the two plants:

Japanese mint (*Mentha arvensis piperascens*) is a perennial herb spreading by rootstocks which creep along the ground or just under the surface and root at the nodes. The erect stems of midsummer, 1 to 3 feet in height, are usually branched and bear flower clusters in the leaf axils. This differs from peppermint, *M. piperita*, which bears its flowers in more or less interrupted, terminal, usually leafless, spikelike panicles. The stems of Japanese mint are covered with

soft white hairs, as are the leaves and calyces. Peppermint is usually glabrous throughout, and if hairs are present they are sparse and are mostly near the nodes at the lower part of the stems. The leaves of Japanese mint are lanceolate and broad-lanceolate with triangular blunt teeth. The leaf is gradually acumi-

FIGURE 8.—Flowering top of peppermint (*Mentha piperita*).

nate at the base with a margin extending nearly to the base of the petiole. The leaf of peppermint is similar, but differs in having sharper acuminate teeth, and the base is acute or abruptly acuminate with the petiole scarcely margined. Peppermint rarely, if ever, produces seed in the United States while Japanese mint produces seed freely.

COMPARISON OF OILS FROM JAPANESE MINT AND PEPPERMINT

The oils distilled from the Japanese mint and peppermint differ in two important respects which determine their relative usefulness for certain purposes. (1) Japanese-mint oil contains, when produced under favorable conditions, from 75 to 85 percent of menthol, of which up to 90 percent is usually present as such, while the remainder occurs in combination as esters. Peppermint oil, on the other hand, contains approximately only 50 percent of menthol, this also being present largely as such. (2) Peppermint oil has the pleasant, aromatic flavor that has long been accepted by the consumer as the characteristic peppermint flavor, whereas Japanese-mint oil is described as harsh and lacking in the fine bouquet that distinguishes the other. This so-called bouquet is due to the combined effect of several other constituents present rather than to the menthol, although the latter is responsible for the peculiar "cooling" sensation associated with the peppermint flavor. These important differences in the character of the two oils determine the uses to which each has been put and have, under normal conditions, prevented the substitution of the one for the other.

Owing to its much higher content of menthol, the Japanese-mint oil is a much more valuable source of this product than peppermint oil. A large proportion of the menthol can be removed from it by refrigeration, and additional quantities can be subsequently removed by fractionation and other treatment. Peppermint oil can be utilized commercially as a source of menthol only when the latter is abnormally high in price and the oil is relatively cheap. Consequently, the world supply of natural menthol is derived entirely from Japanese-mint oil whenever such oil is available and normal trade relations are not interfered with.

For flavoring purposes peppermint oil, for the reason stated, is much superior to Japanese-mint oil. In high-grade confections and other products in which the peppermint flavor predominates the latter cannot be used without unfavorably affecting such products. For cheaper goods, or in countries where the public is less discriminating than in the United States, Japanese-mint oil may at times be used, especially when it is available at a lower price. Dementholized Japanese-mint oil, that is, the oil from which some of the menthol has been removed, no doubt finds a market at times for such purposes. In the enforcement of the Federal Food and Drugs Act it has been assumed that the public, when buying products designated as mint flavored, expects that such products contain peppermint oil, and it has been ruled, therefore, that products in which Japanese-mint oil is used, whether natural or dementholized, must be labeled "flavored with corn mint" or "flavored with field mint."[3]

FIELD TESTS AND OBSERVATIONS

The earliest recorded attempt to cultivate Japanese mint in the United States appears to have been in 1885, when J. W. Colcord set out about 50 plants at Lynn, Mass.[4] Two crops were secured the following year, but there seems to be no record of the final outcome

[3] UNITED STATES DEPARTMENT OF AGRICULTURE. CORN-MINT OIL. U.S. Dept. Agr. Serv. and Regulat. Announc. Chem. 28: 35-36.

[4] ANONYMOUS. JAPANESE PEPPERMINT IN AMERICA. Chemist and Druggist 31: 73, 1887.

of the experiment. Other attempts may have been made from time to time without definite results, reports of which did not get into the literature.

SOURCES OF PLANTING STOCK

For a number of years prior to 1919 the Division of Drug and Related Plants, Bureau of Plant Industry, secured mint plants from Japan that were reported to be of the type grown commercially in that country for the production of menthol. These plants, however, were found undesirable because the oils obtained from them did not contain sufficient menthol. The first authentic material, consisting of roots, was received in December 1919, through Koji Abiko, agronomist, from the Hokkaido Agricultural Experiment Station, Japan. These roots were planted in quarantine, where they were kept throughout the following year. By the spring of 1921, 14 plants obtained from these roots were finally made available to the Division of Drug and Related Plants, but only 1 of these survived. From this 1 plant, cuttings were made during the winter of 1921–22.

The rooted cuttings were planted in clay-loam soil at the Arlington Experiment Farm of the United States Department of Agriculture, Rosslyn, Va., in May 1922. They made a fair growth, started to bloom early in July, and were harvested in October, much later than desirable. Fresh herb at the rate of 6,000 pounds per acre was obtained. This was distilled, but, due to faulty equipment, some of the oil was lost, and therefore accurate data on the yield were not obtained. The oil was examined with the following results: Specific gravity at 25° C., 0.9010; acid value, 0; menthol as esters, 18 percent; free menthol, 70.69 percent; total menthol, 88.69 percent. The relatively large proportion of menthol in combination as esters was no doubt due to the fact that the oil was not distilled until long after the full-blooming period. The high total menthol content, however, was sufficient evidence that the original planting stock was of a desirable type. Subsequently, these plants, designated as M-2, furnished most of the planting stock for experiments, at the Arlington Experiment Farm and elsewhere.

Plants also were received from other sources. In 1922 a small bed, designated as exhibition bed no. 33, was set out with plants propagated from a single plant with a strong menthol odor, selected from a small planting of doubtful origin that had been maintained for a number of years. No propagating stock was at any time taken from this bed, but it was kept undisturbed for 7 years, and the character of the oil obtained from it was observed throughout that period. Thus it was possible to note the effect on the menthol content of prolonged culture of the plant in the same locality, and on the same plot of ground without replanting and with practically no working of the soil, with the exception of light surface tillage in the spring and some hand weeding. This planting was designated M–1. The condition of the plants in this bed in the fourth year is shown in figure 4.

In January 1922, a mint grower in Colon, Mich., obtained some plants from Japan labeled "Bingo Bitchu," reported to be a high menthol-yielding strain. After a period in quarantine, six of these plants were retained in the Department and propagated in the greenhouse until the spring of 1923 when a 100-foot row was set out on clay-loam soil in section E and designated M-3.

The Division of Foreign Plant Introduction, Bureau of Plant Industry, received a supply of mint plants in December 1923, from the Kitami branch of the Hokkaido Experiment Station, Nokken-shimachi, Kitami, Japan. They were in such poor condition that only nine were obtained from quarantine for propagating. They were set in a bed under the slat shade at the Arlington farm, and in 1925 a row in section E was planted with runners obtained from this bed. These plants were labeled M-6.

A consignment of plants was received in 1923 from Greensboro, N.C., where they were propagated in the greenhouse from stock obtained from Japan. These were also set out in a 100-foot row in section E and labeled M-5.

All of the foregoing plantings were maintained where originally planted. As stated, M-1 in exhibition bed no. 33 could not be given

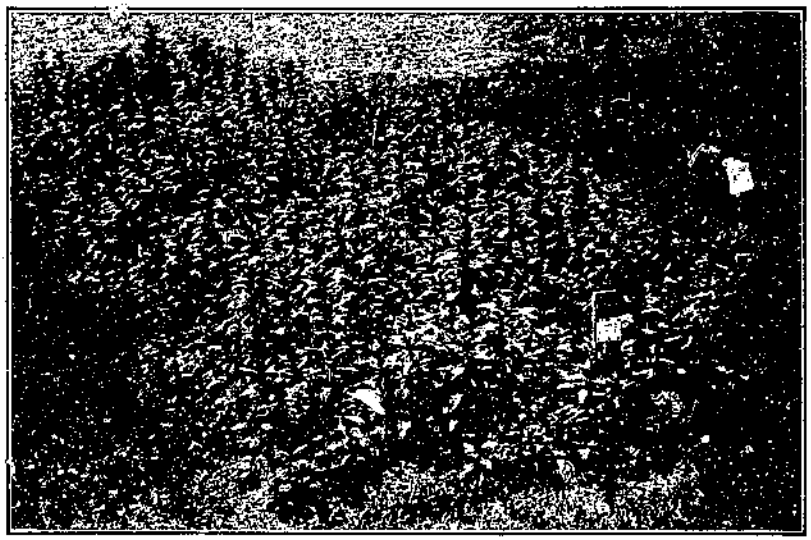

FIGURE 4.--Condition of plants in exhibition bed no. 33 after 4 years with only light surface tillage in the spring and some hand weeding.

any cultural treatment, but those planted in rows were cultivated, hoed, weeded, and in some cases new rows were set out from the old after the plants had spread enough to prevent further working of the soil. All were fertilized occasionally with manure to maintain reasonable soil fertility and to improve the physical condition of the heavy clay loam. Only the M-2 stock was used for trials elsewhere, both on the silt-loam soil of the farm flats and in various sections of the country where cooperators desired to experiment with this mint.

PROPAGATION AND CULTURE

Mint plants grow and spread through numerous underground runners, hence they require, for normal development, a deep soil, rich in humus and retentive of moisture, but well drained. Light loose soils that dry out quickly and heavy clay soils are equally unsuitable for mint culture. Favorable types are muck land, sandy loam river-bottom land, and well-cultivated loamy upland. Peppermint and

spearmint have been satisfactorily cultivated on such soils, and there is ample evidence that these should also be selected for Japanese mint.

