CA Melon Research Board
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Project: Weed control and cost benefit analysis of automated cultivators and herbicides to control within-row weeds in melons.

Summary: A weed management trial was conducted in a late-season commercial cantaloupe field in the Dos Palos area and at the UC WSREC near Five Points to evaluate weed management, crop safety, and an economic analysis of using finger weeder and robotic cultivators compared to standard herbicides registered for melon production in California. Cultivar "Karameza" was transplanted on May 25, 2022, on 80" centers. Herbicide treatments included Curbit (ethalfluralin), Prefar (bensulide), and Sandea (halosulfuron) applied 0 and 2 weeks after planting. At WSREC, mechanical cultivation treatments were performed at 2 weeks after planting and only cultivated the narrow band in the plant row. Standard cultivation treatments were performed outside the planting line. Crop injury was observed in one row from the robotic cultivator and in the treatments that received post-emergence applications of Sandea herbicide. Both cultivators significantly reduced in-row weeds as compared to no cultivation at 2 and 4 weeks after treatment, however, weed pressure was equivalent by the end of the season. Nonetheless, hand weeding costs were reduced $37 - $54 per acre. The Sandea herbicide treatment had significantly better weed control as compared to all others, over 90% at all evaluation dates. As a result, hand weeding costs were lowest for this treatment, reduced over $100 per acre, and fruit yield was greatest at 1306 boxes/A. In those plots where weeds were allowed to compete with the crop all season, yields declined nearly 40%

Methods.

This trial began on May 24, 2022, at the UC Westside Research and Extension Center (WSREC), near Five Points in Fresno County. A second location was also added in July in a commercial field near Dos Palos in Merced County. The objective of both trials was to evaluate weed control and crop safety of the Robovator robotic cultivator and Steketee finger weeder as compared to registered herbicides. Herbicide treatments were Prefar (bensulide) 6 qts/A PPI, Sandea (halosulfuron) 1 oz/A 14 days POST, Curbit (ethalfluralin) at 4 pts/A 14 days POST, mechanical cultivation using finger weeders 14 days POST, mechanical cultivation using automatic cultivator (Robovator) 14 days POST, and an untreated control.

At WSREC, Prefar (bensulide) at 6 qts/A was applied to select plots on preformed beds using a backpack CO_2 sprayer with TeeJet 8002 nozzles and 40 gpa water volume, then incorporated to 3" using a power

rotary cultivator. Melon cultivar 'Karameza' was transplanted on May 25, 2022, using cone mechanical transplanters on 24" spacing and 250 gpa water. After transplanting, the field was sprinkler irrigated for about 12 hours to apply about 2" of water, then irrigated via subsurface drip irrigation for the remainder of the season. On June 7, the trial was cultivated using a Steketee finger weeder and a Robovator robotic cultivator. The finger weeder was operated at 3.5 mph, while the Robovator worked at 1.8 mph. The Robovator used standard 5" blades set to leave a 2" buffer zone around each plant at a depth of about 1" below the soil surface. Using a camera guidance system and a wheel to provide information on forward speed, the blades open around the plants to prevent injury; the finger weeder used Steketee "medium" 14-inch fingers with a slight overlap (Figure 1).

Applications of Sandea and Curbit were made on June 10. Curbit was directed as a band application on either side of the plant row to minimize contact with foliage, then lightly incorporated by hand. Herbicides were applied with a CO_2 backpack sprayer at 38 psi with a 4-ft boom using two Tee Jet 8002 flat fan nozzles and two 8002 OC nozzles on the ends, calibrated to 26.8 gpa equivalent. Spray swath was 60" when measured ~24" above the soil surface for Prefar, and 30" for Sandea.

Plots were hand weeded in reps 3 and 4 on June 21 and times recorded for 1 person to visually remove all weeds from the center of each plot. The bed shoulders had been mechanically cultivated the week prior. These times were used to estimate hand weeding costs as affected by treatment. An hourly wage of $15.50 was assumed. Reps 1 and 2 were not hand weeded so that the impact of uncontrolled weeds on yields could be compared.

