MONTANA
STATE UNIVERSITY
AGRICULTURAL
EXPERIMENT STATION

1998 MONTANA MINT

RESEARCH REPORT

RESEARCH PROJECTS FOR THE NORTHWESTERN AND WESTERN AGRICULTURAL RESEARCH CENTERS

WEB PAGE: http://www.montana.edu/wwwnwarc/northw.htm

**Plan to attend the Northwestern Ag Research Center
Mint Tour on June 30, 1999**

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Summary of growing degree day (GDD) data for mint at the Northwestern Agricultural Research Center May 1, 1949 through September 15, 1998.

GDD = Temp Max + Temp Min ÷ 2 - 50
Min Temp < 50F substituted with 50

Average growing degree days by month and year.

YEAR	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL
1949	314.0	356.5	473.0	525.0	170.0	1838.5
1950	208.0	308.0	460.5	466.0	196.5	1639.0
1951	223.0	251.5	516.0	421.5	135.5	1547.5
1952	243.5	309.0	465.0	476.0	155.0	1648.5
1953	194.5	252.5	527.0	468.5	212.5	1655.0
1954	270.5	255.0	479.0	387.0	149.0	1540.5
1955	165.0	375.5	451.5	509.5	213.0	1714.5
1956	282.0	354.0	502.0	443.0	183.0	1764.0
1957	312.5	350.5	519.0	470.5	191.0	1843.5
1958	430.5	401.0	514.0	583.5	208.5	2137.5
1959	187.0	371.0	524.5	419.0	158.0	1659.5
1960	202.5	380.5	621.0	386.5	189.0	1779.5
1961	248.0	491.5	548.0	589.0	127.5	2004.0
1962	201.0	370.5	460.0	444.5	144.0	1620.0
1963	265.0	335.5	472.0	531.0	210.5	1814.0
1964	219.5	324.5	490.0	357.0	109.0	1500.0
1965	222.0	329.5	495.0	462.5	82.0	1591.0
1966	307.5	291.0	500.0	452.5	215.0	1766.0
1967	255.0	354.5	557.0	586.5	237.5	1990.5
1968	207.5	349.0	522.0	410.5	163.0	1652.0
1969	293.5	339.5	461.5	522.0	201.5	1818.0
1970	281.5	402.0	483.5	483.0	117.5	1767.5
1971	259.0	263.0	442.5	604.0	141.0	1709.5
1972	228.5	350.0	427.5	529.0	159.5	1694.5
1973	259.5	322.5	538.0	523.0	179.0	1822.0
1974	152.5	407.5	489.5	436.5	145.0	1631.0
1975	180.0	283.5	604.5	363.0	156.0	1587.0
1976	251.0	249.5	467.5	401.0	165.5	1534.5
1977	184.0	422.5	436.0	438.5	159.0	1640.0
1978	131.0	349.5	446.5	379.0	144.0	1450.0
1979	225.5	370.5	505.0	518.0	164.5	1783.5
1980	268.0	290.0	442.0	361.0	159.5	1520.5
1981	209.0	210.5	447.0	556.0	199.5	1622.0
1982	195.0	370.0	406.5	480.5	159.5	1611.5
1983	259.5	315.5	358.5	530.0	136.0	1599.5
1984	162.0	295.5	529.0	526.5	129.5	1642.5
1985	294.5	350.5	604.0	395.0	110.5	1754.5
1986	252.0	462.5	363.0	544.5	105.0	1727.0
1987	287.5	406.5	446.5	390.0	211.5	1742.0
1988	218.5	400.5	466.5	524.0	206.0	1815.5
1989	178.5	350.5	530.0	401.0	122.5	1582.5
1990	165.5	297.0	492.5	475.5	233.5	1664.0
1991	175.0	243.0	465.5	509.5	179.5	1572.5
1992	277.0	414.5	375.0	456.5	120.0	1643.0
1993	306.0	273.5	260.0	383.0	153.5	1376.0
1994	261.5	316.0	539.0	567.0	159.5	1843.0
1995	219.5	275.0	427.5	383.0	204.0	1509.0
1996	91.5	322.0	512.0	442.0	158.5	1526.0
1997	229.0	295.5	423.5	470.5	178.5	1597.0
1998	267.5	243.5	575.5	535.0	251.0	1872.5
MEAN	234.4	334.1	481.2	470.3	167.2	1687.3

YEAR: 1998 NORTHWESTERN AGRICULTURAL RESEARCH CENTER

MINT

May	MAX	MIN	GDD	June	MAX	MIN	GDD	July	MAX	MIN	GDD
1	76	38	13.0	1	61	50	5.5	1	81	52	16.5
2	76	36	13.0	2	69	42	9.5	2	72	47	11.0
3	77	46	13.5	3	61	35	5.5	3	83	54	18.5
4	78	49	14.0	4	66	35	8.0	4	85	53	19.0
5	72	41	11.0	5	67	42	8.5	5	77	57	17.0
6	77	42	13.5	6	70	45	10.0	6	70	49	10.0
7	75	42	12.5	7	69	49	9.5	7	75	52	13.5
8	73	41	11.5	8	62	41	6.0	8	81	52	16.5
9	77	38	13.5	9	68	42	9.0	9	82	54	18.0
10	75	43	12.5	10	70	50	10.0	10	89	61	25.0
11	67	37	8.5	11	67	55	11.0	11	84	60	22.0
12	69	37	9.5	12	70	56	13.0	12	74	57	15.5
13	73	41	11.5	13	70	49	10.0	13	73	48	11.5
14	69	48	9.5	14	61	43	5.5	14	76	50	13.0
15	50	41	0.0	15	62	49	6.0	15	78	53	15.5
16	56	29	3.0	16	57	45	3.5	16	84	54	19.0
17	65	36	7.5	17	61	42	5.5	17	85	53	19.0
18	50	42	0.0	18	66	50	8.0	18	87	56	21.5
19	54	31	2.0	19	67	45	8.5	19	88	54	21.0
20	69	37	9.5	20	62	50	6.0	20	87	52	19.5
21	81	44	15.5	21	66	42	8.0	21	82	51	16.5
22	64	48	7.0	22	75	45	12.5	22	84	54	19.0
23	49	46	0.0	23	70	49	10.0	23	86	54	20.0
24	60	48	5.0	24	66	47	8.0	24	88	62	25.0
25	63	40	6.5	25	67	52	9.5	25	82	56	19.0
26	77	47	13.5	26	63	51	7.0	26	87	57	22.0
27	76	42	13.0	27	55	48	2.5	27	90	58	24.0
28	53	38	1.5	28	61	48	5.5	28	88	60	24.0
29	62	36	6.0	29	69	46	9.5	29	86	55	20.5
30	69	43	9.5	30	75	47	12.5	30	85	56	20.5
31	52	48	1.0					31	84	61	22.5

AV MAX	AV MIN	GDD	AV MAX	AV MIN	GDD	AV MAX	AV MIN	GDD
67.2	41.1	267.5	65.8	46.3	243.5	82.4	54.6	575.5

August	MAX	MIN	GDD	Sept.	MAX	MIN	GDD	Oct.	MAX	MIN	GDD
1	82	60	21.0	1	90	47	20.0	1			0.0
2	65	60	12.5	2	88	49	19.0	2			0.0
3	80	54	17.0	3	91	47	20.5	3			0.0
4	85	54	19.5	4	89	47	19.5	4			0.0
5	89	52	20.5	5	91	46	20.5	5			0.0
6	92	59	25.5	6	89	47	19.5	6			0.0
7	92	53	22.5	7	89	47	19.5	7			0.0
8	83	48	16.5	8	86	49	18.0	8			0.0
9	82	46	16.0	9	77	59	18.0	9			0.0
10	86	48	18.0	10	67	51	9.0	10			0.0
11	88	51	19.5	11	74	43	12.0	11			0.0
12	88	52	20.0	12	74	42	12.0	12			0.0
13	86	51	18.5	13	77	43	13.5	13			0.0
14	89	54	21.5	14	79	42	14.5	14			0.0
15	90	54	22.0	15	81	43	15.5	15			0.0
16	86	53	19.5	16			0.0	16			0.0
17	79	42	14.5	17			0.0	17			0.0
18	73	40	11.5	18			0.0	18			0.0
19	72	40	11.0	19			0.0	19			0.0
20	74	41	12.0	20			0.0	20			0.0
21	88	41	19.0	21			0.0	21			0.0
22	84	55	19.5	22			0.0	22			0.0
23	80	46	15.0	23			0.0	23			0.0
24	74	50	12.0	24			0.0	24			0.0
25	69	42	9.5	25			0.0	25			0.0
26	78	44	14.0	26			0.0	26			0.0
27	79	44	14.5	27			0.0	27			0.0
28	80	43	15.0	28			0.0	28			0.0
29	85	44	17.5	29			0.0	29			0.0
30	91	46	20.5	30			0.0	30			0.0
31	89	48	19.5					31			0.0

AV MAX	AV MIN	GDD	AV MAX	AV MIN	GDD	AV MAX	AV MIN	GDD
82.5	48.9	535.0	82.8	46.8	251.0	0.0	0.0	0.0

TOTAL GROWING DEGREE DAYS: 1998 1872.5

TITLE: **1998 MINT CULTIVAR TRIAL**

PERSONNEL: Leon E. Welty, Professor of Agronomy, MSU, Kalispell, MT
Louise Strang, Research Specialist, MSU, Kalispell, MT

OBJECTIVE: Determine peppermint and spearmint germplasm response to an Intermountain environment in terms of pest tolerance, oil yield and oil quality.

DURATION: 1998-2000

PROCEDURES: The following cultivars/selection lines were planted May 18 and 19, 1998:

1) Black Mitcham peppermint, stem-cut propagated by MIRC
2) B-90-9 peppermint, stem-cut propagated by MIRC
3) Murray Mitcham peppermint, stem-cut propagated by MIRC
4) M-83-14 peppermint, stem-cut propagated by MIRC
5) 92(B-37 x M0110) peppermint, stem-cut propagated by MIRC
6) Lewis McKellip selection, nodal propagated by MIRC
7) UK-1 peppermint, nodal propagated by Lake
8) UK-2 peppermint, nodal propagated by Lake
9) McClelland selection, meristem propagated by Starkel
10) Plant Tech-94 selection, stem-cut propagated by Grey
11) Native spearmint, stem-cut propagated by MIRC
12) N-83-22 spearmint, stem-cut propagated by MIRC
13) Scotch spearmint, stem-cut propagated by MIRC
14) Scotch 770 spearmint, stem-cut propagated by MIRC
15) S-90-9 spearmint, stem-cut propagated by MIRC

Experimental design was two side-by-side randomized complete blocks (peppermint and spearmint) with four replicates. Each plot consisted of four 20-ft long rows spaced 22 inches apart with 3 ft between plots. Plant spacing was one foot within each row. Appropriate management practices (irrigation, fertility, and weed and pest control) were employed to insure maximum mint oil production. Stand vigor was rated August 7. Plots were harvested August 25, 1998, when peppermint entries were at the full bud to midbloom stage and spearmint entries were at full bloom. Some entries were exhibiting severe rust symptoms. Rust severity was estimated by visual ratings on August 19. Plant height and growth stage was determined the day before harvest. Yields were determined by swathing a 92 ft^2 area of each plot, drying a 500 g subsample to determine dry matter content, and drying a 20 lb. sample for distillation. Oil was distilled and collected by steam distillation with a research still at the NWARC. Oil samples were analyzed for quality by gas chromatography at A.M. Todd company, and the data compiled and statistical analyses performed at NWARC using MSUSTAT (Version 5.22, R.E. Lund, 1994).

RESULTS AND DISCUSSION: All entries established well with very good transplant survival. Mid summer stand evaluation indicated M-83-14 and the McClelland peppermints and Native spearmint were most vigorous, while Scotch 770 was least vigorous (Table 1). Brownish-red spots typical of the rust uredial stage were seen in all plots to different extents. At this time, symptoms were most severe in Scotch spearmint and least in the 92(B-37 x M0110) and UK-1 peppermints.

By harvest time in late August, rust symptoms had increased in severity and extent, particularly in the spearmints (both *M.cardiaca* and *M.spicata*) and in B-90-9 peppermint (Table 2). Obviously both strains of *Puccinia menthae* were active at NWARC in 1998.

In this establishment year of the study, there was variation in yield parameters among cultivars and selection groups (Table 2). No peppermint entry produced significantly more dry matter than Black Mitcham, and (B-37 x M0110), UK-2 and Plant Tech 94 produced significantly less. Of the spearmint entries, the derived line N-83-22 produced less dry matter than the parent Native, while Scotch 770 and S-90-9 produced less than the parent Scotch did.

B-37 x M0110 was lower in oil content (% of dry matter) than Black Mitcham. N-83-22 produced less oil per unit dry matter than Native, while S-90-9 had less than Scotch (Table 2). B-90-9, M-83-14, and the McKellip selection matched the Black Mitcham check entry in oil yield, while the other peppermint lines were less productive. N-83-22 spearmint produced significantly less oil than Native. S-90-9 spearmint produced significantly less oil than Scotch and Scotch770 (Table 2). None of the new cultivars or selections showed improvement over the checks in oil yield during the first year of this study.

In comparing levels of seven major components of peppermint oil to the Black Mitcham check entry, the highest menthol levels were found in Black Mitcham, B-90-9, B-37 x M0110, and the McClelland selection. (Table 3). Menthol is usually maximized when the mint approaches the full bloom stage. Black Mitcham, B-90-9, and B-37 x M0110 were at the early to mid bloom stage, but the McClelland entry had only reached full bud.

Of the spearmints, carvone levels were similar except for N-83-22, which was lower than the other entries (Table 3). For the other components listed, the Scotch and its derivations differed in content from the Native and N-83-22.

Table 1. Stand establishment evaluation of peppermint and spearmint entries in the Mint Cultivar Trial at Kalispell, MT on August 7, 1998.

Selection/Cultivar	Source	Cover *(0-5)*[1/]	Vigor *(0-5)*[2]	Stolon Spread *(0-5)*[3]	Rust *(0-5)*[4/]
PEPPERMINT					
Black Mitcham	stem-cut/MIRC	4.5	4.5	4.5	1.5
B-90-9	stem-cut/MIRC	5.0	4.5	3.0	1.0
Murray Mitcham	stem-cut/MIRC	4.0	4.0	3.5	2.5
M-83-14	stem-cut/MIRC	5.0	5.0	3.5	1.0
92 (B-37 x M0110)	stem-cut/MIRC	3.0	3.5	2.0	0.5
Lewis McKellip	nodal/MIRC	4.5	4.5	4.5	1.0
UK-1	nodal/Lake	5.0	4.0	3.5	0.5
UK-2	nodal/Lake	4.0	3.5	3.0	1.0
McClelland	meristem/Starkel	5.0	5.0	4.5	1.5
Plant Tech 94	stem-cut/Grey	3.0	3.0	3.5	1.0
SPEARMINT					
Native	stem-cut/MIRC	4.0	5.0	2.5	2.5
N-83-22	stem-cut/MIRC	3.0	3.0	1.5	2.5
Scotch	stem-cut/MIRC	5.0	4.5	1.5	3.5
Scotch 770	stem-cut/MIRC	3.0	2.5	1.0	1.0
S-90-9	stem-cut/MIRC	3.0	3.0	1.0	2.0
	LSD(0.10)	0.5	1.1	1.1	2.1

Planted 5/19/98
Harvested 8/25/98

[1/] 0=empty; 5=total plot coverage
[2/] 0=dead; 5=very healthy, vigorous growth
[3/] 0=no visible spread from crowns; 5=extensive spreading
[4/] 0=no rust symptoms; 5=very severe, leaf necrosis

Table 2. Heights, rust severity, total dry matter and oil yields for entries in the Mint Cultivar Trial established at Kalispell, MT in 1998.

Selection/Cultivar	Source	Height *inches*	Rust *(0-5)**	Hay Yield *t/a*	Oil Content *%dm*	Oil Yield *lbs/a*
PEPPERMINT						
B-90-9	stem-cut/MIRC	24	5	1.98	1.5	59.8
Black Mitcham	stem-cut/MIRC	23	4	1.98	1.4	59.3
M-83-14	stem-cut/MIRC	23	3	2.05	1.4	56.7
Lewis McKellip	nodal/MIRC	22	4	2.15	1.3	55.3
McClelland	meristem/Starkel	22	4	1.98	1.3	51.0
Plant Tech-94	stem-cut/Grey	18	3	1.73	1.4	49.5
UK-1	nodal/Lake	21	4	1.83	1.4	49.5
Murray Mitcham	stem-cut/MIRC	24	4	1.87	1.3	48.0
UK-2	nodal/Lake	20	4	1.60	1.5	46.5
92 (B-37 x M0110)	stem-cut/MIRC	25	4	1.67	1.1	38.4
SPEARMINT						
Scotch	stem-cut/MIRC	26	5	1.76	1.3	44.5
Scotch 770	stem-cut/MIRC	20	5	1.39	1.3	38.0
Native	stem-cut/MIRC	26	5	1.84	1.0	34.6
S-90-9	stem-cut/MIRC	22	5	1.41	1.0	26.3
N-83-22	stem-cut/MIRC	26	5	1.57	0.5	17.7
	LSD(0.10)	3	1	0.27	0.2	7.4
	CV(s/mean x100)	10.2	12.5	12.5	2.5	13.7

Planted 5/19/98
Harvested 8/25/98

Table 3. Oil quality components of entries in the Mint Cultivar Test at Kalispell, MT in 1998.

