2016 Annual Report for the California Melon Research Board

Integrated weed management in California's desert melons: evaluation of split herbicide applications and plastic mulch for weed control and crop injury under drip and furrow irrigation in melon-Sudangrass rotations

Principal Investigators:

Travis Bean
Weed Science Specialist
University of California
Riverside, CA 92521
Office: (951) 827-5130
Mobile: (951) 205-3974
Fax: (951) 827-4437
bean@ucr.edu

Jairo Diaz
Director, ANR Desert Research & Extension Center
1004 E. Holton Rd.
Holtville, CA 92250
Office: (760) 356-3065
Mobile: (760) 791-0521
Fax: (760) 356-3073
jdiazr@ucanr.edu

Oli Bachie
Agronomy Advisor and Director, UC Cooperative Extension Imperial County
1050 E. Holton Rd.
Holtville, CA 92250
Office: (760) 352-9474
obachie@ucanr.edu

Cooperating Personnel

Brent Boutwell
Staff Research Associate
UCCE Imperial County
1050 E. Holton Rd.
Holtville, CA 92250
Office: (760) 352-9474
beboutwell@ucanr.edu

Gilberto Magallon
Staff Research Associate
ANR Desert Research & Extension Center
1004 East Holton Road
Holtville, CA 92250
Office: (760) 356-3060
gmagallon@ucanr.edu

Project Objectives:

Our project goal was to establish a prescription for integrated weed management in desert melons and melon-Sudangrass rotations, supplementing chemical control with mechanical or cultural approaches to maximize weed suppression and minimize crop injury. Specific objectives were to:

1) Determine the weed management efficacy and crop injury of post planting, pre-emergence herbicides in the desert growing region for both single and split applications. Do split applications provide longer lasting weed control than single post-plant

applications in melons? Is Sudangrass yield affected differently by different herbicides in single or split applications?

2) Evaluate plastic mulch efficacy as an alternative to chemical weed control. Does plastic mulch provide comparable weed control in melons as herbicides? Does plastic mulch reduce crop injury in melons and/or Sudangrass?

3) Evaluate differential effects of drip and furrow irrigation on herbicides and plastic mulch for weed management and crop injury. Do different herbicide products, their application as split or single applications, or plastic mulch result in different levels or weed management or crop injury in drip vs. furrow-irrigated fields?

4) Evaluate water usage and soil water status in melons for drip and furrow irrigated fields.

Research procedures

Plot layout and experimental design

Plots were located at the University of California Desert Research and Extension Center in Holtville, CA. Soil was a silty clay loam (Imperial-Glenbar series, pH 8.0-8.2). Beds were shaped into 80-inch “Yuma” beds in April 2016, subsurface drip installed for irrigation where appropriate, and melon seeds (‘Navigator’ cantaloupe) were planted into dry beds on 3/17/2016. Plots consist of three adjacent beds each 30 ft in length, with the center bed being utilized for evaluations and the outer beds serving as buffers from other treatments (Figure 1A). Untreated buffers of 10 feet separated each of the plots in the same bed. Beds were oriented from east to west with the head end at the west end of the fields and the field drains at the east end. Replicates were blocked east to west with the direction of irrigation and field slope. Glyphosate was applied to all beds immediately before and after experimental treatments to kill emerged weeds and start the experiment with a clean field.

Herbicide treatments

The experiment was organized into separate furrow and subsurface drip fields (Figure 1B) using a randomized block design with 4 replications and 12 treatments. This included a single full rate herbicide application post planting preemergence, and half rate applications applied simultaneously with the full rate application and again 3 weeks later (Table 1). The treatments included the herbicides Curbit, Dual Magnum, Prefar, Sandea, and Zeus, a plastic mulch treatment (Figure 2), and an untreated check. Initial herbicide treatments were applied on 4/12/2016 using a tractor-mounted CO_2 unit. The spray boom utilized 10 TeeJet flat fan 8002 nozzles spaced at 20 inches, and situated 20 inches over the bed top. Herbicide treatments were applied in a single pass at 25 psi and the swath was measured to cover all three beds from extreme bed shoulder to bed shoulder of the outside plot beds (200 inches). The tractor was operated at 1600 rpm in low third gear and the calibrated carrier volume was 14.8 gal ac^{-1}.

Measurements

For melons, weed species cover (Table 2A and 2B) and density (Table 3A and 3B) were measured in three subplot samples per plot. Melon injury was rated on a 0-10 scale, leaves per plant counted, width of largest leaf and length of vine measured, and flowers and fruits per plant counted (Table 4A and 4B, Figure 3). Following herbicide "break" plots were hand weeded (6/22/2016 to 6/23/2016) and time to weed each plot (person-hours) was recorded (Table 5). At melon harvest, we recorded the number of marketable and non-marketable melons per plot and total melon weight per plot (Table 6, Figure 4).

