COMPARATIVE PERFORMANCE OF DIFFERENT STRAWBERRY CULTIVARS WITH AND WITHOUT METHYL BROMIDE FUMIGATION IN FIELD SOIL NATURALLY INFESTED BY *PHYTOPHTHORA* SPP. AND *VERTICILLIUM* SP. AND FEASIBILITY OF USING RESISTANCE OF STRAWBERRY CULTIVARS AS AN ALTERNATIVE TO METHYL BROMIDE SOIL FUMIGATION

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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. 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. 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 (57:43%) 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. 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 the 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* (*P. cac*), *P. citricola* (*P. cit*), in artificially infested soil under greenhouse conditions revealed marked differences in resistance to *P. cit* and *P. cac* among the twelve strawberry cultivars (Fig. 1).

During the 1994-95 growing season we studied the effects of preplant soil fumigation with methyl bromide:chloropicrin on growth and yield of seven different strawberry cultivars (Capitola, Chandler, Douglas, Irvine, Pajaro, Seascape and Selva) in soil naturally infested with *P. cactorum*, *P. citricola*, *Phytophthora* sp. SB890, and *Verticillium dahliae* in Watsonville, California. A field of uniformly, naturally infested soil with the aforementioned pathogens was divided into three equal sections. One section was preplant fumigated on 8/25/94 (F94) 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 was preplant fumigated in the same manner in the previous year (8/20/93) but not fumigated for the 1994-1995 growing season (F93NF94); and one section was left untreated in both 1993-1994 and 1994-1995 growing seasons (NF9394). Fifty-two inch planting beds were prepared with drip irrigation lines and covered with white over black polyethylene mulch. Strawberry plants were planted 16 inches apart in two rows on each bed, either on September 1 or September 22 (summer planting) or on November 4 or November 11 (winter planting) depending on cultivar. Some cultivars were both summer and winter planted. Each cultivar was represented in either 8 or 4 replicated plots, whereas each replicate plot consisted of 10 plants per cultivar. The replicate plots were randomized within the fumigated and nonfumigated sections. The effects of methyl bromide:chloropicrin soil fumigation as well as relative resistance of individual strawberry cultivars was based on the disease severity rating (DSR) recorded monthly and cumulative yield (trays/acre) collected by weekly harvest from April 18 through July 27, 1995. DSR was based on the above ground symptoms in strawberry plants where: 0 = good vigorous growth; 1 = slightly stunted growth; 2 = visible stunted growth; 3 = pronounced stunted growth with very few fruits; 4 = nearly dead plant, and 5 = dead plant. Isolations of *Phytophthora* spp. and *Verticillium dahliae* were attempted from all dead plants.

The results on the effects of methyl bromide:chloropicrin preplant soil fumigation on vigor and yield of seven strawberry cultivars (Capitola, Chandler, Douglas, Irvine, Pajaro, Seascape and Selva) in naturally infested field soil are summarized in Table 1 and Fig. 2.

In naturally infested, nonfumigated soil (NF9394) summer planted Pajaro, Chandler and Capitola had 100%, 95% and 49% of plants with DSR ≥3, respectively (Fig. 2), and yielded 360, 1,218 and 2,062 trays/acre,

respectively (Table 1). The same cultivars in methyl bromide:chloropicrin preplant fumigated soil in 1993 but not fumigated in 1994 (F93NF94) had DSR ≥3 of 99%, 92% and 30% (Fig. 2), and yielded 510, 1,729 and 3,053 trays/acre, respectively (Table 1). In soil that was methyl bromide:chloropicrin preplant fumigated in 1994 (F94) the same cultivars had respectively 8%, 14% and 0% DSR ≥3 (Fig. 2) and yielded 3,903, 4,716 and 4,080 trays/acre (Table 1). The relative performance of the winter planted Pajaro, Chandler and Capitola cultivars in naturally infested nonfumigated, and fumigated soil was similar to the performance of the same cultivars that were summer planted (Table 2).

Summer planted Douglas, Selva, Seascape, and Irvine in nonfumigated soil (NF9394) had 67%, 83%, 80% and 92% of plants with DSR ≥3 (Fig. 2) and yielded 1,627, 1,129, 1,644 and 388 trays/acre (Table 1), respectively. The same cultivars in methyl bromide:chloropicrin fumigated soil in 1993 but not fumigated in 1994 (F93NF94) had 80%, 75%, 80% and 90% plants with DSR ≥3 (Fig. 2) and yielded 2,997, 1,701, 2,459 and 786 trays/acre respectively (Table 1). In contrast the same cultivars in methyl bromide:chloropicrin fumigated soil in 1994 (F94) had 0%, 3%, 0% and 23% of plants with DSR ≥3 (Fig. 2) and yielded 6,740, 5,727, 4,966 and 4,307 trays/acre respectively (Table 1).

