ALTERNATIVE PRE-PLANT SOIL FUMIGATION TREATMENTS FOR DECIDUOUS TREE CROPS

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Introduction. Pre-plant use of methyl bromide (MB) for perennial deciduous tree crops in California is directed at management of complex biological "replant problems" and meeting sanitation standards for nursery stock certification. Mature orchards commonly support populations of plant parasitic nematodes, pathogenic fungi and bacteria, and unknown biological agents that can interfere with establishment and growth of replanted trees. The negative effects of these agents can be pronounced in the first few years after tree planting, but economic impacts of replant problems typically persist for the life of an orchard. Pre-plant fumigation has provided growers with an efficient and generally economical means to manage these complex replant problems, but the loss of MB and increasing regulatory restrictions on other fumigants is requiring continued reassessment of treatment options. California nursery crop certification programs rely to a large extent on pre-plant fumigation to produce clean stock, and certification protocols have emphasized complete control of plant parasitic nematodes. As MB is phased out, it will be challenging to meet the certification standards, particularly on fine-textured soils where fumigants generally are less effective. Deciduous nurserymen have relatively little experience with some of the MB alternatives or with virtually impermeable films (VIF). VIF has proven effective in optimizing fumigant applications for strawberry (3) and could provide similar benefits for orchard and nursery industries.

Objectives. In fall 2003, we initiated research with the following objectives:

1. To determine effects of promising short-term MB alternatives on vegetative performance of almond and walnut nursery stock at commercial nurseries.
2. To determine effects of the alternatives on weed, nematode, and disease incidence at commercial nurseries.
3. To determine effects of promising short-term MB alternatives on health and productivity of replanted almond trees in commercial orchards.
4. To determine relative benefits of tree-site, row-strip, and broadcast treatments with the alternatives in commercial almond orchards
5. To complete cost-benefit analyses for the MB alternatives at commercial almond and walnut nurseries and almond orchards.
6. To demonstrate the performance of promising MB alternatives to the nurserymen and orchardists and provide them with the key biological and economic information that they need for efficient transition to alternative fumigation strategies.

First-year progress. During 2003/04 we fumigated and planted two nursery trials, one for walnut and another for peach and prune rootstocks, and two orchard trials, one with almond replanted after almond and the other with almond planted after grape. The walnut nursery trial is in Yuba County on a clay loam soil, whereas the peach and prune nursery trial is in Stanislaus County on a sandy loam. Both orchard trials are located in Madera County on loam soils. Fumigation treatments also were applied for two additional nursery trials that will be planted in fall 2004, and it is anticipated that 1 or 2 additional orchard trials will be established in 2004-06.

Data were collected in 2003/04 on nematode, weed, and pathogen survival in the established nursery fumigation trials (Tables 1, 2), and plant growth data were collected in the nursery and orchard trials (Table 3). We buried propagules of *Pythium ultimum*, citrus nematode, and several species of weeds at different depths in soil of the nursery plots before fumigation and retrieved them after fumigation to determine incidence of survival. Natural populations of nematodes and weeds and time taken for hand weeding are also being monitored in the plots.

In each nursery trial, all fumigation treatments killed most bagged inoculum of *P. ultimum* and all bagged inoculum of citrus nematode. No inoculum of *P. ultimum* survived at 15 or 30 cm depths in fumigated plots at either nursery, but some survived at 60 and/or 90 cm depths (Table 1). Mid-winter weed populations were reduced by each of the fumigants (Table 1). Additional weed data from the nursery trials are presented in a separate report at this conference (see Shrestha et al).

To date, nursery fumigation treatments have had only small or negligible effects on performance of the planted stock. Seedling emergence counts were marginally increased by most of the fumigation treatments, but there was little initial effect of fumigation treatments on stem growth or plant height (Table 2).

In Orchard Trial 1, which involved replanting almond after pre-plant fumigation treatments in the cleared site of an old almond orchard, most of the broadcast and row-strip treatments with Telone II, Telone C35, IM:Pic, and Pic marginally increased tree trunk diameters, compared to the non-fumigated controls (Table 3, Experiment 1A). Trunk growth following MB broadcast and MB row strip treatments was intermediate between that of the controls and that of most other fumigation treatments, and MB row strip treatments under VIF did not improve tree growth. The tree site treatments, which were applied later than the broadcast and row-strip treatments caused phytotoxicity and did not improve plant growth (Table 3, Experiment 1B).