Sudangrass was planted (7/25/2016) following melon harvest on 7/13/2016 and 7/18/2016 (drip) and 7/12/2016 and 7/19/2016 (furrow). Prior to cutting Sudangrass for harvest, we measured height, visually estimated injury, and measured greenness with a Trimble Greenseeker handheld NDVI meter (Table 7 and 8). At harvest, Sudangrass harvest per plot (a five ft swath of the center bed) was weighed fresh, and subsamples of biomass recorded fresh and dry for each plot to compare with instant read moisture probe measurements (data not shown).

Irrigation, fertilization and insect and disease management schedules followed the University of California Cooperative Extension guidelines. All data were subject to analysis of variance using SAS PROC GLM and Tukey Honest Significant Differences to separate means.

Summary of research findings

Although weed population and melon plant health differences were evident among treatments, these treatment differences did not translate to a difference in melon harvest weight drip nor furrow irrigated fields. However, a split application of Dual Magnum did produce more marketable melons than some other treatments under drip (but not furrow) irrigation. Similarly, certain herbicide treatments (different application timings of Dual Magnum, Sandea, or Prefar) were associated with less manual weeding time following herbicide break than other treatments (Zeus). These treatment differences were also associated with differences in Sudangrass (the next crop in rotation) health (approximated by NDVI) and yield for furrow-irrigated plots at 19 to 21 weeks after the initial herbicide application in melons.

In general, Dual Magnum and Sandea had lowest weed cover and density across species sampled, followed by Curbit and Prefar. Single herbicide applications of a full label rate were generally more effective than split applications, but not surprisingly effects of both dissipated between six to nine weeks after the initial treatment application (WAT). Zeus and mulch treatments consistently had higher weed cover and density, and took longer to hand weed after herbicide treatments broke. Treatment differences were most apparent for furrow rather than drip-irrigated treatments. Though not statistically significant, single full herbicide rate treatments under drip-irrigation seemed to have lower weed density and cover than the split application of the same herbicide, and the reverse was seemingly true for furrow irrigation. Mulch treatments did not cover the entire bed top and the soil disturbance involved with installation seemed to exacerbate weed growth, which may have also stunted melon production. Cover plots had unusually low weed cover and density, though they also performed well for melon health measurements, making it less likely that overspray was at fault.

For results of Objective 4 (water usage and soil water status in melons for drip and furrow irrigated fields) see Appendix A.

Results

Weed control

Several weed species were identified, but only lambsquarters (*Chenopodium album*) and volunteer cotton (*Gossypium hirsutum*) occurred in sufficient numbers across treatments for both drip and furrow fields to apply statistical analysis. Grasses were lumped into a single grouping, though most grasses were likely *Echinochloa* (jungle rice and related species). Other species present in lower numbers included sunflower (*Helianthus annus*), pigweed (*Amaranthus* spp.), purslane (*Portulaca oleracea*), puncture vine (*Tribulus terrestris*), and sow thistle (*Sonchus oleraceus*).

For grass cover and density, no differences in treatments were observed for the drip-irrigated plots. No differences among treatments were observed at nine WAT for furrow-irrigated plots. For furrow-irrigated plots at 6 WAT, grass cover in Dual Magnum (either application timing), Curbit (either timing), the control, and a single application of Prefar or Sandea was lower than for the mulch treatment. For grass density in furrow-irrigated plots, a single application of Prefar, Dual Magnum (either application timing), and the control was lower than a split application of Sandea, Zeus (either application timing), and the mulch treatment. A single application of Curbit also had lower grass density than Zeus (either application timing) or the mulch treatment. Similarly a split application of Prefar, a split application of Curbit, and single application of Sandea had lower grass density than either a single application of Zeus or the mulch treatment.

For lambsquarters cover in the drip-irrigated field, the control was lower than the mulch treatment at nine but not six WAT. Lambsquarters cover in the furrow irrigated field was lower for either application timing of Sandea, and the control than for the split application of Curbit or the split application of Prefar at six WAT, while at nine WAT, the single application of Sandea was lower than either application timing of Dual Magnum. Lambsquarters density in the drip-irrigated field was lower for the split application of Sandea and the control than the mulch treatment at six but not nine WAT. Lambsquarters density in the furrow-irrigated field was lower for either application timing of the Sandea or the control than for the split application of Zeus or control treatment at six WAT. At nine WAT, lambsquarters density in the furrow-irrigated field was lower for the single application of Sandea than for the split application of either Zeus or Curbit, and was lower for the control that the split application of Curbit.

No differences in volunteer cotton cover or density were observed among the treatments for drip- or furrow-irrigated fields. No differences were observed for other species' cover in drip irrigated plots, but cover was lower for a single application of Curbit or Prefar, and either application timing of Dual Magnum or Sandea, and the control than the single application of Zeus or the mulch treatment at six but not nine WAT in furrow-irrigated plots. Similarly, no differences were observed for other species' density in drip-irrigated plots, and the same was true for density in furrow-irrigated plots.

