VARIABILITY IN "VERTICILLIUM DAHLIAE" AND THE VERTICILLIUM "STRAIN" ISSUE: ACTIVITY OF MINT AND NON-MINT ISOLATES INOCULATED INTO PEPPERMINT AND SPEARMINT

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Abstract

In a 1996 test, two strawberry isolates ofVerticillium dahliae *were pathogenic to Murray peppermint but only one of these was pathogenic to Todds peppermint. Black Mitcham 's reaction to these two isolates was mixed. The reaction of Todd's and Black Mitcham varied with spore concentration, and growth was promoted at low concentration for both varieties.*

In 1997, rooted cuttings of Black Mitcham, Todds, Roberts and Murray peppermint and Scotch and Native spearmint were root-dip inoculated with 1 x 10⁷/ml spore suspensions ofV. dahliae *just prior to individual potting. Pots were held in a greenhouse for 8-10 wk. Varieties varied in severity of reaction to 17 isolates recovered from wilted mint in mint-producing regions of the United States. Fourteen of the 17 isolates generally were aggressive against all varieties except Native spearmint. Symptoms rangedfrom moderately stunting and yellowing, to total plant death, within 7-10 wk following inoculation. Stem length and dry weight of stems and foliage were reduced 30-80%. On Native spearmint, effects were limited to 10% mean reduction of stem length and dry hay weight. Much reduced symptoms were noted for 3 of 17 mint isolates, although certain varieties were disproportionately damaged by these isolates. For some plants within replications, symptoms failed to materialize at all (presumably by a failure of the inoculation to become systemic, although this was not verified), in which case growth enhancement was commonly measured: no wilt symptoms, with leaf and stem size and dry hay weight 10-30% greater than non-inoculated plants. In other cases, wilt symptoms were delayed compared to most symptomatic plants, in which case growth enhancement was measured early but wilt symptoms and reduced growth developed later. For a few plants, some stems developed wilt symptoms and growth reduction through stem death early in the course of the experiments, but other stems were symptomless and growth enhanced. In this later case, most stems eventually developed symptoms and growth reduction by the end of the trial period.*

Isolates of V. dahliae *recovered from wilted potato, purple coneflower* (Echinacea purpurea), *maple and cauliflower generally elicited growth enhancement and no wilt symptoms on any peppermint or spearmint varieties. An exception may have occurred in which Black Mitcham inoculated with the maple isolate eventually developed moderate wilt and growth reduction, when a single replication of all varieties within one test were held 15 weeks for demonstration purposes.*

Of two isolates recoveredfrom a single, commercially field grown mint plant in Northern California, one elicited rapid and severe wilt on all mint varieties, including severe stunting (but not death) of Native Spearmint. The other California isolate gave a mixed reaction, damaging some varieties but growth enhancing other varieties.

In general, isolates of V. dahliae *associated with mint wilt show high ability to incite disease on all mint varieties (except Native spearmint). The presence of isolates associated with wilting of other crops may generally enhance mint growth, although aggressive exceptions may occur among non mint isolates.*

Introduction

Verticillium dahliae is distributed worldwide, causing a rapidly developing systemic wilt on many different types of plants including vegetables, woody and herbaceous ornamentals, forest trees, mint, hops, etc. Survival structures of *V. dahliae,* called microsclerotia (MS), are abundantly produced in the stems and leaves of diseased plants after stem death. Infected stems and leaves may be incorporated into soil, where their decay releases MS over time, usually 1 to 2 years for herbaceous stems (Ashworth et al, 1979; Crowe, 1997). Roots are infected from close association with MS in soil (Huisman, 1988a and 1988b).

Crop specialization with respect to wilt induction is known to occur with *V. dahliae,* and the term "strain" is commonly used to distinguish pathogenic affinities. In contrast to this specialization associated with wilt disease, *V. dahliae* as a species is generally considered able to infect from MS into surface cells of nearly all plant roots. Such infections likely are unimportant in population dynamics of MS, as few MS form in such surface cell infections. Perhaps only 1 such infection in thousands may develop into a systemic infection (Gerik and Huisman, 1985). It has been speculated however, but with only limited data, that an intermediate behavior existed also: systemic invasion but without wilt development. Uncertainties associated with such intermediate behavior included (a) whether such any crop specialization is associated with systemic invasion and (b) whether any meaningful level of MS production might result from wilt-less systemic invasion. The resolution to these uncertainties would impact crop rotational considerations.