PEPPERMINT

Selection/Cultivar	Source	Stage*	Total Ketones %	Total Alcohol %	MF %	Menthone %	Menthol %	Ester %	Pulegone %
Black Mitcham	stem-cut/MIRC	ebl	28.4	46.4	3.89	24.6	38.4	2.09	0.46
B-90-9	stem-cut/MIRC	mbl	28.0	46.8	4.42	24.2	38.8	1.82	0.47
Murray Mitcham	stem-cut/MIRC	mbl	31.5	44.5	3.16	27.6	35.2	1.81	0.45
M-83-14	stem-cut/MIRC	mbl	32.3	44.2	3.89	27.6	36.3	1.99	0.75
92 (B-37 x M0110)	stem-cut/MIRC	mbl	30.5	46.3	3.54	27.0	38.3	1.82	0.44
Lewis McKellip	nodal/MIRC	lb	30.1	44.7	3.77	26.2	36.9	1.77	0.36
UK-1	nodal/Lake	fb	30.5	44.5	4.68	26.6	36.7	1.97	0.38
UK-2	nodal/Lake	mbl	30.7	44.5	4.53	26.9	36.7	1.91	0.39
McClelland	meristem/Starkel	fb	28.3	47.2	3.28	24.4	39.2	2.09	0.30
Plant Tech 94	stem-cut/Grey	ebl	32.0	43.3	4.23	28.1	35.8	1.63	0.35
	mean		**30.2**	**45.2**	**3.94**	**26.3**	**37.2**	**1.89**	**0.43**
	LSD(0.10)		**1.5**	**1.6**	**0.44**	**1.3**	**1.2**	**0.20**	**0.11**
	CV(s/mean)x100		**4.1**	**2.9**	**9.4**	**4.2**	**2.7**	**8.6**	**21.6**

SPEARMINT

Selection/Cultivar	Source	Stage*	A:Pinene	B:Pinene	Limonene	Cineole	Octanol	Dihydro-carvone	Carvone
Native	stem-cut/MIRC	fbl	0.96	1.39	12.80	2.54	0.91	2.31	61.53
N-83-22	stem-cut/MIRC	fbl	1.03	1.42	15.45	2.53	0.73	0.92	55.65
Scotch	stem-cut/MIRC	fbl	0.89	1.27	20.58	1.72	2.11	0.71	62.64
Scotch 770	stem-cut/MIRC	fbl	0.87	1.26	21.29	1.51	1.93	0.53	62.49
S-90-9	stem-cut/MIRC	fbl	0.90	1.34	20.89	1.83	1.73	0.51	61.36
	mean		**0.93**	**1.33**	**18.20**	**2.02**	**1.48**	**1.00**	**60.73**
	LSD(0.10)		**0.05**	**0.07**	**1.09**	**0.15**	**0.09**	**0.18**	**1.81**
	CV(s/mean)x100		**4.0**	**4.2**	**4.7**	**5.8**	**4.7**	**14.5**	**2.4**

*** mb = midbud; fb = full bud; lb = late bud; ebl = early bloom; mbl - midbloom; fbl = full bloom**

TITLE: **1997 SPEARMINT CULTIVAR/PROPAGATION TRIAL**

PERSONNEL: Leon E. Welty, Professor of Agronomy, MSU, Kalispell, MT
Louise Strang, Research Specialist, MSU, Kalispell, MT

OBJECTIVE: Evaluate new spearmint cultivars / propagation methods for vigor, hay and oil production.

DURATION: 1997-1999

PROCEDURES: Nuclear plants of Native, N-83-5, and Scotch 770 spearmint were provided by the following propagators:

Summit – stem-cut
Starkel – meristem
Lake – nodal

The meristem and nodal tissue propagated material was planted 5/20/97, and the stem-cut material was planted 5/29/97. The entries were planted in a randomized complete block design in 20-ft long plots consisting of 4 rows of 20 plants with 20-inch row spacing.

Stands were rated for vigor and stolon spread on 4/22/98. All plots were harvested 7/1/98 at the vegetative stage of maturity. A second harvest was taken 9/2/98 at the late bud to early bloom stage. Rust symptom ratings were taken prior to harvest. Harvest method and hay an oil yield calculations were the same as the other mint trials. A.M. Todd Company conducted oil quality analyses.

RESULTS AND DISCUSSION: Scotch 770 had the most vigorous early season growth, followed by N-83-5 and Native (Table 1). Spearmint propagated by nodal culture showed more extensive stolon spread than that propagated by either meristem or stem cutting.

For the first cutting, Scotch 770 had much higher oil content (%oil in dry matter) than Native and its derivative N-83-5 (Table 2). The nodal propagated Scotch 770 had a higher concentration of oil than meristem propagated. Native produced significantly more dry matter but Scotch 770 produced significantly more oil than the other cultivars. The interaction effect between cultivar and propagation source was significant in regards to hay yield. Meristem Scotch 770 produced more hay than the other propagation types, but stem cut and nodal Native and nodal N-83-5 produced more hay than meristem for these cultivars. Scotch 770 produced 67% more oil than Native and N-83-5, and the nodal propagated entries produced more than stem cut or meristem.

Rust had invaded all plots by the second cutting. Scotch 770 was more seriously affected than the Native types (Table 3). As in the first harvest, N-83-5 was tallest and Scotch 770 was shortest. Scotch 770 was the most mature, having started to bloom.

There was no significant difference between Native and N-83-5 in second harvest hay yield (Table 3). Scotch 770 produced significantly less hay. Scotch 770 had over 40% higher oil content than the other cultivars. As in the first cutting, the nodal propagated Scotch 770 contained significantly more oil per pound dry matter than the same cultivar propagated by meristem or stem cutting. Because of the higher concentration, Scotch 770 also had the highest oil yield of the three cultivars. The nodal propagated line produced over 114 lbs/acre in the second harvest.

Total oil yields are displayed graphically in Figure 1. The superiority of Scotch 770 nodal propagated material is obvious. Scotch 770 produced on the average 45% more oil than Native or N-83-5, and the nodal line produced 25% more oil than the meristem or stem cut lines. Since the nuclear plants came from three different propagators, there may have been variation in the parent material from which these lines were derived.

Differences in major quality components in first cutting oil were mainly due to species differences. None of the entries had reached the budding stage. Scotch 770 had higher carvone and limonene levels than Native or N-83-5 (Table 4). At the second cutting, Scotch 770 was slightly more mature than the Native lines. Carvone levels were significantly higher in the meristem-derived plots, but only slightly higher in the stem cut and nodal lines (Table 5). Scotch was again higher in limonene content than Native and N-83-5.

Table 1. Stand ratings for spearmint cultivars/propagation sources on 4/22/98.

VIGOR (1-5)

	Stem cut	Meristem	Nodal	means
Native	3.0	3.0	2.8	2.9
N-83-5	3.0	3.0	3.3	3.1
Scotch 770	4.0	4.0	4.3	4.1
means	3.3	3.3	3.4	LSD(0.10): cultivar: 0.2 propagation & interaction: NS

STOLON SPREAD (1-5)

	Stem cut	Meristem	Nodal	means
Native	3.3	3.5	4.0	3.6
N-83-5	3.3	3.5	4.0	3.6
Scotch 770	3.3	3.8	4.3	3.8
means	3.3	3.6	4.1	LSD(0.10) propagation: 0.5 cultivar&interaction:NS

Table 2. Height, hay yield, oil content, and oil yield of cultivars at the first cutting – 7/1/98.

HEIGHT (inches)

	Stem cut	Meristem	Nodal	means
Native	37	35	35	35
N-83-5	37	36	38	37
Scotch 770	31	31	30	31
means	35	34	34	LSD(0.10)

cultivar: 1
propagation: NS
interaction: NS

HAY YIELD (tons/acre)[1/]

	Stem cut	Meristem	Nodal	means
Native	4.05	3.64	4.10	3.93
N-83-5	3.44	3.35	4.03	3.60
Scotch 770	3.15	3.94	3.28	3.46
means	3.54	3.64	3.81	LSD(0.10)

factor means: 0.19
interaction: 0.32

OIL CONTENT (%dm)

	Stem cut	Meristem	Nodal	means
Native	.36	.38	.42	.38
N-83-5	.42	.46	.44	.44
Scotch 770	.76	.59	.87	.74
means	.51	.48	.57	LSD(0.10)

factor means: 0.08
interaction: 0.11

OIL YIELD (lbs/acre)[1/]

	Stem cut	Meristem	Nodal	means
Native	29.2	27.2	33.2	29.9
N-83-5	28.5	30.3	34.7	31.1
Scotch 770	47.0	46.5	57.9	50.4
means	34.9	34.6	41.9	LSD(0.10)

factor means: 4.5
interaction: NS

[1/] All spearmints were in the vegetative stage on 7/1/98.

Table 3. Height, disease, growth stage, hay yield, oil content, and oil yield of cultivars at the second cutting – 9/2/98.

HEIGHT (inches)

	Stem cut	Meristem	Nodal	means
Native	27	26	27	27
N-83-5	29	29	29	29
Scotch 770	27	24	23	25
means	28	26	27	

LSD(0.10)
cultivar: 1
propagation: 1
interaction: 2

RUST (0-5)*

	Stem cut	Meristem	Nodal	means
Native	2.8	2.3	3.3	2.8
N-83-5	3.3	3.3	2.8	3.1
Scotch 770	4.3	4.8	3.8	4.3
means	3.4	3.4	3.3	

LSD(0.10)
cultivar: 0.6
propagation: NS
interaction: NS

*0=no symptoms; 5=heavily infested

GROWTH STAGE

	Stem cut	Meristem	Nodal
Native	late bud	full bud	late bud
N-83-5	late bud	late bud	prebloom
Scotch 770	early bloom	prebloom	early bloom

Table 3. (cont.)

HAY YIELD (tons/acre)

	Stem cut	Meristem	Nodal	means	
Native	2.89	2.89	3.09	2.96	
N-83-5	3.08	2.90	3.03	3.00	
Scotch 770	2.65	2.62	2.47	2.58	
means	2.87	2.80	2.86	LSD(0.10)	
				factor means:	0.13
				interaction:	NS

OIL CONTENT (%dm)

	Stem cut	Meristem	Nodal	means	
Native	1.3	1.3	1.3	1.3	
N-83-5	1.4	1.3	1.3	1.3	
Scotch 770	1.7	1.7	2.2	1.9	
means	1.5	1.5	1.6	LSD(0.10)	
				factor means:	0.1
				interaction:	0.2

OIL YIELD (lbs/acre)

	Stem cut	Meristem	Nodal	means	
Native	70.9	75.1	78.4	74.8	
N-83-5	82.6	75.7	78.3	78.9	
Scotch 770	89.9	91.4	114.4	98.5	
means	81.1	80.7	90.4	LSD(0.10)	
				factor means:	6.8
				interaction:	11.7

Table 4. Quality components of 3 spearmint cultivars and 3 propagation types for the first harvest, 1998.

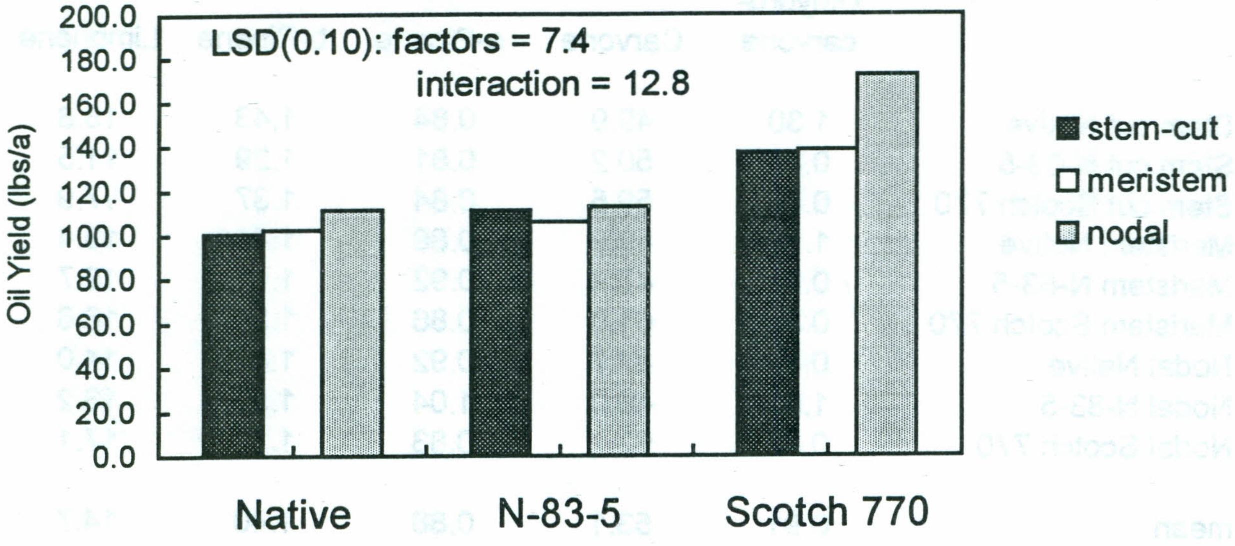
	Dihydro-carvone	Carvone	a-Pinene	b-Pinene	Limonene	Cineole
Stem cut Native	1.30	49.9	0.84	1.43	15.8	1.01
Stem cut N-83-5	0.80	50.2	0.81	1.29	11.5	1.20
Stem cut Scotch 770	0.55	59.5	0.84	1.37	17.9	1.04
Meristem Native	1.17	49.9	0.88	1.41	13.4	1.03
Meristem N-83-5	0.82	47.4	0.92	1.41	12.7	1.19
Meristem Scotch 770	0.80	61.0	0.86	1.39	16.6	0.89
Nodal Native	0.89	47.7	0.92	1.44	14.0	0.85
Nodal N-83-5	1.06	49.0	1.04	1.54	13.2	0.97
Nodal Scotch 770	0.82	63.7	0.83	1.32	17.1	0.85
mean	0.91	53.1	0.88	1.40	14.7	1.00
LSD(0.10)	0.26	3.5	NS	NS	2.4	0.20
CV(s/mean)	23.5	5.5	13.5	11.0	13.3	16.2

Table 5. Quality components of 3 spearmint cultivars and 3 propagation types for the second harvest, 1998.

	Dihydro-carvone	Carvone	a-Pinene	b-Pinene	Limonene	Cineole
Stem cut Native	1.88	61.4	1.11	1.60	11.6	2.24
Stem cut N-83-5	1.11	61.1	1.14	1.62	11.4	2.32
Stem cut Scotch 770	0.68	63.0	1.07	1.57	16.1	1.94
Meristem Native	1.27	62.1	1.10	1.58	13.5	1.99
Meristem N-83-5	0.87	60.6	1.16	1.61	11.6	2.31
Meristem Scotch 770	0.84	65.7	0.99	1.48	16.7	1.51
Nodal Native	0.92	62.6	1.10	1.53	11.9	1.74
Nodal N-83-5	0.91	62.3	1.10	1.59	13.5	2.18
Nodal Scotch 770	0.85	64.7	1.04	1.51	16.0	1.73
mean	1.04	62.6	1.09	1.56	13.6	1.99
LSD(0.10)	0.34	2.3	NS	NS	2.6	0.48
CV(s/mean)	26.8	3.0	7.7	5.8	16.1	19.9

Analysis by A. M. Todd

Figure 1. Total oil yield of spearmint cultivars/propagation types at NWARC in 1998.



TITLE: **1996 BLACK MITCHAM PROPAGATION TRIAL**

PERSONNEL: Leon E. Welty, Professor of Agronomy, MSU, Kalispell, MT
Louise Strang, Research Specialist, MSU, Kalispell, MT
Dr. Bill Grey, Asst. Research Professor, MSU, Bozeman, MT
Cathy & Tom Smith, Summit Labs, Fort Collins, CO

OBJECTIVE: Determine effect of propagation source and method on vigor, hay yield, oil yield, and oil quality of Black Mitcham peppermint.

DURATION: 1996-1999

PROCEDURES: Nuclear plants representing stem-cut, *in vitro* nodal and meristem culture were propagated from a single plant or from a randomly selected group of plants from the Black Mitcham mother block by Summit Labs. These seven entries plus plants from a contaminated culture of Lake's were planted on June 4 and 5, 1996. Seven lines from various sources were stem-cut propagated at the NWARC and planted on June 17, 1996.

The MIRC 1, 2, 5, and 7 entries came from a cutting off a single plant from the Black Mitcham mother bed at Summit Plant Laboratories, Inc.(Table 1.) Entries MIRC 3, 4, and 6 originated from a group of plants randomly selected from the mother bed. Stem cut plants (MIRC 1, 6, 7) were grown directly from cuttings off the original parent or the random plant selection group. Nodal tissue culture plants (MIRC 2, 4) were grown from surface disinfected, trimmed nodal cuttings placed in sterile culture medium with no growth regulators. One month later, the explants that remained free of contamination were transferred as nodal cuttings to another culture medium to increase populations. Rooted *in vitro* plantlets were then transferred to plug trays in the greenhouse. The meristem/parent plant entry (MIRC 5) originated from *in vitro* plantlets created from nodes subcultured from the single parent plant and grown under standard growth conditions in the laboratory for 8 weeks. The mature cultures were then heat treated at 34^{0}-36^{0} C for 6 days. Meristem explants were grown *in vitro* under standard conditions, increased, and finally transplanted into plug trays in the greenhouse. The meristem/random selection entry (MIRC-3), however, received no heat treatment. Meristems were taken from randomly selected *in vitro* plants in the commercial production block in the laboratory. The 5 surviving meristem lines from this process provided the material for this entry. The MIRC-7 entry was stem cut from a separate bed created from rooted *in vitro* plantlets derived from the single parent.

The NWARC lines consisted of material obtained from two meristem fields located at the NWARC (R-5 and R-7), material obtained from the 1994 cultivar evaluation trial (Lake 94 and Plant Tech 94), material from two productive Black Mitcham fields in the Flathead (Montana 1, Montana 2), and material obtained from George McClelland (Idaho) (Table 1). Stolons were dug from each source location on February 14, 1996 and planted in separate flats in the NWARC laboratory. After shoot emergence, stem segments containing two leaf nodes were removed and planted in trays containing potting medium (half in plugs and half in open trays). Plantlets were grown at ambient lab temperature under fluorescent lights. All propagation lines were successfully established in a randomized block design. Appropriate management practices (irrigation, fertility, weed and pest control) were employed to insure maximum mint growth and oil production.