Total weed cover in drip-irrigated plots was lower for the control than the mulch treatment at six WAT, while the control was lower than the mulch, single application of Curbit, and either application timing of Zeus at nine WAT. At six WAT, total weed cover in furrow-irrigated plots was lower for a single application of Sandea or the control than for than for a single application of Prefar, either application timing of Zeus, or the mulch treatment, with a single application of Dual Magnum or Curbit or a split application of Sandea being lower than either application timing of Zeus or the mulch treatment, and a split application of Dual Magnum or Prefar being lower than the mulch treatment. No differences were observed among treatments for total weed cover in furrow irrigated plots at nine WAT. No differences were observed for total weed density in drip irrigated plots. At six WAT, total weed density in furrow irrigated plots was lower for the control, either application timing of Dual Magnum or Prefar, a single application of Sandea or a split application of Curbit than for either application timing of Zeus or the mulch treatment. No differences were observed among treatments for total weed density in drip irrigated plots at nine WAT.

Time to weed

Plots were hand weeded before harvest, and time to weed per plot was recorded. For drip-irrigated plots, time to weed was 22.5 to 53.8 minutes per plot (Table 5). Control plots had lower weeding times than a single Zeus application or the mulch treatment. For furrow-irrigated plots, time to weed was 22.5 to 80 minutes per plot. A single application of Dual Magnum had lower weeding times than Zeus (either application timing), a split application of Sandea, and the mulch treatment. The control and single application of Prefar had lower weeding times than the mulch and split application of Zeus. The split application of Dual Magnum and the single application of Sandea had lower weeding times than the split application of Zeus.

Melon injury

For drip-irrigated plots, melon injury (eight WAT) was lower for a split application of Dual Magnum or Zeus or either application timing of Prefar than for a single application of Dual Mangum or a split application of Sandea. Leaves per plant was highest for the control, and no treatment differences were observed for the width of the widest leaf. Either application timing of Curbit, Sandea, or Prefar, or the control had a longer vine length than either application timing of Dual Magnum or Zeus or the mulch treatment. A split application of Curbit, either application timing of Sandea, the control, or a single application of Prefar had more flowers per plant at eight WAT than a split application of Zeus or the mulch treatment. No treatment differences were observed among the drip irrigated plots for number of fruits per plant at eight WAT.

For furrow irrigated plots, melon injury was lowest for either application timing of Zeus or Prefar, the control, a single application of Curbit, the mulch treatment, or a split application of Dual Magnum. The control, a single application of Prefar or Dual Magnum, a split application of Sandea, or either application timing of Curbit has more leaves per plant than either application timing of Zeus or the mulch treatment. The control and single application timing of Curbit or Dual Magnum had wider leaves than the split application of Zeus. The control and a single application of Prefar or Curbit had longer vines than the mulch treatment, a single application of Sandea, or either application timing of Zeus. At eight WAT, Curbit had more flowers per plant than a single application of Sandea, the mulch treatment, or either application timing of Zeus. A single application timing of Prefar had more fruits per plant than all other treatments except a single application of Curbit and the control.

Melon yield

For drip-irrigated plots, a split application of Dual Magnum had a greater number of marketable melons per plot than the Control or a split application of Curbit, , and a single application of Dual Magnum had a greater number of marketable melons per plot than a split application of Curbit. No differences in the number of non-marketable melons per plot or the total harvest weight per plot were observed among treatments for drip-irrigated plots. No differences in the number of marketable or non-marketable melons per plot or the total harvest weight per plot were observed among treatments for furrow-irrigated plots.

Sudangrass injury

No differences in Normalized Vegetation Difference Index (NDVI, a measure of plant health) were detected among treatments for drip irrigated plots, but differences were detected for furrow-irrigated plots for the two latest sampling dates. At nineteen WAT (post plant pre emergence herbicide treatments applied to melons, Sudangrass planted immediately following melon harvest), an application of Dual Magnum at either timing or the control had a higher (more healthy) NDVI than the much treatment or single application of Zeus. At 21 WAT, the control and single application of Sandea had a higher NDVI than the mulch treatment or single application of Zeus. No visual differences in injury were detected among treatments for either the drip or furrow irrigated plots.

Sudangrass yield

No differences in Sudangrass height, moisture content, or fresh weight were observed among treatments for drip irrigated plots. For furrow irrigated plots, Sudangrass height was greater for a single application of Prefar than for a single application of Zeus. Moisture content was higher for a split application of Prefar than a split application of Curbit. Fresh harvest weight was greater for a single application of Dual Magnum, Prefar, or Sandea than for Zeus at either application timing of the mulch treatment.

Figure 1: Plot layout for both drip- and furrow-irrigated fields. (Not to scale.)

