Evaluation of Pre-plant Fumigation and Post-plant Treatments for Replanted Peach Orchards

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Abstract. Pre-plant fumigation with methyl bromide has been an important practice when cling peach orchards have been replanted in soil previously occupied by orchards of *Prunus* spp. Methyl bromide will no longer be available for use after 2004. Pre-plant fumigation disinfests the soil of pathogenic nematodes and microorganisms that feed on peach roots and result in poor growth, reduced yields and increased susceptibility to bacterial canker and other problems. This trial compares various preplant fumigation materials in combination with several post-plant nematicides, fertilizers and amendments in a replanted cling peach orchard.

Initially, fumigation with methyl bromide, Vapam and Telone II all but eliminated ring, root lesion and root knot nematodes in this trial. Nematode numbers stayed low in all fumigated areas for the first two years but by the end of the third growing season had increased to levels significantly higher than unfumigated areas. Postplant nematicides applied to unfumigated areas reduced nematode numbers initially after application but nematode numbers rebounded to untreated levels by the next year. Despite high nematode numbers, fumigated trees were much more vigorous, had higher nitrogen and potassium leaf levels and had higher yields. Yields were increased by 68%, 107%, and 168% in Telone II, Vapam and methyl bromide treated areas, respectively compared to unfumigated areas. Black polyethylene mulch and foliar micronutrients were the only post-plant treatments to increase yield, and only in unfumigated areas. Pre-plant fumigation and supplemental calcium and nitrogen significantly reduced lesion size in trees inoculated with *Pseudomonas syringae*.

Introduction. As old peach orchards are replaced, growers are faced with a poorly understood replant problem that involves pathogenic nematodes and soil-borne microorganisms. The most problematic nematodes in the North San Joaquin Valley are ring (*Mesocriconema xenoplax*), root lesion (*Pratylenchus vulnus*) and rootknot (*Meloidogyne spp*.). Ring nematode is associated with the bacterial canker complex, a disease that kills young trees in replanted orchards. Methyl bromide has been used successfully as a pre-plant fumigant for many years but it will no longer be available to U.S. growers after 2004. Alternative fumigants generally do not perform as well as methyl bromide. The use of post-plant nematicide and foliar fertilizer treatments in combination with alternative fumigants may be necessary to maintain tree health. Microbiological soil additives have recently become popular with claims to improve soil "health" and reduce nematodes and disease. These claims need to be evaluated scientifically.

A trial was initiated in 2000 in a commercial, replanted peach orchard with high nematode numbers and a history of bacterial canker. Preplant fumigants Telone II and Vapam were compared to methyl bromide fumigated and unfumigated areas. Several post plant fertilizers, nematicides and microbiological amendments have been applied for three years after planting in fumigated and non-fumigated areas. Treatments are listed below.

- **<u>Treatments applied at planting:</u>**
  Composted green waste and steer manure @ 4.7 tons per acre each plus ten pounds of oyster shell flour per tree were applied to berms prior to planting and back-filled into planting holes. Composted green waste was applied as a side dress @ 3 tons per acre in February 2002.

- **Post-plant treatments:**
  Post-plant treatments have been applied for three years to fumigated and non-fumigated areas through the drip irrigation system or as foliar sprays**.**

List of Post-plant Treatments

- **Untreated**
- **Enzone®** @ 1000 ppm each October
- **Nemacur® 3 EC** @ 1 gallon per acre each October
- **DiTera®** @ 10 lb. per acre each April and October
- Foliar **low biuret urea** @ 50 lb. nitrogen / acre (100 lb. of granular product per acre)
- Compost & oyster shell at planting + foliar and drip-applied **calcium** in-season.
- Compost & oyster shell + microbiological soil additives (**Tilth® or Evenmore Classic Soil® & Iota®)**
- Compost & oyster shell + **Kelp extract** (Shurcrop Supra®) & **humic acid**
- Oyster shell pre-plant + **foliar micronutrients** (5 lb. per acre Response®)
- Black polyethylene mulch (applied April 2001).

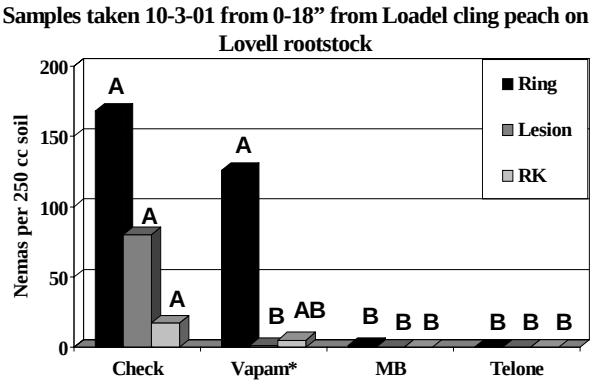
Effects of pre-plant fumigation on nematodes. Despite being fallow for two years prior to initiation of the trial, there were high numbers of parasitic nematodes below a depth of two feet. Soil samples taken prior to planting indicated methyl bromide and Vapam significantly reduced plant parasitic, fungal and bacterial-feeding nematodes down to at least five feet (Table 1). Vapam did not reduce nematodes well in one out of four replications.