Our research 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.

In naturally infested and nonfumigated soil the yield loss of seven strawberry cultivars ranged from 91% for Pajaro to 49% for Capitola as compared to the yield of the same cultivars in naturally infested but preplant methyl bromide:chloropicrin fumigated soil (Table 1). Likewise, a substantial yield loss during the 1994-95 growing season occurred in soil naturally infested with *Phytophthora* spp. and *Verticillium dahliae* that was preplant fumigated in August 1993, planted with strawberry for the 1993-94 growing season and then again planted with strawberry for the 1994-95 season but without preplant fumigation. The yield loss in this treatment ranged from 87% for Pajaro to 25% for Capitola as compared to the yield in the naturally infested but preplant fumigated soil (Table 1).

Our research also revealed a marked difference in the relative resistance to *Phytophthora* spp. and *Verticillium* among seven tested strawberry cultivars as measured by the disease severity and the cumulative yield of individual cultivars in naturally infested field soil. For example, in infested and preplant fumigated soil the yield of Pajaro, Capitola and Douglas was, respectively, 3,903, 4,080 and 6,740 trays/acre; the difference in the increased yield of 4% and 73% for Capitola and Douglas respectively over the yield of Pajaro is, perhaps, inherently linked to the specific cultivars (Table 3). On the other hand, in infested and nonfumigated soil the yield was significantly lower as compared to the yield on fumigated soil for the same three cultivars that was, respectively 360, 2,062 and 1,627 trays/acre. But, exceedingly greater differences in increased yield that was 427% for Capitola and 360% for Douglas above the yield of Pajaro in the presence of pathogens than in the absence of pathogens suggests marked differences in the genetic makeup that conditions resistance among the tested cultivars to *Phytophthora* spp. and *Verticillium dahliae* (Table 3).

Our results showed that among the seven cultivars (Douglas, Selva, Chandler, Irvine, Capitola, Seascape and Pajaro) growing in nonfumigated, infested soil with *Phytophthora* spp. and *Verticillium dahliae* in the 1994-95 growing season, Pajaro and Irvine were poor performers whereas Capitola, Seascape and Douglas performed relatively well, as indicated by the disease severity ratings and yield (Table 1). Repeated experiments at different locations may be necessary for the firm conclusions on performance of these seven cultivars in soil infested with *Phytophthora* spp. and *Verticillium dahliae*. These results corroborated our previous findings on relative resistance of the same strawberry cultivars in artificially infested soil in greenhouse experiments. Results from the present studies indicate that the degree of resistance alone to *Phytophthora* spp. and *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.

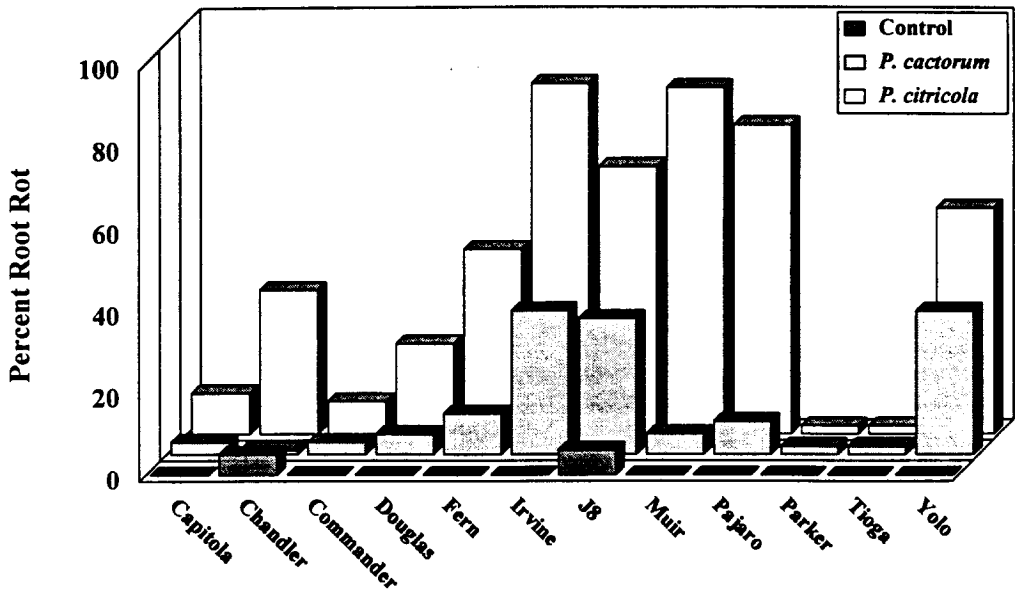

Figure 1. Percent root rot of tweleve strawberry cultivars grown in the greenhouse for three months in soil artificially infested with *P. cactorum* or *P. citricola*.