Plot size for the herbicide treatments was 1 bed (80") by 75 ft; the cultivation treatments were 1 bed by 300 feet. The experimental design was a RCB split plot with 4 replications, with cultivation as the main plot and herbicide treatment as the split plot. Imidacloprid was applied twice through the drip tape for insect control. The trial area was fertilized with 200 lbs/A monoammonium phosphate (10-52-0) pre-plant incorporated followed by UAN32 through the drip tape beginning 21-June to supply another 60 lbs N/A. The trial was irrigated to meet estimated crop ET using data from the CIMIS station located on the field station. A total of approximately 18" of water was applied. Additional treatment and trial information is listed in Table 1.

This second trial began on July 5, 2022, in a commercial late-season field near Dos Palos, in Merced County. Melon variety 'Karameza' was direct seeded on June 10 on 80" centers and 16" seed row spacing. No pre-emergent herbicides had been applied prior to the initiation of this project. All herbicide treatments were applied after crop emergence but before weed emergence. The initial herbicide application was made on July 7 with an over-the-top application of Prefar when melons were 1 true leaf, then incorporated into the soil by hand. Cultivation treatments were done July 5 (Figure 1). Herbicide treatments were Prefar 6qts/A, Sandea 1 oz/A, Curbit at 4 pts/A, mechanical cultivation using finger weeders, mechanical cultivation using automatic cultivator (Robovator), and an untreated control. Plot size for the herbicide treatments was 1 row (80") by 35 ft; the cultivation treatments were 1 bed by field length (about 900 ft). The experimental design was an RCB with 4 replications.

At both locations, weed and crop injury ratings were made every 2 weeks after cultivation or herbicide treatments were applied. At WSREC, the first weed evaluation occurred after mechanical cultivation treatments on June 10. Weed and crop phytotoxicity ratings were done using a subjective scale, where 0 = no weeds/no phyto, 1 = 1 – 2.5%, 2 = 2.5 - 10%, 3 = 10 - 21%, 4 = 21 - 35%, 5 = 35 - 50%, 6 = 50 – 65%, 7 = 65 – 79%, 8 = 79 – 90%, 9 = 90 – 97.5%, and 10 = 97.5 - 100% weeds or crop injury. At the first rating, weed control was also estimated by scoring the plots based on the presence of weeds in-between plants within the plant row, based on the plant stand. A once-over harvest was conducted on Aug 22 by counting the number of harvestable melons in each plot. Melon counts were separated into 3 size categories: 6 and larger, 9, and 12 fruit per box or smaller. Fruit weight was measured from a

subsample within several plots to estimate yield in lbs/A. Average weight was 5.3, 4.3, and 3.0 lbs for size 6, 9, and 12, respectively. Brix readings were done on 5 sample melons from each treatment using a handheld refractometer at room temperature. All data were analyzed using analysis of variance for a replicated block design; means comparisons were performed using Fishers Protected LSD at 95% confidence level.

Figure 1. Robovator (left) and Steketee finger weeder (right) at WSREC and Dos Palos, CA, 2022.

Prefar + finger weeder + Sandea	Prefar + no cultivation	UTC

Figure 2. puncture and pigweed were the dominant weeds at the WSREC location.

Table 1. Herbicide and cultivator trial information and treatments, Merced County 2022.

	Trial 1: WSREC	Trial 2: commercial field
Location	UC WSREC	Dos Palos
	Five Points (Fresno County)	Branco Rd, N. of 152
Cooperator		Doug Goodman
Soil	Cerini clay loam	El nido sandy loam, poorly drained
Variety and plant date	Karameza, transplanted May 25, 2022. 1 row, 24" (3265 plants/A)	Karameza, June 12, 2022. Direct seed, 12" spacing
Plot size	Herbicide plots: 1 bed (80") x 75 ft	Herbicide: 1 bed x 35 ft
	Cultivation plots: 1 bed x 300 ft	Cultivation: 1 bed x 900 ft
Irrigation	sprinklers, then drip	drip
Herbicide incorporation	power mulcher	hand hoe
Weed evaluation	6/10, 6/21, 7/7, 7/21	
Harvest	22-Aug-22	26-Aug-22
days	89	75