Table 1. Nematode Populations in Fumigated and Unfumigated Soil Prior to Planting.

		Average Number of Nematodes per Liter of Soil				
	Soil Depth (feet)	*M. xenoplax* (ring)	*P. vulnus* (lesion)	*Heterodera*	*Rhabditida spp.*	*Aphelinchida spp.*
Untreated	0-1	13	62	258	18,045	1771
	1-2	165	384	69	2644	769
	2-3	698	596	0	2854	527
	3-4	913	1041	0	882	357
	4-5	828	588	0	355	103
M. bromide	0-1	15	0	0	2381	241
	1-2	0	0	0	832	402
	2-3	1	0	0	49	12
	3-4	1	0	0	151	11
	4-5	4	0	0	68	2
Vapam	0-1	3	0	0	4136	640
	1-2	87	35	0	1063	118
	2-3	79	27	0	263	74
	3-4	11	11	0	251	64
	4-5	0	0	0	94	42
Telone	0-1			0	1086	162
	1-2			0	484	80
	2-3			0	816	128
	3-4			0	260	36
	4-5			0	50	16

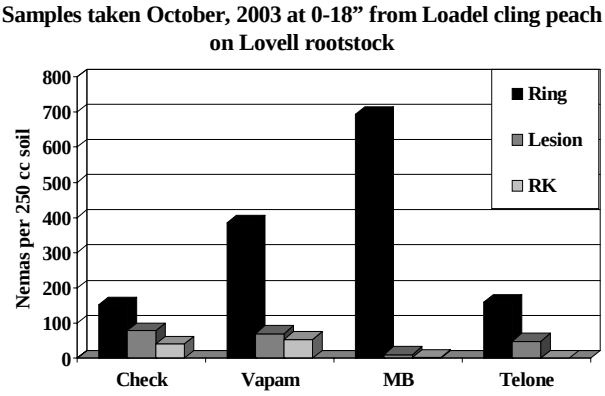
One year after treatment, pathogenic nematodes were still almost zero in the surface 18 inches of soil in areas treated with methyl bromide, Telone II and in the three successful Vapam replications (Fig. 1). Numbers of fungal and bacterial feeding nematodes were similar in untreated and fumigated soil. However, soil sampled in October 2003 (third leaf) indicate pathogenic nematodes in fumigated areas are now significantly higher than unfumigated areas (Fig. 2).

Fig. 1 Pathogenic Nematodes in the Rootzone of First-leaf Peach Trees One Year After Soil Fumigation



*All nematodes in Vapam treatment found in Rep 3 only.

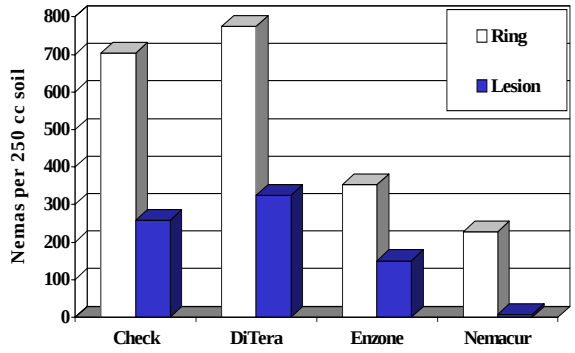
Fig. 2. Pathogenic Nematodes on Third-leaf Peach Trees Three Years After Soil Fumigation



Effects of post-plant nematicides on nematode numbers.

Soil was collected in February 2002 and 2003 to determine the effects of post-plant nematicides and microbial soil amendments. In the first year, ring nematodes were reduced approximately 50% in Enzone treated areas and 70% in Nemacur treated areas. Root lesion nematodes were reduced about 40% with Enzone and almost eliminated by Nemacur. DiTera did not reduce either nematode species. Results from 2003 samples are less clear. Nematode numbers were much lower in 2003 untreated soil than the previous year. Nematicides had no clear effect. Numbers of rootknot nematodes were much higher in all treatments in 2003 and were showing up in areas that previously had no detected rootknot.