Grasses are relatively immune to verticillium wilt symptoms, and because of this were considered as a group to be the best rotational crops--with the assumption that grasses in general do not allow reproduction. For certain crops, some broad leaf plants were considered poor or acceptable rotational crops, with the assumption that this was associated with MS reproduction. Information was presented at the 7th International Verticillium Symposium, 1997, that *V. dahliae* systemically infects many non-host plants, including many but not all grasses and most but not all broadleaved plants, probably forming enough MS to cause increases in soil populations of MS (unpublished data, J. Davis, Univ. Idaho, and 0. Huisman, Univ. California, Berkeley, personal communication, 1997). As such information develops further, effects on crop rotations may be better understood. At the moment, corn, sudan grass and alfalfa are thought to not allow MS reproduction.

Affinities of *V. dahliae* by crop species exist, but it is not clear whether multiple crop affinities exist for strains which incite wilt on mint. As reproduction MS is always highest on wilted plants, knowing whether mint-associated strains may incite wilt on other crops, and whether strains associated with other crops may incite wilt on mint, may be important. Even within a given crop, *V. dahliae* may have varietal affinities, such that "strains" may be distinguished (e.g. on cotton). Such differentiation may be important in varietal evaluation in both greenhouse and field, when only certain isolates may be used for controlled inoculations and infestations. For mint, such varietal-specific strain specificity has not been assessed.

We have observed that *V. dahliae* associated with mint or other crops sometimes promoted growth of mint, i.e., growth was more vigorous than non inoculated mint (Crowe, 1992). In the investigations reported here, we attempted to determine the range of varietal specificity of *V. dahliae* isolates

associated with mint, the affinity of *V. dahliae* isolates for mint which were recovered from wilted plants of some non-mint crops, and to develop methods for clarifying growth promotion. In later studies, we may determine the affinity of mint isolates for other crops, and possibly verify the issue of systemic invasion and reproduction in plants with or without symptoms.

Material and Methods

We previously reported that one of five isolates of *V. dahliae* obtained from strawberries by a cooperator in California incited severe wilt on some, but not all, peppermint varieties. The other strawberry isolates elicited no mint responses (except perhaps enhanced growth). A more careful evaluation with these same five isolates was conducted in 1996, with methods as described above except that only Black Mitcham, Todds and Murray Peppermint varieties were used and only two of the strawberry isolates were used, along with two mint isolates from central Oregon. In addition, two spore-suspension concentrations per isolate were used, 1×10^6 and 1×10^8.

A broader collection of isolates of *V. dahliae* from diseased mint was developed in 1996. Wilted stems were taken from production fields in various states. Some were shipped air dry, some were shipped fresh to the COARC Madras. Sections of stems which had been surface sterilized in .05% NaOC1 for 3 to 5 min were plated onto plain water agar. Fungal growth characteristic of *V. dahliae* was transferred to potato dextrose agar. Eventually, cultures were developed from single conidial spores and stored on PDA test tubes. A few additional cultures were received, which had been isolated by cooperators in other states. These, too, were single spored prior to storage. Initially, 14 cultures were developed from Black Mitcham peppermint in Montana; 4 cultures were developed from Todds and "redefined" and "old" Murray peppermint in the Willamette Valley of Oregon; 10 cultures were developed from Black Mitcham, Roberts or M83-7 peppermint in Idaho; 10 cultures were developed from Black Mitcham peppermint in La Grande, Oregon; 8 cultures were developed from Black Mitcham peppermint and Scotch spearmint in Indiana; 4 cultures were developed from Todds and redefined Murray peppermint in central Oregon; and 8 cultures were developed from Scotch and Native spearmint and Black Mitcham and Murray peppermint in Washington.

Additionally received from cooperators in 1997 were pure cultures of *V. dahliae* originally isolated from wilted potato, strawberry, maple, and cauliflower. In 1997, we isolated *V. dahliae* from wilted commercial purple coneflower *(Echinacea purpurea)* in central Oregon. These cultures were single spored and stored as per isolates from mint.

Of these 54 cultures originating from mint, 17 were eventually tested in 1997 for varietal responses in peppermint and spearmint. These 17 represented the full range of varietal and regional sources. Similarly, we tested the maple, potato, cauliflower, and coneflower isolates on mint varieties.

