ALMOND REPLANT DISEASE & OUTLOOK FOR ORCHARD REPLANT STRATEGIES

Browne, Connell, Holtz, Lampinen; Almond/Walnut Workgroup Tour 2006

Orchard and microplot trials, results and discussion. Trials were conducted in orchards near Chico, CA and microplots near Parlier, CA to examine symptoms and control measures for a replant disease (RD) on almond. In the orchard trials, areas with a recent history of severe RD were cleared, given soil fumigation treatments in the fall, and replanted with almond trees on various rootstocks the following winter.

- The replants in non-fumigated soil developed severe RD (stunting, wilting, chlorosis, defoliation) by the following summer, while those in most fumigated treatments remained healthy.
- Pre-plant tree-site (spot) fumigation treatments with methyl bromide (MB), chloropicrin (CP), 1,3-dichloropropene (1,3-D), 1,3-D + CP, iodomethane, and iodomethane + CP all prevented severe RD and resulted in larger trunk circumferences in the three growing seasons after planting (2003-2005) (**Table 1**). The most pronounced growth benefits occurred the first year after planting.
- CP was especially effective and rates of 0.25 lb per tree site improved growth and first harvest yield as much as 0.5, 1.0, or 2.0 lb per tree site (**Fig. 1**). Broadcast soil fumigation with CP also was effective, but broadcast MB and 1,3-D were ineffective (data not shown, but available).
- (Would treating strips have been better?)
- With Shrini Upadhyaya, UCD Engineering, we are trying to streamline spot treatments using GPS technology.
- Trees in non-fumigated soil developed fewer healthy roots $\leq$ 1mm diameter, compared to the healthy trees (**Fig. 2**).
- Almond developed RD on all rootstocks evaluated (Marianna 2624, Lovell, and Nemaguard), but Marianna 2624 was the most severely affected (**Table 2**).
- In Parlier microplots filled with RD-conducive soil, CP was more potent than MB for prevention of RD on Nemaguard peach (data not shown).
- There was no association between nematodes and RD in orchard or microplot trials. The RD apparently was mediated by biological agent(s) other than nematodes.
- Culture-based and culture-independent (rDNA-based) characterizations of microbial populations from roots of healthy and RD-affected are continuing. Specific fungal and bacterial species have been determined to have associations with RD.
- Brent Holtz rivals Joe Connell for hosting the most complex almond replant trial (Table 3). Note that in Madera Co. as in Butte and Fresno Co. fumigants with CP better than others, including MB.
- CP is becoming much more popular among orchardists, but it is under regulatory review. Careful stewardship of CP is essential.
- Efficient spot treatments desirable, but how effective will they be in nematode infested soils? Can they be integrated with 1-year cultural replant remediation programs?

The Areawide Pest Management Program for MB alternatives, USDA-ARS

- To run 2007-2011, currently being planned and reviewed.
- South Atlantic and Pacific (mainly CA) components.
- In CA, focus on strawberry, deciduous orchards and grape, nursery/floriculture.
- Orchard focus: alternative fumigants, optimizing area treated and delivery methods, site-appropriate prescriptive strategies, cultural remediation.
- Need UCCE input and expertise. Looking for candidate orchard replant sites, diversity among sites (in soil texture, crop and pest history) desirable.

Table 1. Effects of pre-plant soil fumigation treatments applied to planting sites through a hand-held probe on growth of almond trees on Marianna 2624 rootstock near Chico, CA

