ANAEROBIC SOIL DISINFESTATION FOR CONTROL OF PRUNUS REPLANT DISEASE

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Summary
Prunus replant disease (PRD) is a soilborne complex that suppresses growth and productivity of replanted almond and stone fruit orchards, even in the absence of plant parasitic nematodes. Preplant soil fumigation prevents PRD but is increasingly regulated and costly. We reported in 2014 that anaerobic soil disinfestation (ASD) implemented in 2013 with rice bran (20 metric tons/treated ha; in strips covering 50% plot area) was as effective as soil fumigation (Telone C35, 600 kg/treated ha; 50% plot area) for preplant control of *Pythium ultimum* (a PRD contributor) and early stimulation of replanted almond orchard growth, but cost of the ASD was more than double that of soil fumigation. Here, we report: i) full-season orchard responses to 2013 ASD treatments and ii) early responses to new 2014 treatments designed to reduce ASD costs. By end of 2014, the 2013 ASD and soil fumigation treatments had improved replanted almond orchard growth equally, by 85 to 92% of the controls, indicating sustained ASD benefit. The 2014 ASD treatments were applied as in 2013 (bran incorporated to 15-cm depth, covered with clear plastic film, drip irrigated to maintain soil moisture at or above field capacity for 6 wk), except bran rates and treated areas were 100, 60, and 36% of those used in 2013. All 2014 ASD treatments (100, 60, and 36%) were as effective as soil fumigation in reducing *P. ultimum* inoculum density (to 0 to 95 cfu/g soil), compared to controls (2008 to 3663 cfu/g). To date, ASD has provided tree growth stimulation equal to that of soil fumigation. Further research is needed to optimize ASD substrates and application methods for replant problems of almonds and stone fruits.

Materials and Methods

In 2013 and 2014, four orchard replant trials were initiated where stone fruits (nectarines, peaches) had grown on Nemaguard rootstock for >12years (Table 1). ASD and sudan grass crop rotation were tested as preplant alternatives to soil fumigation for prevention of PRD. Treatments were applied to 27.4 x 6.1-m plots, except that treatments 4 and 5 of experiment 3 were applied to 13.7 x 6.1 m plots; a randomized complete block design was used. There were five plots per treatment in experiments 1 and 3 and three plots per treatment in experiments 2 and 4. Depending on the experiment, differential preplant treatment programs (Table 1) were begun in the old stone fruit orchards as early as May, approximately 8 months before the orchards were to be replanted in January. The preplant treatments were concluded by November, 2 months before replanting with almond. Efficacy of the preplant treatments was assessed according to their effects on: i) survival bioassay inoculum of *Pythium ultimum* (a contributor to the PRD complex, buried in nylon bags at 15 and 46 cm soil depths); ii) growth in stem circumference of the replanted almond trees, and iii) the percentage of phososythetically active radiation (PAR) intercepted by the almond canopies in their second growing season after planting (i.e., in June 2015 for experiments 1 and 2). Data were subjected to analyses of variance and means were separated according to 95% confidence intervals.

Results and Discussion.

In 2013 and 2014 experiments, ASD quickly generated and maintained anaerobic conditions and elevated soil temperatures in the 6-wk treatment period (Fig. 1). All 2013 and 2014 ASD and fumigation treatments reduced bioassay populations of *P. ultimum* to near or below detection limits, while the inoculum survived at relatively high populations in control treatments. As indicated by canopy interception of PAR and trunk circumference measurements, ASD in experiments 1 and 2 provided strong, persistent control of PRD, equivalent to that of the fumigation treatments (Table 2). Although beneficial compared to the control, the low-rate, narrow-strip ASD treatment of experiment 3 stimulated tree growth less than the high-rate ASD treatments applied to either narrow or wide strips (Fig. 2). By midsummer, the high-rate ASD treatments, both in narrow and wide strips and both in experiments 3 and 4, were similar in effectiveness to soil fumigation in preventing PRD growth suppression (Fig. 2). Sudan rotation alone provided a small but significant benefit compared to the control. Repeated soil sampling has indicated that plant parasitic nematodes are not contributing significantly to the PRD complex in the ASD experiments at Parlier, whereas sampling and pathogenicity tests have suggested that *Pythium* and *Cylindrocarpon* species present in the soil play a partial role in the growth suppression.