Propagation is usually by means of runners in the same way as peppermint is propagated. If possible, ground that has been deeply cultivated and kept free from weeds the previous season should be selected, in order to assure rapid root growth and a minimum growth of weeds. It is well prepared, and furrows about 3 feet apart are opened to a depth of 4 inches. The roots are placed end to end in these furrows and then covered with soil which is lightly packed down. When the young plants, developing from the roots, appear above the ground the field is harrowed with a light spike-toothed harrow to keep the ground mellow and to destroy weeds. Later, a corn cultivator may be used between the rows until the runners begin to grow into this space, when cultivation must be discontinued. Hand weeding must then be resorted to if conditions require it. As this is expensive, it is undesirable to select ground that is especially weedy. Weeds are usually a more serious problem on muck soils than on other types of ground. If conditions favor a rapid growth of the mint the weeds are in part controlled by being deprived of proper sunlight, particularly within the rows.

Japanese mint does not develop such an abundance of runners as does peppermint, and, therefore, produces less propagating material than the latter, but the runners are not the only means of enlarging a planting. When the young plants that come up from the root system in large numbers are about 4 or 5 inches high they can be pulled out of the ground readily with a small piece of rootstock attached and transplanted with small loss. They are usually set about 15 inches apart in the row. These young plants wilt easily, and care must be taken to prevent this as much as possible, because wilted plants do not become established easily, and considerable loss will result. A good plan is to place the plants in a bucket containing enough water to cover the roots and transfer them as promptly as possible directly from the bucket to the soil. As the setting of plants by hand is a slow operation, it is recommended that plant-setting machines, such as are used for setting tobacco and tomato plants, be used when large areas are to be planted. In figure 5 a transplanter is shown planting Japanese mint in California.

Another method of propagating is by vegetative cuttings. These are made from the herbaceous portion of the plant in much the same way as other vegetative cuttings. They are rooted in sand and are then transferred to pots or set directly in the field. In one case the rooted cuttings were taken from the sand bed and set in the field with only 5 percent loss. This method is doubtless more expensive than those previously described, but it is very practicable for experimental work where it is desired to enlarge the planting without digging up the runners.

Under certain conditions, when planting stock is scarce and costs are of secondary importance, a small quantity of runners can be made to produce many plants by cutting them into small pieces and planting them in 2-inch or 3-inch pots in the greenhouse. This method is very satisfactory for experimental purposes but is too expensive when providing stock for large areas.

Japanese mint produces seed rather freely and the plant may be propagated by this means, but the method is unsatisfactory and does

not produce plants uniformly true to type. In 1923 the plants growing in section E on the Arlington farm and designated M-3 were allowed to mature and produce seed. This was collected late in the fall and sown in the greenhouse the following March. It germinated quickly and uniformly and in 3 weeks produced a fine stand of seedlings, some of which were planted in pots. Early in June these were set in the field without loss. Other seedlings were planted directly to the field on the same day without having been previously transplanted to pots. The loss in this case approximated 50 percent. By the middle of August the plants presented a variegated appearance. The leaves ranged in type from small crinkly ones to unusually

FIGURE 5.—Transplanter being used in setting Japanese mint plants in California.

large ones. The plants were from 8 to 12 inches high, and some were well branched while others were but sparsely branched. The flowering was very irregular. The dry herb yielded on distillation 1.58 percent of oil, with the following physical constants at 25° C.: Specific gravity, 0.8987; index of refraction, 1.4555; angle of rotation, −35.99°. These constants are within the range of those of a normal oil, but the menthol content was much too low. The oil contained 52.41 percent free menthol and 7.8 percent of menthol as esters, or 60.21 percent total menthol. The experiment demonstrates that propagation from seed would be entirely unsatisfactory even if it were not more expensive and did not involve more labor than the recommended methods.

The cultural conditions that affect the cultivation of Japanese mint most unfavorably are soil acidity, spring frosts, and drought. In extensive field tests in several localities in North Carolina[5] it was proved conclusively that in acid soils the plant will make a very poor growth. This is plainly indicated in figure 6, which shows the poor condition of the plants in sections of the field where the soil was very acid, as compared with the condition of plants in sections in which the soil was neutral or only slightly acid. A field where the soil is known or suspected to be acid should, therefore, not be selected for this crop unless the condition can first be corrected by an application of lime.

[5] Conducted by Vick Chemical Co.

Japanese mint is somewhat more unfavorably affected by cold than is peppermint. If a late spring frost kills the young plants that have appeared above the ground, new growth is slow in developing, and if the damage comes when the plants are 3 or 4 inches high the root system does not appear to be capable of producing new growth in sufficient quantity to make a normal stand. Not only is the crop yield thus directly reduced, but the thinner stand results in a heavier weed growth and less conservation of soil moisture, and these factors further contribute to an unsatisfactory yield.

The development of creeping rootstocks, which is characteristic of Japanese and other mints, requires considerable rainfall well distributed throughout the growing season. Periods of drought greatly retard the growth of the plants, and the consequent reduction in herb development lowers the yield of oil obtainable. It also causes the

FIGURE 6.—A field of Japanese mint at Sands, N.C., showing on the left the serious effect of soil acidity on this plant.

leaves to fall, especially those on the lower parts of the plant, which further reduces the oil yield.

Some experiments on the effects of fertilizers on the growth of the crop and on the yield and quality of the oil were undertaken in 1923 on the Arlington farm flats. The fertilizer plots were not continued in subsequent years because the roots were needed as planting stock elsewhere, therefore, the results were inconclusive. Some beneficial effect of potash on herb yield and on the menthol content of the oil was indicated, but definite conclusions from such a limited test are entirely unwarranted. Mention is made of this single experiment because the results point to the importance of a thorough study of this subject. In 1928 and 1929 well-planned fertilizer tests on a considerable scale were made in a number of localities in North Carolina.[6] The complete data obtained in these tests have not been published, but it is reported that whereas the first year's results gave very definite indications of important effects of certain fertilizer elements, some contrary indications were obtained the following year. It is obvious that information concerning the effects of fertilizers on

[6] Conducted by Vick Chemical Co.

Japanese mint and their bearing on the economic aspects of this crop is not yet available and that an elaborate series of carefully controlled experiments over a period of years will be necessary.

HARVESTING

The harvesting of Japanese mint should take place when the plants are as nearly as possible in what is usually referred to as the full-blooming stage. The flowers of the mints develop progressively, that is, there is no time when all the flowers on a plant are at the same stage. There is a time, however, when the field, as a whole, shows a maximum amount of bloom, and that is the proper time to harvest the crop. This may be accomplished either with grass scythes or with a mowing machine, depending on the area under cultivation, the cost of hand labor, and other factors (fig. 7). The cut herb may be distilled immediately or allowed to wilt for some time in the field, according to the practice followed with peppermint and spearmint

FIGURE 7.—Harvesting Japanese mint with scythes at South Bend, Ind.

herb.[7] It may be left in the swath until ready to be distilled, or raked into windrows after a period of wilting and then placed in cocks like hay for further curing (fig. 8). It should not be allowed to dry enough to become brittle, because when handled in that condition many of the leaves will be lost, thus reducing the oil yield. The importance of avoiding the loss of leaves is readily ascertained by distilling the leaves and stems separately. One such test gave the following results: Weight of whole herb thoroughly air dried, 3,008 grams; weight of leaves, 1,812 grams; weight of stems, 1,196 grams; percentage of leaves, 60.23; percentage of stems, 39.77; yield of oil from leaves, 2.2 percent; yield of oil from stems, 0.083 percent; yield of oil from whole herb (calculated), 1.36 percent.

The influence of the time of harvest with respect to the maturity of the plant on the yield and quality of the oil has been observed. In the case of Japanese mint the effect on the menthol content is the important factor rather than the effect on the physical constants and

[7] Commercial practices followed by growers of these mints are described and illustrated in the following publication: SIEVERS, ARTHUR F., PEPPERMINT AND SPEARMINT AS FARM CROPS. U.S. Dept. Agr. Farmers' Bulletin 1555, 26 p., illus. 1929.

other characteristics of the oil. It has been concluded from numerous observations that early harvesting results in an oil deficient in menthol. If harvesting is delayed considerably the oil obtained contains a normal percentage of total menthol, but the latter is present to a larger extent in combination as esters. The yield of oil is likely to be less if the plants are too immature when cut; and if harvesting is delayed too long there is generally a loss of the lower leaves, which also results in a reduced oil yield.

The probable effect of drying the herb on the yield and menthol content of the oil is also of importance. On account of the volatile nature of essential oils it is frequently assumed that drying of the herb will result in a gradual volatilization of some constituents. This, however, is not generally true, although some changes in physical constants may occur, and the relative proportion in which certain

FIGURE 8.—Japanese mint curing in cocks in California.

constituents exist in a free and in a combined state may be affected. In table 2 are summarized the characteristics of the oils obtained from fresh and dried herb in four experiments with M-2 stock.