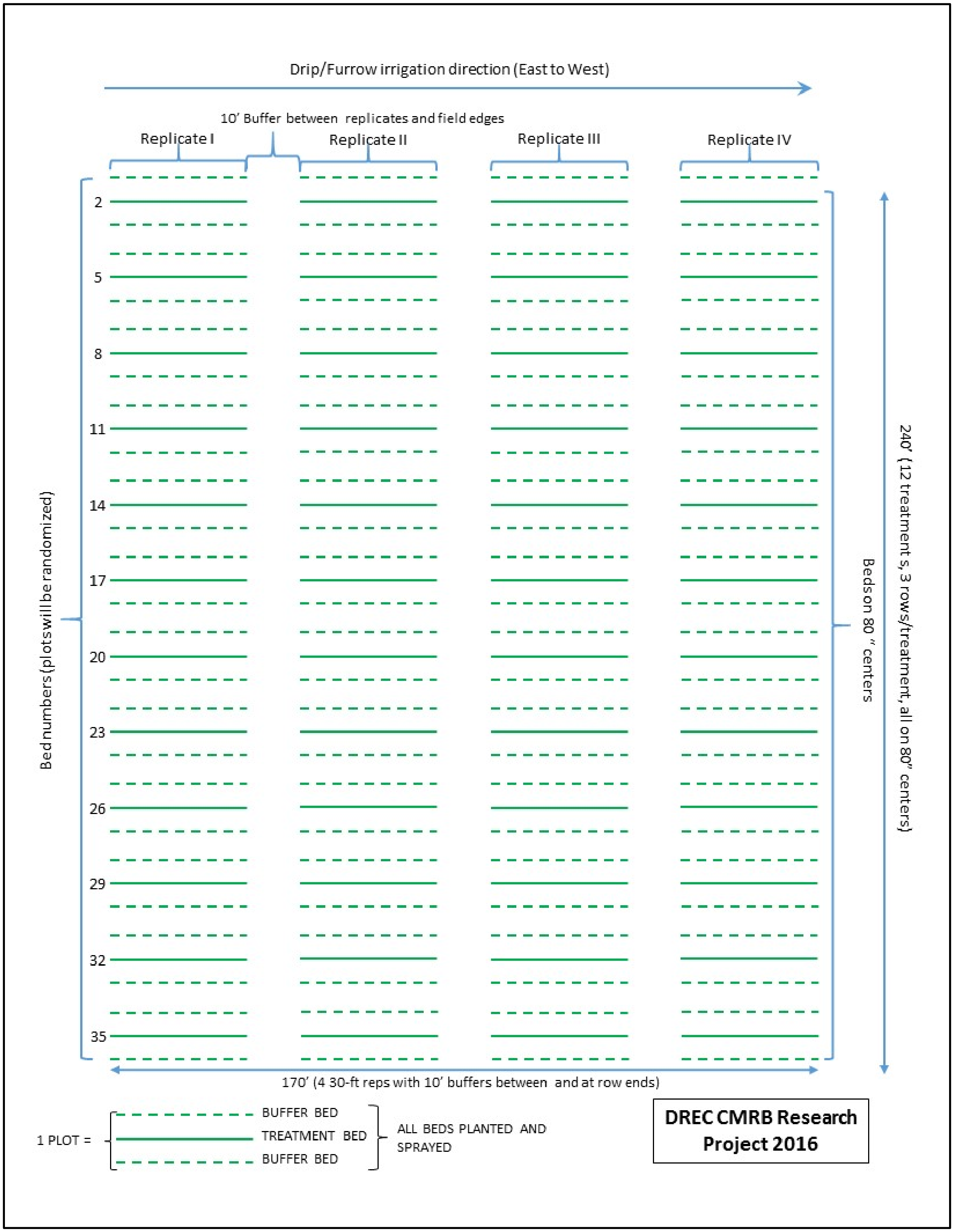

Table 1: Herbicides and rates (oz or fl oz/ac product) used in the experiment.

Treatment	Herbicide	Initial Rate[1]	Rate 3 WAT[1,2]
Curbit Single[3]	ethalfluralin	64	0
Curbit Split[3]	ethalfluralin	32	32
Dual Magnum Single	metachlor	21.33	0
Dual Magnum Split	metachlor	13.67	13.67
Prefar Single	bensulide	160	0
Prefar Split	bensulide	80	80
Sandea Single	halosulfuron	0.75	0
Sandea Split	halosulfuron	0.375	0.375
Zeus Single	sulfentrazone	3.2	0
Zeus Split	sulfentrazone	1.6	1.6
Mulch	NA	NA	NA
Control	NA	NA	NA

[1]Rates are in ounces of product per acre. This is by weight for Sandea and by volume for all other herbicides.

[2]"WAT" = Weeks after initial treatment.

[3]"Single" refers to a single herbicide application at the full label rate. "Split" refers to a split herbicide application, with the half the label rate applied twice in an attempt to extend weed control. Total amount of herbicide applied was the same for both single and split treatments.

Figure 1: Treatments were applied to both furrow and subsurface drip irrigated fields.

Figure 2: Plastic mulch treatments. Each treatment plot consisted of three beds, with measurements being taken on the center bed and the two outer beds serving as guard rows.