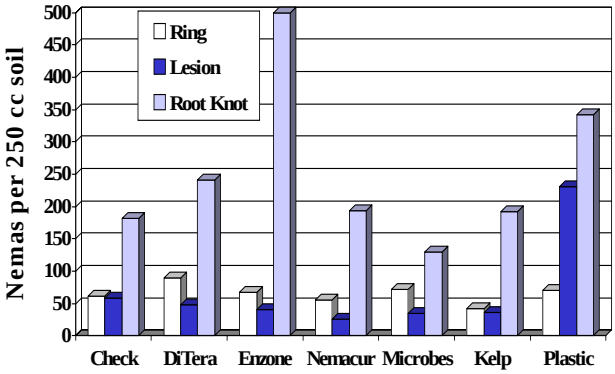
Pathogenic Nematode Numbers on Peach Trees as Influenced by Post-plant Nematicide Treatment - First Year



•Nematicides injected through drip irrigation system October 2001 on first-leaf peach trees in non-fumigated soil.

•Soil sampled February, 2002.

Pathogenic Nematode Numbers on Peach Trees as Influenced by Post-plant Nematicide Treatments - Third Year



•Nematicides injected through drip irrigation system each October for two years in non-fumigated soil.

•Soil sampled in February, 2003.

Soil sampled at the end of the first growing season (2001) from non-fumigated plots showed that black polyethylene mulch significantly reduced ring and lesion nematodes compared to non-mulched trees. The mulch did not reduce rootknot nematode. Two seasons later, samples indicate mulched trees have higher numbers of root lesion and root knot nematodes. Nematodes have not been reduced by the composted green waste & manure, compost plus kelp extract and humic acid, or compost plus biological soil additives.

Treatment Effects on Soil Microbial Communities.
Soil was sampled before fumigation treatments were applied, at planting time and one year after planting. These samples were analyzed for changes in microbial community size and composition using phospholipid fatty acid (PLFA) analysis. Major conclusions are listed below.

- Methyl bromide caused more change (decrease) in total microbial biomass and diversity than Vapam or Telone II.
- The microbial community is highly variable depending on sample date. The variation caused by sampling date was more significant than the variation caused by fumigation treatment.
- The addition of carbon (composted green waste and manure) had the largest impact on the soil microbial community. Microbial biomass and diversity was the highest in these areas.
- Commercial microbial amendments had no effect on community composition.
- Microbial activity was the lowest in methyl bromide treated areas yet these areas had the best tree growth and highest yields.

Effects of compost and oyster shell flour on soil chemistry. Eight months after trees were planted, samples were collected to a depth of 18 inches near trees in amended and non-amended soil. Soil pH was increased from 6.2 in non-amended soil to 7.0 in soil amended with compost and oyster shell flour. Amended soil had higher calcium levels and higher organic matter. Nitrogen differences were not significant.

	Effects of composted green waste and manure plus oyster shell flour on soil chemistry. Soil was sampled from rootzone of first-leaf peach trees eight months after application of amendments.			
	pH	**Ca (meq/l)**	**Total N (%)**	**Organic Matter (%)**
Non-amended	6.2 b	4.1 b	0.08	0.73 b
Amended	7.0 a	12.7 a	0.10	0.96 a

Tree Growth. Leaf tissue analyses of two-year-old trees (2002) indicated trees in unfumigated areas were deficient in nitrogen even though the entire orchard received 120 units of nitrogen per acre. Additional, drip-applied nitrogen fertilizer (50 pounds of N per acre) in the high nitrogen treatment did not increase leaf N levels. This may be due to root injury caused by nematodes and/or root damaging soil-borne fungi. Leaf N was significantly higher in trees growing in methyl bromide fumigated areas (2.6%) and in areas with black plastic mulch (2.6%) compared to unfumigated trees (2.1%). Leaves sampled in 2003 confirmed these results. Nitrogen levels were 2.4%, 2.7% and 2.9% in unfumigated, mulched and methyl bromide-fumigated trees, respectively. Although leaf levels in unfumigated trees were within or exceeded adequate ranges for all other analyzed nutrients, potassium levels were higher in methyl bromide-treated areas (2.0 % and 2.7% for unfumigated and methyl bromide-fumigated trees, respectively in 2002 and 1.6% and 2.1%, respectively, in 2003).