Pathogenicity of isolates was tested against peppermint, including the varieties Black Mitcham, Todds, Roberts, and redefined Murray, and against spearmint, including the varieties Scotch and Native. Rooted cuttings of each variety were received from Summit Plant Labs (Ft. Collins, CO) within 4 days of inoculation and were held in the greenhouse in original shipping flats until inoculated. In the lab, *V. dahliae* hyphae from chosen isolates was grown on PDA until conidia were abundant, conidia were washed from culture plates on the morning of inoculation, and spore concentrations were adjusted to 1×10^7 conidia/m1 of sterile water. All spore suspensions were kept cool until use and were utilized within

4 hours of preparation. Inoculation was accomplished by pulling rooted cuttings from their individual shipping tray cells and immersing 5 such cuttings in 100 to 200 ml of the suspension per isolate. Roots were not intentionally clipped or broken, but some root damage occurred during handling. After 30 to 60 min immersion, rooted cuttings were individually potted in either 4-inch or 6-inch pots containing pre-wetted and pre-mixed potting mixture of 10 parts sterile peat moss, 4 parts each of sterile Pearlite, vermiculite, and washed sand, and 2 tsp of 12-12-12 fertilizer. In addition, % tsp of slow release fertilizer (1/3:2/3 ammonium sulfate:polymer coated urea) was layered onto the soil surface of each pot after potting.

Pots were watered on an as-needed basis, with the watering level varying with the amount of mint growth, the degree of wilt symptoms developed, and heat and light conditions. In general, pots were watered until saturation. Plants were never shorted for water but were not re-watered until the upper 1 cm of potting mix felt dry. Care was taken to not splash soil among pots or to allow drainage water to pass from one pot to another.

Isolates were evaluated in groups of 6 to 8. Treatments were isolate v. variety combinations, including a non-inoculated check. Each inoculation series included 4 to 5 replications. After inoculation, pots were held in a fully randomized pattern in greenhouse benches but were sometimes temporarily resorted by variety and isolate for measurements. Time of progression to disease symptoms varied on the time of year and heat in the greenhouse. Mid-summer and early fall inoculations manifest symptoms as early as 5 wk, symptoms worsened over 5 to 7 wk, and experiments were terminated after final notetaking after 7 to 8 wk. Spring and late fall inoculations began to show symptoms after 6 weeks, wilt symptoms worsened over 6 to8 wk and experiments were terminated after 9 to 10 wk. With a possible exception discussed below, longer waits did not result in late-developing symptoms. The first series were conducted in 4-inch pots, but it was found more difficult to maintain correct soil moisture levels; later experiments were conducted in 6-inch pots.

Top growth was harvested after 50 to 60 days, and regrowth vigor was also rated. Data collected included a 0 through 5 leaf-curl rating, a 0 through 5 leaf stunt rating, stem heights (main stem only), and dry hay weights at harvest. In some series, a 0 through 5 regrowth vigor rating was determined 3 weeks after initial harvest of top growth.

For reporting below, an overall visual integrated 0 through 5 wilt rating was used which combined both leaf curl and leaf stunting. A rating of 0 was equivalent to noninoculated check plants. A rating of 1 through 3 generally described increasing levels of leaf curl, leaf yellowing, and leaf stunting, with 3 a relatively severe rating. A rating of 4 indicated partial plant death, and a rating of 5 indicated total plant death. In general, growth was quite uniform for all noninoculated plants. For plants which grew more vigorously than the non-inoculated check plants, a wilt rating of —I was recorded.

For stem height and dry-hay weight, all treatment means were converted to a proportion of the noninoculated mean. This eliminates inherent differences among varieties with respect to actual stem length and hay weight, so that varietal responses among varieties can be compared directly. Thus, the relative stem length and hay weight for all non-inoculated treatments is 1.0.

Statistical determinations were made by analysis of variance.

Results

Comparisons of mint v. strawberry isolates. Data (Table 1) show only the integrated wilt rating. Mint isolates were highly aggressive, irrespective of mint variety and spore concentration. In contrast, isolates from strawberries were irregularly aggressive on mint, and aggressiveness varied somewhat with spore concentration. Murray Peppermint was highly susceptible to both Isolates S-1 and S-3 from strawberry, even at reduced spore concentration. Todds Peppermint was moderately susceptible to Isolate S-3, but showed no response to Isolate S-1. At high spore concentration, Black Mitcham Peppermint showed a moderate disease response to Isolate S-3, and an irregular response to Isolate S-1, with some growth showing mild symptoms and some growth enhanced in vigor. At low spore concentration, Black Mitcham's growth was enhanced by the presence of Isolate S-1.