TABLE 2.—*Yield and characteristics of oils obtained from fresh and dried herb in four experiments with M-2 mint*

Experiment	Yield and characteristics						
	Yield of oil	Specific gravity at 25° C.	Index of refraction at 25° C.	Angle of rotation at 25° C.	Combined menthol	Free menthol	Total menthol
No. 1:	*Percent*			*Degrees*	*Percent*	*Percent*	*Percent*
Fresh	0.23	0.8953	1.4550	−40.9	7.46	69.87	77.33
Dry	1.29	.8959	1.4569	−41.1	8.99	69.86	78.85
No. 2:							
Fresh	.324	.8957	1.4555	−40.91	5.66	71.92	77.58
Dry	1.14	.8974	1.4556	−41.39	7.24	71.36	78.60
No. 3:							
Fresh	.326	.8956	1.4550	−41.15	5.08	72.10	77.18
Dry	1.44	.8968	1.4555	−41.78	7.04	73.87	80.91
No. 4:							
Fresh	.357	.8957	1.4560	−41.46	5.85	71.91	77.76
Dry	1.656	.8976	1.4569	−41.61	7.04	72.16	79.20

It will be observed that in all cases the drying of the herb had the effect of increasing the percentage of menthol present as esters. The total menthol content appears also to be slightly greater in the oils distilled from the dried herb, although the difference is hardly sufficient to indicate any definite trend. Slight increases also are noted in the specific gravity, index of refraction, and angle of rotation of those oils. On the whole, the results indicate that drying of the herb does not have any important influence on the character of the oil. This fact makes it possible for a large grower to handle his crop at a somewhat lower cost. The capacity of his distilling equipment need not be so large; the weight of the material hauled is considerably less, and economies in distillation are possible through lower fuel consumption. Small growers without distilling equipment can stack or bale their crops and later haul them to a distilling plant in the neighborhood. Whatever procedure is adopted it is necessary at all times to avoid excessive loss of leaves through shattering, for reasons already stated.

Except in regions where long growing seasons prevail, only one crop can be cut in a season. In the South and in the Pacific Northwest it appears that under some conditions two cuttings may be possible, while in central California two cuttings are entirely practicable, and the feasibility of cutting the crop three times has been demonstrated by actual practice. This is discussed more fully on page 33. There are several results that may arise from cutting the crop more than once a season, which should determine to what extent the practice may be followed to advantage. The quality of the oil from second and third cuttings may be unfavorably affected, particularly the menthol content, and the development of two or more full crops in a single season may weaken the plants so that the life of an established field is shortened or the yield and quality of the oil in subsequent seasons is lowered. If such unfavorable effects do not result from it, the practice is obviously advantageous because larger returns are obtained. However, very early and very late cuttings generally yield less herb than those of midsummer, and, consequently, less oil, unless there is a compensating greater percentage of oil present. Some observations with regard to the quality of the oil from first and second cuttings obtained at Greensboro, N.C. are recorded in table 3.

TABLE 3.—*Yield and characteristics of oils distilled from first and second cuttings of M-2 and M-5 mint at Greensboro, N.C., 1923*

Stock	Yield and characteristics							
	Yield from fresh herb	Yield from dry herb [1]	Specific gravity at 25° C.	Index of refraction at 25° C.	Angle of rotation at 25° C.	Combined menthol	Free menthol	Total menthol
M-2:	*Percent*	*Percent*			*Degrees*	*Percent*	*Percent*	*Percent*
First cutting	0.35	1.70	0.8963	1.4570	−41.6	6.22	75.73	81.95
Second cutting	.516	2.07	.8961	1.4572	−41.4	4.33	73.30	77.63
M-5:								
First cutting	.382	1.91	.8963	1.4569	−42.0	8.65	65.51	74.16
Second cutting	.507	2.27	.8962	1.4565	−41.4	5.71	63.65	69.36

[1] Calculated.

An inspection of the data in table 3 reveals several points of interest. The oil from the second cutting in both cases contained a lower percentage of combined, free, and total menthol than the oils from the first cuttings, and the second cuttings yielded a much higher percentage of oil. The latter is probably due to the fact that a second growth of herb usually contains fewer heavy stems and relatively more leaf material. The weight of herb cut from a unit area was not recorded in this experiment, but the amount obtained from the second cuttings was doubtless considerably less than that from the first, therefore, the actual relative yield of oil obtained is not indicated. Samples of oils from the first and second cuttings obtained in California showed no corresponding difference in menthol content, and, according to reports, second cuttings in Japan do not yield oils of inferior quality. Unfavorable conditions late in the summer or failure of the herb to reach the proper stage before it was cut may account for the decline in menthol content indicated in this experiment.

DISTILLING

The removal of the oil from Japanese mint is accomplished by distillation with steam. The equipment required for this process is comparatively simple and consists of a metal or wooden retort or vat, a condenser, and a receiver. The herb is firmly packed into the retort, into the bottom of which steam is admitted. As the steam passes upward through the herb it volatilizes the oil which is carried with it through an outlet at the top of the retort into the condenser, where the combined water and oil vapors are condensed. The mixture of water and oil then flows into a small receiving vessel filled with water. The oil separates and collects in a layer on top of the water, while the latter flows out of the vessel from an opening at the bottom through a bent tube, or gooseneck, the outlet of which is on a level with the top of the oil layer. By this arrangement the distillate water flows from the receiving vessel as fast as it enters from the condenser, thus permitting the upper oil level to remain at the same point.

The details of construction of distilling equipment are described and illustrated in a publication[8] on peppermint and spearmint and, therefore, need not be included here. The general arrangement and set-up of such equipment is shown in figures 9 and 10, which show four sets of retorts, condensers, and receivers used for distilling Japanese mint and peppermint in California. Figure 11 shows a somewhat different arrangement at Shafter, Calif. The various parts of the equipment can be built according to simple specifications or can be obtained from firms that specialize in the manufacture of such equipment.[9]

The time required to exhaust the oil from a charge of herb depends on several factors. If ample steam is supplied to the retort as fast as it can be condensed in the condenser, the herb can be completely exhausted in three quarters of an hour to 1 hour if it has been thoroughly wilted and partly dried, as is usually done in commercial practice. If the green herb is transferred to the retort directly after cutting, considerably more time is required to remove the oil completely, because much of the steam is condensed by the herb itself.

[8] See footnote 7.

[9] Distilling equipment must be properly registered to comply with the law. Registration forms may be obtained on application from the supervisor of permits in the district in which the equipment is to be located or from the Bureau of Industrial Alcohol, Treasury Department, Washington, D.C.

Small quantities of the oil dissolve in the condensed water; rapid distillation insures a minimum loss of oil from this cause.

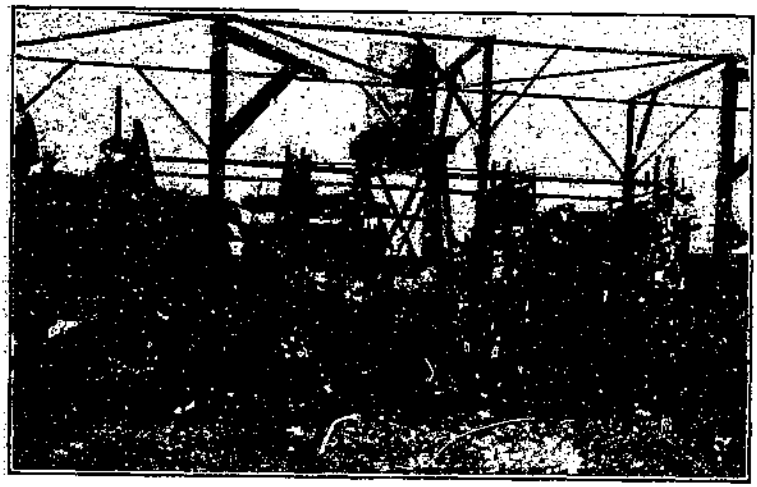

FIGURE 9.—Front view of a 4-unit mint still used for distilling Japanese mint at Porterville, Calif.

An examination of the distillate water obtained from four distillations indicated that from 1.15 to 4.74 percent of the total oil removed from the herb went into the distillate. In terms of pounds of oil

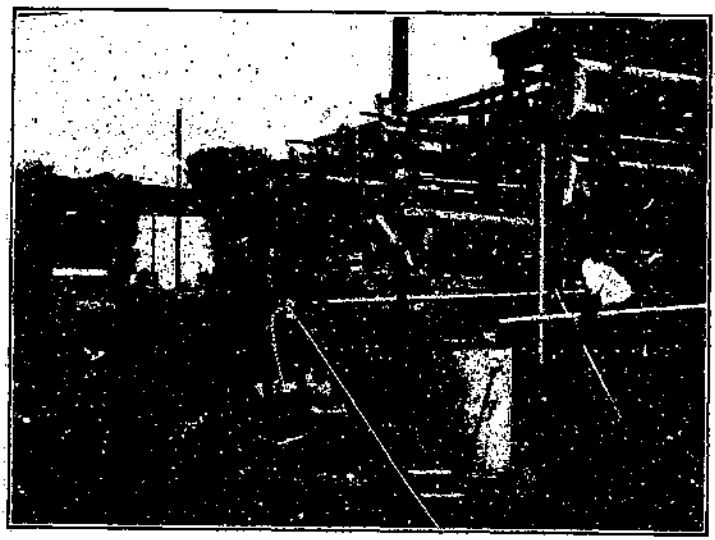

FIGURE 10.—Rear view of the still shown in figure 9.

lost for 2,000 pounds of herb distilled, which is about the quantity usually packed into a retort of commercial size, this loss is equivalent to from 0.4 to 1.32 pounds. In another experiment, 445 pounds of distillate water obtained from about a ton of herb yielded 1.8 ounces of oil. This oil had the following characteristics: Specific gravity at

25° C., 0.9002; index of refraction at 25° C., 1.4556; angle of rotation at 25° C., −30.72°; menthol as esters, 1.6 percent; free menthol, 75.42 percent; total menthol, 77.02 percent. Compared with normal oil, the oil dissolved in the water had a slightly higher gravity, a considerably lower angle of rotation, a smaller percentage of menthol esters, but a normal total menthol content. Although the percentage of oil recovered was small, it would perhaps be feasible in view of its

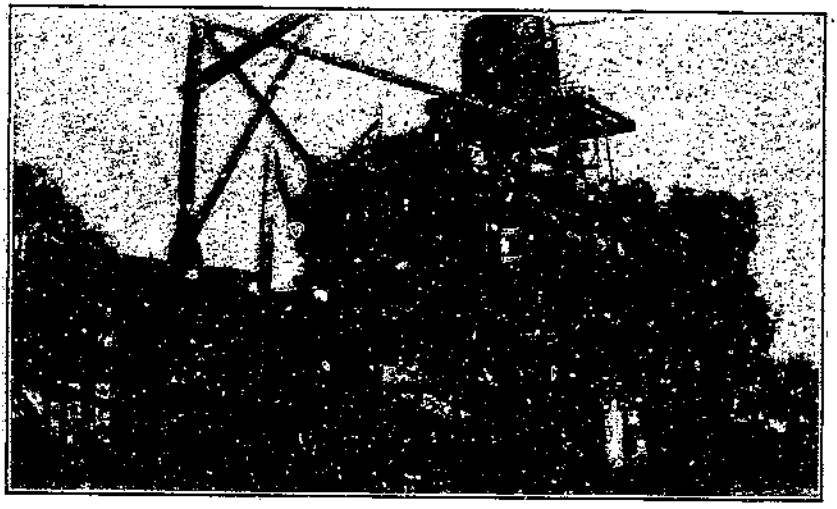

FIGURE 11.—A commercial Japanese-mint still at Shafter, Calif.

menthol content to attempt its systematic recovery in large-scale operations.