			Tree growth and health parameters at end of indicated growing season[b]						
Expt.	Pre-plant treatment[a]		Height (m)	Increase in trunk diameter (mm)			Disease rating		
no.	Fumigant	kg/site	First	First	Second	Third	First	Second	Third
2-Paiv.	Control	0.0	1.4a	8a	--	--	2.0a	--	--
	MB	0.5	1.8ab	12ab	--	--	1.0ab	--	--
	1,3-D	0.8	1.8ab	12ab	--	--	1.0ab	--	--
	CP	0.2	2.0b	17b	--	--	0.4b	--	--
	CP	0.5	2.0b	17b	--	--	0.4b	--	--
	CP	0.9	1.6ab	12ab	--	--	1.7ab	--	--
3-Mart.	Control	0.0	1.0a	6a	16a	31a	3.3a	2.1a	2.0A
	MB	0.5	1.7bc	18bc	47b	63ab	1.0b	0.0b	0.4b
	CP	0.2	2.0c	25d	54b	78c	0.3b	0.0b	0.0b
	CP	0.5	1.9bc	23bcd	56b	80c	0.4b	0.0b	0.0b
	IM:CP	0.2	1.9bc	22bcd	55b	77c	0.3b	0.1b	0.0b
	IM:CP	0.5	1.9bc	21bcd	47b	75bc	0.7b	0.0b	0.3b
	1,3-D	0.2	1.6b	17b	45b	70bc	1.2b	0.0b	0.0b
	1,3-D	0.5	1.7bc	20bcd	50b	74bc	0.7b	0.0b	0.0b
	1,3-D:CP	0.2	1.7bc	20bcd	51b	71bc	0.9b	0.0b	0.0b
	1,3-D:CP	0.5	1.9bc	24cd	53b	76c	0.3b	0.0b	0.0b
4-Mead	Control	0.0	1.2a	3a	19a	40a	3.5a	1.0a	0.0a
	MB	0.5	1.6b	11b	34bc	60bc	0.8bc	0.0b	0.0a
	CP	0.2	2.0d	17e	39bc	63bc	0.1d	0.0b	0.0a
	CP	0.5	2.0d	17e	36bc	66c	0.3cd	0.5b	0.0a
	IM	0.2	2.0d	12bc	36bc	63bc	0.1d	0.1b	0.0a
	IM	0.5	2.0d	14bcde	36bc	62bc	0.2cd	0.0b	0.0a
	IM:CP	0.2	1.8bcd	16cde	40c	65c	0.8bcd	0.0b	0.0a
	IM:CP	0.5	1.9bcd	16de	39bc	65c	0.4bcd	0.0b	0.0a
	1,3-D	0.2	1.7bc	13bcd	32b	55b	0.8b	0.4b	0.0a
	1,3-D	0.5	2.0d	15cde	37bc	62bc	0.3bcd	0.0b	0.0a
	1,3-D:CP	0.2	1.9cd	14bcde	36bc	60bc	0.3bcd	0.3b	0.0a
	1,3-D:CP	0.5	1.9cd	15cde	38bc	64c	0.3bcd	0.0b	0.0a

[a]All fumigants, methyl bromide (MB), chloropicrin (CP), iodomethane (IM), IM:Pic (50:50 wt:wt), 1,3-dichloropropene (1,3-D), and 1,3-D:Pic (61:35 wt:wt, Telone C35) were injected by a hand-held probe at one point at a soil depth of 40 to 50 cm in the center of sites where trees were to be planted.

[b]Tree height was measured at the end of the growing season (mid Oct. to early Dec., depending on experiment). Increases in trunk diameter were determined by measuring the tree trunks near the end of the indicated growing seasons (late Oct. to early Feb., depending on experiment) and calculating the net increase in diameter from the time of planting. Disease ratings made near the end of the indicated growing seasons (late Aug. to mid Oct.) based on a scale of 0=healthy tree, 5=dead tree, and 1, 2, 3, and 4 were progressive increments of disease within the extremes. Means within a column and experiment and without letters in common are significantly different according to 95% confidence intervals.

Table 2. Effects of rootstocks and pre-plant soil fumigation treatments applied to planting sites through a hand-held probe on growth of almond trees Chico, CA