Comparison of mint isolates on mint. Data (Table 2) are shown for a representative comparison of 5 isolates from a single mid-summer inoculation test. Similar data were recorded for other tests, so all 17 isolates tested from peppermint are not included. Within Table 2 it is clear that Isolate 5 incited less wilt symptoms than other isolates, and that Native Spearmint was less affected by all isolates than other mint varieties. Some statistical separation is evident among isolate v. variety combinations, but overall, moderate-to-severe symptoms were observed on all varieties by 4 of the 5 isolates. Dry hay weight is probably the most definitive of the measurements. On average, hay weight was reduced by about 50% by each of Isolates 1 through 4, and 14 of 17 mint isolates for all the tests. Excluding Native spearmint, hay weight of isolates was only 59 to 74% of the mean noninoculated check weight. Although it appears less diseased in Table 1, Murray was not the highest ranking variety in other tests, and in general, no apparent differences were seen among varieties with respect to wilt responses. Native clearly manifest few if any of the typical wilt symptoms: leaf curling, yellowing, or gross stunting However, we consistently measured a growth suppression of 10 to 15% for Native spearmint inoculated with *V dahliae* recovered from wilted mint

Not apparent in Table 2 is some noteworthy variation among the other isolates and varieties with respect to leaf curl and leaf stunt symptoms. For example, the Todds Peppermint variety developed abundant leaf curl in response to Isolate 1, but no leaf stunting. The reverse was true for some other isolates on this variety. On the other hand, varieties (including Todds) commonly showed differences among leaf curl and stunting and yellowing from plant to plant within replications. The overall wilt rating integrated all these measurements and obscured the variable symtomology. It is unlikely that these types of intermediate symptoms are better or worse for crop production in the field. In general, most precede stem death anyway.

Interestingly, the growth of some individual plants was enhanced by inoculation, while other plants were becoming diseased. In some cases, plant growth was initially enhanced, but later declined. In still other cases, enhanced growth could be seen on some stems, at the same time that strong wilt symptoms were present on other stems of the same plant. Other than creating small problems with data summary and analysis, these responses support field data suggestive that *V. dahliae* may promote growth. For Tables 2 and 3 below, all growth enhancement records are included in the mean calculations.

For some greenhouse tests during 1997, attempts to reisolate *V. dahliae* from stems at harvest. Initially, we were somewhat unsuccessful in recovery from stems from 4-inch pots which may have become dry near to harvest (it was also hot at that time). In later tests in 6-inch pots, we were generally successful in

reisolation from symptomatic plants. *V. dahliae* was not routinely reisolated from Native Spearmint, however.

Data is not shown, but with isolates 1, 2, 3, and 4, most varieties regrew less vigorously (some not at all). With the "mild" Isolate 5, both Native Spearmint and Black Mitcham regrowth was greatly affected, and Todds peppermint was somewhat affected by all isolates of *V. dahliae.* However, noninoculated plants struggled to re-grow in some cases, even without the presence of *V dahliae.* This was especially so for both Scotch and Native Spearmint This probably reflects difference in carbohydrate depletion among varieties, perhaps enhanced by *V. dahliae* infection, in this artificial greenhouse situation. Data from other isolates is not shown, but the data shown in Table 2 was similar for other isolates.

Comparison of mint isolates v. isolates from other crops. Table 3 shows the full range of peppermint and spearmint varietal responses to inoculation (1×10^7 spores/ml) with isolates of *V dahliae* from potato, maple, strawberry, and Echinacea, and including a standardly aggressive mint strain from Montana. Also included are two isolates recovered from a single wilted mint plant in a generally wilt-free area of Northern California. Isolates of *V. dahliae* recovered from wilted potato, purple coneflower, maple and cauliflower generally elicited growth enhancement and no wilt symptoms on any peppermint or spearmint varieties.

An exception may have occurred in which Black Mitcham inoculated with the maple isolate eventually developed moderate wilt and growth reduction, when a single replication of all varieties within one test was held 15 weeks for demonstration purposes. At other times, we have held tests or individual pots for extended periods with no such late development of symptoms. It is unclear whether this response was simply delayed, or whether cross contamination with another isolate might have occurred during handling.