Treatments:	**WSREC**	***timing***
1	finger weeder POST	7-Jun
2	no cultivation	---
3	Robovator	7-Jun
a	Prefar 6 qts/A PRE	24-May
b	Prefar PRE + Sandea 1 oz/A POST	May 24 and Jun 10
c	Prefar PRE + Curbit 4 pts/A POST	May 24 and Jun 10
d	no herbicide	---

Herbicide treatments applied at 40 gpa with 8002 nozzles
RCB-SP design with 4 reps

Treatments:	**Doug Goodman**	***timing***
1	UTC	---
2	Prefar 6 qts/A PRE	8-Jul
3	Prefar 6 qts/A + Curbt 4 pts/A PRE	8-Jul
4	Prefar 6 qts/A + Sandea PRE	8-Jul
5	Robovator	5-Jul
6	finger weeder	5-Jul

Herbicide treatments applied at 40 gpa with 8002 nozzles
Prefar and Curbit were hand incorporated. Sandea over-the-top
RCBD with 4 reps

Results

Weed pressure at the WSREC location was dominated by puncture vine (Figure 2); other weeds included field bindweed, pigweed, and nightshade. There were very few grasses at this location, and no grass herbicides were applied. Both the finger weeder worked well and caused no visible crop injury except in one plot where the Robovator malfunctioned and caused a significant reduction in stand. Both the Robovator and finger weeder significantly improved weed control at 2 and 4 weeks after transplanting (Table 1) as compared to the untreated control, but the amount of control was still marginal at these evaluation dates, 73% and 69% for the finger weeder and Robovator, respectively, and no significant difference in weed control was observed later in the season. This likely occurred because the puncturevine continued to germinate throughout the growing season. Herbicides, especially Sandea, had far greater impact on weed control than cultivation in this trial this year. The combination of Prefar PPI followed by a post application of Sandea gave significantly improved weed control as compared to the other treatments at 4 weeks after transplanting on June 21 (Figure 3).

Both Curbit and Sandea herbicides caused some crop injury, especially Sandea with obvious crop stunting and some leaf spotting and chlorosis. However, the crop eventually resumed normal growth, and Sandea was the only treatment that provided any significant suppression of puncture vine (Table 2).

Half of the plots were hand weeded on June 21 and weeding times recorded. The finger weeder significantly reduced hand weeding time as compared to the Robovator or the non-cultivated control, with a savings of $37 to $54 per acre. The Sandea treatment reduced estimated hand weeding costs by over $100 per acre (Figure 4).

Yield results are shown in Table 3. Cultivation treatment did not have a significant effect on total marketable yield (TMY) or size distribution, however, herbicide treatments were significant (Figure 5). The Prefar plus Sandea treatment resulted in highest yield in this trial, at 1306 boxes per acre. Furthermore, this treatment also had significantly more size 6 and 9 fruit, and less small fruit in the size 12 (or smaller) category, as compared to all the other treatments (Figure 6). No differences were observed for fruit Brix, which was 12.1% across all treatments. There was a significant correlation between yield and weed control at the July evaluation date, with improved yield where weeds were controlled (Figure 7). Average yield with 80% or better weed control was about 1300 boxes per acre, whereas yield was 700 boxes per acre at 20% weed control, a reduction of 38%.

At the Dos Palos location, crop size varied from 2 to 6 true leaves, and pigweed ranged from 2” to 12”. Cultivation treatments again performed well, with little crop injury. Weed control varied based on weed size, with large weeds left standing after running the equipment. The herbicides Sandea and Curbit again caused some slight crop phytotoxicity in the first two weeks after application (Table 4). Weed pressure was minimal in this field, and hand weeding times could not be made, however, weed counts were significantly lower in both the Curbit and Sandea treatments as compared to the untreated control. Harvest estimates were made on Aug 23 by counting 6, 9, and 12 sized fruit in each plot. Best TMY was observed in the Sandea plots at 1591 boxes per acre, but these were not significantly different than the untreated control.