				Tree growth and health parameters at end of indicated growing seasons						
		Pre-plant treatment[a]		Height (m)	Increase in trunk diameter (mm)[b]			Disease rating		
Expt. no.	Rootstock	Fumigant	kg/site	First	First	Second	Third	First	Second	Third
9	Mar. 2624	Control	0	1.1a	4a	--	--	2.9a	--	--
		MB:CP	0.5	1.9cd	15b	--	--	0.4b	--	--
		CP	0.5	1.9cd	14b	--	--	0.6b	--	--
	Lovell	Control	0	1.6b	7a	--	--	1.7a	--	--
		MB:CP	0.5	2.1cd	15b	--	--	0.3b	--	--
		CP	0.5	2.3d	17b	--	--	0.0b	--	--
10, 11	Mar. 2624	Control	0	1.1a	4a	23a	39a	3.4a	1.3a	0.8a
		MB:CP	0.5	1.9c	20cd	47c	68b	0.6c	0.0b	0.3a
		CP	0.5	2.0cd	22cd	52c	76b	0.3c	0.0b	0.0a
	Lovell	Control	0	1.5b	9b	33b	57a	2.1b	0.1b	0.0a
		MB:CP	0.5	2.3d	21cd	48c	73b	0.1c	0.0b	0.0a
		CP	0.5	2.2d	22d	51c	76b	0.2c	0.0b	0.0a
	Nemaguard	Control	0	1.4b	7a	30b	54a	2.6ab	0.3b	0.0a
		MB:CP	0.5	2.0cd	18c	46c	71b	0.3c	0.0b	0.0a
		CP	0.5	2.2d	20cd	46c	71b	0.2c	0.0b	0.0a

[a]Methyl bromide + chloropicrin (MB:CP, 75% MB 25% CP) and chloropicrin (CP) were injected to a soil depth of hand-held probe at one point at a soil depth of 40 to 50 cm in the center of sites where trees were to be planted.

[b]Tree height was measured at the end of the growing season (mid Oct. to early Dec., depending on experiment). Increases in trunk diameter were determined by measuring the tree trunks near the end of the indicated growing seasons (late Oct. to early Feb., depending on experiment) and calculating the net increase in diameter from the time of planting. Disease ratings made near the end of the indicated growing seasons (late Aug. to mid Oct.) based on a scale of 0=healthy tree, 5=dead tree, and 1, 2, 3, and 4 were progressive increments of disease within the extremes. Means within a column and experiment group (i.e., Ex. 9, or Ex. 10,11) and without letters in common are significantly different according to 95% confidence intervals.

Table 3. Effects of preplant fumigation treatments on growth of Nonpareil almond on Nemaguard rootstock at two replant sites in Madera County, USDA-CSREES team trials; Holtz, Browne, Lampinen, and Schneider[a]

Fumigant, rate	Treated area (% of total)	Tarp system	Trunk circumference increase (% change from control)	
			2004	2005
Control	None	None	0	0
Control	None	VIF row strip	-6	-2
MB, 400 lb/ac	Row strip (38%)	None	-4	1
MB, 400 lb/ac	Row strip (38%)	VIF row strip	-2	-3
MB, 400 lb/ac	Broadcast (100%)	None	4	3
Telone II, 340 lb/ac	Row strip (38%)	None	6	4
Telone II, 340 lb/ac	Row strip (38%)	VIF row strip	0	0
Telone II, 340 lb/ac	Broadcast (100%)	None	11	9
CP, 400 lb/ac	Row strip (38%)	None	30	19
CP, 400 lb/ac	Rowstrip (38%)	VIF row strip	28	17
CP, 400 lb/ac	Broadcast (100%)	None	17	12
IM:CP (50:50), 400 lb/ac	Row strip (38%)	None	19	19
IM:CP (50:50), 400 lb/ac	Broadcast (100%)	None	29	18
Telone C35, 535 lb/ac	Row strip (38%)	None	27	16
Telone C35, 535 lb/ac	Broadcast (100%)	None	16	17
Control, 1 lb	Tree site	None	0	0
MB, 1 lb	Tree site	None	0	0
Telone II, 1 lb	Tree site	None	-11	-7
CP, 1 lb	Tree site	None	-13	0

[a]Trial occurred at an old almond orchard site. Broadcast and row-strip treatments were applied as shank treatments (shank nozzles 12 in apart and 18 in deep in soil) on 27 Oct. 2003. Tree site treatments were applied by a hand-held probe at one point per tree site at 20-in depth in soil on 10 Nov. 2003. Almond trees were planted in January 2004 and the tree trunk circumferences were measured during tree dormancy.

