Physical Weed Management Systems for Leafy Greens

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Topics

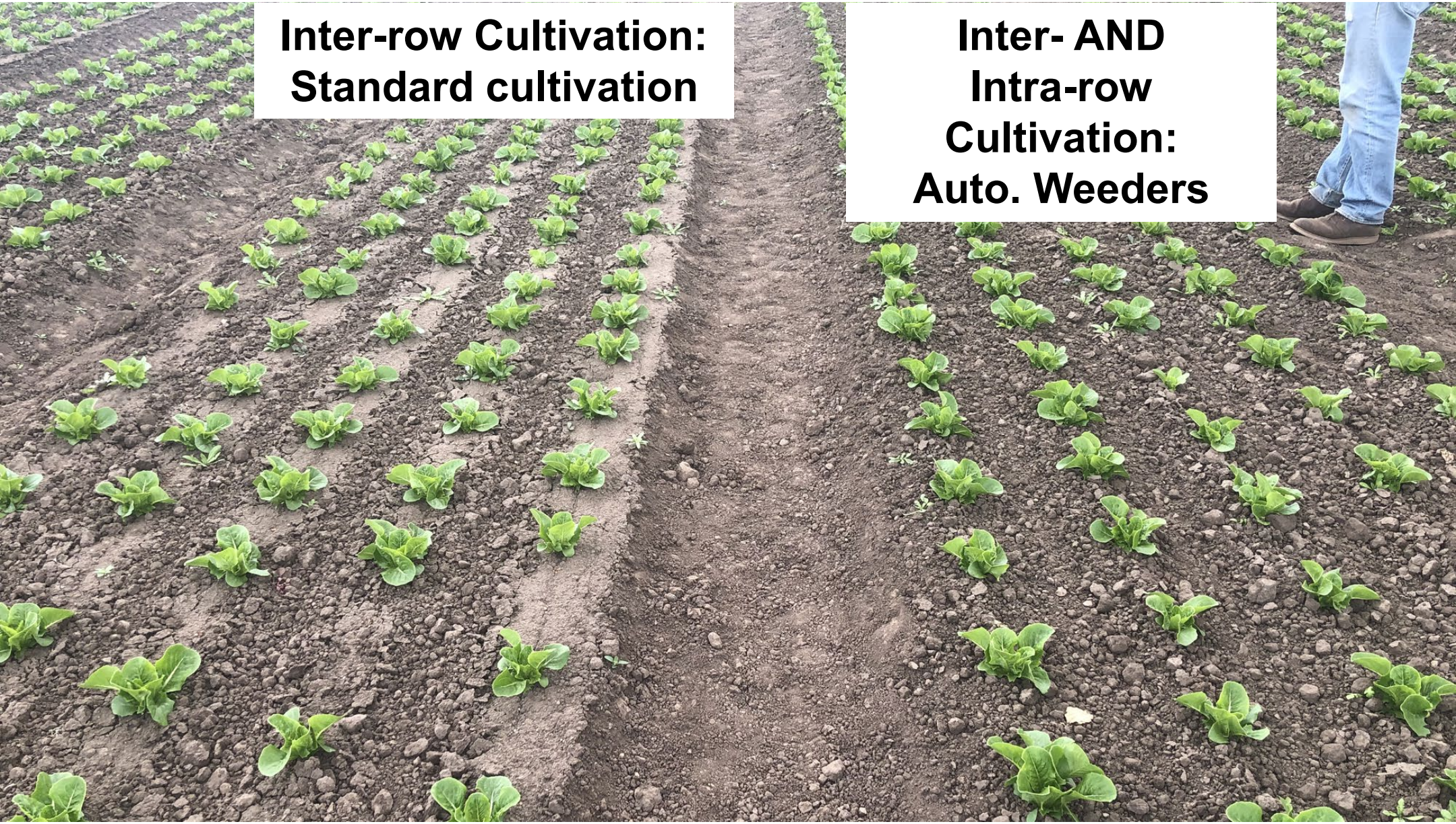
- Evaluate the weed control efficacy of auto weeders in lettuce.
- Evaluate soil disinfestation with band steam in lettuce and spinach.