Entries were evaluated for stand vigor indicators May 29, 1998. All plots were harvested August 5. Hay yield was measured, and 20 pounds green material from each plot was dried and the oil separated by steam distillation to determine oil yield. Oil samples from each plot were sent to A.M.Todd Co. for quality component analysis.

Data were analyzed using MSUSTAT Version 5.22 (R.E. Lund, Montana State University).

RESULTS AND DISCUSSION: The seven MIRC entries allow us to compare different propagation methods carried out in the same laboratory, eliminating variance due to the propagation environment (equipment, personnel, source material, etc.). As in 1997, plants propagated from meristem culture produced significantly more dry matter than non-meristem plants (Fig.1). This supports previous observations that meristem derived Black Mitcham exhibits more vigorous growth than non-meristem peppermint. There was no difference in hay yield between single parent derivation and propagation from a group.

Unlike 1997, oil yield was not affected by propagation method directly. Parental selection, however, and its interaction with propagation method were significant (Fig.2). Non-meristem propagated plants derived from a randomly selected parental group produced more oil than meristem propagated plants from the random selection. Meristem-propagated plants cloned from a single plant yielded slightly more oil than those from the random group. The superiority of using a random selection of parental plants reinforces the previous indication that there is variation within the Black Mitcham mother block for some trait influencing oil yield. The fact that this was **not** observed in the entries that had been propagated by meristem culture suggests that this high oil factor was reduced or eliminated by this technique.

The objective of propagating at NWARC was to determine if the high vigor/lower oil yield characteristic attributed to *in vitro* nodal or meristem culture could be transferred through the stem-cut process. Plants derived from the Lake 94 (source: Lake 92) nodal material produced slightly more dry matter and 14% less oil than that derived from the Plant Tech 94 stem cut material (Table 2). This is the same relationship observed in 1997, except the difference in dry matter production is not significant. This confirms the persistence of the high oil yield trait associated with the Plant Tech material.

In 1997, correlations between response variables revealed a strong negative correlation between dry matter production and oil yield. This relationship was no longer significant in 1998 (Table 3). Oil yield and early season stand vigor are not significantly related.

Oil quality analysis revealed variation among entries in certain components (Table 4). All plots were in the late bud stage of development. The oil was characteristic of immature oil, being low in menthol and esters and high in menthone. The menthofuran levels are high for this region considering no blossoms were present.

Table 1. Descriptions of entries in Black Mitcham peppermint propagation evaluation planted at NWARC in 1996.

Source	Propagator	Method	Origin
MIRC 1	Summit Labs	stem cut	parent plant
MIRC 2	Summit Labs	nodal tissue culture	parent plant
MIRC 3	Summit Labs	meristem tissue culture	random selection
MIRC 4	Summit Labs	nodal tissue culture	random selection
MIRC 5	Summit Labs	meristem tissue culture	parent plant
MIRC 6	Summit Labs	stem cut	random selection
MIRC 7	Summit Labs	stem cut	reestablished tissue culture from parent plant
Lake 96	Lake's	nodal tissue culture	bacteria infected culture
Lake 94	NWARC	stem cut	1994 trial - nodal
Plant Tech 94	NWARC	stem cut	1994 trial - stem-cut
R-5 field	NWARC	stem cut	meristem low vigor field
R-7 field	NWARC	stem cut	meristem high vigor field
Montana 1	NWARC	stem cut	stem-cut high yield field
Montana 2	NWARC	stem cut	stem-cut high yield field
Idaho	NWARC	stem cut	McClelland stolons

Table 2. Stand observations, hay and oil yields of Black Mitcham propagation lines in 1998.

	Evaluated 5/29/98		Harvested 8/5/98		
Source	Row Cover %	Vigor (0-5)[1/]	Oil Yield lbs/acre	Hay Yield tons/acre	Oil Content % dm
Summit Labs					
stem/single	79	2.8	58.4	2.52	1.2
nodal/single	85	3.5	62.5	2.36	1.3
Meristem/random	91	4.8	61.3	2.66	1.1
nodal/random	80	3.0	69.8	2.48	1.4
Meristem/single	89	4.5	64.8	2.72	1.2
stem/random	79	2.8	69.7	2.31	1.5
stem/nodal/single	81	3.5	58.7	2.52	1.2
Lake 96	84	3.0	73.8	2.70	1.4
NWARC					
Lake 94	85	3.8	63.2	2.42	1.3
Plant Tech 94	81	3.3	73.5	2.34	1.6
R-5 field	59	2.3	64.4	2.23	1.4
R-7 field	76	3.5	66.9	2.37	1.4
Montana 1	81	3.8	70.1	2.38	1.5
Montana 2	76	2.5	65.9	2.16	1.5
Idaho	78	2.8	77.7	2.21	1.7
LSD(0.10)	8	0.9	6.8	0.24	0.2
CV(s/mean x100)	8.5	22.3	8.6	8.3	10.0

[1] 0=no growth; 5=plants exhibiting healthy, vigorous growth

Table 3. Pearson correlations (r^2) with P-values of vigor, yield, and oil content levels of Black Mitcham propagation lines at Kalispell in 1998.

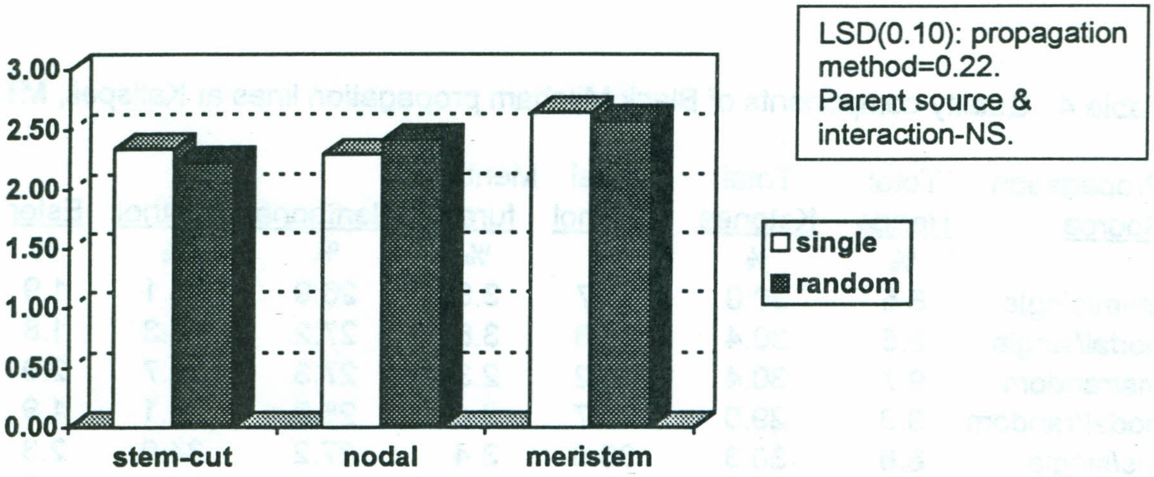
		Hay Yield	Oil Yield	Oil Content
Vigor	r^2	0.6463	-0.2845	-0.5677
	P	0.0092	0.3041	0.0273
Hay Yield	r^2		-0.2724	-0.7055
	P		0.3260	0.0033
Oil Yield	r^2			0.8568
	P			0.0000

Table 4. Quality components of Black Mitcham propagation lines at Kalispell, MT (GC%).

Propagation Source	Total Heads %	Total Ketones %	Total Alcohol %	Mentho-furan %	Menthone %	Menthol %	Ester %	Pulegone %
stem/single	8.5	30.0	36.7	3.6	26.9	34.1	1.9	1.01
nodal/single	9.5	30.4	35.8	3.6	27.2	33.3	1.8	0.91
ms/random	9.7	30.4	36.2	2.3	27.3	33.7	2.0	0.50
nodal/random	9.9	29.0	36.7	3.4	26.0	34.1	1.9	0.73
ms/single	8.8	30.3	36.6	3.4	27.2	34.0	2.3	0.72
stem/random	9.6	28.2	37.7	2.9	25.1	35.1	2.3	0.62
st/nod/single	8.5	30.4	34.7	3.8	27.3	32.1	2.0	0.95
Lake 96	9.8	30.7	35.5	2.8	27.6	33.1	1.9	0.67
Lake 94	9.6	28.6	37.1	3.7	25.8	34.3	2.1	0.79
Plant Tech	9.9	29.3	36.7	3.1	26.2	34.2	1.8	0.76
R-5 field	9.3	28.3	38.2	3.4	25.3	35.6	1.9	0.71
R-7 field	9.4	29.7	36.5	3.4	26.6	34.0	1.9	0.77
Montana 1	10.0	30.1	35.6	3.5	25.9	33.9	2.0	0.81
Montana 2	10.1	28.8	36.6	3.4	25.8	34.1	1.9	0.75
Idaho	9.8	29.0	37.2	3.4	25.2	35.1	2.0	0.74
Mean	9.5	29.5	36.5	3.3	26.3	34.0	2.0	0.76
LSD(0.10)	0.7	NS	1.4	0.4	NS	1.4	NS	0.15
CV(s/mean)%	6.0	1.8	3.2	9.8	5.7	3.4	0.3	16.4

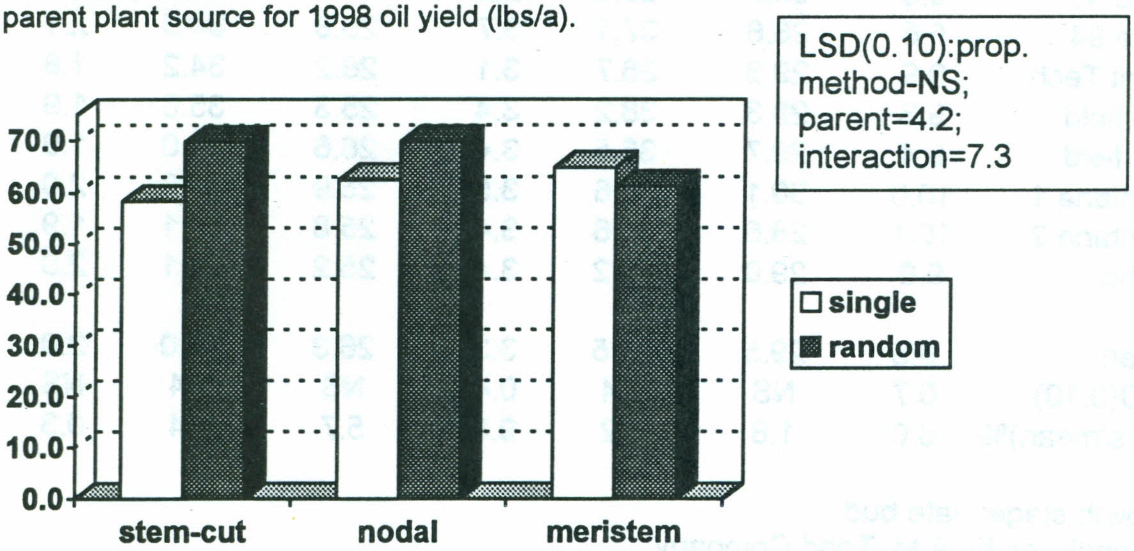
Growth stage: late bud
Oil analyses by A.M. Todd Company

Figure 1. Comparisons among MIRC propagated entries by propagation method and parent plant source for 1998 dry matter yield (tons/a).



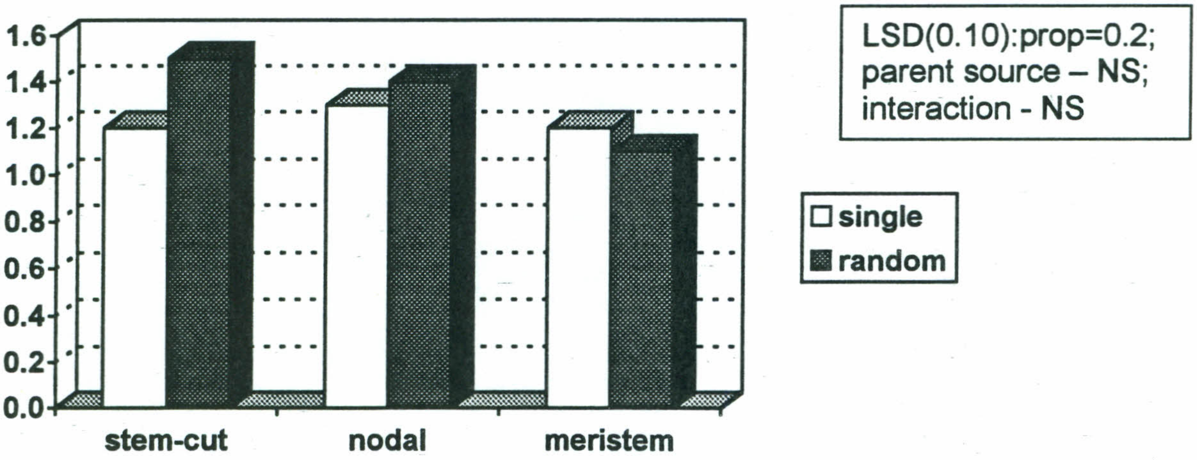
LSD(0.10): propagation method=0.22. Parent source & interaction-NS.

Figure 2. Comparisons among MIRC propagated entries by propagation method and parent plant source for 1998 oil yield (lbs/a).



LSD(0.10):prop. method-NS; parent=4.2; interaction=7.3

Figure 3. Comparisons among MIRC propagated entries by propagation method and parent plant source for 1998 oil content (% of dry matter).



LSD(0.10):prop=0.2; parent source – NS; interaction - NS

TITLE:	**PEPPERMINT FALL HARVEST MANAGEMENT TRIAL**
PERSONNEL:	Leon E. Welty, Professor of Agronomy, MSU, Kalispell, MT Louise Strang, Research Specialist, MSU, Kalispell, MT Gail Sharp, Research Assistant, MSU, Kalispell, MT
OBJECTIVE:	Determine the effect of harvest timing on peppermint hay yield, oil yield, oil quality, and spring vigor.
DURATION:	1996-1999

PROCEDURES: The study was initiated in 1996. Plots (10' x 30') were laid out in an established stand of Black Mitcham, meristem derived (stolon source – Sonstelie Farms), and treatments assigned in a randomized complete block design with 4 replicates. Treatments in were 7 harvest dates at 10-day intervals (July 31-Sept.30) and an uncut check. Stolons were dug from a one-foot square area in each plot on 3/25-27/98 and weighed to determine the effect of 1997 harvest timing on stolon mass. The same harvest dates were imposed on each plot in 1998. At each harvest, morphological stage, height, lodging, and dry matter yield were determined. Approximately 20 pounds of herbage from each plot was air dried and the oil removed by steam distillation. Oil yield was calculated and samples sent to A.M. Todd Co. for chemical analyses.

In 1998, 250 lbs/a N, 52 lbs/a P_2O_5, 100 lbs/a K_2O and 34 lbs/a S were applied. Assure II (15 oz/a) was applied on 5/13/98. Sinbar was applied in May at one lb AI/acre.

RESULTS AND DISCUSSION: The mint was at the full bud stage on the first harvest date and was senescent by the last harvest on Sept. 30. The first frost (28^0 F) did not occur until after the final harvest. The frost free period was 137 days in 1998, compared to a 49-year average of 114 days. There were 1873 growing degree days (GDD) for mint in 1998 compared to 1597 GDD in 1997.

Maximum stolon mass was found in plots harvested 8/11/97 and minimum stolon mass in plots harvested 9/30/97, which was one week before the first killing frost (Figure 1).

Dry matter yield increased to 3.30 tons/acre on 8/31, when the mint reached the full bloom stage (Table 1c). It decreased to 2.79 tons/acre by 9/30 (Figure 2). Oil yield increased to 95.3 lbs/acre on 9/10 when the mint had reached full bloom, and then declined to 65.1 lbs/acre by the time leaves senesced (Table1c). This represented a 51% increase in oil yield when harvest was delayed from July 31 to Sept. 10. In 1997 oil yield decreased after the first harvest. There was no relationship between spring stolon mass and oil yields (Figures 1 & 3).

Levels of the oil quality components corresponded with the stage of maturity of the mint at time of harvest. Total ketones and menthone decreased as the mint progressed from bud to full bloom, with the exception of the 8/31 harvest (Table 2c). Total alcohols and menthol continued to increase through the last harvest as did % esters. Menthofuran increased until 8/20 (85% bloom) and then leveled off at approximately 10% (Table2c). Menthofuran levels for prime quality Montana peppermint usually range from 1-4%. Except for the first harvest, before flowering commenced, MF levels exceeded 4% in 1998 as in 1997. MF levels from the research still are somewhat higher than production stills. In 1998, we compared whole vs chopped mint in the research still and found that chopped hay had higher menthol and lower MF levels than whole hay. To date the mint research plots are cooked whole. Desirable oil contains 45% menthol. Menthol in 1998 did not reach this level until the 9/23 harvest, when the plants were approaching maturity (Table 2c). Oil yield increased from 7/31 to 8/31 and 9/10 and then declined as the mint senesced.

Optimum harvest date is affected by environment/year. In 1996 and 1998, later harvests produced the most oil, whereas in 1997 early harvests produced the most oil (Figure 3). The relationship between oil production and Growing Degree Days (GDD) was not very consistent (Tables1a, 1b, 1c). In 1996 oil production peaked at about 1300 GDD, whereas in 1998 yields were not maximized until GDD 1600. Total GDD was low in 1996 because May and August were below normal. June, however, was close to normal and July exceeded the norm by 31 GDD. This may explain why later harvests in 1996 produced more oil.

Table 1a. Hay and oil yields for peppermint harvested in **1996**.