Fig. 1. Effect of different pre-plant doses of chloropicrin, injected at planting sites at soil depth of 40 to 50 cm, on growth of almond trees on Marianna 2624 rootstock in Experiment 5. **A**, increases in trunk diameter by the end of indicated growing seasons after planting; and **B**, marketable nut (kernel) yield from the first harvest at the end of the third growing season. For each line, the mean growth increases and yields were significantly greater in fumigated plots than in non-fumigated plots (based on 95% confidence intervals). The nut yield means were fit to the line described by $y = 0.63(1 - e^{-19.67})$ with an r^2 value of 0.95.

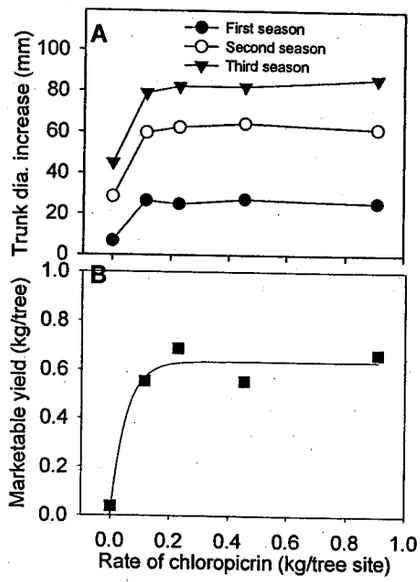
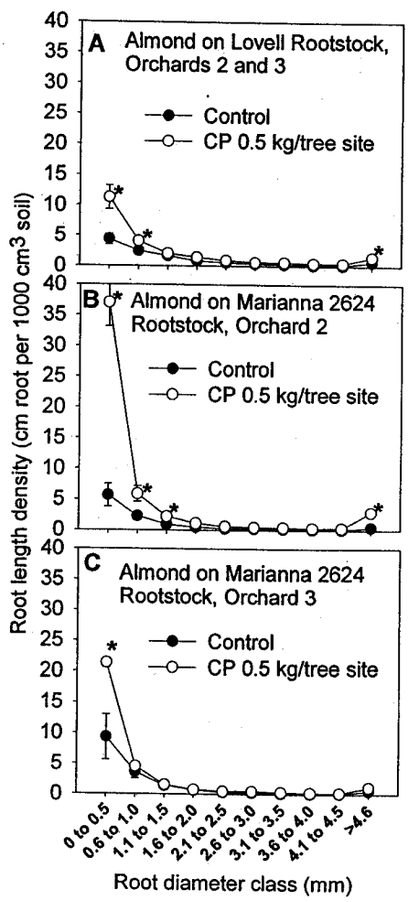


Fig. 2. Effect of pre-plant fumigation with chloropicrin (CP), injected at planting sites at soil depth of 40 to 50 cm, on root length density of almond trees on Lovell peach and Marianna 2624 rootstocks in commercial orchards affected by replant disease near Chico, CA. The trees were planted in Feb. 2004. On 20 Oct. 2004, root system samples were collected from known volumes of soil around three randomly selected trees on each rootstock in each of the orchards. Vertical bars are 95% confidence intervals; asterisks indicate means greater than the control.



PARTIAL MAP AND KEY, ANTHONY MARTINEZ REPLANT TRIAL, DURHAM, CA

(PLANTED 2003, WITH SECONDARY PLANTING IN 2004)

FUMIGANT KEY (RATE 1 LB PER TREE SITE OR OTHERWISE GIVEN ON MAP IN LB/TREE SITE)

ck= not fumigated
mp= methyl bromide : chloropicrin (75:25)
p= chloropicrin

mb= methyl bromide
t= Telone II (1,3-dichloropropene [1,3-D])
c35=Telone C35 (1,3-D:CP 61:35)
im:p= iodomethane : chloropicrin (50:50)

CHLOROPICRIN RATE TRIAL:

48		
47 p,0.5	47	
46 p,2.0		
45	46 ck	
	45 ck	
44 p,2.0	44	
43 p,1.0		
42	43 ck	42
	42 p,2.0	
41 p,0.25	41	41 ck
40 p,1.0		40 p,0.25
39	40 p,0.25	39
	39 p,0.25	
38 p,0.5	38	38 ck
37 p,0.5		37 p,0.5
36	37 p,1.0	36
	36 p,0.25	
35 p,1.0	35	35 p,1.0
34 ck		34 p,0.5
33	34 p,2.0	33
	33 p,2.0	
	32	