Auto weeders

- Designed to be labor efficient weeding machines
- Guided by machine learning (Farmwise, Stout) and GPS NAIO

Evaluations

- Evaluations of Stout, Titan and Dino on commercial fields and field station
- Replicated 4 times and arranged in a RCBD
- Weed control and hand weeding times


Inter-row Cultivation:
Standard cultivation
Inter- AND
Intra-row
Cultivation:
Auto. Weeders

Weed control & hand weeding times - Farmwise

Treatment	Weed removal	Hand weed
Trial 1	%	Hr/A
Titan	69.0	10.9
Standard	0.2	19.9
Trial 2		
Titan	31.7	9.8
Standard	0.1	11.2

Richard Smith – On farm assessments

Weed control & hand weeding times - Stout

Treatment	Weed removal	Hand weed
Trial 3	%	Hr/A
Stout	98	4.6
Standard	2.1	11.4
Trial 4		
Stout	52.9	8.6
Standard	1.7	10.1
Trial 5		
Stout	98.7	4.6
Standard	0	11.5

Richard Smith – On farm assessments

Percent weed control & hand weeding times - Stout

Treatment	Weed number	Hand weed
	1,000/A	Hr/A
Stout	90 b	30.4 b
Standard	786 a	78.3 a

Lettuce harvest- Stout

Treatment	Head weight	Yield
	Lbs./ head	Tons/A
Stout	1.9	25.2
Standard	1.7	25.2
P value	0.2277	0.9879

Weed control & hand weeding times - Dino

Treatment	Weed removal	Hand weed
Gonzales	%	Hr/A
Dino	59.5	7.4
Standard	0.0	11.9

Steve Fennimore – On farm assessments, Gonzales, CA

Percent weed control & hand weeding times – NAIO Dino

Treatment	Weed control	Hand weed
	%	Hr/A
Dino	61.5	17.8 b
Standard	41.9	30.5 a

Percent weed control & hand weeding times – Farmwise Titan

Treatment	Weed control	Hand weed
	%	Hr/A
Titan	91.3 a	10.6 b
Standard	67.1 b	23.4 a

Overall summary

Treatment	Weed control	Hand weed
	%	Hr/A
Autoweeder	70.0 a	7.7 b
Standard	0.0 b	12.8 a

Richard Smith 2021

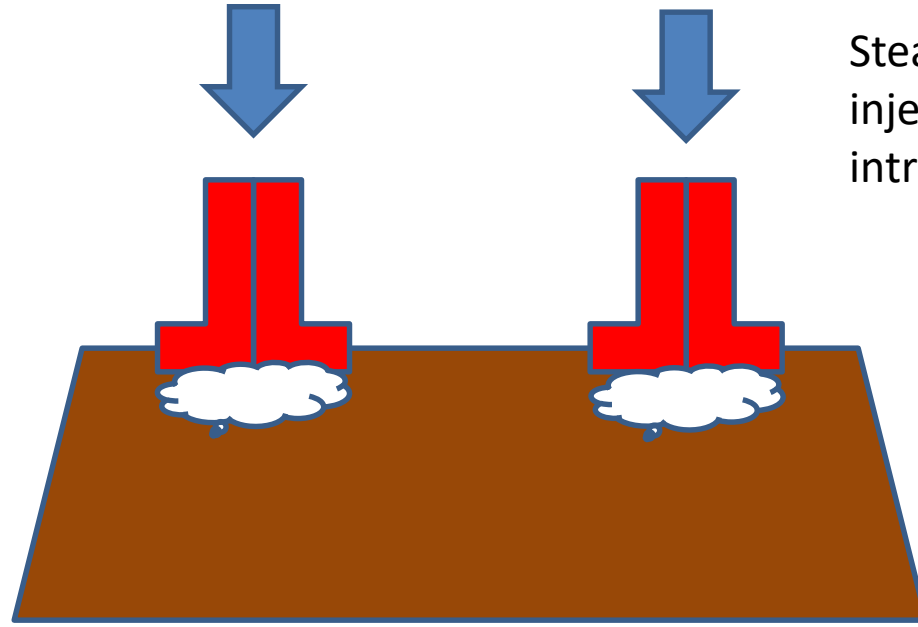
Summary - cultivators

- The Stout, & Titan are both very capable intra-row weeders
- The Dino is a versatile autonomous robot equipped with finger weeders and torsion cultivation tools

Why soil disinfestation with steam?