ACREAGE YIELDS OF OIL

The available data on acreage yield of oil in the numerous localities in which Japanese mint has been grown are inconclusive. Most of the experimental plots were too small and were not continued over a sufficient number of years to permit conclusions to be drawn from the data obtained. On the whole, however, the scattered reports from eastern and central localities justify the statement that the yield of oil from an acre of this mint in good condition will average 30 pounds, which is about the same as the yield obtained from peppermint. Naturally, the yields reported from individual small acreages and those calculated from small plots at the Arlington Experiment Farm have shown a wide range. On favorable soil with good cultural practices 50 or 60 pounds of oil may be obtained, while on the poorer upland soils yields below the average must be expected. In those regions where climatological conditions make more than one cutting possible, relatively larger yields should be obtained.

DISEASES AND PESTS

In the course of the numerous trial plantings that were made in various localities it has been observed that Japanese mint is subject to two diseases that will under certain conditions cause serious losses. The frequency of their occurrence and the degree of their severity is

determined largely by climatic conditions. On the Pacific coast, especially in California, a form of mildew attacks the plant at times and causes a severe loss of leaves. It has been associated with the prevalence of fogs, but this connection has not been positively established. The other important disease of this mint, which also causes losses on peppermint and spearmint, is a rust fungus. This likewise attacks the leaves and causes them to drop, thus greatly reducing the yield of oil. This disease is present throughout the commercial mint-growing districts in the United States, but it is only under weather conditions that generally favor the development of such organisms that it becomes an important problem.

There are apparently no practical means of controlling either the mildew or the rust. Regions in which these are severe year after year are not adapted to the growing of Japanese mint. When they occur occasionally the best procedure is to cut the crop before the damage becomes excessive. Even so, some loss will result if the crop has to be distilled before it attains the proper stage of maturity. The menthol content of the oil is also likely to be below normal.

In some of the early experiments at Greensboro, N.C., a form of root rot was found in some of the plots which caused the plants to wilt. It also appeared in the bed of M–1 mint at the Arlington farm in the summer of 1924, but disappeared after abundant rains. It is supposed to be favored by lack of cultivation. This theory, however, is scarcely supported by the fact that the rot did not reappear in the bed although no systematic cultivation of the ground was possible. In the fall of the same year a more serious occurrence of what appeared to be the same disease was observed in the plantings at South Bend, Ind. In California, especially in the central part of the State, some trouble has been experienced at times with a decay of the roots when newly planted, entire fields having been lost on some occasions. It is not known whether this was caused by the same disease, and the exact nature of the trouble does not appear to have been determined.

Unfavorable cultural conditions, especially the lack of proper soil and moisture, sometimes cause a chlorotic condition evidenced by a yellowing of the leaves which drop off in large numbers. It is not likely that this condition will produce any large and continued losses.

The limited extent to which Japanese mint has been cultivated in this country does not permit any positive statement regarding the insect pests that are likely to cause important damage if large areas of the crop were grown in a locality for some time. Cutworms have been found to do some damage when conditions are favorable, especially in new plantings set out on ground that was in sod the previous season. These may be controlled by means of poisoned bait.[10] In North Carolina small beetles did considerable damage in several plots by eating the foliage, their presence being indicated by numerous small round holes in the leaves. Unless the beetles are very numerous, damage to the plant itself is not likely to result, but the loss of oil from the herb is in proportion to the amount of leaf consumed. In the districts in Indiana and Michigan where peppermint and spearmint are grown the mint flea beetle (*Longitarsus menthaphagus* Gentner) is a threatening pest. The adult beetles do damage

[10] WALTON, W. R., CUTWORMS AND THEIR CONTROL IN CORN AND OTHER CEREAL CROPS. U.S. Dept. Agr. Farmers' Bul. 730, 8 p., illus. 1922. (Revised ed.)

by consuming the leaves, but more serious losses are caused by the larvae that invade the main roots and stems where they feed on the tissues, thus making the plant wilt and die. It is to be expected that this insect will be equally destructive to Japanese mint. Some measure of control is possible through the use of poison dust.[11]

COMPARISON OF OILS FROM VARIOUS SOURCES

OILS OBTAINED AT THE ARLINGTON EXPERIMENT FARM

The results of the analyses of the samples of oils obtained at the Arlington Experiment Farm are given in the following paragraphs, together with an interpretation of them on the basis of the conditions under which the oils were obtained. In order to present the data in their principal relationships, they have been grouped in tables 4 and 5. Table 4 deals entirely with the oils distilled from the plants designated as M-1, M-2, M-3, M-5, and M-6, the sources of which have been described previously, and all of which were grown in rather heavy clay-loam soil. Table 5 pertains to oils produced from M-2 plants grown in somewhat larger areas on the better silt-loam soil on that part of the farm usually referred to as the flats.

[11] Information on the mint flea beetle and the methods of controlling it are contained in the following publication: GENTNER, L. G., THE MINT FLEA-BEETLE (LONGITARSUS MENTHAPHAGUS GTNR.). Mich. Agr. Expt. Sta. Spec. Bul. 155, 13 p., illus. 1926.

TABLE 4.—*Data on oils obtained from stock M-1, M-2, M-3, M-5, and M-6 grown in heavy clay-loam soil on the Arlington Experiment Farm, Rosslyn, Va.*

Stock	Location	Year	Date of cutting	Stage of maturity when cut	Yield of oil from fresh herb	Physical constants of oil				Acid number [1]	Menthol in oil		
						Color	Specific gravity at 20° C.	Index of refraction at 20° C.	Angle of rotation at 25° C.		Combined	Free	Total
					Percent						*Percent*	*Percent*	*Percent*
M-1	Bed no. 33	[2] 1922											
		1923	Aug. 20	Early blooming	0.388		[3] 0.8966	[3] 1.4560	−43.0		9.19	72.34	81.53
		1924	Sept. 5	Full bloom	.205		[3] .8973	[3] 1.4550	−43.5		9.75	68.10	77.85
		1925	Sept. 17	Past blooming	.30						7.24	76.37	83.61
		1926	Sept. 20	Full bloom	.29	Very pale straw	.9001	1.4580		Less than 1	9.34	71.37	80.71
		1927	Sept. 12	do	.22	Greenish yellow	.9006	1.4590		do	11.03	71.25	82.28
		1928	Sept. 14	do	.28	Slightly yellow	.9001	1.4592		do	10.03	67.40	77.43
M-2	100-foot row, section E	1922	Oct. 12	Past full bloom			[3] .9010			do	18.0	70.69	88.69
		1923	Aug. 20	Full bloom	.385		[3] .8974	[3] 1.4560		do	8.64	72.68	81.32
		1924	Aug. 30		.20		[3] .8974	[3] 1.4556			9.97	65.23	75.20
		1925	Sept. 4	Full bloom	.294						11.14	71.64	82.78
		1926	Sept. 20	do	[4] 1.24	Very pale straw	.9008	1.4585		Less than 1	11.70	70.25	81.95
		1927	Sept. 12	do	.22	Greenish yellow	.9025	1.4585		do	12.00	69.12	81.12
M-3	do	[2] 1923											
		1924	Sept. 5	Partial bloom	.30		[3] .8960	[3] 1.4552			8.61	72.30	80.91
		1925	Sept. 4	Full bloom	.34	Very pale green	.9023	1.4581	−42.60	Less than 1	8.90	76.73	85.63
		1926	Sept. 20	do	[4] 1.20	Straw	.9020	1.4585		do	11.29	73.58	84.87
		1927	Sept. 12	do	.25	Pale straw	.9002	1.4090			11.70	69.01	80.71
M-5	do	1923	Aug. 20	do	.475		[3] .8962	[3] 1.4545	−41.1		8.08	62.14	70.22
		1924	Sept. 5	do	.30		[3] .8959	[3] 1.4540	−43.68		10.17	59.45	69.62
		1925	Sept. 4	do	.42	Slightly yellow	.9002	1.4573	−40.50	Less than 1	10.07	65.37	75.44
		1925	Sept. 3	do	.20	Pale yellow	.9025	1.4575	−41.0	1.22	9.64	70.24	79.88
M-6	do	1926	Sept. 20	do	[4] 1.71	Straw	.9017	1.4580		Less than 1	12.48	70.72	83.20
		1927	Sept. 12	do	.27	Pale straw	.9017	1.4583		do	12.09	67.40	79.49
		1928	Sept. 14	do	.23	do	.9001	1.4588		do	9.75	66.06	75.81

[1] Freshly distilled oils are neutral or contain only traces of acids. Higher values are often found if the oils are examined some time after distillation.
[2] No distillation made.
[3] At 25° C.
[4] Calculated on dry basis.