Date	Accum GDD	Growth Stage	Hay Yield tons/ac	Oil Content % DM	Oil Yield lbs/ac
8/1	925.5	20% bud	1.89	1.3	48.1
8/12	1060.5	full bud	2.33	1.3	59.8
8/22	1211.0	10% bloom	2.98	1.3	74.5
8/30	1336.0	20% bloom	3.01	1.3	77.9
9/10	1442.0	mid bloom	3.61	0.9	62.4
9/19	1526.0	90% bloom	2.98	1.1	62.9
9/27	1526.0	frozen	2.67	1.0	56.1
mean			2.78	1.2	63.1
LSD(0.10)			0.27	0.1	6.5

Table 1b. Hay and oil yields for peppermint harvested in **1997**.

Date	Accum GDD	Growth Stage	Hay Yield tons/ac	Oil Content % DM	Oil Yield lbs/ac
8/1	948.0	mid bud	5.66	0.6	71.3
8/12	1140.5	full bud	4.30	0.7	60.4
8/22	1283.0	mid bloom	4.23	0.8	65.6
8/30	1394.5	late bloom	4.35	0.9	59.9
9/10	1539.0	late bloom	4.02	0.8	63.8
9/19	1597.0	late bloom	2.99	0.7	40.8
9/29	1597.0	mature	2.74	0.4	22.1
mean			4.04	0.7	54.8
LSD(0.10)			0.83	0.1	13.0

Table 1c. Hay and oil yields for peppermint harvested in **1998**.

Date	Accum GDD	Growth Stage	Hay Yield tons/ac	Oil Content % DM	Oil Yield lbs/ac
7/31	1064.0	full bud	2.32	1.4	63.0
8/10	1257.5	mid bloom	2.23	1.5	65.8
8/20	1433.5	85% bloom	2.73	1.1	61.5
8/31	1602.0	full bloom	3.30	1.4	92.7
9/10	1796.0	full bloom	3.20	1.5	95.3
9/23	1872.5	seed set	3.07	1.3	79.5
9/30	1872.5	leaf drop	2.79	1.2	65.1
mean			2.80	1.3	74.7
LSD(0.10)			0.25	0.2	8.3

Table 2a. Quality components of peppermint harvested on different dates in **1996.**

DATE	Menthol	Neo-menthol	Menthone	D-iso-menthone	Esters	MF	Pulegone
				GC%			
8/1	38.9	3.2	24.8	2.9	3.7	1.9	0.15
8/12	43.1	3.6	20.1	2.6	3.7	2.3	0.19
8/22	42.9	3.5	19.1	2.3	3.6	3.3	0.47
8/30	42.2	3.5	18.9	2.2	3.9	4.2	0.57
9/10	43.7	3.6	16.8	1.9	5.2	4.6	0.38
9/19	45.4	3.7	14.4	1.7	6.3	4.9	0.21
9/27	47.2	3.7	13.4	1.7	6.2	4.4	0.17
MEAN	43.3	3.5	18.2	2.2	4.6	3.7	0.30
LSD(0.10)	1.3	0.1	1.7	0.1	0.5	0.3	0.05

Table 2b. Quality components of peppermint harvested on different dates in **1997.**

DATE	Menthol	Total Alcohol	Menthone	Total Ketones	Esters	MF	Pulegone
				GC%			
8/1	37.2	47.3	28.3	30.8	4.1	2.1	0.3
8/12	36.8	46.7	25.5	27.9	4.0	4.7	1.1
8/22	39.3	49.7	20.7	22.7	4.5	7.4	1.2
8/30	43.2	55.2	15.1	16.9	5.8	7.7	1.1
9/10	44.0	56.9	12.9	14.4	7.0	10.3	0.8
9/19	44.5	57.8	13.2	14.5	7.9	10.9	0.4
9/29	46.6	60.7	12.3	13.5	8.7	10.3	0.3
MEAN	41.7	53.5	18.3	20.1	6.0	7.6	0.7
LSD(0.10)	1.1	1.3	1.2	1.2	0.4	0.6	0.1

Table 2c. Quality components of peppermint harvested on different dates in **1998.**

DATE	Menthol	Total Alcohol	Menthone	Total Ketones	Total Ester	MF	Pulegone
				GC%			
7/31	36.6	45.5	25.3	29.3	3.4	3.8	0.7
8/10	39.4	49.6	18.7	22.7	4.2	6.1	1.7
8/20	38.7	49.4	15.8	19.5	4.8	9.8	2.4
8/31	39.2	49.8	17.6	21.1	4.9	9.7	1.3
9/10	41.5	53.0	15.8	19.0	6.1	9.9	0.6
9/23	44.6	57.5	12.7	15.7	7.7	9.9	0.4
9/30	46.3	59.6	10.7	13.5	8.1	10.1	0.3
MEAN	40.9	52.0	16.7	20.1	5.6	8.5	1.1
LSD(0.10)	1.3	1.6	1.1	1.2	0.3	0.6	0.[illegible]

Figure 1. Stolon masses of mint harvested on different dates in 1997.

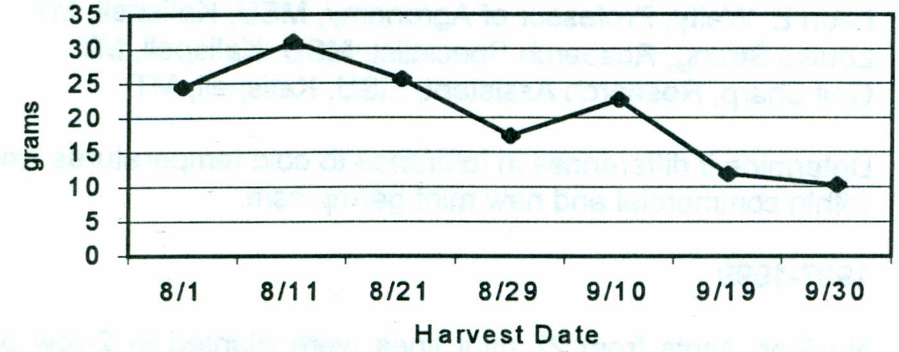


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Figure 2. Hay yields of peppermint harvested at 7 dates in 1998.

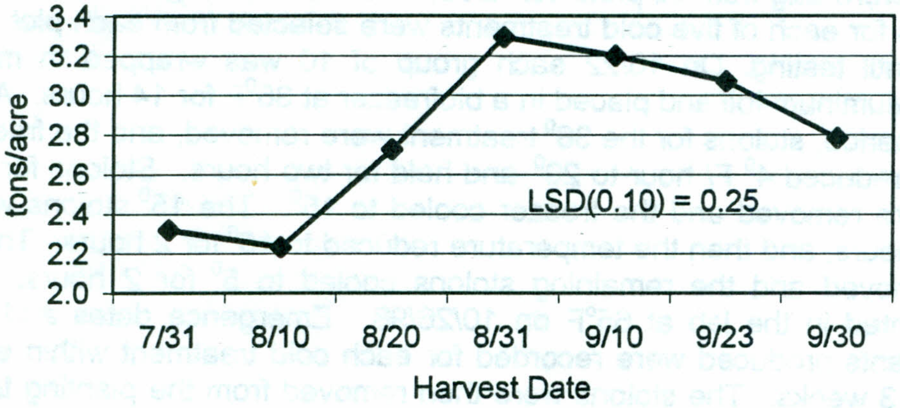
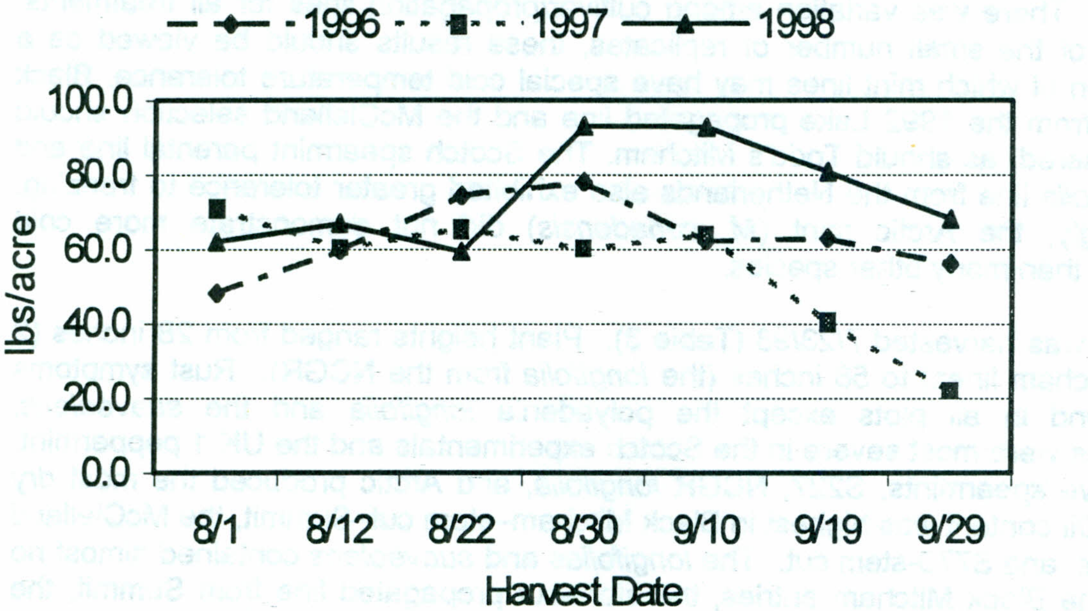


Figure 3. Oil yields of peppermint harvested at 7 dates in 1996, 1997, and 1998.



LSD(0.10):

1996 = 6.5
1997 = 13.0
1998 = 8.3

TITLE: **EFFECT OF FREEZING ON SURVIVAL OF PEPPERMINT AND SPEARMINT RHIZOMES/STOLONS.**

PERSONNEL:
Leon E. Welty, Professor of Agronomy, MSU, Kalispell, MT
Louise Strang, Research Specialist, MSU, Kalispell, MT
Gail Sharp, Research Assistant, MSU, Kalispell, MT

OBJECTIVE: Determine if differences in tolerance to cold temperatures exist within commercial and new mint germplasm.

DURATION: 1997-1999

PROCEDURES: Nuclear plants from 27 mint lines were planted in 2-row plots between 5/21/97 and 6/3/98 in a randomized block design with 2 replicates (Table 1). The mint was harvested 7/23/98, and fall regrowth was removed 9/15/98. The stolons/rhizomes were dug from all plots 10/16/98, cleaned and weighed. Ten, two-inch stolon pieces for each of five cold treatments were selected from each plot and stored at 40°F until testing. On 10/22 each group of 10 was wrapped in moist cheesecloth and aluminum foil and placed in a biofreezer at 36°F for 14 hours. After this conditioning period, stolons for the 36° treatment were removed, and the freezer temperature was reduced 4° F/ hour to 20° and held for two hours. Stolons for the 20° treatment were removed and the freezer cooled to 15°. The 15° stolons were removed after 2 hours, and then the temperature reduced to 10° for 2 hours. These stolons were removed and the remaining stolons cooled to 5° for 2 hours. The stolons were planted in the lab at 65°F on 10/26/98. Emergence dates and the number of live plants produced were recorded for each cold treatment within each stolon source for 3 weeks. The stolons were then removed from the planting trays and biomass recorded.

RESULTS AND DISCUSSION: Stolon survival data are summarized in Table 2 and Figure 1. There was variation among cultivar/propagation lines for all treatments. Because of the small number of replicates, these results should be viewed as a suggestion of which mint lines may have special cold temperature tolerance. Black Mitcham from the 1992 Lake propagated line and the McClelland selection should be considered, as should Todd's Mitcham. The Scotch spearmint parental line and the *longifolia* line from the Netherlands also exhibited greater tolerance to freezing. Surprisingly, the Arctic mint (*M. canadensis*) did not demonstrate more cold tolerance than many other species.

The mint was harvested 7/23/98 (Table 3). Plant heights ranged from 28 inches (2 Black Mitcham lines) to 58 inches (the *longifolia* from the NCGR). Rust symptoms were found in all plots except the polyadenia *longifolia* and the *suaveolens*. Symptoms were most severe in the Scotch experimentals and the UK-1 peppermint. The Native spearmints, S227, NCGR *longifolia*, and Arctic produced the most dry matter. Oil content was highest in Black Mitcham–stem cut–Summit, the McClelland selections, and S770-stem cut. The *longifolia*s and *suaveolens* contained almost no oil. Of the Black Mitcham entries, the stem-cut propagated line from Summit, the MIRC92 line, the McClelland lines, Todd's Mitcham and M-83-7 produced the most oil. The Scotch spearmint lines S213 and S770-stemcut propagated were among the top producers, as was the *M.canadensis* "Arctic" entry.

Table 1. Entries in the *Mentha* cold tolerance study at NWARC.

Species	**Cultivar**	**Propagation Method**	**Source**	**Propagator**
piperita	Black Mitcham	meristem	MIRC	Summit
piperita	Black Mitcham	meristem	MIRC	Starkel
piperita	Black Mitcham	nodal	MIRC-92	Lake
piperita	Black Mitcham	nodal	McClelland	Lake
piperita	Black Mitcham	nodal	English 1	Lake(Margetts-Roberts)
piperita	Black Mitcham	nodal	English 2	Lake
piperita	Black Mitcham	nodal	McClelland	Lake(Mc96-7)
piperita	Black Mitcham	nodal	McClelland	Lake(Mc96-19)
piperita	Black Mitcham	stemcut	MIRC	Summit
piperita	Black Mitcham	stemcut	McClelland	Clarke
piperita	M-83-7	stemcut	MIRC	Summit
piperita	Murray Mitcham	stemcut	MIRC	Summit
piperita	Roberts Mitcham	stemcut	MIRC	Summit
piperita	Todd's Mitcham	stemcut	MIRC	Summit
cardiaca	Scotch	stemcut	MIRC	Summit
cardiaca	Scotch 213	stemcut	MIRC	Summit
cardiaca	Scotch 227	stemcut	MIRC	Summit
cardiaca	Scotch 770	meristem	MIRC	Starkel
cardiaca	Scotch 770	stemcut	MIRC	Summit
spicata	N-83-5	stemcut	MIRC	Summit
spicata	Native	meristem	MIRC	Starkel
spicata	Native	stemcut	MIRC	Summit
canadensis	Arctic	nodal	I.P.Callison	Lake
longifolia	*hymaliensis*	stemcut	Davis	Grey
longifolia	*polyadenia*	stemcut	Davis	Lake (S.Africa)
longifolia		nodal	NCGR	Lake (Netherlands)
suaveolens	rotundifolia	nodal	NCGR	Lake (Minnesota)

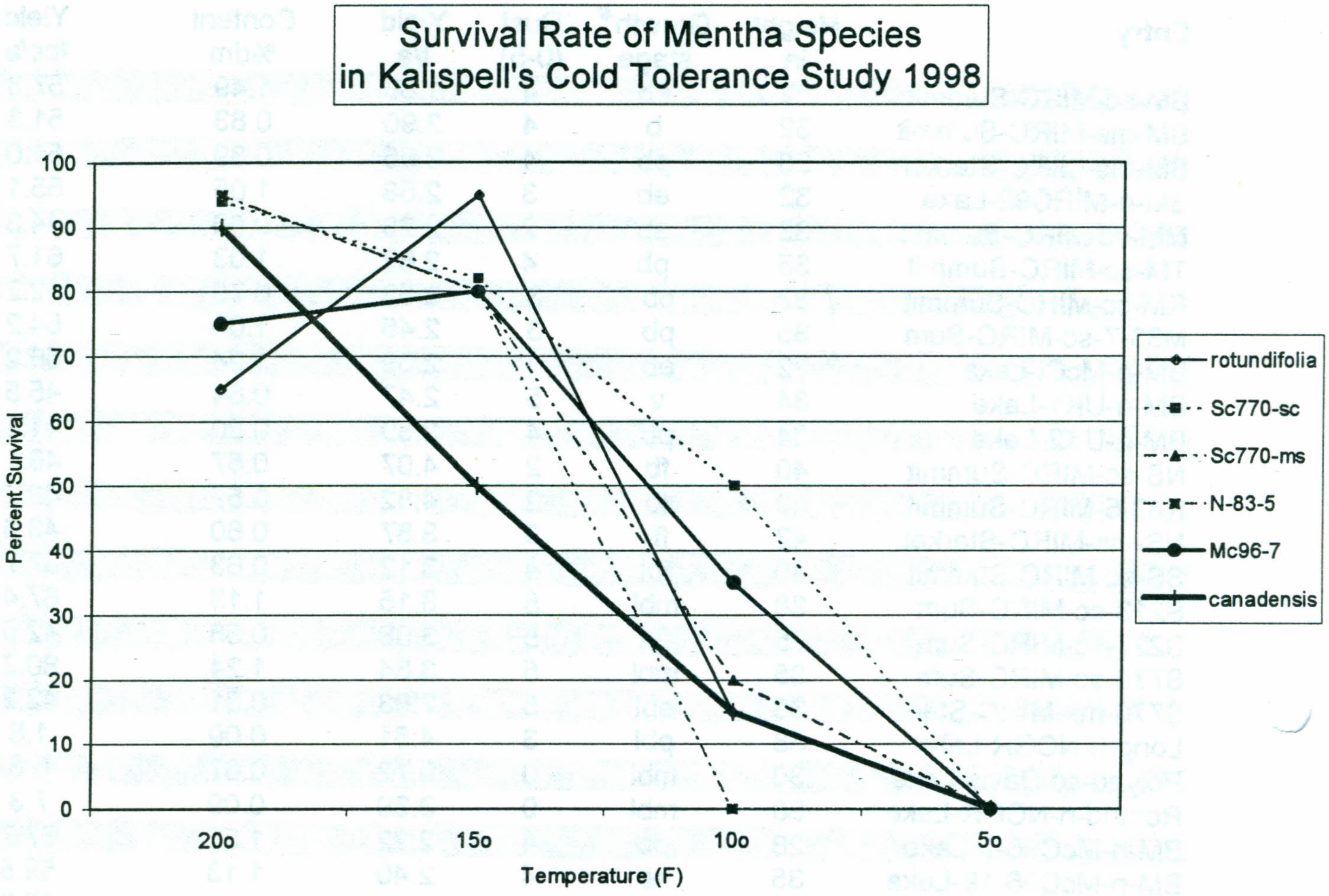
Table 2. Survivorship of stolon segments at four freezing treatments.