Our results indicate that commercial adoption of ASD may be feasible but will require further optimization and testing. Total cost of the ASD treatments used in this study ranged from similar to that of the Telone C35 treatment to roughly double that of the fumigation treatment. Rice bran is a relatively expensive component of the tested ASD treatments. Research is planned to examine the effectiveness of alternative, less expensive ASD substrates and application methods for orchards.

Table 1. Overview of trials including anaerobic soil disinfestation at orchard sites affected by Prunus replant disease but not plant parasitic nematodes

Year	Expt.	Trt. no.	Treatment name	Month of old orchard tree removal	Month of sudan rotation	Fall/winter soil disinfestation treatment
2013	1	1	Control, no sudan	Sep	None	None
		2	Control, with sudan	May	May-Oct	None
		3	ASD, high bran rate, wide strip, with sudan	May	May-Oct	ASD, 20 metric tons /treated ha, 3.0-m-wide strips
		4	Fumigation in Oct, no sudan	Sep	No	Telone C35, 600 kg/treated ha in Oct, 3.4-m-wide strips
		5	Fumigation in Oct, with sudan	May	May-Oct	Telone C35, 600 kg/treated ha in Oct, 3.4-m-wide strips
		6	Fumigation in Dec, no sudan	Sep	None	Telone C35, 600 kg/treated ha in Dec, 3.4-m-wide strips
	2	1	Control, no sudan	May	None	None
		2	ASD, high bran rate, wide strip, no sudan	May	None	ASD, 20 metric tons /treated ha, 3.0-m-wide strips
		3	Fumigation in Oct, no sudan	May	None	Telone C35, 600 kg/treated ha in Oct, 3.4-m-wide strips
2014	3	1	Control, no sudan	Sep	None	None
		2	Control, with sudan	May	May-Oct	None
		3	ASD, high bran rate, wide strip, with sudan	May	May-Oct	ASD, 20 metric tons /treated ha, 3.0-m-wide strips
		4	ASD, high bran rate, narrow strip, no sudan	Sep	None	ASD, 20 metric tons /treated ha, 1.8-m-wide strips
		5	ASD, low bran rate, narrow strip, no sudan	Sep	None	ASD, 12 metric tons /treated ha, 1.8-m-wide strips
		6	Fumigation in Oct, no sudan	Sep	None	Telone C35, 600 kg/treated ha in Oct, 3.4-m-wide strips
		7	Fumigation in Oct, with sudan	May	May-Oct	Telone C35, 600 kg/treated ha in Oct, 3.4-m-wide strips
	4	1	Control, no sudan	May	None	None
		2	ASD, high bran rate, wide strip, no sudan	May	None	ASD, 20 metric tons /treated ha, 3.0-m-wide strips
		3	Fumigation in Oct, no sudan	May	None	Telone C35, 600 kg/treated ha in Oct, 3.4-m-wide strips

Table 2. Effects of preplant treatments on growth of trees in 2013 experiments 1 and 2

Expt.	Treatment	Increase in trunk circumference by Nov 2014 (cm)	Increase in trunk circumference by July 2015 (cm)	% PAR June 2015
1	Control, no sudan	3.7	16.4	11.9
	Control, with sudan	4.9	19.1	14.2
	ASD, hi bran rate, wide strip, with sudan	7.4	27.0	24.0
	Fumigation in Oct, no sudan	7.0	25.6	20.8
	Fumigation in Oct, with sudan	7.5	26.6	22.3
	Fumigation in Dec, no sudan	6.7	24.7	20.0
	(95% confidence limits):	*(+/- 0.5)*	*(+/-1.3)*	*(+/- 1.9)*
2	Control, no sudan	3.3	27.1	12.8
	ASD, hi bran rate, wide strip, no sudan	7.1	27.3	26.6
	Fumigation in Oct, no sudan	7.4	17.1	24.8
	(95% confidence limits):	*(+/-0.7)*	*(+/- 1.0)*	*(+/- 2.1)*