TABLE 5.—*Data on oils distilled from plants grown from M-2 stock on silt-loam soil (flats) on the Arlington Experiment Farm, Rosslyn, Va.*

Series of experiments	Year planted	Crop year	Date of cutting	Stage of maturity when cut	Yield of oil from fresh herb	Physical constants of oil				Acid number [1]	Menthol in oil		
						Color	Specific gravity at 20° C.	Index of refraction at 20° C.	Angle of rotation at 25° C.		Combined	Free	Total
					Percent						*Percent*	*Percent*	*Percent*
No. 1	1923	First (1923)	Aug. 21	Full bloom	0.37		[2] 0.8959	[2] 1.4569	−41.11		6.99	69.86	78.85
		Second (1924)	Aug. 29	Budding	.324		[2] .8957	[2] 1.4555	−40.91		5.66	71.92	77.58
		Third (1925)	Sept. 3	Full bloom	.334	Light straw	.8996	1.4578	−38.50	Less than 1	6.45	70.82	77.27
		Fourth (1926)	Sept. 16	do	.331	Very pale straw	.8969	1.4580		do	6.27	71.16	77.43
		Fifth (1927)	Sept. 7	do	.21	Light yellow	.9002	1.4590		do	5.92	68.48	74.40
No. 2	1924	First (1924)	Aug. 29	Partly in bloom	.326		[2] .8956	[2] 1.4550	−41.15		5.08	72.10	77.18
		Second (1925)	Aug. 27	Budding	.296	Pale greenish yellow	.9003	1.4575	−38.35		6.91	69.92	76.83
			Sept. 1	Full bloom	.281	do	.9002	1.4585	−38.72	Less than 1	6.85	69.60	76.45
			Sept. 24	Past bloom	.32	Light straw	.9014	1.4580	−39.90	do	9.22	73.30	82.52
		Third (1926)	Sept. 20	Full bloom	.36	Slightly yellow	.8992	1.4583		do	6.69	71.96	78.65
		Fourth (1927)	Sept. 7	do	.331	do	.8989	1.4600		do	5.85	69.15	75.00
		Fifth (1928)	Sept. 12	do	.32	Pale straw	.8778	1.4580		do	5.85	67.15	73.00
No. 3	1925	First (1925)	Sept. 2	do	.26	Dark reddish yellow	.9037	1.4580	−38.97	1.16	7.75	73.26	81.01
		Second (1926)	Sept. 20	do	.32	Slightly yellow	.9003	1.4580		Less than 1	8.20	69.43	77.63
		Third (1927)	Sept. 7	do	.37	Light yellow	.8990	1.4590		do	6.04	70.70	76.74
		Fourth (1928)	Sept. 24	do	.395	Pale straw	.9004	1.4583		do	7.24	69.41	76.65
No. 4	1928	First (1928)	do	do	.395	do	.8998	1.4585		do	6.41	66.59	73.00
		Second (1929)	Sept. 16	do	.425	do	.8998	1.4584		do	8.58	68.69	77.27
		Fourth (1931) [3]	do	do	.36	do	.8997	1.4583		do	7.40	62.50	69.90

[1] Freshly distilled oils are neutral or contain only traces of acids. Higher values are often found if the oils are examined some time after distillation.
[2] At 25° C.
[3] No harvest in 1930 on account of severe drought.

According to table 4, the planting stock M-1, M-2, M-3, M-5, and M-6, all obtained from different sources, was reasonably acceptable with respect to its menthol-yielding qualities. Those designated M-3 yielded oils with a total menthol content of over 80 percent from the same planting for 4 successive years. Most of the propagating stock obtained from the Arlington farm for planting elsewhere was furnished from M-2 plants, both from the row growing in heavy clay-loam soil and from the larger plots on the farm flats. It will be noted that on the heavier soil the quality of the oil remained consistently good over a period of 6 years. In bed no. 33, M-1 plants with very little cultivation maintained themselves for 8 years with no significant downward trend in the menthol content of the oil, although the general vigor and growth of the plants depreciated gradually from year to year. The M-5 plants, obtained from Greensboro, N.C., where the original stock was sent from Japan, showed a distinctly lower menthol content over a 3-year period.

The two points of special interest indicated by data in table 4 are: (1) The satisfactory menthol content of oils produced on the clay-loam soil, and (2) the failure of the menthol content to decline with continuous cultivation. The theory has been held that under certain soil and climatic conditions Japanese mint deteriorates in menthol content. If this should prove to be correct, the possibilities of growing the mint commercially in the United States would be greatly reduced. It is interesting to examine the data in table 5 with particular reference to that point. As stated, the oils represented in this table were obtained from M-2 plants grown on silt-loam soil of fair fertility and less heavy than the soil referred to in the previous table, but not of the friable texture generally considered desirable for this crop. In this group of experiments a series of plantings approximately an eighth of an acre each were made annually in 1923, 1924, and 1925 and kept under cultivation for a number of years. In 1928 another new planting was made, which has been continued through 1931. The first two series furnished continuous records for 5 years, the third series for 4 years, and the final series has also been maintained for 4 years, but no data were obtained in 1930. It is at once obvious when the data is compared with that in table 4 that these plantings have been less productive of menthol than the M-2 plants grown in the clay-loam soil. There were only two instances when the oils contained over 80 percent of total menthol.

Furthermore, there appears to have been a rather distinct reduction in menthol content after the third or fourth years. In seeking an explanation of this tendency, which is contrary to the behavior of the same stock in the clay-loam soil, several factors suggest themselves. The difference in soil may be responsible, although one would more logically consider this the cause if the two soil types differed more than they do. The methods of culture may in part have been responsible. The smaller plantings on the clay-loam soil consisted of single rows, with the exception of M-1 in bed no. 33. Cultivation was somewhat more thorough for that reason than was the case in the large plots in which the plants were permitted to cover the ground after the first year. This made cultivation difficult, except in early spring, and weed control by hand weeding was less thorough than is possible in row plantings. The prevalence of grass contributed to the cultural difficulties in these plots and, as a result, in all the series

of plantings the fields were retained several years longer than their condition would warrant in commercial practice. It is true that bed no. 33, also, could not be effectively cultivated, but here and in the row plantings cleaner culture by hand weeding was possible.

From the standpoint of commercial advantage it is desirable that the oils contain a low percentage of combined menthol. Reference to the tables shows that the oils from the larger plots contain, on the whole, a smaller proportion of combined menthol than the others. Consequently, the two groups of oils are more in accord with respect to their free menthol content than with respect to their total menthol content.

OILS OBTAINED BY COOPERATORS IN VARIOUS LOCALITIES

In order that the effect of climatic and soil conditions on the character of the oil produced might be studied, persons interested in the possibilities of this mint were furnished with M-2 stock from the Arlington farm for trial plantings in many localities. In addition to the data thus obtained, it is possible to present with it in table 6 considerable additional data furnished by a cooperator [12] under whose supervision other plantings were made, especially in North Carolina. Most of these plantings were made from stock originally furnished to the cooperator from the Department's M-2 stock. A total of 52 localities are represented in the table, of which 15 are in North Carolina, 7 in California, 4 in Indiana, 3 each in Michigan and Virginia, 2 each in Oregon, Georgia, and New York, and 1 in each of the following: Florida, Alabama, Oklahoma, South Carolina, Pennsylvania, Tennessee, North Dakota, Idaho, Wisconsin, Washington, Illinois, Maryland, New Mexico, and Missouri. From Greensboro, N.C., data are available for 7 consecutive years; from Carroll County, Va., and Sands, N.C., 6 years; from Taylorsville, N.C., 5 years; from Seneca Falls, N.Y., Gainesville, Fla., and Colon, Mich., 4 years; from South Bend, Fort Wayne, and Warsaw, Ind., Auburn, Ala., Washington, N.C., Puget Island, Wash., Demorest, Ga., Norman, Okla., and Blacksburg, Va., 2 years; and from the remaining localities, 1 year.

[12] Vick Chemical Co., Greensboro, N.C.

TABLE 6.—*Data on oils distilled from plants grown in various localities other than Rosslyn, Va.*