	36°check	20°	15°	10°	5°
BM-ms-MIRC-Summit	85	85	70	0	0
BM-sc-MIRC-Summit	100	95	85	5	0
BM-ms-MIRC-Starkel	95	80	95	25	0
BM-n-MIRC92-Lake	95	95	100	85	0
BM-McClelland/Clarke	100	90	80	30	0
BM-n-McC96-19-Lake	79	70	55	15	0
BM-n-McC96-7-Lake	95	75	80	35	0
BM-n-McC-Lake	85	95	95	30	5
BM-n-UK1-Lake	95	90	85	0	0
BM-n-UK2-Lake	95	80	75	0	0
M83-7-sc-MIRC-Sum	95	75	80	0	0
MM-sc-MIRC-Summit	95	95	95	10	0
RM-sc-MIRC-Summit	100	90	90	0	0
TM-sc-MIRC-Summit	95	85	100	75	0
N83-5-MIRC-Summit	100	95	80	0	0
NS-ms-MIRC-Starkel	95	75	85	0	0
NS-sc-MIRC-Summit	100	60	65	35	0
S770-ms-MIRC-Starkel	95	95	80	20	0
S770-sc-MIRC-Sum	40	94	82	50	0
S213-sc-MIRC-Sum	95	80	80	0	0
S227-sc-MIRC-Sum	96	35	80	0	0
SS-sc-MIRC-Summit	60	75	70	35	20
Hymal-sc-Davis-Grey	100	95	85	0	0
Long-n-NCGR-Lake	100	100	100	30	0
Poly-sc-Davis-Lake	85	50	75	15	0
Arctic-n-Callison-Lake	95	90	50	15	0
Rotund-n-NCGR-Lake	95	65	95	15	0
mean	91	80	80	18	1
CV(s/mean)%	15	17	24	141	

Table 3. Height, growth stage, rust symptoms and yield components of entries.

Entry	Height in	Growth[4/] stage	Rust (0-5)	Yield t/a	Content %dm	Yield lbs/a
BM-sc-MIRC-Summit	32	eb	4	1.86	1.49	57.3
BM-ms-MIRC-Summit	32	b	4	2.90	0.83	51.3
BM-ms-MIRC-Starkel	28	pb	4	2.85	0.89	51.0
BM-n-MIRC92-Lake	32	eb	3	2.58	1.05	55.1
MM-sc-MIRC-Summit	33	eb	2	2.28	0.90	44.3
TM-sc-MIRC-Summit	35	pb	4	2.82	1.03	61.7
RM-sc-MIRC-Summit	32	pb	3	2.83	0.70	42.2
M83-7-sc-MIRC-Sum	35	pb	3	2.45	1.06	54.2
BM-n-McCl-Lake	32	eb	4	2.39	1.24	56.2
BM-n-UK1-Lake	34	v	5	2.47	0.84	45.5
BM-n-UK2-Lake	34	pb	4	2.39	0.80	41.1
NS-sc-MIRC-Summit	40	fb	2	4.07	0.57	46.1
N83-5-MIRC-Summit	40	lb	2	4.82	0.57	48.7
NS-ms-MIRC-Starkel	42	fb	3	3.87	0.60	43.6
SS-sc-MIRC-Summit	40	fbl	4	3.12	0.63	37.7
S213-sc-MIRC-Sum	38	mbl	5	3.15	1.13	67.4
S227-sc-MIRC-Sum	35	fbl	5	3.68	0.58	42.5
S770-sc-MIRC-Sum	35	mbl	5	3.34	1.24	80.2
S770-ms-MIRC-Star	36	ebl	5	2.83	0.81	42.2
Long-n-NCGR-Lake	58	pbl	3	4.51	0.00	1.8
Polyad-sc-Davis-Lake	30	mbl	0	0.72	0.67	6.8
Rotund-n-NCGR-Lake	30	mbl	0	3.39	0.09	7.3
BM-n-McC96-7-Lake	28	pb	4	2.22	1.55	67.7
BM-n-McC96-19-Lake	35	eb	4	2.40	1.13	59.5
Arctic-n-Callison-Lake	37	mb	4	4.21	0.85	67.6
mean				2.96	0.85	47.2
LSD(0.10)				1.16	0.37	26.4
CV(s/mean)%				22.9	19.6	25.4

Figure 1. Survival of stolons from various *Mentha* species subjected to freezing treatments.



TITLE: **PEPPERMINT HILLING STUDY**

PERSONNEL:
Leon E. Welty, Professor of Agronomy, MSU, Kalispell, MT
Louise Strang, Research Specialist, MSU, Kalispell, MT
Gail Sharp, Research Assistant, MSU, Kalispell, MT
Dale Sonstelie, Producer, Flathead County, MT
Phil Clarke, Producer, Flathead County, MT
Myron Mast, Producer, Flathead County, MT

OBJECTIVE: Determine if different management practices affect the viability of peppermint stolons.

DURATION: 1997-1998

PROCEDURES: Black Mitcham rhizomes/stolons derived from *in vitro* nodal propagation (from 1995 nuclear plants – Lake 94 source), generation #1, were dug in May of 1997 from the Myron Mast farm and replanted in replicated plots at NWARC. The following cultural treatments were imposed:

Trt	Culture	Operation	Harvest
1	Flat	No hilling	None
2	Flat	Cultivate between rows 7/1, 7/16	9/24
3	Disk Hill	½ coverage 8/6, 2/3 on 9/2, Stolons covered 9/17 & 10/8	None
4	Flat	No hilling	8/25
5	Shank/Disk	¼ shank 7/1, 7/16, 8/1 1/3 disk 8/15, ½ disk 9/2 Stolons covered 9/17 and 10/8	None
6	Disk Hill	½ coverage 7/1	None
7	Disk Hill	½ coverage 8/6, 2/3 on 9/2 Stolons covered 9/17	None
8	Disk Hill	½ coverage 8/6, 2/3 on 9/2 Stolons covered 10/8	None

Stolons/rhizomes were dug from a 3-foot square area in each plot between 4/6 and 4/8/98. The entire mass was rinsed and weighed, and 20 two-inch segments from the healthiest looking stolons were removed. The remainder of the stolon mass was air dried and weighed. Another 3-square-foot area was dug from each plot and 20 segments chosen at random (not selected for "quality"). The stolons were planted in a randomized complete block design with 3 replicates, with the "best" segments on one side and the "random" segments on the other side of the plot.

On 7/21 and 7/22/98 plant height was measured and all plants dug from each plot. Number of live rhizomes were counted, and the top growth separated from the crowns and underground growth. These components were weighed wet and then air dried and weighed again. Hilling treatments were submitted to ANOVA and mean effects separated by LSD (student's t) at the 0.10 significance level.

RESULTS AND DISCUSSION: There were no significant differences in total dry weight or in the wet weight of the 2" pieces selected from the "best" stolons (Table 1). Treatments having the highest stolon mass (wet) were the non-harvested flat culture and the flat culture harvested 8/25. The shank/disk and disk hill treatment covered once on 7/1 also had good stolon mass. The flat culture harvested 9/24 had approximately half the stolon mass of that harvested earlier in the season, indicating that a late harvest just before the first frost had a detrimental effect on stolon vigor the following spring.

There were no significant differences in plant height or root mass among the treatments planted in 1998 (Table 2). The unharvested flat culture, the early harvest flat, and two of the disking treatments had the greatest number of live rhizomes. These two flat culture treatments and three of the disk treatments produced the most topgrowth. The differerence between the two harvest dates on the flat cultures can be explained by the the greater amount of regrowth on the early harvest providing more carbohydrate reserves to the roots as well as the insulating protection of the residue. Differences among the disk treatments are harder to explain. Perhaps the 3 shanking treatments early in the season damaged the stolons.

Table 1. Stolon/rhizome weights for various cultural methods for peppermint root production.

1997 Treatment*	Total Wet	Total Dry	Best 2" Stolen Segments Wet	Random 2" Stolon Segments Wet
		gms		
Flat-1	359.4	66.7	22.2	17.5
Flat-2	224.5	48.3	22.3	13.0
Disk Hill-1	233.8	36.4	20.4	14.7
Flat-3	434.3	58.7	23.3	19.9
Shank/Disk	363.7	38.6	20.5	12.0
Disk Hill-2	458.5	48.9	24.8	14.0
Disk Hill-3	217.4	51.5	20.6	11.6
Disk Hill-4	256.1	37.6	23.3	14.4
mean	318.5	48.3	22.2	14.6
LSD(0.10)	127.5	NS	NS	3.8
CV(s/mean)%	27.8	55.0	10.6	18.2

Table 2. Height and biomass yield of plants grown from stolon segments from the peppermint hilling study in 1997.

1997 TREATMENT*	HEIGHT	RHIZOMES	TOP_{wet^*}	TOP_{dry^*}	$ROOT_{wet}$	$ROOT_{dry}$
	in	#	*gms*	*gms*	*gms*	*gms*
Flat-1	24.4	17.2	562.3	113.1	240.7	52.1
Flat-2	22.3	13.3	431.2	88.7	188.4	42.4
Disk Hill-1	22.0	12.5	389.2	79.6	164.2	37.6
Flat-3	22.8	15.2	531.4	107.9	225.9	52.6
Shank/Disk	23.1	12.5	461.5	91.5	195.1	41.2
Disk Hill-2	22.7	15.2	485.3	98.3	195.2	43.0
Disk Hill-3	23.0	12.8	525.6	104.8	225.9	50.3
Disk Hill-4	21.7	16.3	514.1	104.4	208.1	44.5
mean	22.8	14.4	487.6	98.5	205.4	45.5
LSD(0.10)	NS	2.8	92.2	18.9	NS	NS
CV(s/mean)%		20.3	19.4	19.7	22.2	25.2

***1997 TREATMENTS**

Flat-1	No Harv
Flat-2	Harv 9/24
Disk Hill-1	1/2 on 8/6, 2/3 on 9/2, cover 9/17 & 10/8
Flat-3	Harv 8/25
Shank/Disk	1/4 shank on 7/1, 7/16, & 8/1; 1/3 disk on 8/15,
Disk Hill-2	1/2 cover on 7/1
Disk Hill-3	1/2 cover on 8/6, 2/3 cover on 9/2, cover on 9/17
Disk Hill-4	1/2 cover on 8/6, 2/3 cover on 9/2, covered on 10/8.

Long-Term Quackgrass Control in Peppermint with Assure II

Quackgrass is a weed which commonly infests mint fields in western Montana. While Assure II has demonstrated significant activity toward this weed, annual applications are needed to maintain acceptable levels of control. This study was conducted to monitor long-term control of quackgrass when utilizing annual applications of Assure II with the intent of optimizing herbicide inputs.

Assure II was applied at 7, 10, and 15 oz/A with either a nonionic surfactant (NIS) or methylated seed oil (MSO) plus 28% urea ammonium nitrate liquid fertilizer (UAN). These treatments were applied either in the fall or spring when 6 to 8 inches of quackgrass regrowth was present. Sequential applications also were included which consisted of fall plus spring treatments applied to the same plots.

The first series of treatments were applied during the 1996/1997 season. Fall treatments were applied on 9/23/96. Single spring treatments were applied on 5/6/97 and sequential spring treatments were applied on 5/29/97. Treatments were then reapplied to the same plots during the 1997/1998 season. Fall treatments were made on 9/8/97 and all spring treatments were applied on 4/21/98. This report details the results of the 1997/1998 treatments.

The effect of quackgrass competition on mint hay yields is apparent in the nontreated check. Left uncontrolled, quackgrass developed into a sod, completely eliminating the mint crop. Initially, control was most complete with fall applications. However, long-term control appeared to be most affected by rate and surfactant type. Sequential fall plus spring treatments provided the greatest control, with no significant differences in control being observed among Assure II rates. In contrast, control increased as Assure II rates increased for single applications made in the fall or spring. The effect of surfactants was slight, but control appeared to be greater when Assure II was applied with MSO plus 28% UAN.

Long-Term Quackgrass Control in Peppermint with Assure II

Site Description

Crop: Peppermint Variety: Black Mitchum Planting Date: 4-4-93
Planting Method: Roots
Study conducted on established stand of peppermint

Plot Width, Unit: 10 FT Plot Length, Unit: 15 FT Reps: 3
Site Location: R-7 Study Design: RCB

Plot Maintenance: Wheel line irrigation

Fertility:	4-11-97	150 Lbs. N, 30 Lbs. S
	6-16-97	50 Lbs. N
	10- 8-97	17 Lbs. N, 78 Lbs. P, and 90 Lbs. K
	3- 2-98	101 Lbs. N and 36 Lbs. S
Weed Control:	4-17-97	Stinger at .5 pt/A
	5-14-97	Basagran at 2 qt/A + Buctril at .5 pt/A
	4-29-98	Stinger at 1 pt/A

Soil Description

Texture: Coarse Silty Mix % OM: 4.4 % Sand: 40 % Silt: 50 % Clay: 10
pH: 7.8 Soil Name: Creston Silt Loam

Application Information

Application Date:	9-23-96	5-6-97	5-29-97	9-8-97	4-21-98
Time of Day:	1:30 PM	11:00 AM	10:00 AM	11:00 AM	11:00 AM
Application Method:	BACKPACK	BACKPACK	BACKPACK	BACKPACK	BACKPACK
Application Timing:	POST	POST	POST	POST	POST
Air Temp., Unit:	54 F	55 F	68 F	68 F	63 F
% Relative Humidity:	58	51	55	48	41
Wind Velocity, Unit:	7 MPH	3 MPH	3 MPH	0 MPH	0-3 MPH
Dew Presence (Y/N):	N	Y	Y	Y	N
Soil Temp., Unit:	50 F	50 F	62 F	68 F	60 F
Soil Moisture:	GOOD	GOOD	GOOD	GOOD	GOOD
% Cloud Cover:	0	85	30	0	10

	Weed Species	Weed Stage
9-23-96	Quackgrass	4-8"
5- 6-97	Quackgrass	6-8"
5-29-97	Quackgrass	6-9"
9- 8-97	Quackgrass	4-8"
4-21-98	Quackgrass	4-8"

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

Long-Term Quackgrass Control in Peppermint with Assure II

Trt No	Treatment Name	Rate Unit	Grow Stg	QUACK CONTROL PERCENT 4-22-98	QUACK CONTROL PERCENT 5-26-98	QUACK CONTROL PERCENT 7-29-98	QUACK DRY MAT TON/ACRE 7-29-98	MINT DRY MAT TON/ACRE 7-29-98	MINT OIL YLD LBS/ACRE 7-29-98
1	ASSURE II	7 oz pr/A	FALL	91.0	50.0	58.3	2.24	0.96	28.9
1	NIS	1 qt pr/A	FALL						
2	ASSURE II	7 oz pr/A	FALL	95.7	74.3	75.0	1.42	1.39	36.8
2	MSO	1 qt pr/A	FALL						
2	UAN 28%	2 qt pr/A	FALL						
3	ASSURE II	10 oz pr/A	FALL	96.3	86.7	80.0	1.42	1.42	43.6
3	NIS	1 qt pr/A	FALL						
4	ASSURE II	10 oz pr/A	FALL	97.0	86.7	83.3	1.96	1.07	48.7
4	MSO	1 qt pr/A	FALL						
4	UAN 28%	2 qt pr/A	FALL						
5	ASSURE II	15 oz pr/A	FALL	97.7	94.7	95.7	0.34	2.07	45.1
5	NIS	1 qt pr/A	FALL						
6	ASSURE II	15 oz pr/A	FALL	99.0	97.0	94.7	0.03	2.30	56.8
6	MSO	1 qt pr/A	FALL						
6	UAN 28%	2 qt pr/A	FALL						
7	ASSURE II	7 oz pr/A	SPRING	33.3	36.7	30.0	2.40	0.68	27.5
7	NIS	1 qt pr/A	SPRING						
8	ASSURE II	7 oz pr/A	SPRING	25.0	53.3	30.0	2.72	0.77	29.5
8	MSO	1 qt pr/A	SPRING						
8	UAN 28%	2 qt pr/A	SPRING						
9	ASSURE II	10 oz pr/A	SPRING	56.7	63.3	63.3	1.49	1.36	50.6
9	NIS	1 qt pr/A	SPRING						
10	ASSURE II	10 oz pr/A	SPRING	72.0	87.7	86.0	1.30	1.56	61.2
10	MSO	1 qt pr/A	SPRING						
10	UAN 28%	2 qt pr/A	SPRING						
11	ASSURE II	15 oz pr/A	SPRING	73.3	95.3	95.7	0.94	1.78	57.7
11	NIS	1 qt pr/A	SPRING						
12	ASSURE II	15 oz pr/A	SPRING	80.0	97.3	96.0	0.25	2.15	62.3
12	MSO	1 qt pr/A	SPRING						
12	UAN	2 qt pr/A	SPRING						
13	ASSURE II	7 oz pr/A	FALL	97.7	96.7	98.0	0.01	2.33	66.7
13	NIS	1 qt pr/A	FALL						
13	ASSURE II	7 oz pr/A	SPRING						
13	NIS	1 qt pr/A	SPRING						
14	ASSURE II	10 oz pr/A	FALL	98.3	97.0	97.3	0.17	2.30	67.5
14	NIS	1 qt pr/A	FALL						
14	ASSURE II	10 oz pr/A	SPRING						
14	NIS	1 qt pr/A	SPRING						
15	ASSURE II	15 oz pr/A	FALL	99.3	97.7	99.7	0.00	2.12	65.1
15	NIS	1 qt pr/A	FALL						
15	ASSURE II	15 oz pr/A	SPRING						
15	NIS	1 qt pr/A	SPRING						
16	NONTREATED			0.0	0.0	0.0	3.82	0.01	1.7
LSD (.05) =				16.2	15.3	21.3	1.44	0.85	22.0
Standard Dev.=				9.74501	9.16144	12.7642	.866418	.511647	13.1501
CV =				12.86	12.07	17.26	67.58	33.73	28.07
Treatment F				30.720	28.584	16.700	5.164	5.453	5.760
Treatment Prob(F)				0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

1996 Mint Carryover Study

Establishing a new stand of mint requires a significant investment in labor as well as dollars. As such, questions have arose regarding herbicide carryover injury to baby mint. This study was conducted to investigate the carryover potential of three ALS inhibitors - Assert, Pursuit, and Imazamox.