Acknowledgements
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Table 2. Weed control and melon crop injury results at 2, 4, 6, and 8 weeks after transplanting, WSREC 2022.

Main plot	split plot	10-Jun stand #	0 - 10 weed score	between weeds, %	21-Jun weed score	%control	0 - 10 crop injury	weed time hr/A	$/A	7-Jul weed score	%control	0 - 10 crop injury	21-Jul weed score	%control	0 - 10 crop injury
1. finger weeder POST		35.3	2.4	64.8	3.25	73.0	1.2	7.8	$ 121.00	3.3	70.7	0.7	4.3	58.1	0
2. no cultivation		34.7	4.1	78.6	4.6	55.0	1.3	11.3	$ 175.00	4.3	68.2	0.3	4.8	52.6	0
3. Robovator		35.7	3.1	74.1	3.6	68.8	1.0	10.2	$ 158.00	3.5	59.9	0.5	4.9	50.9	0
Main plot LSD 0.05		ns	0.97	ns	0.93	13.7	ns	1.5	$ 23.00	ns	ns	ns	ns	ns	---
	a Prefar 6 qts/A PRE	34.8	2.8	67.8	4.4	58.3	0.3	11.2	$ 174.00	4.1	60.8	0.4	5.5	43.1	0
	b Prefar PRE + Sandea 1 oz/A POST	35.0	3.0	69.9	1.7	92.2	3.6	4.5	$ 70.00	1.6	91.8	1.3	1.6	92.1	0
	c Prefar PRE + Curbit 4 pts/A POST	35.3	3.2	76.5	4.0	64.7	0.6	11.5	$ 178.00	3.5	70.7	0.2	5.0	49.7	0
	d no herbicide	36.0	3.8	75.8	5.3	47.3	0.2	11.8	$ 183.00	5.7	41.5	0.2	6.7	30.6	0
	Split plot LSD 0.05	ns	ns	ns	0.76	10.2	0.8	3.6	$ 56.00	1.25	16.2	0.7	1.4	17.9	---
Cultivation x herbicide interaction, p value		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	---
	CV, %	6.75	45.2	20.3	23.8	18.6	80.2	28.3	28.2	40.4	29.2	161.5	34.9	39.8	---

stand: number of live plants per 70 ft 2 weeks after planting.

0 - 10 scale. Subjective scale.

0 = no weeds/no crop phytotoxitity
1 = 2.5%
2 = 10%
3 = 21%
4 = 35%
5 = 50%
6 = 65%
7 = 79%
8 = 90%
9 = 97.5%
10 = all weeds/total crop loss

between weeds: weeds present between plants in the plant row on June 10, %

Main broadleaf (BL) weeds: pigweed, puncturevine, and field bindweed

$/A = estimated cost to hand weed, 1 person at $15.50/hour one month after planting (June 21)

LSD 0.05 = Least significant difference at the 95% confidence level. NS = not significant. --- = not enough data to perform statistical analysis.

CV% = coefficient of variation

Table 3. Melon yield and size distribution as affected by weed management treatment. WSREC 2022.

	boxes/A			TMY	lbs/A			TMY	% of TMY			
Main plotsplit plot	**>6**	**9**	**<12**	**boxes/A**	**>6**	**9**	**<12**	**lbs/A**	**>6**	**9**	**<12**	**Brix, %**
1. finger weeder POST	245	412	407	1064	7788	15947	14642	38376	21%	36%	42%	12.6
2. no cultivation	242	339	412	993	7695	13113	14834	35643	23%	32%	45%	10.9
3. Robovator	226	411	411	1048	7201	15897	14782	37879	19%	37%	45%	12.9
Main plot LSD 0.05	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	---
a Prefar 6 qts/A PRE	170	352	430	952	5398	13606	15487	34492	16%	34%	51%	13.6
b Prefar PRE + Sandea 1 oz/A POST	415	557	334	1306	13186	21563	12035	46784	31%	42%	27%	13.3
c Prefar PRE + Curbit 4 pts/A POST	215	309	477	1001	6840	11968	17167	35975	20%	29%	51%	11.8
d no herbicide	152	331	398	880	4821	12804	14321	31946	17%	35%	48%	10.1
Split plot LSD 0.05	85.4	126.9	ns	176.1	3901	4907	ns	6208	9.3	8.9	15.9	---
Cultivation x herbicide interaction, p value	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	---
CV, %	61.5	39.1	32.8	20.3	61.6	39.1	32.8	19.9	53.5	30.5	43.1	---

