CALIFORNIA LEAFY GREENS RESEARCH PROGRAM

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EVALUATION OF AN AUTOMATED LETTUCE THINNER

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ABSTRACT

A project was undertaken to test an automatic lettuce thinner developed by the University of Arizona and using software developed by Blue River Technology. The test was conducted in a commercial lettuce field near Salinas, CA during August to October 2012. The automatic lettuce thinner sprayed selected lettuce plants with sulfuric acid to kill them while leaving the "saved" plants. Automatic lettuce thinning was compared to conventional hand thinning. Automatic thinning left many "doubles" – closely spaced lettuce plants that had to be removed by hand. In the end the total time for the hand thinning/weeding crew was similar between automatic and hand thinning, and the cost for automatic thinning was higher than for hand thinning. However, more even seed spacing would likely improve the performance of the automatic lettuce thinner. Also with increased speed and improved accuracy, the cost of automatic lettuce thinning could probably be reduced.

OBJECTIVE

Evaluate spray-ready products for effectiveness in removal of lettuce with an automated thinner in a single-pass operation.

METHODS

A lettuce thinning and weeding study was initiated August 23, 2012 west of Salinas, CA on a Cropley silty clay soil. The experimental design was a randomized complete block design with four treatments and four replications. Treatments included using an automated thinner to spray three different materials to kill seedlings and a hand thinning control. Spray products included

75% AN20 (20% ammonium nitrate solution), 7% v/v Scythe and 10% v/v sulfuric acid. Each plot was one 40-inch bed wide by 660 ft long.

The University of Arizona/Blue River Technology lettuce thinner was calibrated to spray 126 GPA applying 4-inch bands to twin row 40-inch lettuce beds. The machine was used to thin lettuce on August 23, 2012 when the plants were at the 1-2 leaf stage of growth and approximately 0.9 inches in diameter. Machine travel speed was 0.6 mph. Lettuce was thinned by hand on August 28 and the time it took to thin each plot was recorded. Figures 1 to 6 show photos of the operation during and after machine thinning. The number of "doubles" (closely spaced lettuce seedlings within 1.5 inches of each other) was counted after thinning. All plots were hand weeded on September 11 and the time to remove weeds and double lettuce seedlings that had been missed during the thinning operation was recorded. Lettuce yields were measured October 23 by harvesting 32 heads per plot and weighing them for untrimmed biomass and then trimming them to marketable heads and reweighing.

RESULTS

Scythe and AN 20 were found to be ineffective at killing lettuce seedlings at the application rates and concentration levels used. As a consequence, detailed data analysis was not conducted for these treatments. Use of sulfuric acid with the University of Arizona/Blue River Technology lettuce thinner reduced the lettuce stand from 169,272 plants/A to 34,343 (Table 1). Time requirements to thin by machine and hand were 1.2 and 4.6 hrs./A respectively. However, there were 7,139 doubles/A in the machine thinned with sulfuric acid treatment compared to 24 doubles/A in the hand thinned treatment. A probable explanation for the machine's poor double removal rate was that the unsprayed "safety zone" before and after the "saved" plant was excessive and closely spaced plants were not killed. The subsequent hand weed and double removal operation took 5.7 hours/A in the machine thinned treatment as compared to 2.8 hrs./A in the hand thinned treatment. The total time to thin and weed the lettuce was 7.4 hours/A in the standard operation vs. 6.9 hours/A in the machine thinned operation.

Although the automated thinner used in this trial was 1 bed wide and traveled at 0.6 mph, it is expected that a commercial machine would be 4 beds wide and travel at 1.5 mph. Projecting development of such a machine, operating costs of machine thinning with sulfuric acid are estimated at $46/A ($7/A material, $11/A machine labor, $28/A fuel, lube, repairs) and require an additional 1.2 hours/A or $15/A hand labor for a total practice cost of $61/A (Table 2). This is essentially the same cost as hand thinning (the current grower standard), which is estimated at $57/A using a total of 4.6 hand labor hours/A. When evaluating total practice costs, including weeding and doubles removal, costs/A for an automated lettuce thinner are higher than the grower standard at $132 and $92 respectively (Table 2). However, the hand labor requirements associated with an automated thinner would be reduced by roughly 75% as compared to the grower standard, and may therefore be a helpful alternative when labor availability is constrained.

There were fewer total plants/A in the automated thinner treatment following removal of the doubles. There was no difference in mean head weight between treatments, but the lower plant count of the automated thinner reduced total overall and marketable yield in that treatment (Table 1). Ultimately, this resulted in lower net returns to growers above operating costs for the automated lettuce thinner as compared to the grower standard of hand thinning and weeding

(Table 3). Two areas in which machine performance improvements may beneficially impact cost estimates are increased machine speeds and enhanced thinning precision. If these two improvements could be realized, an automated lettuce thinner may be more attractive to growers from an operation and economic perspective.

CONCLUSIONS

The results of this test indicate that while it is possible to machine thin lettuce, considerable work needs to be conducted to optimize the efficiency of the operation. Lettuce seeding may need to be more precise and evenly spaced to allow accurate detection of the lettuce plants by the machine vision equipment. The automatic lettuce thinner must travel at a faster speed and approach the accuracy of hand thinning if this system is to be commercially acceptable. Additionally a consistent and effective spray treatment for lettuce and weed removal is needed.

Table 1. Thinning and weeding evaluations based on timing of commercial hand crew (660 linear feet of row). Lettuce yields presented as untrimmed head weights, weight per head and marketable yields.

