EVALUATION OF RELATIVE RESISTANCE OF DIFFERENT STRAWBERRY CULTIVARS TO *PHYTOPHTHORA* AND *VERTICILLIUM DAHLIAE* AS A POTENTIAL ALTERNATIVE TO METHYL BROMIDE

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Strawberries in California's commercial fields are subject to decline and death caused by soil-borne pathogens such as: *Verticillium dahliae*, *Colletotrichum acutatum* and several *Phytophthora* spp. (*P. cactorum*, *P. citricola*, *P. fragariae*, *P. parasitica*) and an unidentified *Phytophthora* sp. (designated as isolate SB890). Our studies showed that *P. cactorum* is the most frequently isolated *Phytophthora* sp. from strawberry and that *P. citricola* and *Phytophthora* sp. SB890 are usually recovered from fields with a high incidence of dead plants. *P. fragariae* has been occasionally isolated from collapsed plants during cool wet weather. Pathogenicity tests in artificially infested soil also revealed that *P. citricola* and *Phytophthora* sp. SB890 are more virulent in strawberry than either *P. parasitica* or *P. cactorum*.

Methyl bromide:chloropicrin mixture as a preplant soil fumigant effectively controls several soil-borne pests and pathogens, including *Phytophthora* and *Verticillium* species. These fungi can greatly affect profitability of strawberry production in California. We have investigated the feasibility of using genetic resistance to *Phytophthora* spp. and *Verticillium* sp. in strawberries as an alternative to methyl bromide fumigation. The approach, particularly if combined with careful soil water management, could be both economically effective and environmentally desirable, and could serve as one component of an integrated strategy for control of Verticillium wilt and Phytophthora root and crown rot of strawberry.

Our previous research on the relative resistance of 12 strawberry cultivars (Capitola, Chandler, Commander, Douglas, Fern, Irvine, Muir, Pajaro, Parker, Sheehy, Tioga and Yolo) to *P. cactorum* and *P. citricola* in artificially infested soil under greenhouse conditions revealed marked differences in resistance to these pathogens among the twelve strawberry cultivars.

During the 1996-97 growing season we studied comparative growth and yield of ten different strawberry cultivars (Anaheim, Camarosa, Capitola, Chandler, Irvine, Laguna, Marmolada, Pajaro, Seascape and Selva) in the field. Treatments were as follows: one section naturally infested with *Verticillium dahliae* and experimentally infested with field soil containing *P. cactorum*, *P. citricola* and *Phytophthora* sp. SB890 was preplant fumigated in August 1994, 1995 and 1996 (EI94F949596) with a methyl bromide:chloropicrin mixture (57:43%) at the rate of 375 lbs/acre by the flat bed fumigation method and covered immediately with sealed polyethylene tarps; one section containing the same pathogens was nonfumigated in the 1993-1994, 1994-1995, 1995-1996 and 1996-1997 strawberry growing seasons (EI93NF93949596); one section never previously cropped to strawberry and naturally infested with *Verticillium dahliae* was not preplant fumigated during the 1996-1997 growing season (NEINF9596). Fifty-two inch planting beds were prepared with drip irrigation lines and covered with black over black polyethylene mulch. Strawberry plants were planted 14 inches apart in two rows on each bed, either on October 24, November 14 or December 4, 1996 depending on cultivar. Each cultivar was represented in 5 replicated plots, whereas each replicate plot consisted of 10 plants per cultivar. The replicate plots were randomized within blocks within the sections. The effects of methyl bromide:chloropicrin soil fumigation as well as relative resistance of individual strawberry cultivars was based on the cumulative total (marketable + nonmarketable) yield (trays/acre) collected by weekly harvest

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from April 7 through August 11, 1997. Isolations of *Phytophthora* spp. and *Verticillium dahliae* were attempted from collapsed or dead plants. Soil from each fumigation treatment was assayed for *Phytophthora* spp. and *Verticillium dahliae* at season end.

Phytophthora spp. and *Verticillium* dahliae were consistently recovered from symptomatic plants throughout the 1996-1997 growing season. In addition, we assayed soil from replications of selected treatments to determine the inoculum density of *Verticillium dahliae* in August 1997.