TMY = Total Marketable Yield, the sum of size 6 or larger, size 9, and size 12 or smaller.
lbs/A yield estimates based on fruit subsamples with average weight of 5.3, 4.3, and 3.0 lbs for size 6, 9, and 12 fruit.
LSD 0.05 = Least significant difference at the 95% confidence level. NS = not significant. --- = not enough data to perform statistical analysis.
CV% = coefficient of variation

Table 4. Plant stand, weed control, and melon yield as affected by treatment at the Dos Palos location, 2022.

	plant stand	weeds	0 - 10	boxes/A			TMY	
treatment	**#/acre**	**#/acre**	**crop injury**	**>6**	**9**	**<12**	**boxes/A**	**Brix, %**
1 UTC	5365	280	0.0	101	684	723	1508	10.1
2 Prefar 6 qts/A PRE	5225	327	0.5	62	643	739	1443	11.3
3 Prefar 6 qts/A + Curbt 4 pts/A PRE	4665	93	1.3	78	477	684	1239	10.1
4 Prefar 6 qts/A + Sandea PRE	5365	47	2.3	70	534	987	1591	9.9
5 Robovator	5178	117	0.0	62	601	828	1491	10.1
6 finger weeder	5178	152	0.0	86	695	587	1367	11.2
Average	5162	169	0.7	76	606	758	1440	10.4
LSD 0.05	ns	190	0.8	ns	153	ns	194	---
CV, %	13.5	74.7	79.1	60.9	16.8	23.3	8.9	---

stand: number of live plants per acre 2 weeks after planting.
crop injury, subjective scale. 0 = none, 1 = 2.5%, 2 = 10%
TMY = Total Marketable Yield, the sum of size 6 or larger, size 9, and size 12 or smaller.
LSD 0.05 = Least significant difference at the 95% confidence level. NS = not significant. --- = not enough data to perform statistical analysis.
CV% = coefficient of variation

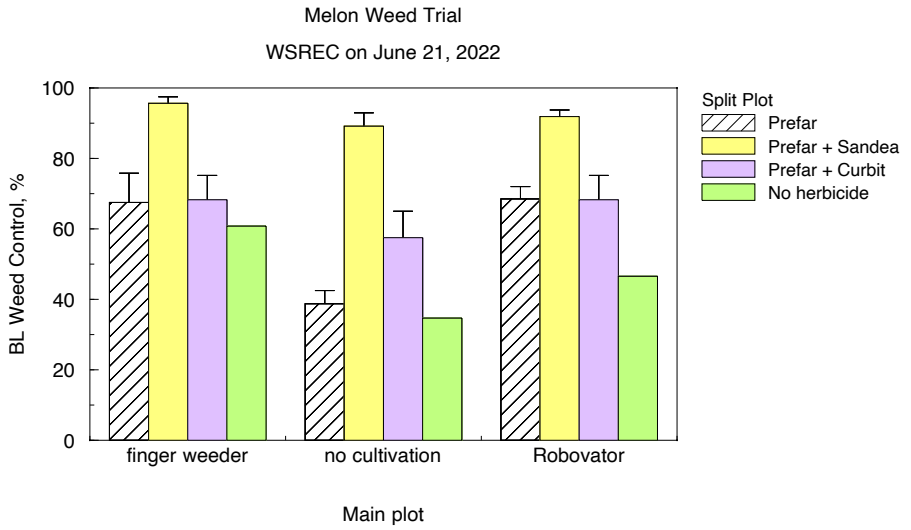

Figure 3. Weed control 4 weeks after planting as affected by cultivation and herbicide treatment.