NORTH

ROW NUMBER

5	6	7	8	9	10	11	12	13	14	15	16	17	18
32													
31 c35,.5													
30 c35,.5													
29													
28 p,.5			28										
27 p,.5													
26		26	27 t,.5	26									
			26 t,.5										
25 c35,1	25	25 p,1		25 t c35, .5	25								
24 c35,1		24 p,1	25	24 t c35, .5									
23	24 c35,1				24 ck								
	23 c35,1	23	24 mb, 1	23	23 ck								
22 mb,1		22 p,.5	23 mb, 1										
21 mb,1	22	21 p,.5		22 im:p, .5	22		22						
20	21 t,1		22	21 im:p, .5		20		20		20			
	20 t,1	20	21 p,1	20	21 im:p, 1		21 p,1						
19 im:p,.5		19 ck	20 p,1	19 ck	20 im:p, 1	19 ck	20 p,1	19 ck	19	19 p,1	19		19
18 im:p,.5	19	18 ck	19	18 ck	19	18 ck	19	18 ck		18 p,1		19	
17	18 p,1		18 ck		18 p		18 ckNG		18 ck		18 ck		18 ck
	17 p,1	17	18 mpLO	17	17 p	17	17 ckNG	17	17 ck	17	17 ck	17	17 ck
16 ck		16pLO	17 mpLO	16 mpMA		16 mpNG		16 ckLO		16 p,1		16 p,1	
15 ck	16	15 pLO	16	15 mpMA	16	15 mpNG	16	15 ckLO	16	15 p,1	16	15 p,1	16
14	15 ckMA		15 ckLO		15 pNG		15 pNG		15 pMA		15, p		15 ck
	14 ckMA	14	14 ckLO	14	14 pNG	14	14 pNG	14	14 pMA	14	14, p	14	14 ck
13 t,1		13 pMA		13 ckNG		13 pLO		13 mpNG		13 ck		13 p,1	
12 t,1	13	12 pMA	13	12 ckNG	13	12 pLO	13	12 mpNG	13	12 ck	13	13 mpNG	13
11	12 mpLO		12 pLO		12 mpMA		12 ckLO		12 ckMA		12 mpNG		12 ck
	11 mpLO	11	11 pLO	11	11 mpMA	11	11 ckLO	11	11 ckMA	11	11 mpNG	11	11 ck
10 im:p,1		10 mpMA		10 mpLO		10 mpNG		10 pNG		10 ck		10 p,1	
9 im:p,1	10	9 mpMA	10	9 mpLO	10	9 mpNG	10	9 pNG	10	9 ck	10	9 p,1	10
8	9 ckMA		9 pMA		9 pMA		9 ckNG		9 ckNG		9 ck		9 mp,p,2
	8 ckMA	8	8 pMA	8	8 pMA	8	8 ckNG	8	8 ckNG	8	8 ck	8	8 mp,p,2
7 t,.5		7 mpLO		7 mpNG		7 ckMA		7 ckLO		7 p,1		7 ck	
6 t,.5	7	6 mpLO	7	6 mpNG	7	6 ckMA	7	6 ckLO	7	6 p,1	7	6 ck	7
5	6 pNG		6 pMA		6 pLO		6 ckMA		6 mpMA		6 mp,1,2		6 mp,1,2
	5 pNG	5	5 pMA	5	5 pLO	5	5 ckMA	5	5 mpMA	5	6 mp,2,1	5	6 mp,2,1
4 p,1		4 pLO		4 mpLO		4 pNG		4 ckLO		4 ck		4 ck	
3 p,1	4	3 pLO	4	3 mpLO	4	3 pNG	4	3 ckLO	4	3 ck	4	3 ck	4
2	3 ckNG		open		3 mpMA		open		3 mpNG		4 mp,p,2		4 ck,2 mp,p,2
	2 ckNG	2	open	2	2 mpMA	2	open	2	2 mpNG	2	2 ck,2 mp,p,2	2	2 mp,p,2
1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	6	7	8	9	10	11	12	13	14	15	16	17	18

(BREAK)

ROW NUMBER