In general, trees have grown more vigorously in fumigated areas compared to non-fumigated areas. Trees in methyl bromide-treated soil have grown the largest (24.8 cm trunk circumference at the end of 2002), compared to trees in Vapam-treated soil (20.1 cm) and unfumigated soil (15.1 cm). Weights

of pruned brush in April 2003 showed similar results. Post-plant amendment effects are more complicated. Black polyethylene mulch increased trunk circumference and summer pruning weights in nonfumigated soil but not in fumigated soil. No post-plant treatment has increased trunk size in methyl bromide fumigated areas. Foliar micronutrient sprays increased summer pruning weights in nonfumigated areas and areas fumigated with Vapam. Amending the soil with compost and oyster shell flour with or without microbiological soil additives or kelp extract plus humic acid did not increase tree size.

Trunk circumference, 2nd Leaf

Patterson Road Replant Trial. November, 2002

Trunk Circumference (cm)

	Unfumed	M. B.	Vapam	Average	Telone
Untreated	**15.1**	**24.8**	**20.1**	**20.0**	**--**
Enzone	**14.9**	**21.6**	**22.0**	**19.5**	
Nemacur	**14.8**	**23.6**	**16.5**	**18.3**	
DiTera	**16.2**	**24.0**	**19.7**	**20.0**	
Nitrogen	**15.1**	**23.9**	**21.2**	**20.1**	
Calcium	**17.5**	**24.3**	**18.9**	**20.2**	
Biologicals	**15.1**	**22.8**	**18.1**	**18.7**	
Humic acid	**14.8**	**21.8**	**17.2**	**17.9**	
Black Plastic	**18.8**	**23.2**	**19.4**	**20.5**	
Foliar Micros	**17.0**	**23.0**	**21.6**	**20.5**	
Average	**15.9**	**23.3**	**19.5**		

"Dormant" Pruning Weights, 2nd Leaf

Patterson Road Replant Trial. April 15, 2003

Brush Weight (lb. per tree)

	Unfumed	M. B.	Vapam	Average	Telone
Untreated	2.7	13.5	7.2	**7.8**	7.1
Enzone	2.2	11.7	5.7	**6.5**	
Nemacur	3.2	11.5	4.6	**6.4**	
DiTera	2.4	13.7	6.0	**7.4**	
Nitrogen	2.4	12.5	6.9	**7.3**	
Calcium	1.4	11.4	4.9	**5.9**	
Biologicals	2.6	12.5	5.2	**6.7**	
Kelp & Humic A.	2.1	10.0	4.5	**5.5**	
Black Plastic	**6.1**	13.5	7.2	**8.9**	
Foliar Micros	4.0	13.1	8.2	**8.4**	
Average	**2.9**	**12.3**	**6.0**		

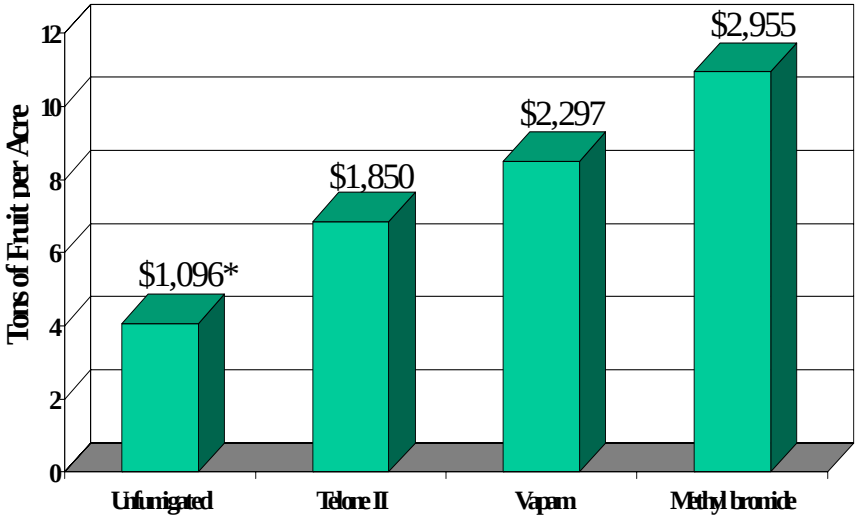
Effects on Yield and Gross Revenue.

All pre-plant fumigation treatments significantly increased yield and gross revenue of the first significant harvest. In 2003 (third leaf), the equivalent of 4.1 tons per acre was harvested in unfumigated areas, 6.9 tons per acre in Telone II treated areas, 8.5 tons per acre in Vapam treated areas and 11.0 tons per acre in methyl bromide areas. Based on a 2002 price of $270 per ton for Loadel cling peaches, this represents a gross revenue increase of about $1860 per acre (minus extra harvest costs) in methyl bromide areas compared to untreated areas. Vapam and Telone II increased per acre revenue by about $1200 and $750, respectively. Black polyethylene mulch and the foliar micronutrients + fall foliar nitrogen were the only post-plant treatments to increase yield. Post-plant treatment effects occurred only in unfumigated areas.