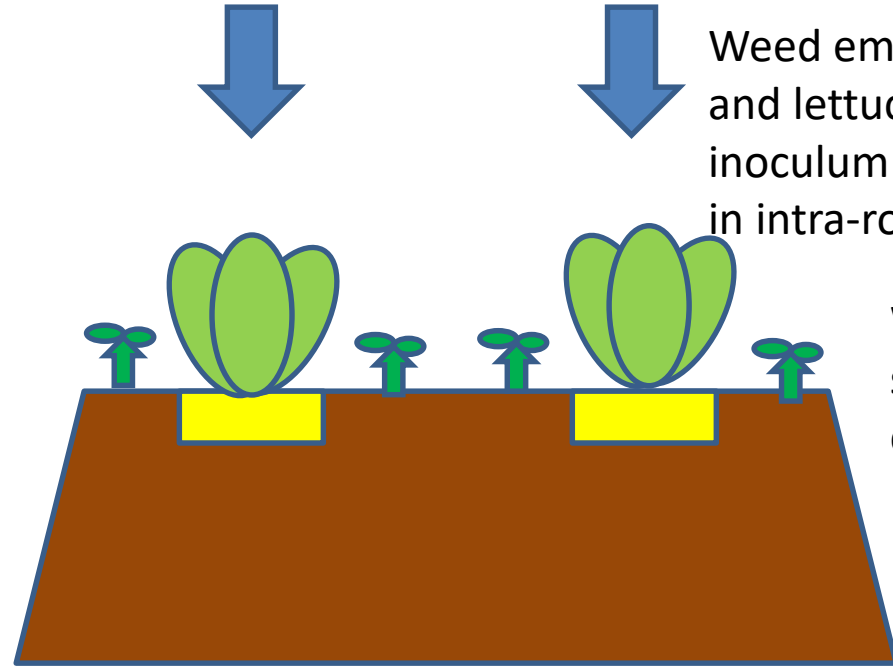
1. It kills soil pests
2. No one owns it
3. Not a pesticide – is a device
4. Is a sanitation treatment – organic compliant
5. Is flexible and safe
6. No buffer zones, township caps, or notifications

Seed lines disinfested with steam



Steam is injected into intra row soil

Seed lettuce into the disinfested band



Weed emergence and lettuce drop inoculum is reduced in intra-row

Weeds outside seedline can be cultivated out.

2020 trials

Trial 1 & 2 July 1st and July 21th 2020 (Romaine Lettuce)

-done using simple bed shaper equipped with shanks injected steam in a band

-3 inches deep by 4 inches wide

-3.3*3 ft wide plots*

Trial 3 (Spinach) Merrak Rz F1 variety October 26th 2020

-JSE Korean steamer that has 15 steam injectors.

-Spinach trial had 8 seedlines

-Flat, 5 ft wide plots

****All Treatments were replicated 4- 6 times and arranged in a randomized complete block design****

2021 Trials

-Trial 4: July 8th 2021 (Romaine Lettuce)

Done with a prototype field steam applicator equipped with a bed shaper with shanks injected steam in a band from Yuma, Arizona

-3 inches deep by 4 inches wide

-3.3*3 ft wide plots*

Trial 5: July 9th 2021 (Carrot)

Done with the Yuma, Steamer

****All Treatments were replicated 4- 6 times and arranged in a randomized complete block design****


ZIMMER

Data collected

- Soil temperatures
- Weed control, weeding times
- Pathogen control: *Pythium* spp.*, Sclerotinia minor, Fusarium oxysporum lactucae*
- Lettuce yield

Soil temperature duration results: time >158°F

Treatments	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 4 (Lettuce)	Trial 5 (Carrot)
Time (minutes)					
Steam	88 a	67 a	176 a	98 a	105 a
Control	0 b	0 b	0 b	0 b	0 b

Sclerotinia minor colony reduction result (via flotation method)

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 4 (lettuce)	Trial 5 (carrot)
	% colony reduction				
Steam	72 b	87 b	89 b	72 b	69 b
No steam	0 a	0 a	0 a	0 a	0 a