Figure 3: Field measurements of melon crop injury and plant morphology.

Figure 4: Total melon weight per plot was measured and melons were determined to be marketable or non-marketable.

Table 2A: Cover (%) of weed species six and nine weeks after initial herbicide treatment for drip-irrigated plots.

Treatment	Grass (%)		Lambs-quarters (%)		Cotton (%)		Other Species (%)		Total Cover (%)	
	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT
Curbit Single	7.8 a*	21.3 a	7.8 a	16.3 ab	5.8 a	8.8 a	30.0 a	37.5 a	51.3 ab	83.8 a
Curbit Split	17.0 a	37.5 a	5.0 a	2.5 ab	1.3 a	12.5 a	3.0 a	7.5 a	26.3 ab	60.0 ab
Dual Magnum Single	26.3 a	23.8 a	7.8 a	23.8 ab	2.0 a	6.3 a	8.8 a	3.8 a	45.3 ab	57.5 ab
Dual Magnum Split	0.0 a	0.0 a	6.5 a	7.5 ab	4.5 a	15.0 a	20.5 a	22.5 a	31.5 ab	45.0 ab
Prefar Single	13.5 a	20.0 a	9.0 a	13.5 ab	7.8 a	5.0 a	2.5 a	1.3 a	32.8 ab	39.8 ab
Prefar Split	2.8 a	18.8 a	12.0 a	30.0 ab	6.0 a	15.0 a	13.3 a	8.8 a	34.0 ab	72.5 ab
Sandea Single	17.8 a	40.0 a	7.3 a	3.8 ab	6.3 a	10.0 a	1.3 a	8.8 a	32.5 ab	62.5 ab
Sandea Split	2.8 a	26.3 a	0.25 a	5.0 ab	2.8 a	5.0 a	3.3 a	1.3 a	9.0 ab	37.5 ab
Zeus Single	26.3 a	55.5 a	6.8 a	17.5 ab	4.3 a	13.8 a	17.8 a	0.0 a	57.5 ab	86.3 a
Zeus Split	10.0 a	40.0 a	7.0 a	15.0 ab	4.5 a	11.3 a	17.3 a	16.3 a	38.8 ab	82.5 a
Mulch	26.3 a	38.8 a	16.3 a	33.8 a	3.8 a	1.3 a	35.0 a	7.5 a	81.3 a	81.3 a
Control	2.3 a	15.0 a	0.0 a	0.0 b	2.0 a	0.0 a	1.3 a	2.5 a	3.3 b	17.5 b

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 2B: Cover (%) of weed species six and nine weeks after initial herbicide treatment for furrow-irrigated plots.

Treatment	Grass (%)		Lambs-quarters (%)		Cotton (%)		Other Species (%)		Total Cover (%)	
	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT
Curbit Single	4.0 b*	0.0 a	7.5 ab	30.0 ab	0.8 a	0.0 a	2.8 c	31.3 a	15.0 de	31.3 a
Curbit Split	3.5 b	1.3 a	5.5 ab	41.3 a	1.8 a	2.5 a	8.3 abc	25.0 a	19.0 cde	27.5 a
Dual Magnum Single	0.0 b	0.0 a	7.0 ab	42.5 a	0.0 a	3.8 a	0.8 c	6.3 a	7.8 de	10.0 a
Dual Magnum Split	0.8 b	0.0 a	22.0 ab	40.8 a	0.8 a	7.8 a	3.0 c	8.7 a	26.5 bcde	16.0 a
Prefar Single	2.0 b	0.0 a	11.5 ab	12.5 ab	2.3 a	3.8 a	1.0 c	40.0 a	16.8 cde	43.8 a
Prefar Split	6.8 ab	5.0 a	32.0 a	28.8 ab	0.0 a	10.0 a	5.0 bc	33.8 a	43.8 bcd	43.8 a
Sandea Single	2.5 b	0.0a	0.0 b	0.0 b	0.0 a	0.3 a	0.0 c	30.5 a	2.5 e	31.6 a
Sandea Split	5.0 ab	12.5 a	1.5 b	27.5 ab	0.8 a	0.0 a	0.5 c	47.5 a	7.8 de	47.5 a
Zeus Single	17.5 ab	25.0 a	9.5 ab	21.3 ab	0.3 a	0.0 a	35.3 ab	51.3 a	62.5 ab	51.3 a
Zeus Split	17.0 ab	37.5 a	15.3 ab	15.0 ab	0.3 a	20.0 a	25.0 abc	22.5 a	57.5 abc	42.5 a
Mulch	22.5 a	12.5 a	25.0 ab	27.5 ab	2.5 a	6.3 a	37.5 a	47.5 a	87.5 a	53.8 a
Control	1.8 b	2.5 a	0.0 b	3.8 ab	0.0 a	0.0 a	0.0 c	3.8 a	1.8 e	3.8 a

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 3A: Density (# per plot) of weed species six and nine weeks after initial herbicide treatment for drip-irrigated plots.

