SYSTEMS TO DISINFEST SOIL WITH HEAT FOR STRAWBERRY AND FLOWER PRODUCTION

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Summary. Lack of energy efficient steam applicators and relatively inexpensive fumigants has limited the use of steam in commercial fields. Stricter fumigant regulations and more efficient steam applicators may improve opportunities for steam. Our objective is to develop a cost-effective solarization and steam heat, soil disinfestation system for flowers and strawberry. Field studies were conducted in coastal California during the 2008-09 growing season. For both crops, results show that steam with and without solarization controlled pests equal or better than methyl bromide + chloropicrin (MBPic). In the calla lily trial, no differences were observed among treatments for the total number of saleable bulbs produced or total selling price of the graded bulbs. Strawberry yields from steam treatments in 2008-09 were similar to MBPic.

Materials and Methods. For both flower and strawberry, raised beds were prepared as finished beds with fertilizer and drip irrigation tape installed. Beds were 52 to 72-in wide and 20 to 100 ft long. For all studies steam was applied to raise the soil temperature to 158°F for 20 min. Steam was either applied through a 5-in polypropylene mesh hose with 8-in steel spikes, or through 2 to 3-in buried polyethylene tubing that was placed 8-in below the soil surface.

Strawberry Methods. This trial was conducted at the USDA-ARS research farm near Salinas, CA. MBPic 67:33 at 350 lbs/A was included as a standard. Other treatments included a control, solarization, steam alone and steam + solarization. Solarization was conducted 8.24 to 9.21.08. Steam was applied on 9.15 to 9.17.08. Hobo temperature recorders were installed at 2, 6, and 12-in. Mesh bags with weed seeds were installed at 6-in deep and *Verticillium* infested soil samples were installed at 6, 12, and 18-in deep before treatment. After treatment, the samples were tested for viability. Strawberry 'Albion' was planted on 11.16.08. Weed control and weeding times were measured 10.16.08, 1.7, 2.4, and 3.10.09. Marketable fruit yields are reported for 3.31 to 8.17.09. Crop injury was evaluated 1.16.09 (0=safe, 10= dead). The trial was arranged in a randomized complete block with 4 replicates. Data was subjected to ANOVA and mean separation was performed using LSD's at P= 0.05.

Calla Lily Methods. Plots were one 72-inch wide bed by 50 ft long. Treatments were the same as the strawberry trial above. MBPic was applied on 9.3.2008. Solarization treatments used clear tarp, with treatments lasting for four weeks.

Steam was applied 9.18 through 9.23.08. Hobo temperature recorders and weed seed and *Verticillium* samples were installed as described in the strawberry study. Calla bulbs were planted on 10.18.08. Weed density counts, weed biomass, and hand weeding times were measured on 12.01.08, 1.27.09, 4.20.09 and 6.23.09. The trial design and analysis are the same as the strawberry trial above.

Asiatic Lily Methods. The trial was initiated on 2.12.09 with a MB treatment applied by the cooperating grower using the hot-gas application technique. All other treatments were applied 2.23.09 through 2.25.09. Treatments included MB, and two steam treatments where soil was treated as described above. All treatments were repeated four times. Beds were 4 ft wide by 100 ft long. Asiatic lily bulbs were planted on 2.25.09 and 2.26.09. Soil samples were collected from all treatments on 2.25.09 and analyzed for *Fusarium* sp. and *Pythium* sp. populations. Weed counts were taken one and two months after treatment (MAT) on 3.24.09 and 4.28.09, respectively, and crop heights measured 3 MAT (5.19.09). Data was analyzed as described above.

Strawberry Results. Weed biomass, density and hand weed times were lower in the plots that were steamed or treated with MBPic. Weed control with solarization was not as good as MBPic or steam (Table 1). *Verticillium* control was best in MBPic followed by steam treatments. Best weed seed control resulted from steam and MBPic (Table 2). Control of little mallow with steam was better than MBPic. Solarization alone gave better control of nutsedge, and knotweed propagules compared to the control (Table 3). No crop injury was observed (data not shown). Fruit yield with steam and MBPic were similar (Table 4).

Calla Lily Results. Data combined for the first two weed data collection dates showed steam pipe to be the best treatment. Weed density in steam spike treatments were similar to steam pipe treatment. Treatment effect on hand weeding times was significant at α =0.1. The low weed pressure in 2008-09 resulted in less treatment separation. *Verticillium* viability in steam treated plots at 6 in. depth was comparable to MBPic. At 12 in. depth, *Verticillium* control was best in MBPic, steam pipe and steam spike/no solarization treatments. Little mallow seed were controlled better by steam than MBPic (Table 2). For all other weed species, steam treatments gave control similar to MBPic. Solarization alone gave better control of nutsedge, knotweed, chickweed and little mallow as compared to the control (Tables 2 and 3). There were no significant differences among treatments for the total number of saleable calla bulbs produced or selling price of the bulbs in 2007-08 growing season (Table 4).