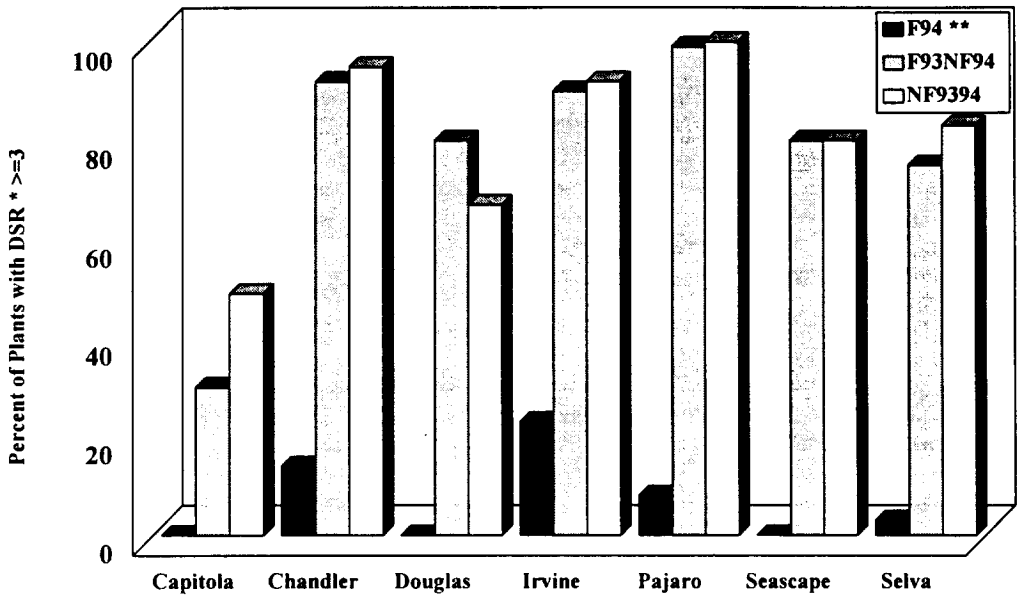

Figure 2. Effectiveness of preplant soil fumigation with methyl bromide: chloropicrin mixture (57:43%) 375lba/A on disease severity rating (DSR) of seven strawberry cultivars in field soil naturally infested with *Phytophthora cactorum, P. citricola, Phytophthora* spp. SB890 and *Verticillium dahliae*.

*** DSR based on: 0 = symptomless, vigorous plant; 3 = severly stunted, no or few fruit; 5 = dead plant**

**** Treatments for 1994-95 growing season:**
F94 = Fumigated 8/22/94
F93NF94 = Fumigated 8/20/93 and under strawberry 1993-94 growing season ; nonfumigated 8/22/94 and under strawberry 1994-95 growing season
NF9394 = Nonfumigated 8/20/93 and under strawberry 1993-94 growing season; nonfumigated 8/22/94 and under strawberry 1994-95 growing season

Table 1. Cumulative yield[1] of seven different summer planted strawberry cultivars in soil infested with *Phytophthora* spp. and *Verticillium dahliae* that was preplant fumigated with methyl bromide:chloropicrin (57:43%) mixture at the rate of 375lbs/A and nonfumigated soil in Watsonville, California.

	TREATMENTS							
	Fumigated 1994 (F94)[2]		Fumigated 1993 Nonfumigated 1994 (F93NF94)[3]			Nonfumigated 1993 and 1994 (NF9394)[4]		
Cultivar	Yield (Trays/Acre)		Yield (Trays/Acre)		Percent Yield Loss[5]	Yield (Trays/Acre)		Percent Yield Loss[5]
Douglas	6,740	A[6]	2,997	A	56	1,627	AB	76
Selva	5,727	AB	1,701	B	70	1,129	B	80
Seascape	4,966	AB	2,459	AB	50	1,644	AB	67
Chandler	4,716	AB	1,729	B	63	1,218	B	74
Irvine	4,307	B	786	C	82	388	C	91
Capitola	4,080	B	3,053	A	25	2,062	A	49
Pajaro	3,903	B	510	C	87	360	C	91