Year grown and locality	Planting stock	Age of planting[1]	Oil in dry herb	Physical constants				Acid number	Menthol			Remarks
				Color	Specific gravity at 20° C.	Index of refraction at 20° C.	Angle of rotation at 25° C.		Combined	Free	Total	
1923:			*Percent*						*Pct.*	*Pct.*	*Pct.*	
Greensboro, N.C.	M-2	First year	2.07		[2] 0.8961	[2] 1.4572	−41.4		4.33	73.30	78.03	
Do.	M-5	do	1.91		[2] .8963	[2] 1.4569	−42.0		8.65	65.51	74.16	
Seneca Falls, N.Y.	M-2	do	1.30		[2] .8963	[2] 1.4585	−42.0		5.29	77.61	82.96	
Junction City, Oreg.	do	do	1.36		[2] .8946	[2] 1.4500	−39.9		4.23	65.57	71.80	Herb partly heated and molded.
South Bend, Ind.	do	do	1.47		[2] .8963	[2] 1.4578	−42.9		5.71	77.73	83.44	
Florence, S.C.	do	do	1.60		[2] .8964	[2] 1.4569	−39.3		4.74	71.07	75.81	
1924:												
Greensboro, N.C.	do	Second year	1.16		[2] .8982	[2] 1.4560	−39.9		5.29	71.61	76.90	
Do.	M-5	do	1.65		[2] .8960	[2] 1.4545	−39.3		4.51	62.63	67.14	
Seneca Falls, N.Y.	M-2	do	89		[2] .8960	[2] 1.4556	−43.44		7.24	68.00	75.20	
South Bend, Ind.	do	do			[2] .8961	[2] 1.4560	−39.79		7.98	72.89	80.87	
Carroll County, Va.	do	First year	1.68		[2] .8950	[2] 1.4550	−40.22		4.50	67.90	72.40	
North Wilkesboro, N.C.	do	do	.92			[2] 1.4553	−34.67		3.90	61.30	65.20	
Taylorsville, N.C.	do	do	.73		[2] .8940	[2] 1.4554	−43.24		6.45	70.17	76.62	
Sands, N.C.	do	do	.73		[2] .8950	[2] 1.4560	−41.20		4.50	70.70	75.20	
Gervais, Oreg.	do	do	.88		[2] .8966	[2] 1.4555	−42.24		5.86	72.37	78.03	
1925:												
Bethlehem, Pa.	do	do				1.4602		1.28	7.44	69.53	76.97	
Cumberland City, Tenn.	do	do	.85	Dark		1.4600		2.75	8.30	71.74	80.04	Herb moldy.
Au Gres, Mich.	do	do	1.13	Light yellow	.8998	1.4588	−39.7	.98	6.75	71.41	78.16	Do.
Fairmount, N.Dak.	do	do	1.39	Dark		1.4600		4.23	6.75	78.09	84.84	
Warsaw, Ind.	do	do	1.40	do		1.4598		5.33	16.32	69.36	85.68	
Delano, Calif.	do	do	1.42	Straw	.9023	1.4578	−39.0	.90	7.94	74.91	82.85	
Lewiston, Idaho	do	do	1.86	do	.8986	1.4584	−38.4	.65	3.77	73.01	76.78	
Greensboro, N.C.[3]	do	Third year							9.19	56.36	65.55	Plot no. 3.
Do.[3]	M-5	do							10.86	62.14	73.00	Plot no. 1. Yield only 21 pounds per acre on account of drought.
Do.[3]	do	do							11.70	58.10	69.80	Plot no. 2. Yield 30 pounds per acre.
Groomtown, N.C.[3]	M-2	First year							3.76	61.02	64.78	
Do.[3]	do	do							6.13	68.07	74.20	
Seneca Falls, N.Y.[3]	do	Third year							5.42	56.67	62.10	
Do.[3]	do	do							7.80	72.08	79.88	Yield 32 pounds per acre.
Brevard, N.C.[3]	do	First year							6.41	61.07	67.48	
Sands, N.C.[3]	do	Second year							6.69	73.19	79.88	Yield 20 pounds per acre.
Taylorsville, N.C.[3]	do	do							6.41	74.71	81.12	Yield 15 pounds per acre.

Carroll County, Va.[3]	do	do	1.6					8.36	70.09	84.45	Yield 25 pounds per acre.
Selma, N.C.[3]	do	First year								67.87	
Colon, Mich.[3]	Cooperator's stock.	Not known						3.62	74.63	78.25	Yield 16 pounds per acre.
1926:											
Greensboro, N.C.[3]	M-2	Fourth year						7.80	69.63	77.43	Plot no. 3. Yield 28 pounds per acre.
Do.[3]	M-5	do						6.13	65.28	71.41	Plot no. 1. Yield 14 pounds per acre (drought).
Do.[3]	do	do						6.41	69.40	75.81	Plot no. 2. Yield 32.5 pounds per acre.
Sands, N.C.[3]	M-2	Third year						4.05	73.38	77.43	
Taylorsville, N.C.[3]	do	do						5.01	73.23	78.24	Yield 25 pounds per acre.
Carroll County, Va.[3]	do	do						6.13	71.70	77.83	
Seneca Falls, N.Y.[3]	do	Fourth year						7.80	70.40	78.24	
Colon, Mich.[3]	Cooperator's stock.	Not known						5.29	74.18	79.47	Early planting.
Dowagiac, Mich.[3]	From Colon, Mich.	First year						8.91	62.10	71.01	Probably cut too early.
Fort Wayne, Ind.[3]	do	do						5.85	75.27	81.12	
Greensboro, N.C.[3]	do	do						9.19	76.81	86.00	
Los Angeles, Calif.	Not known	do	1.06	Straw	.9018	1.4600		9.36	74.04	83.40	
Princeton, Wis.	M-2	do	1.31	Pale straw	.9011	1.4590		4.72	73.11	77.83	
Puget Island, Wash.	do	do		Slightly yellow	.9024	1.4600		5.47	71.96	77.43	
Warsaw, Ind.	do	Second year	1.54	do	.9000	1.4590		5.85	72.80	78.65	
Sorento, Ill.	do	First year	1.93	do	.9015	1.4605		7.80	74.72	82.52	
1927:											
Greenboro, N.C.[3]	do	Fifth year						7.52	67.48	75.00	Plot no. 3. Yield 30 pounds per acre.
Do.[3]	M-5	do						5.57	65.84	71.41	Plot no. 1. Yield 32 pounds per acre.
Do.[3]	do	do						7.52	65.08	72.60	Plot no. 2. Yield 20 pounds per acre. (Field infested with crabgrass.)
Taylorsville, N.C.[3]	M-2	Fourth year						8.08	74.70	82.78	
Lowgap, N.C.[3]	do	First year						6.69	72.78	79.47	
Sands, N.C.[3]	do	Fourth year						6.27	69.54	75.81	
Carroll County, Va.[3]	do	do						6.69	74.84	81.53	
New Bern, N.C.[3]	do	First year						1.07	69.74	71.41	
Louisburg, N.C.[3]	do	do						4.60	64.80	69.44	
Demorest, Ga.[3]	do	do						6.13	73.34	79.47	
Colon, Mich.[3]	Cooperator's stock.	Not known						13.93	73.48	87.41	Cut late (October).
Do.[3]	do	do						12.54	74.44	86.98	Do.
Fort Wayne, Ind.[3]	From Colon, Mich.	Second year						4.60	64.84	69.44	Cut early (July).
Greensboro, N.C.[3]	do	do						11.40	73.31	84.45	
Chapel Hill, N.C.[4]	M-2	First year						4.46	74.19	78.65	
Newark, N.Y.[3]	Unknown	do						9.75	77.23	86.98	
Nappanee, Ind.[3]	do	do						5.29	67.31	72.60	Probably cut too early.

See footnotes at end of table.

TABLE 6.—*Data on oils distilled from plants grown in various localities other than Rosslyn, Va.*—Continued

Year grown and locality	Planting stock	Age of planting	Oil in dry herb	Physical constants				Acid number	Menthol			Remarks
				Color	Specific gravity at 20° C.	Index of refraction at 20° C.	Angle of rotation at 25° C.		Combined	Free	Total	
			Percent						*Pct.*	*Pct.*	*Pct.*	
Porterville, Calif.[3]	Cooperator's stock.	First year							6.96	77.07	84.03	First cutting.
Do.[3]	do	do							5.01	81.97	86.98	Second cutting.
Modesto, Calif.[3]	do	do							10.27	78.42	88.69	
Torrey Pines, Calif.	M-2	do	1.18	Pale straw		1.4595			5.46	68.34	73.80	Grown in greenhouse.
Auburn, Ala.[5]	do	do	1.02	do	0.9001	1.4585			4.26	68.94	73.20	
Puget Island, Wash.	do	Second year			.9006	1.4590			5.07	71.14	76.21	
Moyock, N.C.	do	do	1.03	Yellow	.9005	1.4604			5.46	69.54	75.00	
Gainesville, Fla.[6]	do	First year	2.81	Pale yellow	.9003	1.4598			6.24	65.56	71.80	Short herb with no large stems.
Preston, Md.	do	do	1.25	do	.9004	1.4595			6.69	69.12	75.81	Herb contained many large stems.
Albuquerque, N.Mex.	do	do	1.00	do	.9083	1.4565			3.90	67.51	71.41	Herb dried in tobacco drier.
1928:												
Greensboro, N.C.[3]	do	Sixth year							4.53	66.67	71.20	Plot no. 3. Yield 25.8 pounds per acre.
Do.[3]	M-5	do							6.47	68.53	75.00	Plot no. 1.
Do.[3]	do	do							6.01	70.61	76.62	Plot no. 2.
Taylorsville, N.C.[3]	M-2	Fifth year							6.24	72.82	79.06	
Sands, N.C.[3]	do	do							3.90	76.84	70.06	
Carroll County, Va.[3]	do	do							5.25	74.22	79.47	
Washington, N.C.[3]	do	First year							3.76	73.42	77.18	
Haywood, N.C.[3]	do	do							4.62	67.92	72.60	
Colon, Mich.[3]	Cooperator's stock.	Not known							7.24	76.79	84.03	
Demorest, Ga.[3]	M-2	Second year							6.28	71.96	78.24	
Davisville, Mo.[3]	do	First year							5.24	74.23	79.47	
Norman, Okla.[7]	do	do	1.20	Greenish yellow	.9004	1.4592			9.20	69.45	78.65	
Auburn, Ala.[5]	do	Second year	1.10	Pale straw	.8979	1.4587			4.74	68.66	73.40	
Savannah, Ga.	do	First year	1.66	Straw	.9000	1.4588			6.13	68.87	75.00	
Shafter, Calif.	Cooperator's stock.	Not known		do	.9018	1.4601			5.01	77.77	82.78	
Blacksburg, Va.[8]	M-2	First year	1.90	do	.9003	1.4590			5.85	71.58	77.43	
Gainesville, Fla.[6]	do	Second year	[9] .292	do	.8977	1.4595			3.90	69.50	73.40	Distilled in fresh condition.
1929:												
Greensboro, N.C.[3]	do	Seventh year							5.42	68.82	74.24	Plot no. 3.
Carroll County, Va.[3]	do	Sixth year			[9] .8975	[9] 1.4583	−40.00		8.05	73.48	81.53	
Sands, N.C.[3]	do	do			[9] .8970	[9] 1.4592	−39.50		5.66	73.66	79.32	