In Orchard Trial 2, which involved replanting almond after pre-plant fumigation treatments on land formerly devoted to an old vineyard, there was no important effect of the pre-plant treatments on growth of the replanted almond trees. All of the replants grew vigorously (Table 3, Experiment 2).

Discussion. Additional data are needed from the trials introduced here and planned for the future before detailed conclusions and economic analyses are possible. Overall, each of the fumigation treatments exhibited similar efficacy in the nursery trials for control of bioassay populations of *P. ultimum* and citrus nematode and natural populations of weeds. Monitoring of plant growth, plant health, natural nematode, weed, and disease incidence will continue through the nursery tree harvests (winter 2004 for almond trial, winter 2005 for the walnut trial).

The two established orchard trials represent two common replant scenarios for the San Joaquin Valley of California, namely planting new almond trees to replace an old almond orchard or an old vineyard. Our plant growth measurements in the first growing season suggest that most of the fumigation treatments will prove beneficial at the old almond site, but there is no current indication of benefit at the old vineyard site. The initial growth responses of the replanted almonds are consistent with peach-grape replant disease cross-specificity trials that we have conducted in pots and micro plots (2). Nevertheless, treatment effects may change as the experimental almond trees develop and plant parasitic nematode populations build (detected before planting at the old vineyard site but not the old almond site), and growth and productivity data will be collected in these orchard trials for several years.

It is important in the future to test alternative tree-site, row-strip, and broadcast treatments in high-risk replant scenarios. For example, a severe replant problem, referred to as replant disease, has occurred in the upper Sacramento Valley (1). There, almond trees replanted at old almond orchard sites have failed to establish (50 to 90% tree losses) in a few severely affected orchard blocks. Tree site or broadcast fumigation with chloropicrin and tree-site fumigation with several other fumigants has prevented replant disease. Another severe replant problem commonly occurs in course-textured soils of the upper San Joaquin Valley, where ring nematode populations can reach high levels and contribute poor tree vigor and development of bacterial canker disease.

References

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Table 1. Preliminary pest survival data, nursery trials established in 2003/04[a]

Trial	Pre-plant fumigation treatment	Mulch	Survival of *Pythium ultimum* (cfu/g soil) at depths in soil[b]				Number. of surviving Citrus nematodes at depths in soil[b]				Winter weed pop. (weeds /m^2)
			15 cm	30 cm	60 cm	90 cm	15 cm	30 cm	60 cm	90 cm	
1	None	None	309	378	406	481	-	1180	1108	1181	12
	MB 98:2	HDPE	0	0	0	81	-	0	0	0	4
	IM:Pic 50:50	HDPE	0	0	0	0	-	0	0	0	4
	Telone II	HDPE	0	0	5	122	-	0	0	0	5
	Telone C35	HDPE	0	0	22	47	-	0	0	0	6
	Telone C35	VIF	0	0	0	0	-	0	0	0	6
2	None	None	431	466	481	556	1109	1204	1080	1219	314
	MB 98:2	HDPE	0	0	0	0	0	0	0	0	19
	IM:Pic 50:50	HDPE	0	0	50	137	0	0	0	0	45
	Telone C35	HDPE	0	0	0	218	0	0	0	0	80
	Telone C35	VIF	0	0	6	131	0	0	0	0	40

[a]Fumigation treatments were applied 2 and 11 September 2003 for Trial nos. 1 and 2, respectively
[b]Survival of *Pythium ultimum* and citrus nematode was determined in artificially infested soil, buried in bags at soil depths indicated, then retrieved to determine viability.