The three herbicides were applied in the spring of 1996 at their respective 1X and 2X use rates. Nontreated controls were also included for each product. The study is designed to evaluate 12 and 24 month recropping intervals. Baby mint was planted in the spring of 1997 in those plots designated for the 12 month rotation interval. These plots were harvested first in 1997 and again in 1998. The plots designated for the 24 month recrop interval were planted to baby mint on April 28, 1998 and were harvested in the fall of the same year.

There were no significant yield reductions associated with the 24 month rotational interval. The plots associated with the 12 month rotation interval treatments continued to demonstrate yield reductions related to the injury observed during the 1997 year of establishment. Pursuit treatments resulted in the greatest yield reductions followed by Assert and Imazamox, respectively. This observation demonstrates the importance of optimizing inputs and management considerations for the establishment of new plantings. A stand that is less than ideal will never recover from the initial stress.

1996 Mint Carryover Study

Site Description

Crop: Peppermint	Variety: Black Mitchum	Planting Date: 4-28-98
Planting Method: Hand		Depth, Unit: 4"
Row Spacing, Unit: 22"	Soil Moisture: Good	Emergence Date: 5-19-98
Plot Width, Unit: 10 FT	Plot Length, Unit: 15 FT	Reps: 3
Site Location: R-3		Study Design: RCB

Plot Maintenance:

Fertility:	4- 2-98	100 Lbs. N, 52 Lbs. P, 60 Lbs. K, and 24 Lbs. S
	5-20-98	100 Lbs. N and 10 Lbs. S
	7-29-98	50 Lbs. N
Weed Control:	4-21-98	Assure II at 15 oz/A
	6-24-98	Sinbar at .5 lb

**** Planting of 12 month treatments was on 4-24-97

Soil Description

Texture: Coarse Silty Mix % OM: 3.0 % Sand: 40 % Silt: 50 % Clay: 10
pH: 7.4 Soil Name: Creston Silt Loam

Application Information

Application Date:	5-3-96	5-24-96
Time of Day:	12:00 PM	11:00 AM
Application Method:	BACKPACK	BACKPACK
Application Timing:	PRE	POST
Air Temp., Unit:	52 F	65 F
% Relative Humidity:	72	31
Wind Velocity, Unit:	0 MPH	3 MPH
Dew Presence (Y/N):	N	N
Soil Temp., Unit:	50 F	58 F
Soil Moisture:	GOOD	GOOD
% Cloud Cover:	0	10

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

1996 Mint Carryover Study

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	MINT DRY MAT TON/ACRE 7-17-98	MINT DRY MAT TON/ACRE 8-26-98
1	ASSERT	2.5	EC	.92	2.62	
1	BARLEY					
1	12 MO					
2	ASSERT	2.5	EC	.46	3.33	
2	BARLEY					
2	12 MO					
3	NONTREATED				3.32	
3	BARLEY					
3	12 MO					
4	PURSUIT	2	EC	.092	2.33	
4	LENTILS					
4	12 MO					
5	PURSUIT	2	EC	.046	2.69	
5	LENTILS					
5	12 MO					
6	NONTREATED				3.04	
6	LENTILS					
6	12 MO					
7	AC299263	2	EC	.063	2.94	
7	LENTILS					
7	12 MO					
8	AC299263	2	EC	.032	3.12	
8	LENTILS					
8	12 MO					
9	NONTREATED				3.03	
9	LENTILS					
9	12 MO					
10	ASSERT	2.5	EC	.92		1.15
10	BARLEY					
10	24 MO					
11	ASSERT	2.5	EC	.46		1.24
11	BARLEY					
11	24 MO					
12	NONTREATED					1.10
12	BARLEY					
12	24 MO					
13	PURSUIT	2	EC	.092		1.16
13	LENTILS					
13	24 MO					

CONTINUED...

1996 Mint Carryover Study

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	MINT DRY MAT TON/ACRE 7-17-98	MINT DRY MAT TON/ACRE 8-26-98
14	PURSUIT	2	EC	.046		1.13
14	LENTILS					
14	24 MO					
15	NONTREATED					1.10
15	LENTILS					
15	24 MO					
16	AC299263	2	EC	.063		1.12
16	LENTILS					
16	24 MO					
17	AC299263	2	EC	.032		1.21
17	LENTILS					
17	24 MO					
18	NONTREATED					1.19
18	LENTILS					
18	24 MO					

LSD (.05) =	0.55	0.21
Standard Dev.=	.316211	.118561
CV =	10.77	10.26
Treatment F	3.304	0.506
Treatment Prob(F)	0.0200	0.8348

Dormant Spring Goal Applications for Toadflax Control

Yellow toadflax is a perennial broadleaf weed which is extremely difficult to control in mint production fields. Preliminary findings indicated that Goal applied postemergence did `burn back' established toadflax plants. Unfortunately, similar injury was noted with the mint crop. This study was established to determine if early dormant spring applications of Goal would control toadflax and provide the needed crop selectivity.

Goal was applied as the liquid formulation as well as impregnated on dry fertilizer. The liquid did have slightly greater activity, but the effects were minor. Although control improved as rates increased, control was inadequate and only temporary regardless of the formulation used.

Site Description

Crop: Peppermint

Plot Width, Unit: 10 FT   Plot Length, Unit: 15 FT   Reps: 6
Site Location : Tutvedt Farm   Study Design: RCB
Plot Maintenance:
Fertility: 4- 3-98 157 Lbs. N, 100 Lbs. P, 120 Lbs. K, 36 Lbs. S, 2 Lbs. B, and 4 Lbs. Zn
Applied to granular treatments as impregnated fertilizer
4- 3-98 100 Lbs. N, 52 Lbs. P, 60 Lbs. K, and 24 Lbs. S
Applied to liquid Goal treatments and non-treated checks
Weed Control: 4-22-98 Buctril at 1.5 pts + Stinger at 1 pt/A

*** Study conducted on established stand of mint

Application Information

Application Date: 4-3-98
Time of Day: 9:00 AM
Application Method: BACKPACK
Application Timing: DORMANT
Air Temp., Unit: 52 F
% Relative Humidity: 71
Wind Velocity, Unit: 1 MPH
Dew Presence (Y/N): N
Soil Temp., Unit: 44 F
Soil Moisture: GOOD
% Cloud Cover: 100

Plant Species	Plant Stage
Toadflax	1"
Mint	Dormant

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

Dormant Spring Goal Applications for Toadflax

Trt No	Treatment Name			TOADFLAX CONTROL PERCENT 6-19-98
1	GOAL	2EC	2.0	35.8
2	GOAL	2EC	1.0	19.2
3	GOAL	2EC	0.5	8.3
4	GOAL	FERT	2.0	24.2
5	GOAL	FERT	1.0	20.0
6	GOAL	FERT	0.5	8.3
7	NONTREATED			0.0
	LSD (.05) =			13.4
	Standard Dev.=			11.3983
	CV =			68.88
	Treatment F			6.600
	Treatment Prob(F)			0.0002

Toadflax Control with Basagran Tankmix Combinations

Yellow toadflax is a perennial broadleaf weed which is extremely difficult to control in mint production fields. This study was established to determine if basagran, tough, or buctril would control toadflax and provide the needed crop selectivity.

Basagran, tough, and buctril were applied as single or sequential treatments alone or in all possible combinations. Of the herbicides evaluated, basagran caused the greatest injury. Control and fresh weight reductions were greatest with sequential applications. Including either tough or buctril along with basagran did not dramatically increase control compared to basagran applied alone.

Site Description

Crop: Peppermint

Plot Width/Area, Unit: 10 FT   Plot Length, Unit: 15 FT   Reps: 3
Site location: Tutvedt Farm   Study Design: RCB
Field Preparation/Plot Maintenance:
***Conducted on established mint stand under center pivot irrigation

Application Information

Application Date:	5-6-98	5-12-98
Time of Day:	1:30 PM	10:00 AM
Application Method:	BACKPACK	BACKPACK
Application Timing:	POST	POST
Air Temp., Unit:	82 F	63 F
% Relative Humidity:	18	55
Wind Velocity, Unit:	3 MPH	0 MPH
Dew Presence (Y/N):	N	N
Soil Temp., Unit:	69 F	58 F
Soil Moisture:	GOOD	EXCELLENT
% Cloud Cover:	0	0

Plant Species	Plant Stage
5- 6-98	
Toadflax	3 to 4"
Mint	1 to 2"
5-12-98	
Toadflax	3 to 6"
Mint	1 to 3"

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H20	20

Toadflax Control with Basagran Tankmix Combinations

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	Rate Unit	Grow Stg	TOADFLAX INJURY PERCENT 5-18-98	TOADFLAX FRESH WT GRM/FT2 6-4-98
1	BASAGRAN	4	EC	2	qt pr/A	E POST	23.3	59.7
1	MSO	1	EC	1	qt pr/A			
1	28%	1	EC	2	qt pr/A			
2	TOUGH	3.75	EC	3	pt pr/A	E POST	3.3	95.5
2	MSO	1	EC	1	qt pr/A			
2	28%	1	EC	2	qt pr/A			
3	BUCTRIL	2	EC	1.5	pt pr/A	E POST	0.0	138.6
4	BASAGRAN	4	EC	2	qt pr/A	E POST	63.3	23.8
4	MSO	1	EC	1	qt pr/A			
4	28%	1	EC	2	qt pr/A			
4	BASAGRAN	4	EC	2	qt pr/A	1 WEEK		
4	MSO	1	EC	1	qt pr/A			
4	28%	1	EC	2	qt pr/A			
5	TOUGH	3.75	EC	3	pt pr/A	E POST	21.7	34.1
5	MSO	1	EC	1	qt pr/A			
5	28%	1	EC	2	qt pr/A			
5	TOUGH	3.75	EC	3	pt pr/A	1 WEEK		
5	MSO	1	EC	1	qt pr/A			
5	28%	1	EC	2	qt pr/A			
6	BUCTRIL	2	EC	1.5	pt pr/A	E POST	21.7	73.3
6	BUCTRIL	2	EC	1.5	pt pr/A	1 WEEK		
7	BASAGRAN	4	EC	2	qt pr/A	E POST	28.3	55.0
7	TOUGH	3.75	EC	3	pt pr/A			
7	MSO	1	EC	1	qt pr/A			
7	28%	1	EC	2	qt pr/A			
8	BUCTRIL	2	EC	1.5	pt pr/A	E POST	21.7	54.6
8	TOUGH	3.75	EC	3	pt pr/A			
8	MSO	1	EC	1	qt pr/A			
8	28%	1	EC	2	qt pr/A			
9	BASAGRAN	4	EC	2	qt pr/A	E POST	25.0	73.3
9	BUCTRIL	2	EC	1.5	pt pr/A			
9	TOUGH	3.75	EC	3	pt pr/A			
9	MSO	1	EC	1	qt pr/A			
9	28%	1	EC	2	qt pr/A			

CONTINUED...

Toadflax Control with Basagran Tankmix Combinations

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	Rate Unit	Grow Stg	TOADFLAX INJURY PERCENT 5-18-98	TOADFLAX FRESH WT GRM/FT2 6-4-98
10	BASAGRAN	4	EC	2	qt pr/A	E POST	63.3	21.1
10	TOUGH	3.75	EC	3	pt pr/A			
10	MSO	1	EC	1	qt pr/A			
10	28%	1	EC	2	qt pr/A			
10	BASAGRAN	4	EC	2	qt pr/A	1 WEEK		
10	TOUGH	3.75	EC	3	pt pr/A			
10	MSO	1	EC	1	qt pr/A			
10	28%	1	EC	2	qt pr/A			
11	BUCTRIL	2	EC	1.5	pt pr/A	E POST	51.7	24.4
11	TOUGH	3.75	EC	3	pt pr/A			
11	MSO	1	EC	1	qt pr/A			
11	28%	1	EC	2	qt pr/A			
11	BUCTRIL	2	EC	1.5	pt pr/A	1 WEEK		
11	TOUGH	3.75	EC	3	pt pr/A			
11	MSO	1	EC	1	qt pr/A			
11	28%	1	EC	2	qt pr/A			
12	BASAGRAN	4	EC	2	qt pr/A	E POST	85.0	13.0
12	BUCTRIL	2	EC	1.5	pt pr/A			
12	TOUGH	3.75	EC	3	pt pr/A			
12	MSO	1	EC	1	qt pr/A			
12	28%	1	EC	2	qt pr/A			
12	BASAGRAN	4	EC	2	qt pr/A	1 WEEK		
12	BUCTRIL	2	EC	1.5	pt pr/A			
12	TOUGH	3.75	EC	3	pt pr/A			
12	MSO	1	EC	1	qt pr/A			
12	28%	1	EC	2	qt pr/A			
13	NONTREATED						0.0	136.3

LSD (.05) =	24.6	49.8
Standard Dev.=	14.6195	29.5798
CV =	46.54	47.91
Treatment F	9.922	5.885
Treatment Prob(F)	0.0001	0.0001

Goal Tolerance Study

Goal controls several troublesome weeds in mint production fields. Treatments are restricted to dormant applications as severe injury results if the mint crop has even a few leaves present. Preliminary results indicate that crop injury can be avoided with nondormant applications if Goal is impregnated on dry fertilizer. This study was conducted to evaluate the mint crop tolerance to impregnated Goal applications relative to conventionally applied dormant treatments.

Goal was applied impregnated on dry fertilizer either as a spring dormant treatment or when the mint crop was four inches tall. No differences were observed in either mint hay yields or oil production, suggesting that post dormant impregnated application of Goal are safe to the mint plant.

Site Description

Crop: Peppermint
Planting Date: 4-15-93
Variety: Black Mitchum
Harvest: 7-8-98

Plot Width, Unit: 10 FT
Plot Length, Unit: 15 FT
Reps: 3
Site Location: R-5
Study Design: RCB
Plot Maintenance:

Fertility:	3-30-98	157 Lbs. N, 100 Lbs. P, 120 Lbs. K, 36 Lbs. S, 2 Lbs. B, and 4 Lbs. Zn Applied as Goal impregnated fertilizer
	6- 1-98	157 Lbs. N, 100 Lbs. P, 120 Lbs. K, 36 Lbs. S, 2 Lbs. B, and 4 Lbs. Zn Applied as Goal impregnated fertilizer
	6-12-98	50 Lbs. N applied as fertigation
	7- 8-98	50 Lbs. N applied as fertigation
Weed Control:	4-21-98	Assure II at 15 oz/A
	4-21-98	Buctril at 1.5 pt/A
	6- 1-98	Assure II at 15 oz/A
Irrigation:		Throughout season as needed with wheel line

Soil Description

Texture: SiL
% OM: 2.8
% Sand: 40
% Silt: 50
% Clay: 10
pH: 6.4
Soil Name: Creston Silt Loam

Application Information

Application Date:	3-30-98	6-1-98
Time of Day:	2:30 PM	1:00 PM
Application Method:	HAND	HAND
Application Timing:	DORMANT	4"
Air Temp., Unit:	62 F	74 F
% Relative Humidity:	48	45
Dew Presence (Y/N):	N	N
Soil Temp., Unit:		72 F
Soil Moisture:	GOOD	GOOD
% Cloud Cover:		60

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

Goal Tolerance Study

Trt No	Treatment Name	MINT DRY WT TONS/A 7-28-98	MINT OIL YIELD LBS/A
1	FERT DORM 2.0	2.2	60.6
2	FERT DORM 1.0	2.4	61.1
3	FERT DORM 0.5	2.6	64.2
4	FERT 4" 2.0	2.8	61.9
5	FERT 4" 1.0	2.7	64.4
6	FERT 4" 0.5	2.6	66.6
7	NONTREATED	2.6	63.7
LSD (.05) =		0.6	10.7
Standard Dev.=		.329258	6.00644
CV =		12.85	9.50
Treatment F		0.978	0.369
Treatment Prob(F)		0.4803	0.8851

Post Harvest Goal Applications for Toadflax Control

Yellow toadflax is a perennial broadleaf weed which is extremely difficult to control in mint production fields. Preliminary findings indicated that Goal applied postemergence did `burn back' established toadflax plants. Unfortunately, similar injury was noted with the mint crop. This study was established to determine if post harvest applications of Goal would control toadflax and provide the needed crop selectivity.

Goal was applied as the liquid formulation at different rates as either single or sequential treatments. Two impregnated treatments were also included. Sequential treatments provided the best control and there were few differences among the rates tested. Although initial control was excellent, weed regrowth had occurred by the next spring. In addition, mint injury was unacceptable.