Treatment	Grass (#)		Lambs-quarters (#)		Cotton (#)		Other Species (#)		Total Cover (#)	
	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT
Curbit Single	13.8 a*	6.3 a	2.5 ab	3.5 a	3.0 a	1.8 a	6.0 a	3.5 a	25.3 a	15.0 a
Curbit Split	21.8 a	10.0 a	3.3 ab	1.0 a	1.5 a	1.3 a	0.3 a	1.5 a	26.8 a	13.8 a
Dual Magnum Single	5.5 a	8.8 a	6.8 ab	17.0 a	1.0 a	0.5 a	3.5 a	0.3 a	16.8 a	14.5 a
Dual Magnum Split	0.0 a	0.0 a	3.3 ab	1.0 a	4.0 a	3.0 a	6.0 a	1.5 a	13.3 a	5.5 a
Prefar Single	16.0 a	5.5 a	4.3 ab	5.0 a	5.8 a	1.0 a	1.8 a	0.3 a	27.8 a	11.8 a
Prefar Split	2.5 a	2.3 a	5.8 ab	4.8 a	4.3 a	2.0 a	2.0 a	1.0 a	14.5 a	10.0 a
Sandea Single	59.3 a	7.5 a	5.8 ab	0.8 a	7.8 a	1.0 a	0.8 a	1.3 a	73.5 a	16.3 a
Sandea Split	38.3 a	6.3 a	0.3 b	1.8 a	2.8 a	2.0 a	0.5 a	1.3 a	41.8 a	10.3 a
Zeus Single	39.8 a	13.3 a	7.0 ab	2.8 a	3.3 a	1.5 a	6.5 a	0.0 a	56.5 a	17.3 a
Zeus Split	10.5 a	8.5 a	4.5 ab	3.0 a	3.8 a	3.0 a	2.5 a	3.0 a	21.3 a	17.5 a
Mulch	45.3 a	9.8 a	10.5 a	7.3 a	2.8 a	0.5 a	7.5 a	1.3 a	66.0 a	16.5 a
Control	0.8 a	2.3 a	0.0 b	0.0 a	0.5 a	0.0 a	0.3 a	0.3 a	1.5 a	2.0 a

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 3B: Density (# per plot) of weed species six and nine weeks after initial herbicide treatment for furrow-irrigated plots.

Treatment	Grass (#)		Lambs-quarters (#)		Cotton (#)		Other Species (#)		Total Cover (#)	
	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT	6 WAT	9 WAT
Curbit Single	3.5 cd*	0.0 a	4.3 ab	4.0 abc	0.3 a	0.0 a	12.3 a	8.5 a	20.3 bc	8.5 a
Curbit Split	5.3 bcd	0.5 a	6.3 ab	11.3 a	0.8 a	0.5 a	2.3 a	5.8 a	14.5 c	6.3 a
Dual Magnum Single	0.0 d	0.0 a	5.5 ab	9.0 abc	0.0 a	1.0 a	0.3 a	2.3 a	5.8 c	3.3 a
Dual Magnum Split	0.3 d	0.0 a	10.8 ab	10.3 ab	0.3 a	0.2 a	1.5 a	3.3 a	12.8 c	4.3 a
Prefar Single	2.0 d	0.0 a	3.8 ab	5.5 abc	1.0 a	0.8 a	1.8 a	7.5 a	8.5 c	8.3 a
Prefar Split	3.8 bcd	1.0 a	8.0 ab	7.5 abc	0.0 a	2.0 a	1.8 a	4.5 a	13.5 c	6.5 a
Sandea Single	6.8 bcd	0.0 a	0.0 b	0.0 c	0.0 a	0.1 a	0.0 a	7.5 a	6.8 c	7.9 a
Sandea Split	24.0 abc	3.0 a	3.8 b	4.0 abc	0.3 a	0.0 a	0.3 a	6.8 a	28.3 abc	6.8 a
Zeus Single	39.8 a	7.5 a	9.0 ab	7.3 abc	0.3 a	0.0 a	6.8 a	10.5 a	55.8 a	10.5 a
Zeus Split	24.3 ab	7.5 a	12.8 a	3.0 abc	0.3 a	4.3 a	13.5 a	5.0 a	50.8 ab	9.3 a
Mulch	28.8 a	2.0 a	12.3 a	7.8 abc	0.5 a	1.3 a	7.0 a	12.0 a	48.5 ab	13.3 a
Control	1.3 d	1.0 a	0.0 b	1.5 bc	0.0 a	0.0 a	0.0 a	5.5 a	1.3 c	5.5 a

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 4A: Melon health eight weeks after initial herbicide treatment for drip-irrigated plots.