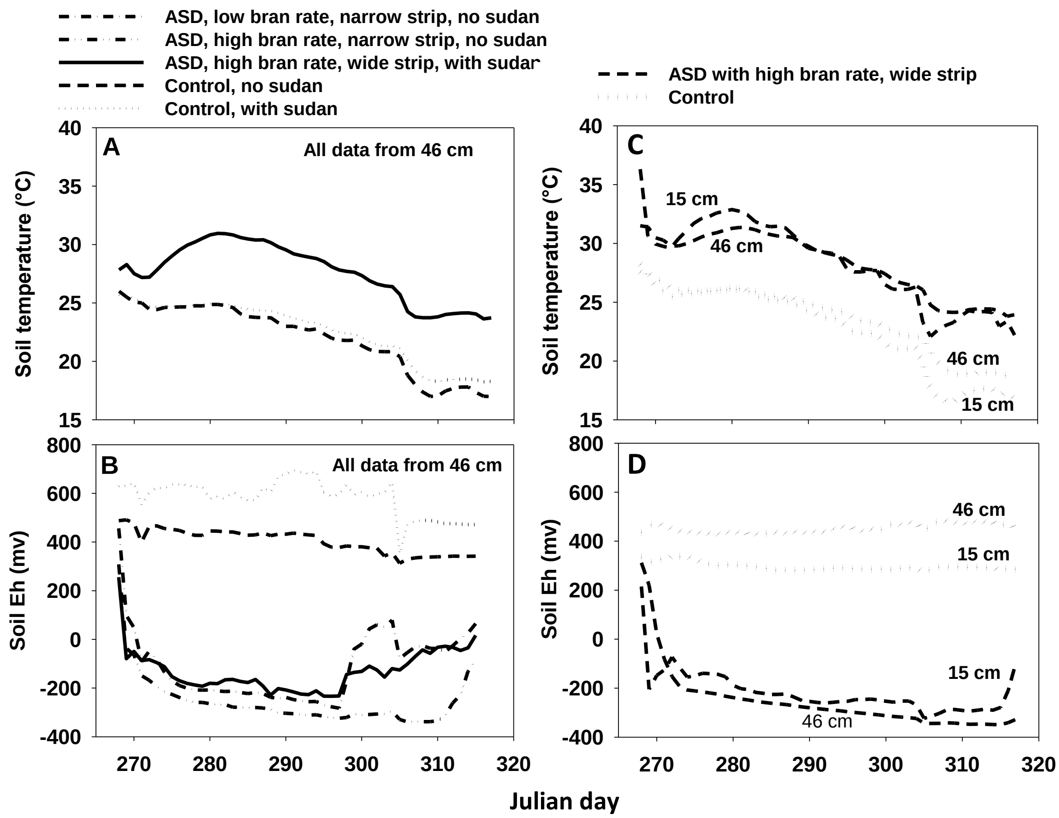

Fig. 1. A and **B,** Effects of ASD and control treatments on temperature and reduction potential in soil, experiment 3; **C** and **D**, effects of ASD and control treatments on temperature and reduction potential in soil, experiment 4.

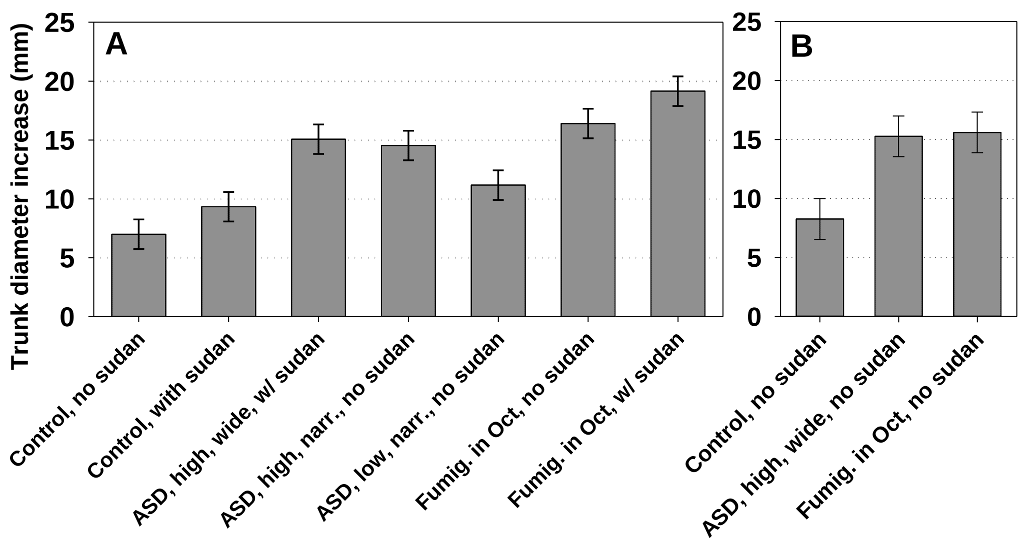

Fig. 2. A, and **B**, effects of preplant treatments on growth of trees in 2014 experiments 3 and 4, respectively. Shown are increases in trunk diameter from the time of planting (Jan 2015) to Jul 2015.