Two isolates recovered from a single commercially field grown mint plant in Northern were included in comparison to other *V. dahliae* isolates. This region is otherwise thought to be free of mint wilt. One of these California isolates elicited rapid and severe wilt on all mint varieties, including severe stunting (but not death) of Native Spearmint The other California isolate gave a mixed reaction, damaging some varieties but growth-enhancing other varieties. We speculate that this Northern California mint plant was infected by a form of *V. dahliae* not previously associated with mint, but which has the capacity to elicit wilt in mint

Conclusions

Our hypothesis is that such growth promotion acts at the root surface. It seems clear that this response is not specific to strains which attack mint Whether this phenomenon can be manipulated to the growers' advantage is uncertain. It is interesting to speculate that a non mint strain might be artificially infested into a field to enhance mint growth. After hearing about these effects, growers have told me that their mint yields in general went up in the early days after mint wilt spread around central Oregon, until the time there was too much wilt to tolerate. It is unknown whether systemic invasion of any crop plant by a nonpathogenic strain will preclude systemic invasion by a pathogenic strain.

In general, when selecting isolates from diseased mint stems for use in experiments, it seems worthwhile to pre-test each isolate for overall aggressiveness. Problems with misinterpretation of results which might arise from variations among isolates can be overcome by including several isolates (collected from a range of sites) within a controlled infestation.

V. dahliae may affect growth and yield of Native Spearmint by as much as 10% in the field, even if few symptoms are noted.

In the greenhouse, Black Mitcham did not seem any more susceptible to isolates of *V dahliae* than other mint varieties. See the variety trial report for additional comment on the susceptibility of Black Mitcham: It may be that its perceived higher susceptibility may be due to enhanced reproduction of MS, rather than susceptibility to infection.

Even isolates of *V. dahliae* which cause relatively mild symptoms on generally susceptible varieties may result in measured reduction in growth and yield.

Isolates of *V. dahliae* from other regions that likely are associated with other plants and which may never have been associated with mint before, may nevertheless cause severe wilt disease on mint varieties. These isolates may be somewhat unpredictable in their ability to attack various mint varieties. It is likely that mint relocated into new regions may encounter such isolates. If so, losses may occur, and these isolates may be confused with introduction of typical mint strains arriving with rootstock or equipment. Continued production of mint in fields infested with these isolates likely will result in selection for types more typical of mint strains in established mint regions.

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Table 1. Wilt response in 1996 mint inoculations onto peppermint varieties of two isolates of *Verticillium dahliae* from peppermint, and two isolates from strawberry'.

	Black Mitcham		Todds		Murray	
Isolate Source	low2	high2	low	high	low	high
Mint-1	5d3	5d	5d	5d	5d	4d
Mint-2	4d	5d	4d	4d	5d	5d
Strawberry-1	0 b	0 b	0 b	0 b	4 d	5 d
Strawberry-3	-1 a	3 c	2.5 c	3 c	2 c	4 d
Non-inoculated	0b	0	0b	0b	0b	0b

[1] Rooted mint cuttings were root-dip inoculated with spore suspensions of *V. dahliae ,* individually potted and held under a light bank for simulated 16-hr days. There were four pots per treatment, and pots were assorted randomly under the lights. Pots were observed for 8 wk.
[2] Low inoculation was with 1 x 10^6 spores/ml; high inoculation was with 1 x 10^8 spores/ml.
[3] Overall wilt rating was 0 = no symptoms, 1 through 3 = mild through severe leaf curl and/or yellowing and stunting. 4 = partial death, 5 = total plant death. Data was processed by analysis of variance. Means followed by the same letter cannot be separated *(P*< 5%).

Table 2. Greenhouse results (1997) of mint inoculations onto peppermint and spearmint varieties of 5 isolates of *Verficifflum dahliae* recovered from wilted peppermint and spearmint in 1996[1].

OVERALL WILT RATING[2] [LSD 5% = 1.0 between individual isolate x variety entries.]