The results on yield of the ten tested strawberry cultivars (Anaheim, Camarosa, Capitola, Chandler, Irvine, Laguna, Marmolada, Pajaro, Seascape and Selva) under the different fumigation treatments are summarized in Table 1. Yield patterns of selected cultivars under the different fumigation treatments are presented in Fig. 1.

Among cultivars planted in *Phytophthora* spp. and *Verticillium* sp. infested, nonfumigated soil (EI93NF93949596) yield ranged from to 682 trays/acre for Pajaro to 1,958 trays/acre for Laguna (Table 1). In soil containing the same pathogens and preplant fumigated in 1994, 1995 and 1996 (EI94F949596), yield ranged from 1,527 trays/acre for Marmolada to 5,134 trays/acre for Chandler (Table1). In soil naturally infested with *Verticillium* sp. and nonfumigated in 1995 and 1996 (NEINF9596) yield ranged from 777 trays/acre for Anaheim to 1,855 trays/acre for Selva (Table 1).

Among the tested cultivars Marmolada exhibited the most stable and least percent yield loss when grown in *Phytophthora* spp. and or *Verticillium* sp. infested, nonfumigated soil relative to infested and then preplant fumigated soil (Fig. 1 and Table 1).

Among all cultivars growing in soil infested with indigenous *Verticillium dahliae* at an average of 8.9 propagules per gram of soil, there was less difference in yield than among the same cultivars grown in soil infested with *Phytophthora* spp. and *Verticillium dahliae* at an average of 7.4 propagules per gram of soil or less (Table 1), suggesting that there are greater differences in resistance among the tested cultivars to *Phytophthora* spp. than to *Verticillium dahliae*. However, the level of resistance to either *Phytophthora* spp. or *Verticillium dahliae* in the tested cultivars may not be sufficient enough to equal the beneficial effect of methyl bromide:chloropicrin preplant soil fumigation for profitable commercial strawberry production in California.

Our research however showed that a preplant soil fumigation with methyl bromide:chloropicrin mixture (57:43%) at the rate of 375 lbs/acre is very effective in controlling several *Phytophthora* spp. and *Verticillium dahliae* in commercial strawberry fields, emphasizing the importance of preplant soil fumigation for profitable production of strawberry in California.

Figure 1. Yield of Camarosa, Marmolada and Selva grown in soil naturally infested with *Verticillium dahliae* and experimentally infested with soil naturally infested with *Phytophthora* spp. in 1993 that was then nonfumigated and under strawberry in the 1993-94, 1994-95, 1995-96 and 1996-97 growing seasons (EI93NF93949596), or grown in soil naturally infested with *Verticillium dahliae* and experimentally infested with soil naturally infested with *Phytophthora* spp. in 1994 that was then preplant soil fumigated annually with a methyl bromide:chloropicrin mixture (57:43%) 375 lbs/acre and under strawberry in the 1994-95, 1995-96 and 1996-97 growing seasons (EI94F949596). Average number of indigenous *Verticillium dahliae* propagules per gram of soil was 0.6 for EI94F949596 and 7.4 for EI93NF93949596 in August 1997.