Site Description

Crop: Peppermint

Plot Width/Area, Unit: 10 FT Plot Length, Unit: 15 FT Reps: 3
Site Type: Tutvedt Farm Study Design: RCB
Plot Maintenance:
Weed Control: 10-21-97 Stinger at 1 pt/A
4-22-98 Buctril at 1.5 pt and Stinger at 1 pt/A

Application Information

Application Date:	8-27-98	9-9-98
Time of Day:	10:30	9:30
Application Method:	BACKPACK	BACKPACK
Application Timing:	POST-HARV	POST-HARV
Air Temp., Unit:	74 F	55 F
% Relative Humidity:	38	74
Wind Velocity, Unit:	0 MPH	0 MPH
Dew Presence (Y/N):	N	N
Soil Temp., Unit:	66 F	58 F
Soil Moisture:	GOOD	GOOD
% Cloud Cover:	20	0

Plant Species	Plant Stage
8-27-98	
Toadflax	2-4"
Mint	1"

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

Post Harvest Goal Applications for Toadflax Control

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	Rate Unit	TOADFLAX INJURY PERCENT 10-20-97	MINT INJURY PERCENT 10-20-97	TOADFLAX CONTROL PERCENT 6-19-98
1	GOAL	.005	G	2.0	lb ai/A	41.7	6.7	5.0
2	GOAL	.005	G	1.0	lb ai/A	30.0	23.3	41.7
3	GOAL	2.0	EC	0.25	lb ai/A	50.0	63.3	3.3
3	MSO	1	EC	1	qt pr/A			
3	UAN	1	EC	2	qt pr/A			
4	GOAL	2	EC	.125	lb ai/A	43.3	70.0	11.7
4	MSO	1	EC	1	qt pr/A			
4	UAN	1	EC	2	qt pr/A			
5	GOAL	2	EC	0.06	lb ai/A	53.3	60.0	16.7
5	MSO	1	EC	1	qt pr/A			
5	UAN	1	EC	2	qt pr/A			
6	GOAL	2	EC	0.25	lb ai/A	96.3	95.0	53.3
6	MSO	1	EC	1	qt pr/A			
6	UAN	1	EC	2	qt pr/A			
6	GOAL	2	EC	0.25	lb ai/A 1 WEEK			
6	MSO	1	EC	1	qt pr/A			
6	UAN	1	EC	2	qt pr/A			
7	GOAL	2	EC	0.125	lb ai/A	93.3	95.0	46.7
7	MSO	1	EC	1	qt pr/A			
7	UAN	1	EC	2	qt pr/A			
7	GOAL	2	EC	0.125	lb ai/A 1 WEEK			
7	MSO	1	EC	1	qt pr/A			
7	UAN	1	EC	2	qt pr/A			
8	GOAL	2	EC	0.06	lb ai/A	76.7	90.0	10.0
8	MSO	1	EC	1	qt pr/A			
8	UAN	1	EC	2	qt pr/A			
8	GOAL	2	EC	0.06	lb ai/A 1 WEEK			
8	MSO	1	EC	1	qt pr/A			
8	UAN	1	EC	2	qt pr/A			
9	NONTREATED					16.7	0.0	10.0
LSD (.05) =						46.0	29.0	39.5
Standard Dev.=						26.5761	16.7774	22.8268
CV =						47.71	30.00	103.58
Treatment F						3.228	14.789	2.186
Treatment Prob(F)						0.0220	0.0001	0.0871

Mint Tolerance and Wild Pansy Control with Roundup

Wild pansy in an annual broadleaf weed which is occasionally found in peppermint fields. Wild pansy can form dense patches and competes successfully with peppermint. No herbicide options are known. Therefore research was conducted to evaluate Roundup for the potential to control this pest.

Roundup did injury wild pansy. The 8 oz rate provided 90 percent control and control increased as rates increased. Unfortunately, wild pansy and peppermint have the same level of tolerance toward Roundup, and crop injury was unacceptable.

Site Description

Crop: Peppermint

Plot Width, Unit: 10 FT Plot Length, Unit: 15 FT Reps: 3
Site Location: Jaquette Farm Study Design: RCB
Field Preparation/Plot Maintenance:
***Study conducted on established stand of mint

Application Information

Application Date:	6-4-98
Time of Day:	11:30 AM
Application Method:	BACKPACK
Application Timing:	POST
Air Temp., Unit:	63 F
% Relative Humidity:	45
Wind Velocity, Unit:	0-3 MPH
Dew Presence (Y/N):	N
Soil Temp., Unit:	60 F
Soil Moisture:	EXCELLENT
% Cloud Cover:	20

Weed Species	Weed Stage	Density at Application
Wild Pansy	8"	60% of total area

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

Mint Tolerance and Wild Pansy Control with Roundup

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	PANSY CONTROL PERCENT 6-29-98	MINT CROP INJ PERCENT 6-29-98
1	Roundup	4	AS	4 oz/A	68.3	75.0
2	Roundup	4	AS	8 oz/A	90.0	90.7
3	Roundup	4	AS	12 oz/A	100.0	97.3
4	Roundup	4	AS	16 oz/A	100.0	100.0
5	Nontreated				0.0	0.0
LSD (.05) =					17.2	12.5
Standard Dev.=					9.13601	6.65332
CV =					12.75	9.16
Treatment F					63.698	118.014
Treatment Prob(F)					0.0001	0.0001

Wild Pansy Control in Peppermint

Wild pansy in an annual broadleaf weed which is occasionally found in peppermint fields. Wild pansy can form dense patches and competes successfully with peppermint. No herbicide options are known. Therefore research was conducted to evaluate Vin-der and basagran for the potential to control this pest.

Basagran had no impact on wild pansy, regardless of the rate used. Vin-der did injury wild pansy. The activity of Vin-der was enhanced with the addition of methylated seed oil (MSO) as a surfactant. Unfortunately, wild pansy and peppermint have the same level of tolerance toward Vin-der, and crop injury was unacceptable.

Site Description

Crop: Peppermint

Plot Width, Unit: 10 FT
Plot Length, Unit: 15 FT
Reps: 3
Site Location: Jaquette Farm
Study Design: RCB
Field Preparation/Plot Maintenance:
***Study conducted on established stand of mint

Application Information

Application Date:	6-2-98
Time of Day:	2:30 PM
Application Method:	BACKPACK
Application Timing:	POST
Air Temp., Unit:	70 F
% Relative Humidity:	29
Wind Velocity, Unit:	5 MPH
Dew Presence (Y/N):	N
Soil Temp., Unit:	66 F
Soil Moisture:	GOOD
% Cloud Cover:	30

Plant Species	Plant Stage	Density at Application
Wild Pansy	8" at full bloom	60% of total area
Mint	5"	

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

Wild Pansy Control in Peppermint

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	Rate Unit	PANSY CONTROL PERCENT	MINT CROP INJ PERCENT
1	Vineder			3	pt pr/A	46.7	45.0
2	Vineder			3	pt pr/A	62.7	63.3
2	MSO			2	pt pr/A		
3	Basagran			1	qt pr/A	0.0	0.0
3	MSO			2	pt pr/A		
3	28%			4	pt pr/A		
4	Basagran			2	qt pr/A	0.0	0.0
4	MSO			2	pt pr/A		
4	28%			4	pt pr/A		
5	Nontreated					0.0	0.0

LSD (.05) =	24.6	39.9
Standard Dev.=	13.0652	21.1936
CV =	59.75	97.82
Treatment F	16.319	6.160
Treatment Prob(F)	0.0006	0.0145

Horsetail Control in Baby Mint

Horsetail is a perennial weed which is adapted to high moisture areas with high water tables. No herbicide options are known for mint production. Therefore research was conducted to evaluate mint herbicides for the potential to control this pest.

Gramoxone and Goal both resulted in complete control. Tough also demonstrated good activity, providing 88 percent control. Buctril and Vin-der were ineffective.

Site Description

Crop: Peppermint

Plot Width, Unit: 10 FT Site Location: Offstation	Plot Length, Unit: 15 FT	Reps: 3 Study Design: RCB

Application Information

Application Date:	5-7-98
Time of Day:	11:00 AM
Application Method:	BACKPACK
Application Timing:	POST
Air Temp., Unit:	70 F
% Relative Humidity:	50
Wind Velocity, Unit:	0 MPH
Dew Presence (Y/N):	N
Soil Temp., Unit:	69 F
Soil Moisture:	GOOD
% Cloud Cover:	0

Weed Species	Weed Stage	Density at Application
Horsetail	1 to 1.5"	30/ft2

Application Equipment

Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height	Nozzle Spacing	Boom Width	GPA	Carrier	PSI
Backpack	2.5	Flatfan	11002XR	14"	20"	10'	20	H2O	20

Horsetail Control in Baby Mint

Trt No	Treatment Name	Form Amt	Fm Ds	Rate	Rate Unit	HORSETAIL CONTROL PERCENT 5-12-98
1	GRAMOXONE EXTRA	2.5	EC	2.4	pt pr/A	100.0
1	NIS	1	EC	.25	% v/v	
2	TOUGH	3.75	EC	3	pt pr/A	88.3
2	MSO	1	EC	1	qt pr/A	
2	28%	1	EC	2	qt pr/A	
3	BUCTRIL	2	EC	1.5	pt pr/A	33.3
3	NIS	1	EC	.25	% v/v	
4	VINE-DER	2	SC	3	pt pr/A	48.3
5	GOAL	2	EC	2	lb ai/A	100.0
5	MSO	1	EC	1	qt pr/A	
5	28%	1	EC	2	qt pr/A	
6	NONTREATED					0.0

LSD (.05) = 34.5
Standard Dev. = 18.9517
CV = 30.73
Treatment F 14.088
Treatment Prob(F) 0.0003

TITLE: **EVALUATION OF MENTHA VARIETIES AND GERMPLASM FOR DISEASE REACTION AND LATENT INFECTION PERIOD TO MINT RUST AND POWDERY MILDEW**

PERSONNEL: **WILLIAM E. GREY**, Research Assistant Professor/Mint Certification Specialist, Department of Plant Sciences, MSU, Bozeman, MT

MAREIKE R. JOHNSTON, Research Associate Professor, Department of Plant Sciences, MSU, Bozeman, MT

ABSTRACT: The purpose of this research is to develop methodology for evaluation of commercial mint varieties and germplasm to mint rust and powdery mildew. The commercial peppermint varieties are susceptible to the 'peppermint' rust biotype whereas, the native spearmint varieties are only susceptible to the 'native spearmint' rust biotype. The scotch spearmint varieties are moderately susceptible to the 'peppermint' rust biotype and susceptible to the 'native spearmint' rust biotype. In contrast, Scotch 770 was moderately-resistant to the 'native spearmint' rust biotype, which may indicate partial resistance in this selection (Table 1).

In cooperation with T. Davis, Univ. New Hampshire, we evaluated the F1 progeny derived from crosses of diploid parents. The parental lines of Mentha longifolia as well as several wild mint species tested, were resistant to both rust biotypes (Table 2, 3). Variation to the rust biotypes was found among the F1 progeny derived from the diploid parents, M. longifolia 'tomentosa' MEN 501 x M. longifolia MEN 018. The F1 progeny from a different cross, M. polyadenia MEN 584 x M. hymalaiensis MEN 635 were highly variable in rust reaction to the 'native spearmint' rust biotype. These same progenies were resistant to the 'peppermint' rust biotype. The findings suggest several sources of resistance and potential genetic markers for rust resistance (Table 3).

In cooperation with L. Welty, NWARC, we evaluated the disease reaction of commercial mint varieties, propagated by stemtip, meristem, or nodal, under field conditions to the 'peppermint' rust biotype (Table 4). The disease reaction of field grown plants were more variable than that of seedling plants inoculated under standardized conditions in the greenhouse. The differences among peppermint varieties are due to variable inoculum pressure or micro-climate differences in the plant canopy rather than to the plant material sources or method of propagation. Scotch 770 was more resistant than the other scotch spearmint varieties to the 'peppermint' rust biotype (Table 4).

Powdery mildew on mint has only been identified as an Erysiphe-type, based on the structure of the cleistothecium, number of asci and ascospores. The sexual structure was obtained from a field of 'Black Mitcham' peppermint that was allowed to naturally senesce rather than be harvested for oil. Commercial mint varieties were evaluated by the detached leaf or whole plant methods for powdery mildew. Native spearmint varieties are immune to infection but there is localized leaf necrosis when the plant is exposed to severe mildew inoculum. Scotch spearmint is highly susceptible and does support abundant sporulation of conidia at 12 days following inoculation. Peppermint varieties are variable in reaction and may have a longer latent infection period, or time from inoculation to sporulation, than the scotch spearmint varieties (Table 5).

OBJECTIVES - Rust

Our objectives were to develop the protocols for inoculating mint plants under uniform conditions with pure isolates of mint rust and to determine the disease reaction and latent infection period of commercial mint varieties and germplasm to the two rust biotypes.

<u>**Mint Rust Introduction**</u>. Mint rust (Puccinia menthae) causes light-yellow, blister-like lesions (aecium stage) on young shoots in the spring, and brownish-red spots surrounded by a yellow halo (uredinium stage) on the leaves later in the season. Rusted leaves may eventually drop off and defoliation of plants can be severe. If rust has infected young shoots, the shoots are usually twisted and distorted and break off easily at the point of infection. In late summer and fall, leaf spots become a deep-chocolate brown (telium stage) as the overwintering spores of the fungus are produced. The 'native spearmint' rust

biotype infects Native spearmint (Menthae spicata) but not Peppermint (M. x piperita); the 'peppermint rust biotype' infects Peppermint but not Native spearmint and both biotypes infect Scotch spearmint (M. x gracilis). The 'peppermint rust biotype' occurs in climates with a cool summer temperature, such as in the Flathead region of Montana and Willamette Valley of western Oregon. The 'native spearmint rust biotype' can tolerate higher summer temperatures and is common where spearmints are grown.

Mint Varieties and Plant Maintenance. Summit Plant Labs, Inc. provided the MIRC commercial varieties (Table 1), T. Davis, Univ. of New Hampshire, provided F1 progeny plants and M. longifolia parental lines and the National Clonal Germplasm Repository -USDA, provided the wild mint species (Tables 2,3,4) as rooted cuttings. Mother plants were irrigated with water warmed to 20 0C and irrigated with Peter's 20-20-20 soluble fertilizer containing minor elements, at 100 ppm nitrogen. Individual stem tips were rooted in pasteurized soil based media for 6 to 8 wks prior to inoculation.

Rust Inoculation Procedures. The 'peppermint mint rust biotype' was obtained from the Flathead region and the 'native spearmint rust biotype' was obtained from D. Johnson, WSU and maintained on peppermint or native spearmint, respectively. The host plant was clasped by a circular 'collar' that rested on the potting container and the host plant was enclosed by a plastic 'plant tower' with the top covered by a nylon mesh. Urediniospores that fell on the white 'collar' were used as inoculum. Rooted cuttings to be tested were inoculated with urediniospores that were suspended in water and rubbed on the lower leaf surface of moistened foliage. The inoculated plants were placed in a dew chamber at 16 0C for 24 hrs with a sample of urediniospores placed on a plastic membrane to monitor spore germination. Inoculated plants were incubated in the growth chamber during a daily cycle of 14:10 hr light:dark and 20:15 0C day:night temperature. Pustules developed in 14 to 21 days.

Rust Disease Evaluation. Plants were evaluated for pustule development and the degree of chlorosis and necrosis, according to an infection type scale developed by D. Johnson (Plant Disease 1995): N = No visible reaction, 0 = Flecking or necrotic spots, no uredinia formed; 1 = Uredinia small, always in necrotic spots, often failing to rupture epidermis; 2 = Uredinia of moderate size and in necrotic spots, necrosis may develop after eruption of fully sized uredinia; 3 = Chlorosis surrounding uredinia but no necrosis, uredinia of any size; 4 = No necrosis or chlorosis surrounding uredinia, uredinia of any size. No visible reaction and infection types 0 to 2 are considered resistant reactions (avirulent isolate) and those of 3 and 4 are considered susceptible reactions (virulent isolate).

CONCLUSIONS - Rust

The commercial peppermint varieties were susceptible to the 'peppermint' rust biotype and the native spearmint varieties were susceptible to the 'native spearmint' biotype. The scotch spearmint varieties are moderately susceptible to the peppermint biotype and susceptible to the native spearmint biotype (Table 1). Interestingly, Scotch 770 was moderately-resistant to the native spearmint biotype. In contrast to the native spearmint varieties, 'Crispa' a curled leaf selection from native spearmint, was resistant to the 'native spearmint' biotype.

In cooperation with L. Welty, NWARC, we determined the disease reaction of the commercial mint varieties to the 'peppermint' rust biotype (Table 4). The disease reaction of the field entries was similar to that found in the greenhouse tests (Tables 1,4). There were no differences in disease reaction among the varieties due to source plant materials and the propagation method, including stem tip, meristem and nodal.

The 'peppermint' rust biotype was the prevalent biotype early in the summer, indicated by the susceptible reaction on the peppermint varieties and the resistant reaction on the native spearmint varieties (Table 4). However, by the end of August and with higher temperatures, the native spearmint varieties were severely diseased (data not shown). The impact of the 'native spearmint' rust biotype on spearmint varieties is unknown but losses may be mitigated if summer temperatures remain cool during the growing season in the Flathead region of Montana.

In cooperation with Tom Davis, Univ. New Hampshire, we evaluated the germplasm study to both rust biotypes in the greenhouse. Variation to both rust biotypes was found among the F1 progeny derived from the diploid parents, M. longifolia 'Tomentosa' MEN 501 x M. longifolia 'Tomentosa' MEN 018 (Tables 2,3). The F1 progeny of M. longifolia 'Polyadenia' MEN 584 x M. longifolia 'Hymalaiensis' MEN 635 were variable in rust reaction to the 'native spearmint' rust biotype but resistant to the 'peppermint' rust biotype. Potential genetic markers for rust resistance may be identified in this germplasm.

OBJECTIVES - Powdery Mildew

Our objectives were to develop the procedures for inoculating mint plants with a pure culture of powdery mildew and to determine the disease reaction and latent infection period of commercial mint varieties and germplasm to this pathogen. We are investigating the taxonomic identity of powdery mildew on mint in Montana and the role of the sexual stage as an overwintering structure in this disease.

Powdery Mildew Introduction. Powdery mildew forms long chains of single celled-conidia on the leaf surface giving a powdery appearance to the mint foliage. Cell necrosis and death occurs as a result of hypersensitive reaction and/or severe infection. The dark-bodied, spherical cleistothecium, or sexual fungal structure, is intertwined amongst the hyaline to white mycelium. Cleistothecia are not common on Black Mitcham peppermint commercial fields during the growing season in Montana. However, we have found the cleistothecia on senesced tissues in the late fall but not on the leaf residue in the spring. The role of the cleistothecia as an overwintering structure for maintaining powdery mildew disease is still unknown in Montana.