	Yield (Pounds per Tree). Third Leaf. July, 2003.				
	Unfumigated	**M. bromide**	**Vapam**	**Mean**	**Telone II**
Untreated	21.8	58.7	45.8	**42.0**	36.7
Enzone	23.1	50.6	43.6	**39.2**	
Nemacur 3	25.3	64.7	37.8	**42.5**	
DiTera	24.4	53.9	40.5	**39.6**	
Microbiological Amendments	22.4	49.5	35.4	**35.9**	
Humic acid & kelp extract	19.8	53.7	32.1	**35.2**	
Calcium	20.5	46.2	31.5	**32.8**	
Nitrogen	27.1	67.8	50.2	**48.4**	
Micronutrients	29.7	62.3	46.6	**46.2**	
Black Poly mulch	33.7	54.1	44.2	**44.0**	
Mean	**24.9**	**56.1**	**40.7**		

Effect of Pre-plant Fumigation on Yield and Gross Income from 3rd-leaf Loadel Peach Trees.

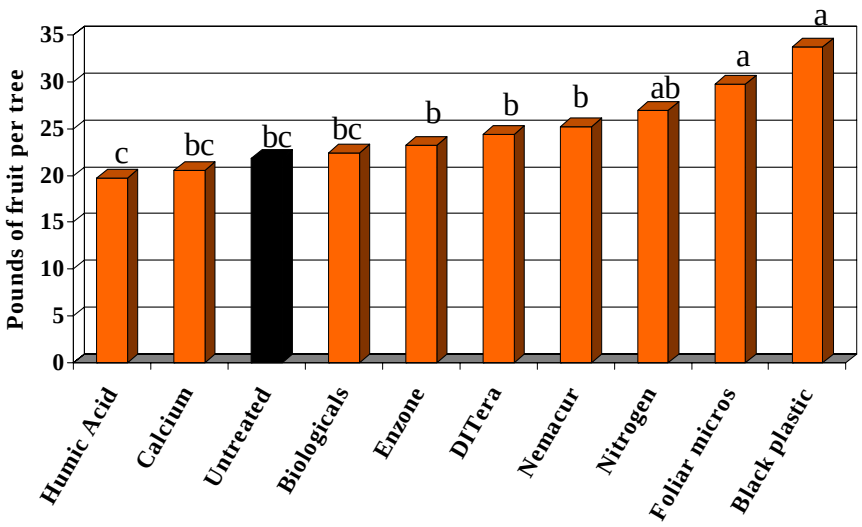
Peach replant trial - Patterson Rd., July 2003



*Gross revenues based on 372.3 trees per acre and a price of $270 per ton

Effect of Post-plant Treatments on Yield of Unfumigated, 3rd-leaf Peach Trees.

Peach replant trial - Patterson Rd. July 2003



Effect of Nitrogen and Calcium Supplemental Fertilization on Development of Bacterial Canker.
In cooperation with Tiesen Cao, Department of Plant Pathology, UC Davis.

It is sometimes difficult to prove whether a certain practice will influence bacterial canker development because disease expression is dependent on environmental factors that may not occur during a period of study. Therefore Dr. Tiesen Cao has developed a method to test whether certain practices may influence the potential for bacterial canker development. Trees were inoculated with *Pseudomonas syringae*, the bacterium associated with bacterial canker, on December 18, 2002. On February 7, 2003, inoculated limbs were removed and canker lengths were recorded. Cankers in unfumigated trees were 11.6 times larger than cankers in trees from methyl bromide fumigated areas. Fertilization with calcium significantly reduced canker length in unfumigated areas. Trees in unfumigated areas treated with supplemental, drip-applied nitrogen fertilizer and foliar low-biuret urea had canker lengths equivalent to fumigated trees. Based on this data, year-end foliar sprays with low-biuret urea and possibly calcium may offer some protection against bacterial canker.

Bacterial Canker Lesion Development as Influenced by Pre-plant Fumigation and Post-plant Fertilizer Treatments.			
Methyl Bromide?	**Fertilization Treatment**	**Length of *Pseudomonas syringae* Canker (mm)**	**Significance**
NO	Grower practices	300.8 ± 383.4	a
NO	Calcium	78.1 ± 160.3	b
NO	Foliar nitrogen	26.7 ± 16.3	c
YES	Grower practices	26.0 ± 18.0	c
YES	Calcium	23.0 ± 10.6	c
YES	Foliar nitrogen	20.0 ± 5.7	c