Asiatic Lily Results. No differences were detected in soil borne pathogen populations among treatments. Weed control at both 1 and 2 MAT and crop growth were significantly better in beds treated with steam or MB compared to the untreated control (Table 5). Flower yield data is currently being collected.

Table 1. Cumulative weed biomass, density and hand weeding time in strawberry (Salinas, CA) and calla lily (Prunedale, CA) in 2008-2009.

Treatment	Weed biomass		Weed density		Weeding time	
	Berry	Flower	Berry	Flower	Berry	Flower
	----------kg/A----------		----no. (1,000/A)---		------time (h/A)-----	
Untreated	1,093.3 a[z]	112.4 a	363.5 a	28.0 a	440.9 a	41.3 a
MBPic	403.1 bc	219.8 a	37.6 c	34.1 a	97.7 d	43.3 a
Solarization	633.5 b	53.7 a	165.6 b	22.3 a	255.4 b	31.2 a
Steam (pipe) + solarization	435.1 bc	4.4 b	68.8 c	4.0 b	161.7 c	8.7 b
Steam (spikes) + solarization	291.5 c	51.7 a	39.7 c	16.0 ab	119.5 cd	20.9 a
Steam (spikes)	444.6 bc	83.3 a	29.4 c	6.5 ab	97.8 d	16.5 ab

Table 2. Weed seed control in strawberry (Salinas, CA) and in flowers (Prunedale, CA) in 2008-09.

Treatment	Chickweed		Little mallow		Common purslane	
	Berry	Flower	Berry	Flower	Berry	Flower
	---------- control (%) ----------					
Untreated	49 c	34 d	60 c	24 e	62 b	41 c
MBPic	96 a	100 a	60 c	66 cd	99 a	100 a
Solarization	71 b	51 c	58 c	53 d	48 b	39 c
Steam pipe + solarization	71 b	100 a	87 b	99 a	96 a	98 ab
Steam spikes + solarization	100 a	93 ab	100 a	82 b	100 a	94 ab
Steam spikes	100 a	85 b	98 a	74 bc	100	94 ab

Table 3. Nutsedge and knotweed control after treatment in strawberry (Salinas, CA) and in flowers (Prunedale, CA) in 2008-09.

Treatment	Nutsedge[z]	Knotweed[z]
	---------- control (%) ----------	
Untreated	75.6 b[y]	23.0 c
MBPic	96.3 a	93.9 a
Solarization	68.4 c	42.0 b
Steam (pipe) + solarization	93.8 a	93.6 a
Steam (spikes) + solarization	97.2 a	95.8 a
Steam (spikes)	92.5 a	89.9 a

[z]Data pooled for both sites.

Table 4. Total saleable calla lily bulbs, selling price of saleable bulbs from 2007-08, and strawberry yields from 2008-09 growing season.

Treatment	Total saleable bulbs[z]	Selling price of saleable bulbs	Fruit/# plants[y]
	-------no./A----	------US$/A---	--------grams--------
Untreated	54,148	29,995	409.7 c
MBPic	51,546	31,373	619.3 ab
Solarization	67,458	41,547	497.7 bc
Steam (blanket)	61,892	34,808	-
Steam (blanket) + solarization	65,401	39,065	-
Steam (pipe) + solarization	-	-	627.1 ab
Steam (spikes) + solarization	-	-	630.8 ab
Steam (spikes)	-	-	691.8 a
Treatment P	0.4077	0.2900	0.0070

[z] Total saleable bulb count includes total of 6 different grades of 10, 12, 14, 16, 18 and 18+ cm bulb sizes.

[y] Yield based on harvest data collected from 31 Mar. 2009 through 22 Aug. 2009.

Table 5. *Fusarium* and *Pythium* population, weed density and crop growth means in a soil disinfestation trial at Nipomo, CA.

	Fusarium	*Pythium*	Weed density[z]		Crop height
Treatment	0 MAT	0 MAT	1 MAT	2 MAT	3 MAT
	propagules/gram	propagules/gram	-no/0.5 m^2-	-no/0.5 m^2-	--cm--
Untreated	2013.4	60	18.5 b	20.5 b	87.5 b
Steam (drain pipe)	615.6	2	3.4 a	4.2 a	98.4 a
Steam (spikes)	1301.5	41	5.1 a	4.5 a	95.8 a
MB	1770.5	20	0.6 a	1.2 a	97.9 a
Treatment P	0.170	0.445	0.035	0.002	0.006

[z] Primary weeds at this site were common chickweed, little mallow, and annual bluegrass.