CALIFORNIA LEAFY GREENS RESEARCH PROGRAM

April 1, 2022 – March 31, 2023

SOIL DISINFESTATION WITH STEAM FOR LEAFY GREENS

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ABSTRACT

Improved weed control can reduce need for hand weeding and improve labor use efficiency. Labor use efficiency gains are essential for the long-term economic viability of vegetable production. Steam injected into the soil can kill weed seed in the seedbank resulting in effective weed control in the steam-treated zone. Preplant application of steam aligned with the seedline band followed by lettuce seeding results in a high level of weed control during the subsequent lettuce production cycle. A steam applicator that applies steam in bands prior to lettuce seeding was evaluated during 2022. This device controlled weeds in the treated area, reduced hand weeding times and incidence of Pythium in the soil.

OBJECTIVE

Evaluate soil disinfestation with steam in lettuce for control of soilborne diseases and weeds in the lettuce seedline.

PROCEDURES

Steam is an effective means of controlling weeds and pathogens in soil. The problem is that there are no steam applicators designed for maximum use efficiency under California vegetable field conditions. During 2022 we built a prototype band steam applicator and have evaluated it in lettuce (Fig. 1). Two trials were conducted during May to October 2022. In the first trial the basic performance of the new steam applicator was verified. In the second trial we evaluated the dimensions of the width and depth of the band that must be treated for optimal effects.

Figure 1. 2022 Version 2 steam applicator treating soil at the Salinas Field Station June 2023.

Methods trial 1. To evaluate effect of band steam application on weeds and soilborne pathogens trial 1 was conducted at the Hartnell research station at Salinas, CA during May to July 2022. The treatments were steam and no steam replicated four times and arranged in a complete randomized design. Steam was injected 2 inches into the soil in 4-inch-wide bands centered on the seed lines. Steam was applied May 3, 2022, and then Romaine was seeded May 5, 2022. Soil temperatures in the treated area were monitored using HOBO data loggers. Soil samples were collected before and after steaming in the treated band. Soil samples were analyzed for abundance of *Pythium* spp. pre and post treatment using a wet plating method on a semi-selective media.

Weed densities and hand weeding times were measured in the treated area May 25, and on June 9, 2022. Time to hand weed two seedlines 30 ft long for each replicate was recorded. The number of diseased and healthy lettuce plants were assessed along a 105 ft section of each bed. Lettuce was harvested on July 15 and 20, 2022. Data were analyzed in JMP 16.0.0 (SAS Institute, Cary, NC, USA, 2021). Independent sample t-tests were used to compare means between treatments.

Trial 1 Results. In trial 1 steam reduced *Pythium ultimum* abundance by 86% from 563 to 77 colony forming units (CFU), before and after steaming respectively. Steam reduced weed densities by100% with the exception of little mallow (74%) and hairy nightshade (16%) and steam reduced weeding times by 45% on May 25 and 70% on June 9 (Tables 1 and 2). Overall INSV was the most prevalent disease, and was not controlled by steam. Weight of marketable lettuce did not differ significantly between steam vs no steam. The lack of yield differences between the treatments likely a result of low disease pressure from lettuce drop (*Sclerotinia minor*).

Table 1. Weed densities June 9, 2022.

	Weed densities No. (1000s/ acre)			
Weed species	Steam treatment	Control	Percent reduction	P-value
Purslane	0 a	185 b	100	<0.0001
Shepherd's purse	0 a	55 b	100	0.0059
Mallow	17 a	65 a	74	0.0689
Burning nettle	0 a	140 b	100	0.0103
Hairy nightshade	21 a	25 a	16	0.8065
Henbit	0 a	20 a	100	0.0813
Pigweed	0 a	5 a	100	0.0909
Groundsel	0 a	20 a	100	0.0813
Total weeds	38 a	525 b	93	<0.0001

Means followed by the same letters within a row are not different (P < 0.05) t-test.

Table *2*. Hand weeding times.

Treatments	May 25, 2022	June 9, 2022
	Mean hand weeding time (Hrs./acre)	
Steam	22.2 a	9.0 a
Untreated	39.3 b	29.7 b
P-value	0.0002	0.0084

Means followed by the same letters within a column are not different (P < 0.05) t-test.