Table 2. Preliminary plant growth data, nursery trials established in 2003/04[a]

Trial	Pre-plant fumigation treatment	Mulch	Emerged seedlings /plot	22/23 May 2004		20 July Plant ht. (cm)
				Stem dia. (mm)	Plant ht. (cm)	
1	None	None	294 ab	9.5 b	96 a	--
	MB 98:2	HDPE	322 a	10.3 ab	102 a	--
	IM:Pic 50:50	HDPE	268 b	11.1 a	104 a	--
	Telone II	HDPE	297 ab	11.3 a	103 a	--
	Telone C35	HDPE	275 b	10.8 a	99 a	--
	Telone C35	VIF	282 b	10.9 a	102 a	--
2	None	None	184 b	9.4 a	56 a	110 a
	MB 98:2	HDPE	240 ab	9.3 a	54 a	106 a
	IM:Pic 50:50	HDPE	246 ab	9.0 a	53 a	98 a
	Telone C35	HDPE	254 ab	9.7 a	54 a	109 a
	Telone C35	VIF	261 a	9.1 a	56 a	105 a

[a]Fumigation treatments were applied as described above (Table 1). Trial 1 was planted with seed of Nemaguard peach rootstock, fall 2003; Trial 2 was planted with Paradox hybrid walnut rootstock, fall 2003.

Table 3. Preliminary plant growth data, Orchard Trials 1 and 2, almond replanted after almond, and almond replanted after grape, respectively

Experiment	Fumigant, rate	Plot area treated	Mulch system	Increase in trunk dia. (mm)[d]
1-A[a]	Control	None	None	24
	Control	None	VIF row strip	23
	MB, 448 kg/ha	Broadcast (100%)	None	25
	MB, 448 kg/ha	Row strip (38%)	None	25
	MB, 448 kg/ha	Row strip (38%)	VIF row strip	21
	Telone II, 380 kg/ha	Broadcast (100%)	None	28
	Telone II, 380 kg/ha	Row strip (38%)	None	27
	Telone II, 380 kg/ha	Row strip (38%)	VIF row strip	24
	Telone C35, 600 kg/ha	Broadcast (100%)	None	31
	Telone C35, 600 kg/ha	Row strip (38%)	None	30
	IM:Pic (50:50), 448 kg/ha	Broadcast (100%)	None	31
	IM:Pic (50:50), 448 kg/ha	Row strip (38%)	None	28
	Pic, 448 kg/ha	Broadcast (100%)	None	26
	Pic, 448 kg/ha	Row strip (38%)	None	31
	Pic, 448 kg/ha	Rowstrip (38%)	VIF row strip	31
			95% confidence interval limits:	*+/-4*
1-B[b]	Control	None	None	24
	MB, 0.5 kg per site	Tree site[e]	None	23
	Pic, 0.5 kg/site	Tree site	None	21
	Telone II, 0.5 kg/site	Tree site	None	19
			95% confidence interval limits:	*+/-3*
2[c]	Control	None	None	34
	Control	None	VIF row strip	34
	MB, 448 kg/ha	Broadcast (100%)	None	32
	MB, 448 kg/ha	Row strip (38%)	None	30
	MB, 448 kg/ha	Row strip (23%)	None	31
	MB, 448 kg/ha	Row strip (38%)	VIF row strip	31
	Telone II, 380 kg/ha	Broadcast (100%)	None	32
	Telone II, 380 kg/ha	Row strip (38%)	None	32
	Telone II, 380 kg/ha	Row strip (38%)	VIF row strip	30
	Telone C35, 600 kg/ha	Row strip (38%)	None	30
	Telone C35, 600 kg/ha	Row strip (38%)	VIF	29
	IM:Pic (50:50), 448 kg/ha	Broadcast (100%)	None	32
	IM:Pic (50:50), 448 kg/ha	Row strip (38%)	None	33
	Pic 448 kg/ha	Row strip (38%)	None	31
	Pic, 448 kg/ha	Row strip (23%)	None	28
	Pic, 448 kg/ha	Rowstrip (38%)	VIF row strip	31
			95% confidence interval limits:	*+/-4*

[a]Fumigants applied 27 October 2003
[b]Fumigants applied 10 November 2003
[c]Fumigants applied 11 November 2003
[d]From 16 March to 31 August 2004
[e]Applied at depth of ca 45 cm, one probe per tree site