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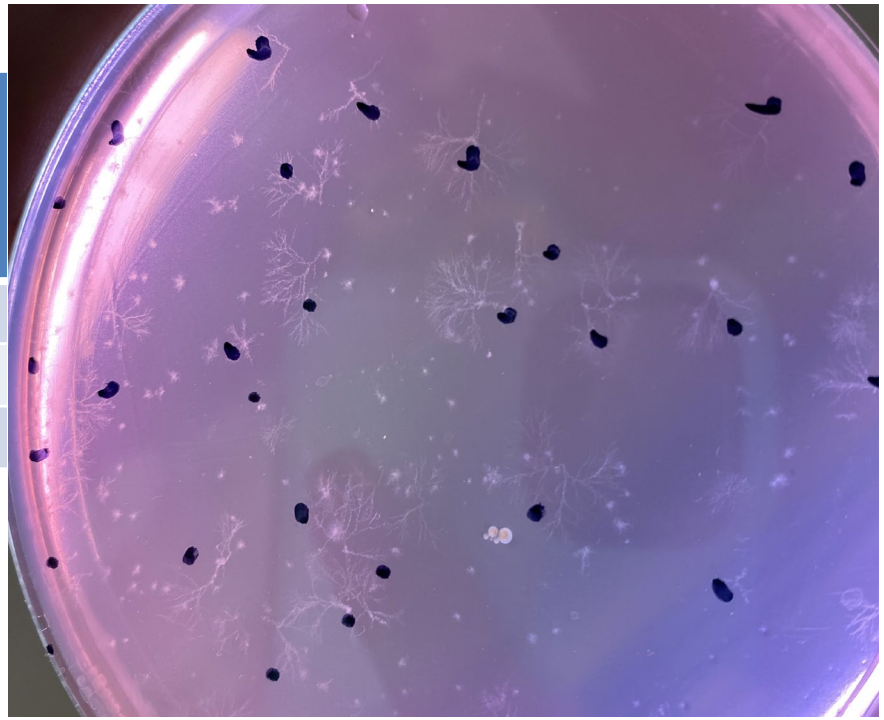
Pythium spp. % colony reduction result

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 4 (lettuce)	Trial 5 (Carrot)
	% colony reduction				
Steam	49 b	89 b	93 b	99 b	95 b
No steam	0 a	0 a	0 a	0 a	0 a



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Diseased plant counts: Lettuce drop, INSV – Arizona steamer

Treatment	Lettuce drop	INSV
	Number per 50ft	
Steam	4.8 b	4.3 b
No steam	12.3 a	12.3 a
LSD	2.6	6.5

Lettuce plant size result

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 4 (lettuce)
	Perimeters inches		
Steam	34 a	26 b	32 a
Control	29 b	23 c	25 b

nontreated Control

Banded-Steam Treatment

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Yield result by trial

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 4 (Lettuce)	Trial 5 (Carrot)
	Tons/A				
Steam	33 a	24 a	13 a	42.3 a	26.6
Control	26 a	21 a	13 a	30.4 b	23.6


Nontreated control
Steam
301


nontreated control


Steam

Hairy nightshade control by trial

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 4 (Lettuce)	Trial 5 (Carrot)
	% control				
Steam	91 a	64 a	93 a	100 a	97 a
Control	0 b	0 b	0 b	0 b	0 b

Shepherd's-purse control by trial

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 4 (Lettuce)
	% control			
Steam	96 a	94 a	81 a	100 a
Control	0 b	0 b	0 b	0 b

Burning nettle control by trial

Treatment	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 5 (carrot)
	% control		
Steam	84 a	89 a	97 a
Control	0 b	0 b	0 b

Hand weeding time result

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 3 (spinach)	Trial 4 (lettuce)	Trial 5 (carrot)
	Hours per acre				
Steam	67 b	51 b	9 b	10 b	25 b
Control	86 a	78 a	49 a	117 a	130 a

Machine costs

Component	Cost $
Manufacture price	$105,051
Price to operator	$136,500

Operating costs per acre

Component	Cost $/A
Labor costs	$394
Fuel (propane)	$450
Total cost/A	$971

Gross revenue stream organic

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 4 (Lettuce)
Steam	$1,934	$1,393	$5,624
Control	$1,508	$1,247	$4,042

Reduced hand weed costs

Treatment	Trial 1 (lettuce)	Trial 2 (lettuce)	Trial 4 (Lettuce)
Steam	$300	$405	$1,621

Conclusions

-These general steam results are encouraging with great reduction of the amount of pythium colonies and sclerotia in the soil in all trials

-Differences in size and yield of lettuce plants

-A good fit for band-steam technology may be organic production where there are no pre-emergence herbicides and fungicide options are limited, and generally not highly effective.

-There still needs to be more steam applicator engineering development to make a more efficient steam applicator.

Acknowledgments

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- Nelly Guerra, Noemi Laros, Tricia Love, John Rachuy

Next moves …

- Combine steam with standard cultivation for 100% weed control and 0% handweeding
- Evaluate soil disinfestation with steam in carrot, lettuce and spinach for control of soilborne diseases and weeds.