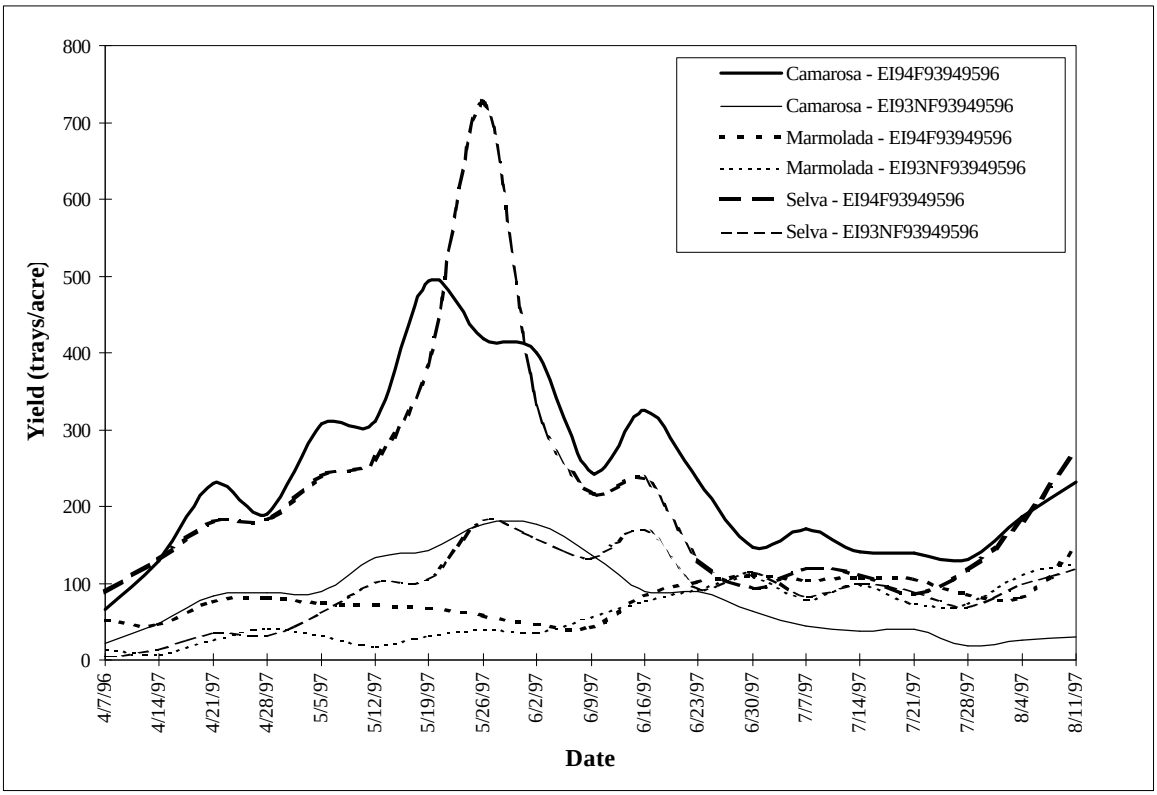

Table 1. Comparative yield of ten different strawberry cultivars in soil experimentally infested with *Phytophthora cactorum*, *P. citricola*, *Phytophthora* spp. SB890, and naturally infested with *Verticillium dahliae* that was preplant fumigated with methyl bromide:chloropicrin (57:43%) mixture at the rate of 375 lbs/acre or nonfumigated in Watsonville, California.

	T R E A T M E N T S					
	EI94F949596 [a]		EI93NF93949596 [b]		NEINF9596 [c]	
Cultivar	Yield (Trays/A)		Yield (Trays/A)	Percent yield loss (d)	Yield (Trays/A)	Percent yield loss (d)
Chandler	5,134 [e]	A [f]	1,434 AB	72	1,699 A	67
Camarosa	4,492	AB	1,534 AB	66	1,127 B	75
Capitola	4,866	AB	1,682 AB	65	883 B	82
Seascape	4,419	AB	1,800 A	59	1,659 A	62
Selva	4,079	AB	1,763 A	57	1,855 A	55
Irvine	3,645	B	1,740 A	52	1,045 B	71
Laguna	3,600	B	1,958 A	46	1,638 A	55
Anaheim	1,899	C	738 DC	61	777 B	59
Marmolada	1,527	C	1,136 BC	26	993 B	35
Pajaro	1,907	C	682 D	64	950 B	50

a EI94F949596 = Experimentally infested with *Phytophthora* spp. in 1994, fumigated in 1994, 1995 and 1996, and under strawberry 1994-95, 1995-96 and 1996-97growing seasons. Average number of indigenous *Verticillium dahliae* propagules per gram of soil was 0.6 in August 1997.

b EI93NF93949596 = Experimentally infested with *Phytophthora* spp. in 1993, nonfumigated and under strawberry 1993-94, 1994-95, 1995-96 and 1996-97 growing seasons. Average number of indigenous *Verticillium dahliae* propagules per gram of soil was 7.4 in August 1997.

c NEINF9596 = Nonexperimentally infested and nonfumigated and under strawberry 1995-96 and 1996-97 growing seasons. Average number of indigenous *Verticillium dahliae* propagules per gram of soil was 8.9 in August 1997.

d Percent yield loss expressed as percent of fumigated 1996 treatment (EI94F949596).

e Yield expressed as trays/acre of both marketable and nonmarketable fruit harvested weekly from 4/7/97 through 8/11/97.

f Figures with the same letter are not significantly different according to Duncan's mean separation at $\alpha = 0.01$