Methods trial 2. The effect of steam treatment band width and depth were evaluated in a factorial study that was initiated in August 2022 near the same location as trial 1. Steam was injected into band widths, 2- and 4-inches wide, at depths of 2, 4 and 6 inches. Each trial had six steam treatments plus a non-treated control treatment that were replicated four times, width (W) x depth (D): 2Wx2D, 2Wx4D, 2Wx6D, 4Wx2D, 4Wx4D, 4Wx6D. Steam was applied on August 2, and 3, 2022, using the same steam applicator as trial 1. Soil temperatures were monitored as before. Romaine was seeded on August 4, 2022. Soil samples were collected and analyzed for abundance of *Pythium* spp. Weed densities and hand weeding times were measured in the treated bands on August 18, 2022, and September 9, 2022. Data were analyzed in JMP 16.0.0 (SAS Institute, Cary, NC, USA, 2021). A factorial analysis was conducted to determine the influence of width, depth and interaction between width and depth on soil temperature, weed densities, hand weeding time, and soil pathogen densities.

Trial 2 results. Soil temperatures were significantly higher in the 4-inch wide treated beds than in the 2-inch wide treated beds. Soil temperatures remained higher when steam was injected 4- and 6-inches deep than when injected 2-inches deep. Treatment band width influenced weed densities for Purslane (P=0.032), Goosefoot (P=0.010), Mallow (P=0.018) and Hairy nightshade (P=0.013). Weed control was better in the 4-inch wide bands than the 2-inch-wide bands (P<0.05). Purslane densities averaged 18,300 weeds/acre in the 2-inch treated bands vs 3,300 weeds/acre in the 4-inch treated bands (P = 0.032). Overall, weed densities were significantly lower in the steam treated beds compared to the non-treated beds (P = 0.001) (Table 3).

Hand weeding time was lower in the 4 inch band, 14.7 hrs./acre compared to 27.7 hours in the 2-inch wide band. Weeding time was also less in the 4-inch-deep treated beds (mean = 16.5hrs/acre) than the 2-inch deep bands (mean = 27.9hrs/acre). Overall, weeding time was less in all steam treatments compared to non-treated control (P<0.05).

Pythium spp. control was better with steam injected at 4- and 6-inches deep, 13 and 4 CFU/g, respectively, than in the 2-inch deep bands (231 CFU/g). Overall *Pythium* spp. propagules were lower in the steam treated beds with post treatment reductions up to 100% in the 2Wx4D and 4Wx6D treatments (Table 4).

Lettuce yield was not influenced by treatment width (P =0.285), depth (P = 0.819) or the interaction between the factors (P=0.889). Lettuce plants were significantly larger in the steam treated beds compared to non-treated beds, but yield did not differ between treated and non-treated beds. The proportion of diseased lettuce at harvest was similar between the treated and non-treated control (P=0.712).

Table 3. Weed density comparisons among the treatments

Treatment (W x D)	Purslane	Shepherds-purse	Nettleleaf goosefoot	Little Mallow	Burning Nettle	Hairy nightshade	Total weeds
				1,000/acre			
1 (2 x 2)	22.5 b	7.5 b	15 b	25 a	0 b	93 ab	163 ab
2 (2 x 4)	22.5 b	0 b	5 b	12.5 a	10 b	23 bc	73 b
3 (2 x 6)	10 b	2.5 b	7.5 b	10.0 a	2.5 b	10 bc	50 b
4 (4 x 2)	0 b	7.5 b	0 b	32.5 a	2.5 b	10 bc	53 ab
5 (4 x 4)	0 b	0 b	0 b	17.5 a	0 b	0 c	17.5 b
6 (4 x 6)	10 b	5 b	0 b	47.5 a	0 b	0 c	65 ab
7 (non-treated)	550 a	430 a	258 a	37.5 a	248 b	120 a	1703 a
P-values	<0.001	<0.001	<0.001	0.0503	<0.001	<0.001	0.001

Means followed by the same letters within a column are not different (P < 0.05) according to Tukey's HSD.

Table 4. Soil Pythium spp. density comparisons among the treatments

		Pythium CFU/g		
Treatment	WXD	Pre treatment	Post treatment	% reduction
1	2 x 2	1263	133 bc	89
2	2 x 4	1101	18 cd	98
3	2 x 6	1197	4 d	100
4	4 x 2	841	329 ab	61
5	4 x 4	874	8 cd	99
6	4 x 6	879	4 d	100
7	Control	887	647 a	27
P- value			<0.001	

Means followed by the same letters within a column are not different (P < 0.05) according to Tukey's HSD.

Conclusions. The band steam applicator reduced pathogens in the soil and weed densities as well as hand weeding times compared to the no steam control. Steam bands 4 inches wide by 4 inches deep provided the best combination of weed and disease control. Where disease pressure is high as we saw in 2021, then we see yield benefits from steam.

Summary. Band steam application reduces weeds, handweeding time, and suppresses *Pythium* spp. in the soil. The next step is to develop a commercial steam applicator.