Powdery Mildew Taxonomy. We have identified the powdery mildew on Black Mitcham peppermint in Montana as an Erysiphe-type. The cleistothecium contained multiple asci with two ascospores and the unbranched, mycelial appendages on the surface that are longer than the diameter of the cleistothecium (<140 um). Of the four Erysiphe species that have been reported on mint, Erysiphe galeopsidis DE Candolle ex Mérat, is characterized as forming mature asci most often in the spring, whereas the remaining three form asci in the fall, Erysiphe biocellata Ehrenberg, Erysiphe cichoracearum DC. Ex Mérat, and Erysiphe polygoni DE Candolle ex Saint-Amans. In Montana, cleistothecia were found on peppermint in the fall season but it is not known if the ascospores were mature and viable. Correct species identification will depend on the a mature cleistothecium and on the determination of the number of mature asci and the size of ascospores.

Powdery Mildew Inoculation. The 'whole plant' method was useful for evaluating many varieties to a common virulence type, whereas, the 'detached leaf' method can be used for comparing several isolates on a single variety. The whole plant method employs a clear plastic 'chimney' to enclose the plant and maintain a higher humidity. With the 'detached leaf' method, a leaf and petiole are placed on a solidified agar growth medium in an individual cell of an organizer box (divided, plastic storage box with 12 cells). The growth medium can support a live leaf in the organizer box up to 6 wks which is sufficient time for mildew to develop. The growth medium contains benzimidazole (118 mg/l), calcium nitrate (472 mg/l), agar (12 gm/l). The whole plant and detached leaf are inoculated by shaking conidia from an infected plant onto the leaf surfaces. The tissues are incubated in a growth chamber at temperature of 17:22 C and night : day cycle of 10:14 hrs with high light intensity (1500 foot candles). Sporulation occurred after 8 - 10 days.

Powdery Mildew Evaluation. The following infection type scale was used: 0 = No powdery mildew; 1 = Light powdery mildew, mycelium / conidia, on upper leaf; 2 = Moderate powdery mildew and/or light leaf flecking; 3 = Heavy powdery mildew and moderate leaf flecking; 4 = Severe powdery mildew, leaf necrosis and leaf drop. No powdery mildew and a disease reaction of 0 to 1 were considered resistant reactions (avirulent isolate) and those of 2 to 4 are considered susceptible reactions (virulent isolate).

CONCLUSIONS - Powdery Mildew

Native spearmint varieties are immune to infection but there is localized leaf necrosis when the plant is exposed to severe mildew inoculum. Scotch spearmint is highly susceptible and does support abundant sporulation of conidia at 12 days following inoculation. Peppermint varieties are variable in reaction and may have a longer latent infection period, or time from inoculation to sporulation, than the scotch spearmint varieties (Table 5). Latent infection period in peppermint and spearmint varieties may indicate partial host resistance to powdery mildew. In addition, leaf morphology and the density of leaf hairs may reduce conidial sporulation, dispersal and secondary infection.

The correct identification of powdery mildew has an impact on disease management in commercial mint. The cleistothecium or surviving fungal structure has not been found on the foliage or dried residue from production mint fields in Montana. Wild mint species and closely related plants may be important hosts for survival of powdery mildew over the winter or as a reservoir to re-infect the mint crop during the growing season. Growers have reported severe mildew epidemics on scotch spearmint but we do not know if there has been a shift in the mildew population to virulence or to fungicide resistance or perhaps to a change in crop management practice. A correct fungal identity and the methods to evaluate plant responses to powdery mildew will help determine the potential development of specialized forms on commercial mint.

Table 1. Disease Reaction of Mentha varieties to the 'peppermint' and 'native spearmint' biotypes of Mint rust (*Puccinia menthae*) in the greenhouse.

Mentha varieties	Disease reaction*	
	Peppermint biotype	Native Spearmint biotype
Peppermint (*Mentha x piperita*)		
Black Mitcham	S	R
Black Mitcham 'uk1'	S	R
Black Mitcham 'uk2'	–	R
Murray Mitcham m-83-7	S	R
Murray Mitcham	S	R
Redefined Murray Mitcham	S	R
Roberts Mitcham m-83-5	S	R
Todds Mitcham t-84-5	S	R
Todds Mitcham	S	R
Native Spearmint (*Mentha spicata*)		
Native Spearmint 'crispa'	R	R
Native Spearmint n-83-5	R	S
Native Spearmint n-83-6	R	S
Native Spearmint n-87-1	R	S
Native Spearmint	R	S
Scotch Spearmint (*Mentha x gracilis*)		
Scotch 213	MS	S
Scotch 227	MS	S
Scotch 770	MS	MR?
Scotch	MS	S

- R = resistant; S = susceptible; MR = moderately resistant; MS = moderately susceptible; – = not tested

Table 2. Disease reaction of Mentha varieties to the 'peppermint' and 'native spearmint' biotypes of Mint rust (*Puccinia menthae*) in the greenhouse.

Mentha varieties	Plant introduction #	Mentha ID	Disease reaction*	
			Peppermint biotype	Native spearmint biotype
Mentha x aquatica				
'Water mint'	PI557572	MEN109	**R**	**R**
'Water mint'	PI557574	MEN111	**R**	**R**
Mentha canadensis				
'Alaska or Artic'			**MR**	--
Mentha longifolia				
Tomentosa	PI557888	MEN501	**R**	**R**
Mentha pulegium				
'Pennyroyal'	PI557772	MEN003	**R**	**R**
'Pennyroyal'	PI196272	MEN502	**R**	--
'Pennyroyal'	PI557780	MEN626	**R**	--
Mentha suaveoleons				
Rotundifolia	PI557903	MEN379	**R**	**R**

* R = resistant; S = susceptible; MR = Moderately resistant; -- = not tested

Table 3. Disease reaction of diploid Mentha species and F1 progenies to the 'peppermint' and 'native spearmint' biotypes of Mint rust (*Puccina menthae*) in the greenhouse.

Mentha spp. Progeny	Plant introduction number	NCGR ID*	F1 ID	Disease Reaction*	
				Peppermint biotype	Native Spearmint biotype
Diploid parents *Mentha longifolia*					
Tomentosa	PI557756	MEN018		field resistant	R
Tomentosa	PI557888	MEN501		R	R
Capensis	PI557767	MEN585		R	R
Hymalaiensis	PI557768	MEN635		–	–
Polyadenia	PI557769	MEN584		R	R
F1 progeny *Mentha longifolia* 'Tomentosa' MEN501 x *Mentha longifolia* MEN018					
			501x18-02	S	S
			501x18-05	S	S
			501x18-06	S	R-S?
			501x18-07	MR	MS
			501x18-08	S	S
			501x18-09	S	S
			501x18-10	R	R
			501x18-11	S	S
			501x18-16	S	R-S?
F1 progeny *Mentha longifolia* 'Polyadenia' MEN584 x *Mentha longifolia* 'Hymalaiensis' MEN635					
			584x635-d01	R	S
			584x635-d02	R	S
			584x635-d06	R	R
			584x635-d08	R	R
			584x635-d11	R	R
			584x635-d12	R	R
			584x635-d16	R	R
			584x635-d19	R	MR
			584x635-d20	R	R
			584x635-d23	R	R
			584x635-d24	R	S
			584x635-d26	R	S
			584x635-d27	R	S
			584x635-d30	R	MR
			584x635-d35	R	MR
			584x635-d36	R	R
			584x635-d37	R	R
			584x635-d39	R	S
			584x635-d40	R	R
			584x635-d42	R	S

* R = resistant; S = susceptible; MR = moderately resistant; Ms = moderately susceptible; – = not tested

Table 4. Disease reaction of Mentha varieties to the 'peppermint' biotype of mint rust (*Puccinia menthae*) in the field nursery at Kalispell, MT, 1998.

Mentha varieties	Propagation Method	Propagator	Source	Disease Reaction*
Peppermint (Mentha x piperita)				
Black Mitcham	meristem	Summit	MIRC	**MS**
Black Mitcham	meristem	Starkel	MIRC	**S**
Black Mitcham 'lake92'	nodal	Lake		**MR**
Black Mitcham 'uk1'	nodal	Lake		**S**
Black Mitcham 'uk2'	nodal	Lake		**S**
Black Mitcham '96-07'	nodal	Lake	McClelland	**S**
Black Mitcham '96-19'	nodal	Lake	McClelland	**MR**
Black Mitcham	stemtip	Summit	MIRC	**S**
Roberts Mitcham	stemtip	Summit	MIRC	**S**
Murray Mitcham	stemtip	Summit	MIRC	**MR**
Murray Mitcham m-83-7	stemtip	Summit	MIRC	**S**
Todds Mitcham	stemtip	Summit	MIRC	**S**
Native Spearmint (*Mentha spicata)*				
Native Spearmint n-83-5	stemtip	Summit	MIRC	**R**
Native Spearmint	meristem	Starkel	MIRC	**R**
Scotch Spearmint (*Mentha x gracilis)*				
Scotch	stemtip	Summit	MIRC	**S**
Scotch 213	stemtip	Summit	MIRC	**S**
Scotch 227	stemtip	Summit	MIRC	**S**
Scotch 770	stemtip	Summit	MIRC	**MR**
Scotch 770	meristem	Starkel	MIRC	**S**
Mentha longifolia				
Tomentosa	nodal	Lake	NCGR	**R**
Hymalaiensis	stemtip	Lake	NCGR	**–**
Polyadenia	stemtip	Lake	NCGR	**–**
Mentha suaveoleons				
Rotundifolia	nodal	Lake	NCGR	**R**
Mentha canadiensis				
'Alaska or Artic'	nodal	Lake	IPCallison	**MR**

* R = resistant; S = susceptible; MR = moderately resistant; MS = moderately susceptible; – = not tested

Table 5. Disease reaction of Mentha varieties to Powdery Mildew determined by the whole plant and detached leaf methods.

Mentha varieties	Disease reaction*				
	Whole Plant			Detached Leaves	
	Exp1	Exp2	Exp3	Exp1	Exp2
Native Spearmint (*Mentha spicata*)					
Native Spearmint n-83-5	R	R	–	R	R
Native Spearmint n-86-6	R	R	–	R	R
Native Spearmint n-87-1	R	R	R	R	R
Scotch Spearmint (*Mentha x gracilis*)					
Scotch 213	S	S	–	S	S
Scotch 770	S	S	–	S	S
Scotch	–	–	S	–	–
Peppermint (*Mentha x piperita*)					
Murray Mitcham m-84-5	S	R	–	S	R
Murray Mitcham m-83-5	S	R	S	S	R
Murray Mitcham m-83-7	S	R	S	R	S
Redefined MurrayMitcham	R	R	R	R	R
Todds Mitcham m-84-5	S	R	R	S	S
Todds Mitcham	S	R	–	R	S
Black Mitcham	–	S	S	R	S
Black Mitcham (invitro)	–	–	S	–	–

* R = resistant; S = susceptible; – = not tested

TITLE: **EARLY-SEASON N FERTILIZATION OF PEPPERMINT**

PERSONNEL: Mal Westcott
Western Ag Research Center, MSU

OBJECTIVES: To evaluate early-season N fertilization programs for peppermint.

PROCEDURES: The eleven N fertilization treatments described in Table 1 were applied to Black Mitcham peppermint in a randomized, complete block design field experiment with four replications at the Northwestern Agricultural Research Center in 1998. Anhydrous ammonia applications were made by shanking at 6 inch depth, 22 in. centers, with coulters in front of the shanks. Urea and ammonium nitrate applications were topdressed on the soil surface. Urea-ammonium nitrate (UAN) was applied with a back-pack sprayer on the crop canopy. Soil solution concentrations at 4 ft. depth were sampled periodically from suction lysimeters installed in each plot. Plant stem samples for nitrate-N concentration in dry tissue and leaf SPAD levels were measured at each time of UAN application in each plot.

The crop was fertilized with 16.5 lbs N/ac, 78 lbs P_2O_5/ac and 120 lbs K_2O/ac in October, 1997. Other management practices were targeted for optimum production.

Plots were harvested on August 12 for determination of hay and oil yields. Soils were sampled in each plot after harvest to a depth of four ft. for determination of soil nitrate distribution (data not available at this point).

***Table 1**. Nitrogen rate, source, and timing treatments applied to peppermint, 1998.*

April 7		24 June	8 July	22 July	Total N
Lbs N/ac	Source	Urea-ammonium nitrate application, lbs N/ac			Lbs N/ac
0		0	0	0	0
0		80	80	80	240
240	Anhy	0	0	0	240
160	Anhy	0	0	80	240
80	Anhy	0	80	80	240
240	Urea	0	0	0	240
160	Urea	0	0	80	240
80	Urea	0	80	80	240
240	Am Nit	0	0	0	240
160	Am Nit	0	0	80	240
80	Am Nit	0	80	80	240

Results: Early-season crop N status (Tables 2 and 3) was roughly proportionate to the amount of initial N applied to each treatment, but as the season progressed stem nitrate levels were greater in the treatments receiving greater amounts of in-season N.

Table 2. *Effects on N rate, source, and timing on seasonal stem nitrate-N concentrations in peppermint.*

Initial N Fertilization	Growing Season N	Sampling date 24 June	8 July	22 July	Mean
	Stem nitrate-N, ppm dry matter basis				
0	0	245	120	129	165
0	240	209	2675	4475	2453
80 Urea	160	481	579	2525	1195
160 Urea	80	1123	1465	900	1163
240 Urea	0	1951	1743	1426	1706
80 Anhy	160	1730	2150	3450	2443
160 Anhy	80	2438	1875	1558	1957
240 Anhy	0	2240	2350	1628	2073
80 Am Nit	160	1203	1303	2250	1585
160 Am Nit	80	1454	2203	1905	1854
240 Am Nit	0	1683	1785	1460	1642
LSD 0.05		1493	1287	1508	837

Table 3. *Effects on N rate, source, and timing on seasonal leaf SPAD levels in peppermint.*

Initial N Fertilization	Growing Season N	Sampling date 24-June	8-July	22-July	Mean
	Leaf SPAD readings				
0	0	38.3	37.7	39.8	38.6
0	240	36.4	43.9	51.1	43.8
80 Urea	160	37.7	38.8	50.9	42.5
160 Urea	80	41.6	41.8	43.8	42.4
240 Urea	041	41.0	42.5	47.9	43.8
80 Anhy	160	40.9	44.0	53.6	46.1
160 Anhy	80	41.6	42.4	45.2	43.0
240 Anhy	0	41.5	41.8	45.6	43.0
80 Am Nit	160	40.6	40.6	52.2	43.2
160 Am Nit	80	42.0	42.3	45.2	43.2
240 Am Nit	0	41.4	40.2	46.3	42.6
LSD .05		2.8	3.2	5.1	2.1

Mid-season soil solution nitrate concentration at 4 ft. depth (Table 4) was greater with the higher rates of initial N application, particularly with the anhydrous source, indicating that nitrate leaching was greater with high rates of initial N.

***Table 4**. Effects of N rate, source, and timing on soil solution nitrate-N concentrations sampled at 4 ft. depth.*

Initial N Fertilization	Growing Season N	Sampling Date				Mean
		24 June	8 July	22 July	12 Aug	
0	0	2	19	23	40	25
0	240	38	49	48	54	44
80 Urea	160	33	60	35	32	34
160 Urea	80	85	73	73	59	74
240 Urea	0	109	77	68	62	87
80 Anhy	160	54	47	79	67	62
160 Anhy	80	87	114	113	88	101
240 Anhy	0	124	158	139	79	115
80 Am Nit	160	63	73	71	49	64
160 Am Nit	80	85	69	70	64	74
240 Am Nit	0	95	76	66	50	72
P-value		0.003	0.0105	0.038	0.3255	0.000
LSD .05		52	59	61	NS	26

Though hay yields were unaffected by N application rate or timing, oil yield response was greater to the N applied during the growing season than to the initial N (Table 5). The N applied in April was obviously poorly utilized by the crop, likely due to leaching below the crop root zone early in the growing season. The months of May and June were unusually rainy (7 inches of precipitation), and the evidence of elevated soil solution nitrate from the suction lysimeters, the decline in stem nitrate and leaf SPAD levels , and the poor oil yield response all point to leaching as the cause for poor N utilization in treatments where heavy applications of early N were made, regardless of the source.

Taken together with the results from the previous two years' of work, it is apparent that any of the three sources of N tested can be effectively applied to peppermint in April or May prior to the onset of rapid crop growth. When conditions are right, this early N can be just as effective as multiple applications made during the growing season. Anhydrous applications will cause some crop dieback near the shank furrow, but the crop will rapidly outgrow this damage and perform very well. The dry formulations are also effective as early-season N sources, though some volatilization loss or even crop damage may occur if urea is not incorporated by rainfall (or irrigation) shortly after application.

The greater concern, however, is the potential for leaching with heavy rates of early season N. In years when rainfall is not excessive and efficient irrigation is practiced, this will not be a problem. But in years such as 1998 where periods of excessive rainfall occur, particularly early in the growing season, significant leaching losses can occur. This is manifest as poor crop response to N fertilization and the potential for environmental damage with nitrate leaching. Since these risks occur as a result of conditions beyond grower control, it is best advised to avoid heavy applications of N early when they will be susceptible to losses.

***Table 5**. Effects on N rate, source, and timing on peppermint hay and oil yields.*

Initial N fertilization	Growing season N	Hay yield	Oil yield
------------------------	lb /ac	------------------	
0	0	3050	38.7
0	240	3994	66.4
80 urea	160	4199	73.4
160 urea	80	4727	69.8
240 urea	0	4222	58.8
80 Anhy	160	3797	71.5
160 Anhy	80	3828	58.4
240 Anhy	0	4006	61.1
80 Am Nit	160	4236	68.8
160 Am Nit	80	4669	65.9
240 Am Nit	0	4150	57.3
LSD .05		NS	11.9