Treatment	Injury (0-10 scale)[1]	Leaves per plant	Width widest leaf	Length longest vine	Flowers per plant	Fruits per plant
Curbit Single	1.0 bcd*	34.3 bcd	4.9 a	20.3 abcd	3.5 bcd	16.2 a
Curbit Split	1.0 bcd	47.8 ab	5.1 a	32.5 a	14.3 a	1.8 a
Dual Magnum Single	2.3 ab	25.2 cde	4.7 a	17.8 bcd	6.0bcd	6.2 a
Dual Magnum Split	0.0 d	33.9 bcd	4.8 a	16.9 cd	5.2 bcd	12.6 a
Prefar Single	0.0 d	38.3 bc	4.9 a	23.8 abc	8.0 abcd	8.0 a
Prefar Split	0.0 d	37.3 bc	5.1 a	20.4 abcd	4.3 bcd	17.2 a
Sandea Single	2.0 abc	31.9 bcd	5.0 a	26.8 abc	9.3 abc	0.3 a
Sandea Split	3.3 a	35.6 bcd	4.8 a	21.9 abcd	10.6 ab	8.7 a
Zeus Single	2.0 abc	16.4 de	4.3 a	15.6 cd	3.0 bcd	7.8 a
Zeus Split	0.0 d	20.4 cde	4.3 a	9.2 d	0.3 d	17.4 a
Mulch	0.5 cd	11.3 e	4.4 a	9.8 d	2.2 cd	9.2 a
Control	0.75 bcd	63.7 a	5.1 a	30.3 ab	10.4 ab	10.3 a

[1]Injury scale of 0 to 10, where 0 is no injury and 10 is dead.

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 4B: Melon health eight weeks after initial herbicide treatment for furrow-irrigated plots.

Treatment	Injury (0-10 scale)[1]	Leaves per plant	Width widest leaf	Length longest vine	Flowers per plant	Fruits per plant
Curbit Single	0.0 d*	46.3 abc	5.0 a	38.8 a	26.6 a	2.3 ab
Curbit Split	0.5 c	44.8 abc	4.8 ab	34.4 ab	20.8 abcd	1.1 bc
Dual Magnum Single	1.8 b	42.5 abc	5.0 a	31.0 abc	22.3 abc	1.2 bc
Dual Magnum Split	0.0 d	28.5 cd	4.9 ab	30.0 abc	13.3 bcde	0.4 bc
Prefar Single	0.0 d	50.6 ab	4.9 ab	39.7 a	24.7 ab	3.3 a
Prefar Split	0.0 d	33.8 bcd	4.7 ab	31.8 abc	14.5 abcde	1.2 bc
Sandea Single	4.0 a	36.3 bcd	4.5 ab	24.0 c	11.8 cde	0.3 c
Sandea Split	4.0 a	46.5 abc	4.8 ab	34.5 ab	21.3 abc	0.8 bc
Zeus Single	0.0 d	20.8 d	4.3 ab	22.2 c	8.0 e	0.3 bc
Zeus Split	0.0 d	20.8 d	4.2 b	26.0 bc	8.8de	0.1 c
Mulch	0.0 d	19.8 d	4.3 ab	27.4 bc	9.0 de	0.3 c
Control	0.0 d	59.4 a	5.1 a	40.2 a	23.4 abc	1.5 abc

[1]Injury scale of 0 to 10, where 0 is no injury and 10 is dead.

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different (P ≤ 0.05).

Table 5: Total labor (minutes) per plot to hand how weeds at 10 weeks after initial herbicide treatments were applied.

Treatment	Minutes to weed	
	Drip	**Furrow**
Curbit Single	31.3 ab*	42.5 abcd
Curbit Split	42.5 ab	48.8 abcd
Dual Magnum Single	41.3 ab	22.5 d
Dual Magnum Split	33.8 ab	33.8 bcd
Prefar Single	40.0 ab	31.3 cd
Prefar Split	30.0 ab	40.0 abcd
Sandea Single	46.3 ab	38.8 bcd
Sandea Split	47.5 ab	70.0 abc
Zeus Single	53.8 a	63.8 abc
Zeus Split	40.0 ab	80.0 a
Mulch	50.0 a	73.8 ab
Control	22.5 b	30.0 cd

*Tukey's Honest Significant Difference (HSD) used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 6: Mean number of marketable and non-marketable fruit harvested per plot and mean total harvest weight per plot. Drip-irrigated plots harvested on 7/13/16 and 7/18/16. Furrow-irrigated plots harvested on 7/12/16 and 7/19/16.