						Non-inoculated		
Variety	**Isolate 1**	**Isolate 2**	**Isolate 3**	**Isolate 4**	**Isolate 5**	**Check**	**Mean**	
Black Mitcham	3.8	3.4	2.9	3.8	0.3	0.0	**2.4**	c3
Roberts	4.9	4.3	4.1	3.3	0.0	0.0	**2.8**	**c**
Murray	3.3	2.8	1.5	2.8	0.0	0.0	**1.7**	**b**
Todd	4.5	4.4	2.8	2.6	2.0	0.0	**2.7**	c
Scotch	3.8	3.8	4.0	3.0	0.0	0.0	**2.4**	**c**
Native	0.0	0.0	0.0	0.8	0.0	0.0	**0.1**	**a**
Mean	**3.4**	**3.1**	**2.5**	**2.7**	**0.4**	**0.0**		
	c[3]	c	c	c	a	a		

STEM HEIGHT RELATIVE TO CHECK[4] [LSD 5% = 1.1 for individual isolate x variety entrees.]

						Non-inoculated		
Variety	**Isolate 1**	**Isolate 2**	**Isolate 3**	**Isolate 4**	**Isolate 5**	**Check**	**Mean**	
Black Mitcham	0.63	0.58	0.58	0.58	0.95	1.00	**0.72**	**b**
Roberts	0.48	0.48	0.65	0.60	0.85	1.00	**0.68**	**b**
Murray	0.80	0.73	0.75	0.78	0.80	1.00	**0.81**	**b**
Todd	0.53	0.60	0.80	0.68	0.80	1.00	**0.74**	**b**
Scotch	0.55	0.50	0.53	0.55	0.95	1.00	**0.68**	**b**
Native	0.95	1.00	0.90	0.85	0.85	1.00	**0.93**	**a**
Mean	**0.95**	**1.00**	**0.90**	**0.85**	**1.00**	**1.00**		
	c	**c**	**c**	**c**	**b**	**a**		

DRY HAY WEIGHT RELATIVE TO CHECK[5] [LSD 5% = 0.9 for individual isolate x variety entrees.]

						Non-inoculated		
Variety	**Isolate 1**	**Isolate 2**	**Isolate 3**	**Isolate 4**	**Isolate 5**	**Check**	**Mean**	
Black Mitcham	0.40	0.58	0.48	0.33	0.98	1.00	**0.63**	**bc**
Roberts	0.23	0.38	0.40	0.48	0.88	1.00	**0.56**	**c**
Murray	0.45	0.68	0.78	0.58	0.85	1.00	**0.74**	**b**
Todd	0.45	0.30	0.60	0.55	0.80	1.00	**0.62**	bc
Scotch	0.43	0.33	0.45	0.38	0.95	1.00	**0.59**	bc
Native	1.10	0.90	0.73	0.60	0.93	1.00	**0.88**	**a**
Mean	**0.51**	**0.53**	**0.57**	**0.48**	**0.91**	**1.00**		
	c	c	c	c	**b**	**a**		

Isolates of *Verticfifium dahliae* represented here were recovered from wilted mint in Oregon, Washington, Idaho, Montana and Indiana. For each experiment, roots of rooted cuttings were dipped into 1 x 10^7 spores of *V. dahliae* per ml water suspension. Each mean represents 4 replications. Experiments lasted 7 to 10 wk depending on greenhouse temperature; this one 7 wk during August and September, 1997.

[2] Wilt rating was -1 = growth promotion. 0 = no symptoms, 1 through 3 = mild through severe stunting and/or yellowing, 4 = some dead foliage and branches, and 5 = dead plant.

[3] Means followed by the same or no letter are not separable *(P*< 5%).

[4] Height of the longest stem was determined for each pot. Means for individual entrees were divided by the mean for the non-inoculated check. A mean greater than 1.0 represents overall average growth promotion for the treatment.

[5] Dry weight of all foliage was determined for each pot. Means for individual entrées were divided by the mean for the check. A mean greater than 1.0 represents overall average growth promotion for the treatment.

Table 3. Greenhouse results (1997) of mint inoculations onto peppermint and spearmint varieties of isolates of *Verticillium dahliae* recovered from wilted plants other than mint[1].

OVERALL WILT RATING[2] [LSD 5% = 0.8 for individual isolate x variety entrees.]