Lenoir, N.C.[3]	do	First year			[2].8964	[2] 1.4593	−36.20	2.87	68.93	71.80	Cut early on account of rust.
Washington, N.C.[3]	do	do			[2].8965	[2] 1.4591	−35.30	2.90	66.32	70.22	From 1928 stock.
Do.[3]	do	Second year			[2].8993	[2] 1.4598	−35.30	3.83	71.98	75.85	
Dublin, Va.[3]	do	First year			[2].8960	[2] 1.4600	−38.55	4.08	77.16	78.24	
Norman, Okla.	do	Second year	1.07	Yellow		1.4582		3.35	80.02	83.37	
Dos Palos, Calif.	do	First year	2.07	Light yellow	.8970	1.4581		3.90	61.73	65.63	Some large stems removed.
Gainesville, Fla.[6]	do	Third year	[9].424	Pale yellow	.8976	1.4602		3.90	67.11	71.01	First cut, distilled in fresh condition on June 24.
Do	do	do		Pale straw	.8981	1.4580		3.51	67.58	71.09	Second cut, distilled on Oct. 22.
Blacksburg, Va.	do	First year	1.20	Straw	.9009	1.4586		8.19	71.36	79.55	
1930:											
Gainesville, Fla.[6]	do	Fourth year	[9].331		.8981	1.4605		5.01	68.79	73.80	First cutting July 8. Distilled in fresh condition.
Do.[6]	do	do	[9].419		.8976	1.4696		4.74	63.52	68.26	Second cutting Oct. 13. Distilled in fresh condition.

[1] This indicates the number of years the plants have been grown in the respective localities, but not in all cases without replanting to new ground.
[2] These constants were determined at 25° C.
[3] Data furnished by Vick Chemical Co., Greensboro, N.C.
[4] Cooperation with School of Pharmacy, University of North Carolina.
[5] Cooperation with Alabama Polytechnic Institute.
[6] Cooperation with School of Pharmacy, University of Florida.
[7] Cooperation with School of Pharmacy, University of Oklahoma.
[8] Cooperation with Virginia Polytechnic Institute.
[9] Calculated on green weight.

Some of the data included was furnished by cooperators; in other cases samples of the oil were furnished for examination, and in still others the dried herb was sent in for distillation. So far as possible all available data are brought into comparison in this table. This includes information concerning the type of planting stock; the number of years the plants from which the oil samples were obtained have been under cultivation in the particular locality; the stage at which the plants were cut; the percentage yield and estimated acreage yield of oil; and physical constants and menthol content of the oils. As many of the factors in connection with the distillations of the oils were not subject to uniform control under the conditions of these widely separated trial plantings, inspection of the data must be made with due consideration to that fact. This is especially true with respect to those localities from which only 1 year's results are available.

In view of the diverse conditions of production under which the oils were obtained, their physical constants show a comparatively narrow range of variation. In the case of those oils that were not examined in the Department laboratories the reported data is confined mainly to the menthol content, hence comparison of the oils from all the localities with respect to physical properties is not possible. Unfortunately the physical constants of some of the oils were determined at 20° C. and those of others at 25°. The specific gravity within the range of 5° appears to lie between 0.8950 and 0.9000, and the limits of the index of refraction are approximately 1.4550 and 1.4590. The angle of rotation at 25° varied from approximately $-35°$ to $-43°$. The majority of oils when freshly distilled are nearly neutral, but, on standing, the acidity increases. In most cases where relatively high acidity is indicated in the table the oils were not examined until some time after they were distilled. All of the oils that were examined were found to be readily soluble in two volumes of 70 percent alcohol.

The most important deductions to be made from this table concern the menthol content of the oils. Since the oils were produced in practically all sections of the country, and in some cases over a period of years, even tentative indications regarding this important character of the oil must be considered significant. The available data may be studied with reference to two principal considerations: (1) The relationship between the geographic source of the oil and the menthol content, and (2) the effect of continued culture in a locality on this character of the oil. To bring out more closely what relationships exist with regard to the former, the data on menthol content has been reassembled in table 7 in groups according to the principal sections of the country.

From the southeast, north-central, and western sections sufficient data are available to permit some conclusions to be drawn. In the north-central and western sections the average total menthol content was very nearly the same, namely, 78.94 and 78.71 percent, respectively, whereas in the southeast section it was only 74.47 percent. According to more limited data, the oils from the south-central section contained 80.24 percent and those from the northeast section 81.01 percent. Among the 25 localities included in the southeast section only 1 is shown with an oil containing as much as 80 percent total menthol, namely, Cumberland City, Tenn. On the other hand, out of 10 localities in the north-central section 5 show percentages of total menthol considerably in excess of 80 percent. Likewise. in the far

TABLE 7.—*Data on the menthol content of the oils grouped according to the sections of the United States in which they were produced*

Section and locality	Years	Samples	Menthol [1]	
			Combined	Total
	Number	*Number*	*Per cent*	*Per cent*
Southeast:				
Greensboro, N.C.	7	19	7.29	74.51
Sands, N.C.	6	6	5.21	77.78
Taylorsville, N.C.	5	5	6.44	79.56
Washington, N.C.	2	3	3.49	73.70
North Wilkesboro, N.C.	1	1	3.90	65.20
Groomtown, N.C.	1	2	4.95	69.49
Brevard, N.C.	1	1	6.41	67.48
Selma, N.C.	1	1	.....	67.87
Lowgap, N.C.	1	1	6.69	79.47
New Bern, N.C.	1	1	1.67	71.41
Louisburg, N.C.	1	1	4.60	69.44
Chapel Hill, N.C.	1	1	4.46	78.65
Moyock, N.C.	1	1	5.46	75.00
Haywood, N.C.	1	1	4.62	72.60
Lenoir, N.C.	1	1	2.87	71.80
Carroll County, Va.	6	6	6.27	78.99
Blacksburg, Va.	2	2	7.02	78.49
Dublin, Va.	1	1	4.08	78.24
Demorest, Ga.	2	2	6.21	78.86
Savannah, Ga.	1	1	6.13	75.00
Gainesville, Fla.	4	6	4.55	71.56
Auburn, Ala.	2	2	4.50	73.30
Florence, S.C.	1	1	4.74	75.81
Cumberland City, Tenn.	1	1	8.30	80.04
Preston, Md.	1	1	6.69	75.81
Average	.....	.....	5.29	74.47
Northeast:				
Seneca Falls, N.Y.	2	2	6.27	79.08
Newark, N.Y.	1	1	9.75	86.98
Bethlehem, Pa.	1	1	7.44	76.97
Average	.....	.....	7.82	81.01
North Central:				
Colon, Mich.	4	5	8.52	83.23
Dowagiac, Mich.	1	1	8.91	71.01
Au Gres, Mich.	1	1	6.75	78.16
South Bend, Ind.	2	2	6.35	82.16
Warsaw, Ind.	2	2	11.09	82.17
Fort Wayne, Ind.	2	2	5.23	75.28
Nappanee, Ind.	1	1	5.29	72.60
Fairmount, N.Dak.	1	1	6.75	84.84
Princeton, Wis.	1	1	4.72	77.43
Sorento, Ill.	1	1	7.80	82.62
Average	.....	.....	7.14	78.94
South Central:				
Norman, Okla.	2	2	6.28	81.01
Davisville, Mo.	1	1	5.24	79.47
Average	.....	.....	5.76	80.24
West:				
Porterville, Calif.	1	2	5.29	85.21
Delano, Calif.	1	1	7.94	82.85
Los Angeles, Calif.	1	1	9.30	83.40
Modesto, Calif.	1	1	10.27	88.69
Torrey Pines, Calif.	1	1	5.46	[2]73.80
Shafter, Calif.	1	1	5.01	82.78
Dos Palos, Calif.	1	1	3.90	65.63
Puget Island, Wash.	2	2	5.27	76.82
Gervais, Oreg.	1	1	5.86	78.03
Junction City, Oreg.	1	1	4.23	[3]71.80
Lewiston, Idaho.	1	1	3.77	76.78
Average	.....	.....	6.03	78.71
Southwest:				
Albuquerque, N. Mex.	1	1	3.90	[4]71.41

[1] These figures are averages where more than 1 sample is included, the group averages being simple averages.
[2] Grown in greenhouse.
[3] Herb heated in transit.
[4] Herb dried at high temperature in tobacco drier.

Western States 5 out of 11 localities produced oils with more than 80 percent total menthol. It should be remembered, in this connection, that in all cases where more than one sample of oil was obtained from a locality the total menthol figures given represent averages.

Reference to the detailed data in table 6 will show that in the southeastern section there were numerous instances of individual oils that contained 80 percent or more of total menthol. Thus among the 6 samples of oil from Carroll County, Va., there were 3 with over 80 percent menthol, and among the 19 samples from Greensboro, N.C., and the 5 samples from Taylorsville, N.C., there were in each case 2 such oils. Although the oils produced at the Arlington farm are not included in these groupings, they could well be included among those of the southeastern section. The 19 samples of oil obtained from the larger plantings on the farm flats average 6.91 percent combined, and 76.70 percent free menthol, but only 2 individual oils contained 80 percent or more of total menthol. It seems, therefore, that conditions in the Southeastern States do not favor the formation of menthol to the same extent as those in the Northern

and Western States. This conclusion is in accord with the opinion that has prevailed to some extent, but which had not heretofore been supported by experimental evidence, that the Japanese mint, with respect to its menthol content, is not as well adapted to the southern as to the northern section of the country.