Treatments	Pre-thin plants/A	Thin hrs./A	Post thin plants/A	Post thin doubles/A remaining	Weed and double removal hrs./A	Plants/A after weed/ double removal	Total time thin/ weed hrs./A	Yield untrimmed Tons/A	Head Weight lbs./head	Yield Market Tons/A
	Aug 23	Aug 28	Aug 30	Aug 30	Sept 11	Sept 25		Oct 23	Oct 23	Oct 23
Standard hand thinning	167,129	4.6	30,253	24	2.8	29,504	7.4	44.9	3.0	27.1
Automated thinner with sulfuric acid	169,272	1.2	34,343	7,139	5.7	26,792	6.9	41.3	3.1	25.1
Pr>F treat	0.6712	NA	0.05	0.01	0.0001	0.07	NA	0.1034	0.6488	0.0018
LSD (0.05)	NS	NA	3,886	2,902	0.21	3,201	NA	NS	NS	0.60

Table 2. Estimated operating costs for lettuce thinning by hand compared to machine thinning with sulfuric acid or AN20 spray. The post thinning weed and lettuce doubles removal was done by hand in all treatments.

Method	Thinner: 0.6 mph – 4 bed unit ($/acre)					Thinner: 1.5 mph – 4 bed unit ($/acre)[1]				
	Material	Thinning Labor	Weeding Labor	F L R[3]	*Total*[4]	Material	Thinning[2] Labor	Weeding Labor	F L R[3]	*Total*[4]
Hand thin/ hand weed	0	57	35	0	*92*	0	57	35	0	*92*
Machine Thin/ Hand Weed										
Sulfuric acid 10% v/v	7	24+15	70	61	*177*	7	11+15	70	28	*132*
AN20 75% v/v	39	24+15	68	61	*207*	39	11+15	68	28	*161*

1 Costs are included for a 4-bed automated thinning machine traveling at speed of 1.5 mph since this is the expected rate of travel for a commercial machine.
2 Machine + non-machine (field) labor.
3 Fuel, lube, repairs.
4 Total includes interest on operating capital.

Table 3. Estimated operating costs and net returns for an automated lettuce thinner using sulfuric acid and AN20 spray compared to hand thinning.

	Thinner: 0.6 mph – 4-bed unit ($/ac)				Thinner: 1.5 mph – 4-bed unit ($/acre)			
	Yield (t/ac)	Gross Ret[1] ($/ac)	Op Costs ($/ac)	Net Ret[2] ($/ac)	Yield (t/ac)	Gross Ret[1] ($/ac)	Op Costs ($/ac)	Net Ret[2] ($/ac)
Hand thin	27.08	11,969	92	11,877	27.08	11,969	92	11,877
Sulfuric Acid	25.08	11,085	177	10,908	25.08	11,085	132	10,953
AN20	NA	NA	207	NA	NA	NA	161	NA

[1] Gross returns = experimental yield in tons/acre x $442/ton.
(2011 price for lettuce – bulk leaf – Monterey County Crop Report Crop Report).
[2] Net returns above estimated operating cost (gross returns – operating costs).

Calculation Assumptions:

Equipment Investment Cost:
New equipment; estimated investment costs of $150,000.

Material Cost:
- Field Grade Sulfuric Acid application rate: 2.5 gal/acre; $2.04/gal.
- AN20 application rate: 18.9 gal/acre; $2.70/gal.

Labor Cost†:
Machine‡: $19.53/hr.
Non-Machine: $12.33/hr.
† Both machine and non-machine labor includes 37% taxes/benefits package.
‡ Labor for operations with machinery are 20% higher than actual operation time noted above to account for the extra labor involved in equipment set up, moving, maintenance, work breaks and field repair.

Fuel Cost:
Diesel: $3.43/gal.
Fuel use for .6 mph = 5.56 gal/acre; fuel use for 1.5 mph = 2.59 gal/acre.

Figure 1. Stage of growth at time of application.


Figure 2. Application of sulfuric acid to lettuce stand (left); treated and nontreated plants (right).


Figure 3. Treated plants dying down and healthy nontreated plants remaining after treatment by automated thinner.

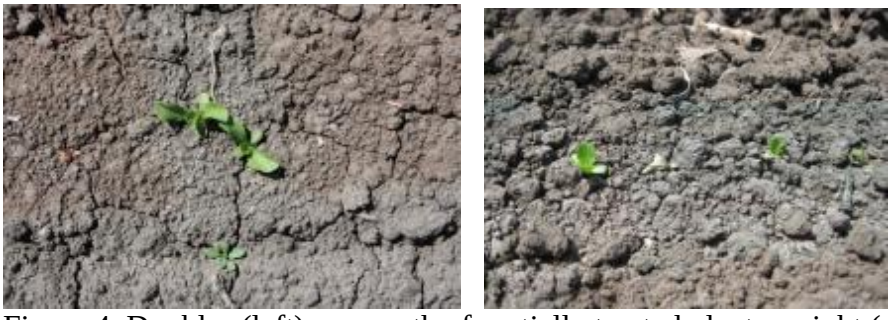
Figure 4. Doubles (left); regrowth of partially treated plant on right (right).

Figure 5. Awkward spacing left by automated thinner in some situations; these required correction in the subsequent double removal operation.

Figure 6. Overview of thinned (by automated thinner) vs. prethinned beds.