EVALUATION OF AN AUTOMATIC STEAM APPLICATOR IN STRAWBERRY: 2012-13 RESULTS

S. Fennimore*[1], T. Miller[1], R. Goodhue[2], N. Dorn[3], J. Broome[4] J. Muramoto[5], C. Shennan[5] and F. Martin[6]

[1]University of California, Davis, at Salinas CA, [2]University of California, Davis, CA, [3]Reiter Affiliated Companies, Salinas, CA, [4]Driscoll's Strawberry Associates, Watsonville, CA, [5]University of California, Santa Cruz, CA, [6]USDA ARS, PWA, Salinas, CA 93905

Summary. Steam-disinfestation of soil as an alternative to chemical fumigation was evaluated in commercial strawberry production fields using a prototype steam applicator that rapidly heated raised beds by physically mixing steam with the soil. Comparisons were made with anaerobic soil disinfestation (ASD) a non-fumigant soil treatment. Steam suppressed weeds and soil borne pathogens. Development of more efficient and economic steam application equipment, currently in progress, suggests that steam is approaching commercial feasibility. Also, the combination of steam treatment with soil amendments of mustard seed meal (MSM), showed very favorable strawberry production in terms of yield, quality, weed and pathogen control. Steam, and steam plus MSM treatments consistently gave higher yields than non-treated strawberry beds. Treatment effects were also noted with respect to available soil nitrogen. Economic analysis showed returns far exceeded costs of steam treatment.

Methods. *Steam Application.* The steam applicator was a tractor-towed wagon with a propane-fueled Clayton 100 HP steam generator that treated one 52 in wide bed. Steam was injected and mixed into the soil through a bed shaper equipped with a rototiller, with multiple steam injection shanks in front and behind the tiller, and steam injection nozzles above the tiller. Treated planting beds were insulated to maintain heat in the raised bed for 7 to 10 minutes. The applicator speed and output was calibrated to raise the soil temperature to 158˚F for >20 minutes. This temperature and time interval is necessary to achieve control of a wide range of soil pests. Two trials near Watsonville, CA were each arranged in randomized complete block designs with four replications per treatment. Treatments included steam alone, steam plus 1.5 T/A MSM (Farm Fuels, Inc., Watsonville, CA) and ASD with rice bran 9 T/A for the carbon sources at both ranches. Molasses at 9 T/A was also included as the carbon source for ASD at ranch 2 only. ASD was applied using standard methods (Fennimore et al. 2013).

Monitoring temperature, weed and pathogen control, soil nitrogen, yield. Soil temperatures in field were measured with Hobo temperature loggers. Weed seed control was assayed by placement of seeds in mesh bags into treated beds. Sensors at several depths, and weed bags were installed in the strawberry beds immediately after passage of the steamer. Weed seeds were later removed and tested for viability with tetrazolium. Weed densities were measured periodically and weeding times were recorded as described in Samtani et al. (2012). Hand weeding was timed and accumulated over the season to determine impact of those weeds surviving in the seed bank. Pathogen presence and level was assayed from soil for *Pythium* spp., at both sites immediately before treatment and again 28 days later by methods previously described in Klose, et al. (2008). Soil nitrogen as available ammonium or nitrate was monitored from treatment until transplanting (8-10 weeks). Fruit harvest was measured by a commercial harvest crew from Apr. 6 through August 10 (ongoing at time of submission).

Economic analysis. The economic viability of the treatments was assessed, incorporating details of applicator costs and capital recovery, time required for applications, subsequent hand weeding labor costs, and net returns from harvest.

Results. Season-long fruit yields with steam and steam plus MSM were 58 to 107% higher than the non-treated. Steam application costs for a two-bed commercial applicator were estimated at $3,500/acre (MSM not included), thus comparable to methyl bromide/chloropicrin fumigation. Control of emerged weeds, weed seed and *Pythium* spp. was good with steam and steam plus MSM. Available soil nitrate was increased by steam and steam plus MSM treatments, and small increases in ammonium were detected (not shown). At ranch 1, heavy soil resulted in large clods remaining during bed formation preventing good mixing of rice bran, and inadequate anaerobic conditions being generated for ASD.

Literature cited

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Season-long relative fruit yields April 6 to August 10, 2013 at two commercial ranches near Watsonville, CA.

Treatment	Ranch 1			Ranch 2
Variety:	Albion	123Q191	273M173	49C129
	relative yields (%)			
non-treated	100 b	100 c	100 c	100 c
steam	188 a	182 b	188 a	158 a
steam + MSM	198 a	200 a	207 a	160 a
ASD – rice bran	117 b	112 c	132 b	133 ab
ASD - molasses				109 bc

All data shown are means from 4 replicated plots per treatment. Mean separations by Duncan's MRT, $P = 0.05$

Winter assays of weed control during the 2012-2013 season at ranch 1 (accumulated 1/14, 2/6, and 3/20)

treatment	number (1000s/ha)	time (h/ha)	dry weight (kg/ha)
non-treated	250.3 b	412.2 b	90.1 b
steam + MSM	14.9 a	51.5 a	12.4 a
steam	5.1 a	29.2 a	1.3 a
ASD -rice bran	322.4 b	483.8 b	123.4 b

All data shown are means from 4 replicated plots per treatment. Mean separations by Duncan's MRT, $P = 0.05$

Weed seed percent germination results from seeds treated winter 2012 at ranch 1

	burning nettle	purslane	malva	chickweed	knotweed
non-treated	92.7 b	83.0 b	84.6	82.8 b	95.3 b
steam	0.7 a	0.0 a	57.7	0.3 a	8.3 a
Steam + MSM	9.4 a	2.3 a	60.0	0.0 a	7.6 a
ASD - rice bran	82.5 b	62.1 b	80.0	84.3 b	85.5 b

All data shown are means from 4 replicated plots per treatment. Mean separations by Duncan's MRT, $P = 0.05$

Pythium spp. (propagules per gram soil) presence in steam and ASD treatments 2012-2013

	Ranch 1		Ranch 2	
	inoculum	post-treatment	inoculum	post-treatment
treatments				
non-treated	187.2	97.4 ab	29.0	112.6 a
steam	80.8	8.6 b	22.3	74.1 bc
steam + MSM	105.0	3.8 b	33.2	1.4 c
ASD – rice bran	127.8	247.0 a	12.9	200.1 a
ASD - molasses	*not represented in trial*		25.6	59.8 ab
	$P = .4115$	$P = .0413$	$P = .8408$	$P = .0106$

All data shown are means from 4 replicated plots per treatment. Mean separations by Duncan's MRT, $P = 0.05$