1 Yield expressed as trays/acre of both marketable and nonmarketable fruit harvested weekly from 4/18/95 through 7/28/95

2 F94 = Fumigated 8/22/94, under strawberry 1994-95 growing season

3 F93NF94 = Fumigated 8/20/93 and under strawberry 1993-94 growing season, nonfumigated 8/22/94 and under strawberry 1994-95 growing season

4 NF9394 = Nonfumigated 8/20/93 and under strawberry 1993-94 growing season, nonfumigated 8/22/94 and under strawberry 1994-95 growing season

5 As compared to the yield in the fumigated 1994 treatment

6 Figures with the same letter are not significanly different according to Duncan's mean seperation at alpha = 0.01

Table 2. Cumulative yield[1] of three different winter planted strawberry cultivars in soil infested with *Phytophthora* spp. and *Verticillium dahliae* that was preplant fumigated with methyl bromide:chloropicrin (57:33%) mixture at the rate of 375lbs/A and nonfumigated soil in Watsonville, California.

	TREATMENTS							
	Fumigated 1994 (F94)[2]		Fumigated 1993 Nonfumigated 1994 (F93NF94)[3]			Nonfumigated 1993 and 1994 (NF9394)[4]		
Cultivar	Yield[1] (Trays/Acre)		Yield (Trays/Acre)		Percent Yield Loss[5]	Yield (Trays/Acre)		Percent Yield Loss[5]
Chandler	3,057	A[6]	1,281	A	58	906	AB	70
Capitola	2,876	A	1,735	A	40	1,336	A	54
Pajaro	2,657	A	586	B	78	434	B	84

1 Yield expressed as trays/acre of both marketable and nonmarketable fruit harvested weekly from 4/18/95 through 7/28/95

2 F94 = Fumigated 8/22/94, under strawberry 1994-95 growing season

3 F93NF94 = Fumigated 8/20/93 and under strawberry 1993-94 growing season, nonfumigated 8/22/94 and under strawberry 1994-95 growing season

4 NF9394 = Nonfumigated 8/20/93 and under strawberry 1993-94 growing season, nonfumigated 8/22/94 and under strawberry 1994-95 growing season

5 As compared to the yield in the fumigated 1994 treatment

6 Figures with the same letter are not significanly different according to Duncan's mean seperation at alpha = 0.01

Table 3. Differential yield[1] of seven different summer planted strawberry cultivars grown in soil naturally infested with *Phytophthora cactorum*, *P. citricola*, *Phytophthora* sp. SB890 and *Verticillium dahliae* that was either preplant fumigated with methyl bromide:chloropicrin (57:43%) or nonfumigated.

	TREATMENTS											
	Fumigated 1994 (F94)[2]				Fumigated 1993 Nonfumigated 1994 (F93NF94)[3]				Nonfumigated 1993 and 1994 (NF9394)[4]			
			Yield Relative to Pajaro				Yield Relative to Pajaro				Yield Relative to Pajaro	
Cultivar	Yield (Trays/Acre)		Trays/Acre	Percent	Yield (Trays/Acre)		Trays/Acre	Percent	Yield (Trays/Acre)		Trays/Acre	Percent
Douglas	6,740	A[5]	+2,837	+73	2,997	A	+2,487	+488	1,627	AB	+1,267	+352
Selva	5,727	AB	+1,824	+47	1,701	B	+1,191	+234	1,129	B	+768	+213
Seascape	4,966	AB	+1,063	+27	2,459	AB	+1,949	+382	1,644	AB	+1,284	+256
Chandler	4,716	AB	+813	+21	1,729	B	+1,219	+239	1,218	B	+857	+238
Irvine	4,307	B	+404	+10	786	C	+276	+54	388	C	+28	+8
Capitola	4,080	B	+176	+5	3,053	A	+2,543	+499	2,062	A	+1,702	+472
Pajaro	3,903	B	-	-	510	C	-	-	360	C	-	-

1 Yield expressed as trays/acre of both marketable and nonmarketable fruit harvested weekly from 4/18/95 through 7/28/95

2 F94 = Fumigated 8/22/94, under strawberry 1994-95 growing season

3 F93NF94 = Fumigated 8/20/93 and under strawberry 1993-94 growing season, nonfumigated 8/22/94 and under strawberry 1994-95 growing season

4 NF9394 = Nonfumigated 8/20/93 and under strawberry 1993-94 growing season, nonfumigated 8/22/94 and under strawberry 1994-95 growing season

5 Figures with the same letter are not significanly different according to Duncan's mean seperation at alpha = 0.01