As the menthol existing in the oil in combination as esters cannot be removed by refrigeration alone, oils with a low percentage of combined menthol are desirable. Viewed from this standpoint, it is found that the oils from the southeastern localities are relatively of slightly greater value than those produced elsewhere, which to some extent offsets the disadvantage of the somewhat lower total menthol content. The data on combined menthol may, however, be misleading in some cases. Esterification increases after the plant reaches the full-flowering stage and, therefore, delay in cutting the herb frequently results in an abnormally high percentage of combined menthol in the oil. Such cases were observed rather frequently, especially in connection with plantings over which there was no close supervision. On account of the close control of most of the plantings in the Southeast by the cooperator at Greensboro, N.C., delayed harvesting was perhaps somewhat less frequent there than in some of the other sections.

The effect of continued culture in the same locality on the quality of the oil is very important in determining whether commercial production in that section can be recommended. If a progressive decrease in the menthol content of the oil takes place from year to year, continued commercial culture would require the frequent introduction of new planting stock, which would result in a higher production cost. It is believed that a locality in which such an effect is invariably observed should not be selected for this mint. Table 8 shows the trend of the menthol content over a period of 2 or more years of continuous culture in those localities from which data for more than 1 year are available. It will be noted that in 7 of the 16 localities included, the oils from the final year contained more total menthol than those from the first year. In the 6 localities in which continuous culture extended over at least 4 years there are 4 in which the oils in the last years were higher in this respect than oils from the first year's planting. During these years of culture the quality of the oils varied, of course, but the important point is whether or not there was a steady decline in quality. Apparently this is not the case.

In this connection attention is directed particularly to the oils from Greensboro, N.C. It will be observed that the total menthol content declined from 78.03 to 76.99 percent in the second year and to 65.55 percent in the third year. When this occurred it appeared that the theory regarding the effects of continued culture in the South, previously referred to, was correct, but the recovery that took place in the fourth year may be considered reasonable evidence that such is not the case. The fluctuations in the total menthol content that occur from year to year are no doubt due to seasonal conditions rather than to any general cumulative effects resulting from climatic conditions in the southern latitudes.

TABLE 8.—*Variation in the percentage of total menthol in oils obtained from the same planting over a period of 2 or more years*

Section and locality	Percentage of total menthol in—						
	First year	Second year	Third year	Fourth year	Fifth year	Sixth year	Seventh year
Southeast:							
Greensboro, N.C.	78.03	76.90	65.55	77.43	75.00	71.20	74.24
Sands, N.C.	75.20	79.88	77.43	75.81	79.06	79.32	
Carroll County, Va.	72.40	84.45	77.83	81.53	79.47	81.53	
Taylorsville, N.C.	76.62	81.12	78.24	82.78	79.06		
Gainesville, Fla.	71.80	73.40	[1] 71.05	[1] 71.03			
Washington, N.C.	77.18	75.85					
Auburn, Ala.	73.20	73.40					
Blacksburg, Va.	77.43	79.55					
Demorest, Ga.	79.47	78.24					
North Central:							
Colon, Mich.	[2] 78.25	79.47	[3] 87.20	84.03			
South Bend, Ind.	83.44	80.87					
Fort Wayne, Ind.	81.12	[4] 69.44					
Warsaw, Ind.	85.68	78.65					
Northeast:							
Seneca Falls, N.Y.	82.96	75.20					
South Central:							
Norman, Okla.	78.65	83.37					
West:							
Puget Island, Wash.	77.43	76.21					

[1] Average of 2 cuttings.
[2] Records do not indicate age of the planting when first data were obtained.
[3] Average from 2 plantings, both cut late (October).
[4] Crop cut early.

COMMERCIAL CULTURE

In the years during which the experimental work was in progress a relatively small total acreage of the crop was under cultivation in the southeastern and north-central sections. Small acreages were maintained in North Carolina (fig. 12), in a number of localities, as well as at South Bend, Ind., and Colon, Mich. (fig. 13). These,

FIGURE 12.—A fine stand of Japanese mint at Greensboro, N.C.

however, were mainly intended to furnish information and a source of planting stock for a larger acreage if it should be considered advisable to extend the crop. In only one State, California, has the crop been grown for commercial purposes, and it was still under cultivation there in 1931. Its establishment in that State and the history of the undertaking since 1925 are briefly set forth in the following paragraphs, insofar as authoritative information on the subject is available.

The first commercial planting, consisting of 2 acres, was made near El Cajon, southeast of San Diego, in 1925, with planting stock presumably obtained from Japan several years previously. The roots thus produced were used the following years for planting 17 acres. Two crops were cut which yielded only 15 pounds of oil per acre.

FIGURE 13.—First-year planting of Japanese mint at Colon, Mich.

Although the quality of the oil, which contained 85 percent of menthol, was satisfactory, the yield, owing to the small growth of the plant on the heavy adobe soil of this locality, was entirely too low to justify further expansion. Consequently, the entire acreage was dug up and the roots were moved to the central part of the State in the San Joaquin Valley, where 60 acres were planted near Porterville. Here the crop, on sandy-loam soil with frequent irrigation, was more of a success. It was cut twice, the second cutting yielding considerably more material than the first. The oils obtained from these cuttings varied little in their quality. The average total menthol content was 85 percent, of which all but 5 was in the free state.

In 1927, while the crop in this locality was continued, a trial planting of 2 acres was made at Shafter, in the lower end of the valley, on a sedimentary type of soil. Two cuttings produced under irrigation yielded 100 pounds of oil. This high yield and the satisfactory behavior of the crop under the conditions prevailing in that locality led to a rapid expansion of the acreage there and the abandonment

of the plantings in the Porterville locality. The industry has since that time been centralized at Shafter, with 250 acres under cultivation in 1931.

With liberal use of fertilizers and with irrigation applied three to four times a month during the growing season, the crop is cut three times from plantings after the first year. The first cutting is light, yielding 10 to 15 pounds of oil per acre. The second is heavier, producing 40 to 60 pounds, while from the third, also light, 5 to 15 pounds are obtained, making a total yield ranging from 55 to 90 pounds of oil to the acre. These are average figures, but much higher yields have been observed. One 15-acre plot produced 50 pounds per acre from the first cuttings, 50 from the second, and 36 from the third, or a total of 136 pounds per acre. Late rains and late frost in the fall make this yield possible. A 1-acre first-year plot heavily fertilized and well cared for in a special test produced 200 pounds of oil. The oils contain on the average about 75 percent of free menthol, but the proportion of menthol in combination in the oils obtained late in the season is 6 to 8 percent, as compared with 3 to 4 in those distilled from the first cutting.

In 1928 the crop was given a trial on a somewhat heavier sedimentary soil in the vicinity of Dos Palos, Calif., where the growing season is shorter. The results were encouraging and the acreage was consequently increased. About 150 acres were under cultivation there in 1931. Yields of 40 pounds of oil are obtained on the average from two cuttings. Oils from the first crop contain about 8 percent of menthol in combination and 85 percent of total menthol. Crops obtained later in the season contain a slightly higher percentage of combined and total menthol.

POSSIBILITIES OF THE CROP IN THE UNITED STATES

When it is considered that in the United States Japanese-mint oil would find its principal commercial outlet as a source of natural menthol, it is obvious that the possibilities of the crop in this country are determined entirely by the economic status of that commodity. The continued use of menthol in the industries is assured, but the production of the oil in Japan and the availability of the synthetic product must be recognized as the factors controlling the price situation. So long as menthol remains available at the low prevailing price, the extensive introduction of the crop under domestic conditions does not seem advisable. However, it would require an increase of only a few dollars a pound in the market value of this product to assure reasonable returns from the crop in favorable localities. The experiments herein described indicate with reasonable certainty that the plant is adapted to many sections of the country, particularly in the North and West, and that the quality of the oil may be expected to be maintained with continued culture under the climatic conditions prevailing there.

During the years when menthol prices are reasonably high it would appear feasible to grow the crop in small acreages in sections where labor costs are not too high and where it would not be in competition with other crops yielding high returns. This is especially true if production costs can be reduced by the use of one distilling outfit so placed that it can conveniently serve a number of small growers. The crop

appears to offer better opportunities in California than elsewhere. Much larger yields of oil are possible there, because 2 and 3 cuttings are obtained in a season and because the oils produced seem to have a uniformly high menthol content. Production costs are no doubt higher where irrigation is necessary, but the much larger returns more than offset the additional cost.

This investigation, if it has shown that the Japanese mint is not a practical possibility as a farm crop at this time, has also demonstrated that under certain conditions this country could in a reasonable time produce a large proportion of its menthol requirements.

SUMMARY

An investigation was undertaken to determine the possibilities of Japanese mint as a crop in the United States to furnish a source of natural menthol, which is required in large quantities in domestic industries and is at present obtained mostly from Japan where the crop is grown extensively.

Authentic planting stock of this mint, known botanically as *Mentha arvensis piperascens*, was obtained from Japan, and its cultural requirements were determined by experiments on the Arlington Experiment Farm, Rosslyn, Va., near Washington, D.C., and in numerous other localities where growers were furnished with planting stock for the purpose. Information and data were also contributed by private firms and institutions that were interested in this crop.

The qualities of the oils obtained from various localities and under varying conditions were studied with particular reference to their value as sources of menthol. It was found that oils produced in the North and West contain, on the whole, a larger percentage of total menthol than those produced in the Southeast. Continuous cultivation over a period of years indicates that seasonal conditions cause fluctuations in the menthol content of the oils, but that there is no general tendency for the menthol content to decline gradually as a result of the prevailing conditions in any one locality. It was shown conclusively that Japanese-mint oil of satisfactory quality can be produced in this country.

The development of a commercial acreage of Japanese mint in California is described, the economic factors that would determine the success of the crop there and in other sections are discussed, and the possibility of a rapid expansion of the acreage to meet domestic requirements when conditions make it necessary is emphasized.

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