Variety	Maple	Cauliflower	Potato	Peppermint Coneflower	Peppermint Montana[3]	Peppermint California-1[3]	Non-inoculated California-2[3]	Check	Mean	
Black Mitc	-0.4	0.2	0.2	-0.2	2.9	-0.6	2.3	0.0	**0.5**	b4
Roberts	0.0	0.0	0.0	-0.2	2.1	1.0	4.2	0.0	**0.9**	bc
Murray	-0.3	-0.2	-0.6	-0.2	2.0	0.4	2.5	0.0	**0.5**	b
Todd	0.0	0.0	0.0	0.2	1.7	0.6	4.1	0.0	**0.8**	bc
Scotch	0.2	-0.4	-0.4	0.0	4.5	1.0	4.4	0.0	**1.2**	c a
Native	0.0	-1.0	-1.0	-0.8	0.6	-1.0	3.1	0.0	**0.0**	
Mean	**-0.1**	**-0.2**	**-0.3**	**-0.2**	**2.3**	**0.2**	**3.4**	**0.0**		
	a[4]	*a*	*a*	*a*	c	*b*	c	ab		

STEM HEIGHT RELATIVE TO CHECK[5] [LSD 5% = 0.3 for individual isolate x variety entrees.]

Variety	Maple	Cauliflower	Potato	Coneflower	Peppermint Montana	Peppermint California-1	Peppermint California-2	-inoculated Check	Mean
Black Mitc	1.10	1.30	1.10	1.20	0.90	1.40	0.80	1.00	**1.10**
Roberts	1.20	1.20	1.20	1.20	1.00	0.90	0.60	1.00	**1.04**
Murray	1.00	1.00	1.20	1.10	0.80	1.20	1.00	1.00	**1.04**
Todd	1.10	1.00	0.90	1.00	1.00	1.10	0.50	1.00	**0.95**
Scotch	1.00	1.00	1.10	1.00	0.60	1.00	0.50	1.00	**0.90**
Native	1.00	1.00	0.90	0.90	1.00	0.90	0.70	1.00	**0.93**
Mean	**1.07**	**1.08**	**1.07**	**1.07**	**0.88**	**1.08**	**0.68**	**1.00**	
	b	b	b	b	ab	b	a	b	

DRY HAY WEIGHT RELATIVE TO CHECK[6] [LSD 5% = 0.4 for individual isolate x variety entrees.]

Variety	Maple	Cauliflower	Potato	Coneflower	Peppermint Montana	Peppermint California-1	Peppermint California-2	-inoculated Check	Mean
Black Mitc	1.30	1.70	1.60	2.00	1.80	1.50	0.70	1.00	**1.45**
Roberts	1.20	1.60	1.10	1.20	0.70	0.90	0.30	1.00	**1.00**
Murray	1.10	1.20	1.40	1.90	0.30	1.70	0.60	1.00	**1.15**
Todd	1.40	1.60	1.90	1.30	1.30	1.40	0.20	1.00	**1.26**
Scotch	0.90	1.20	1.10	1.00	0.10	1.10	0.40	1.00	**0.85**
Native	1.30	1.30	1.30	1.00	1.10	1.30	0.50	1.00	**1.10**
Mean	**1.20**	**1.43**	**1.40**	**1.40**	**0.88**	**1.32**	**0.45**	**1.00**	
	d	d	d	d	bc	cd	a	c	

Non mint isolates of *Verticillium dahliae* were recovered from wilted plants of the type listed; for each experiment, roots of rooted cuttings were dipped into 1 x 10^7 spores of *V. dahliae* per ml water suspension. Each wilt and stem mean represents 5 replications; each weight mean 4 replications. Experiments lasted 7 to 10 wk depending on greenhouse temperature; this one 10 wks because of cool fall temperatures.

[2] Wilt rating was -1 = growth promotion, 0 = no symptoms, 1 through 3 = mild through severe stunting and/or yellowing, 4 = some dead foliage and branches, and 5 = dead plant.

[3] The two California isolates were recovered from the same plant in 1997. The Montana mint isolate was previously tested and was considered a positive check. For a single replication held in a light bank for 13 wks, the severity of the reaction on all varieties worsened with the Montana isolate, but California isolates and non mint isolates remained similar. For the Montana isolate, wilt rating increased to over 4, stem height dropped to a rating of 0.70 and dry hay weight rating dropped to 0.65.

[4] Means followed by the same or no letter are not separable *(P*< 5%).

[5] Height of the longest stem was determined for each pot. Means for individual entrees were divided by the mean for the noninoculated check. A mean greater than 1.0 represents overall average growth promotion for the treatment.

[6] Dry weight of all foliage was determined for each pot. Means for individual entrées were divided by the mean for the check. A mean greater than 1.0 represents overall average growth promotion for the treatment.