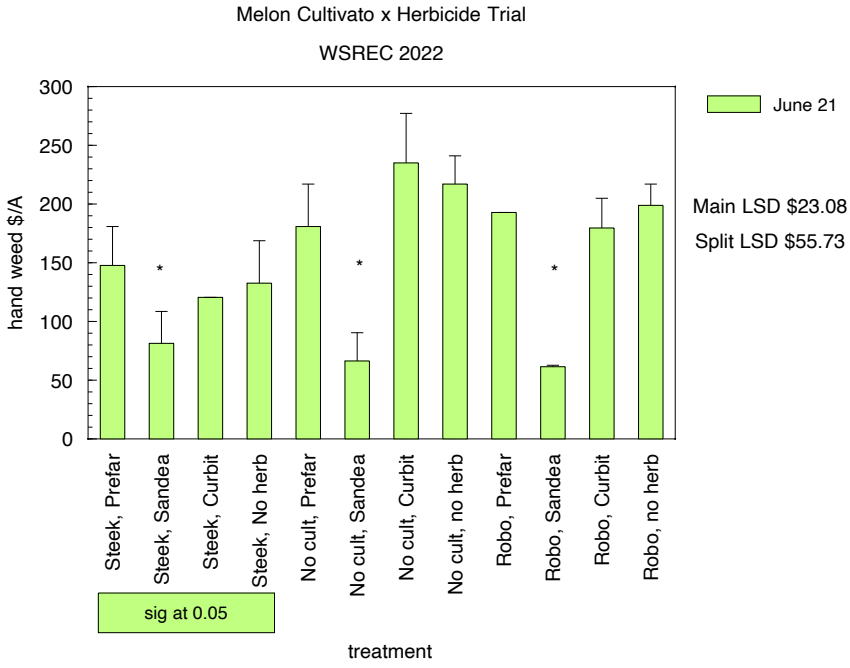

Figure 4. Estimated hand weeding costs by weed management treatment.

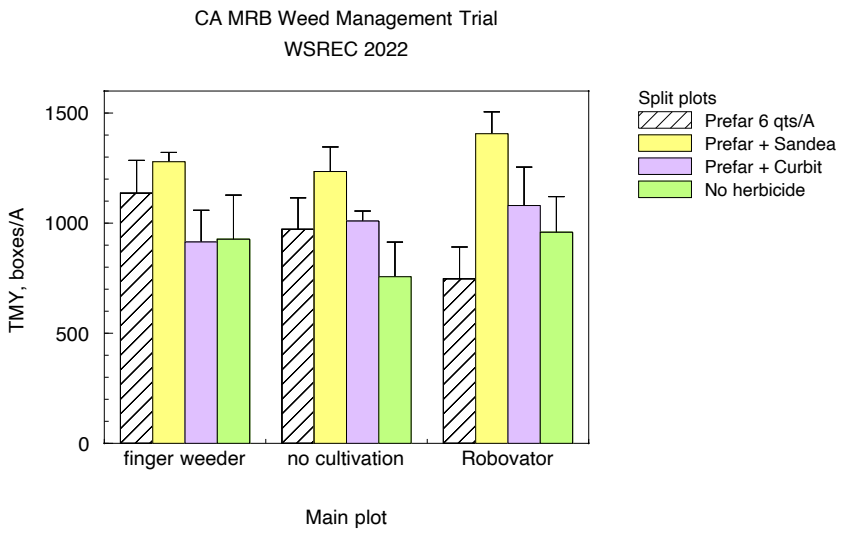

Figure 5. Total marketable yield (TMY) as affected by cultivation and herbicide treatment.

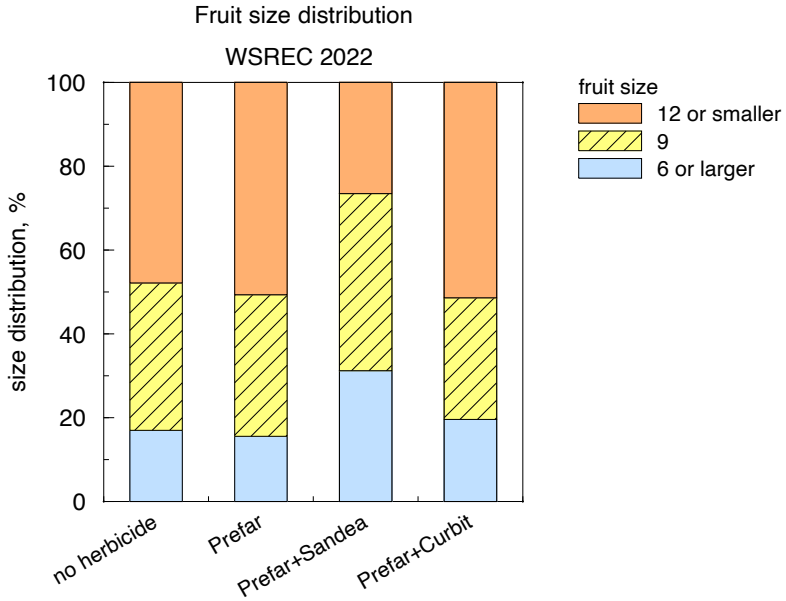

Figure 6. Total marketable yield fruit size distribution as affected by herbicide treatment.

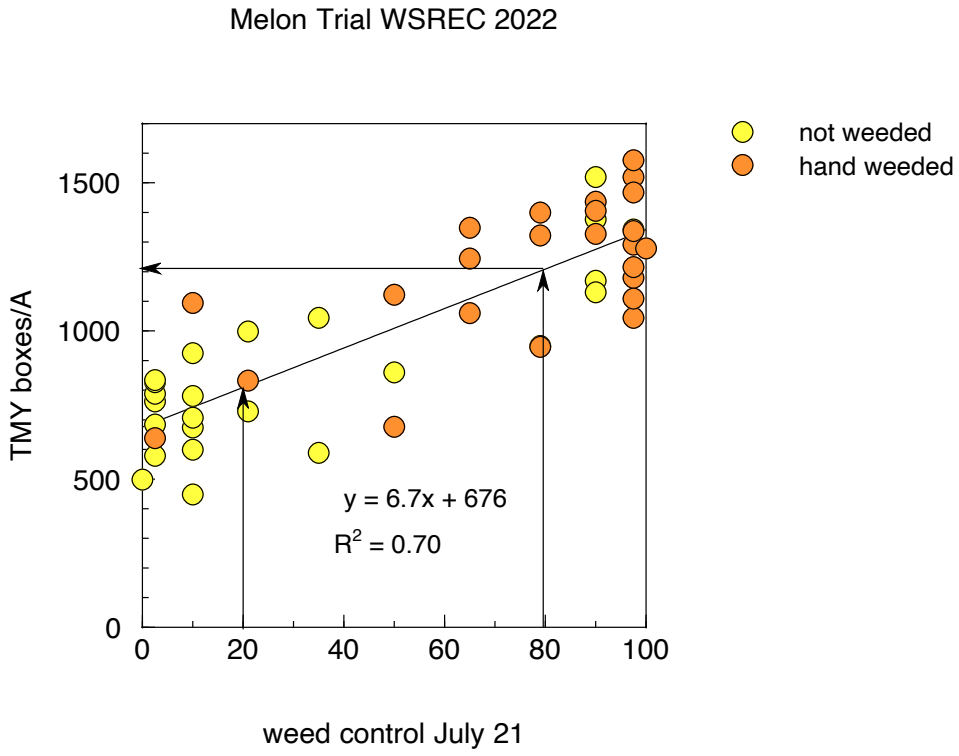

Figure 7. Correlation between late season weed control and melon yield.