Treatment	Drip			Furrow		
	Marketable (#/plot)	Non-marketable (#/plot)	Total weight (kg)	Marketable (#/plot)	Non-marketable (#/plot)	Total weight (kg)
Curbit Single	5.0 abc*	4.3 a	6.1 a	6.0 a	5.3 a	9.9 a
Curbit Split	2.3 c	1.3 a	2.6 a	6.5 a	4.8 a	8.7 a
Dual Magnum Single	8.3 ab	3.3 a	7.6 a	6.3 a	9.0 a	14.3 a
Dual Magnum Split	8.8 a	2.0 a	8.3 a	8.5 a	8.3 a	14.5 a
Prefar Single	5.3 abc	2.3 a	4.8 a	13.3 a	5.0 a	14.3 a
Prefar Split	4.0 abc	2.5 a	4.5 a	7.0 a	6.5 a	9.9 a
Sandea Single	3.3 abc	1.3 a	3.2 a	18.5 a	5.3 a	19.4 a
Sandea Split	6.8 abc	0.5 a	5.3 a	8.8 a	7.0 a	10.8 a
Zeus Single	7.5 abc	1.0 a	5.2 a	8.5 a	5.5 a	9.0 a
Zeus Split	4.5 abc	3.0 a	5.5 a	7.8 a	9.5 a	9.1 a
Mulch	6.0 abc	4.3 a	5.8 a	4.5 a	6.8 a	6.1 a
Control	3.0 bc	1.0 a	3.3 a	7.8 a	4.5 a	7.7 a

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 7: Sudan Normalized Vegetation Difference Index (NDVI) for drip- and furrow-irrigated plots. Sudan grass was planted on 7/25/2016.

Treatment	Drip			Furrow		
	8/06/2016 (NDVI)[1]	8/20/2016 (NDVI)	9/17/2016 (NDVI)	8/06/2016 (NDVI)[1]	8/26/2016 (NDVI)	9/17/2016 (NDVI)
Curbit Single	0.41 a*	0.81 a	0.71 a	0.31 a	0.72 ab	0.67 ab
Curbit Split	0.42 a	0.79 a	0.62 a	0.35 a	0.71 ab	0.65 ab
Dual Magnum Single	0.44 a	0.81 a	0.64 a	0.39 a	0.77 a	0.68 ab
Dual Magnum Split	0.37 a	0.81 a	0.68 a	0.32 a	0.76 a	0.66 ab
Prefar Single	0.43 a	0.79 a	0.69 a	0.32 a	0.72 ab	0.68 ab
Prefar Split	0.39 a	0.80 a	0.72 a	0.35 a	0.70 ab	0.62 ab
Sandea Single	0.41 a	0.76 a	0.68 a	0.30 a	0.75 ab	0.69 a
Sandea Split	0.37 a	0.79 a	0.65 a	0.32 a	0.69 ab	0.65 ab
Zeus Single	0.44 a	0.75 a	0.63 a	0.33 a	0.64 b	0.61 b
Zeus Split	0.42 a	0.79 a	0.71 a	0.32 a	0.68 ab	0.64 ab
Mulch	0.44 a	0.76 a	0.66 a	0.34 a	0.64 b	0.61 b
Control	0.41 a	0.79 a	0.64 a	0.33 a	0.71 ab	0.69 a

[1]NDVI is calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light.

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Table 8: Sudan injury, height, moisture (%, directly measured with via probe), and fresh weight (kg per plot) for drip- and furrow-irrigated plots. Sudan grass was planted on 7/25/2016 and harvested on 10/13/2016 to 10/14/2016

Treatment	Drip				Furrow			
	Injury (0-10)[1]	Height (in)	Moisture (%)	Fresh weight (kg)	Injury (0-10)[1]	Height (in)	Moisture (%)	Fresh weight (kg)
Curbit Single	1.0 a*	81.0 a	43.2 a	25.8 a	1.8 a	60.0 ab	42.5 ab	13.2 ab
Curbit Split	1.8 a	78.8 a	37.5 a	23.3 a	1.5 a	69.0 ab	35.8 b	13.8 ab
Dual Magnum Single	1.5 a	79.5 a	37.9 a	23.8 a	1.8 a	62.3 ab	42.5 ab	18.7 a
Dual Magnum Split	1.3 a	83.3 a	42.5 a	28.3 a	1.8 a	67.5 ab	42.2 ab	14.8 ab
Prefar Single	1.3 a	85.3 a	43.8 a	27.6 a	1.3 a	74.3 a	41.9 ab	22.0 a
Prefar Split	1.0 a	85.5 a	41.5 a	29.4 a	2.5 a	59.8 ab	46.0 a	12.4 ab
Sandea Single	1.5 a	80.8 a	38.9 a	22.3 a	1.3 a	68.0 ab	42.2 ab	18.0 a
Sandea Split	1.5 a	78.5 a	42.9 a	25.7 a	1.8 a	66.8 ab	41.5 ab	15.0 ab
Zeus Single	1.5 a	70.8 a	37.7 a	21.2 a	2.0 a	50.3 b	37.6 ab	7.8 b
Zeus Split	1.0 a	78.8 a	44.6 a	25.1 a	1.8 a	56.8 ab	44.3 ab	7.4 b
Mulch	1.8 a	77.3 a	36.3 a	23.5 a	1.8 a	66.3 ab	36.8 ab	14.5 b
Control	1.3 a	71.5 a	42.3 a	24.6 a	2.3 a	53.3 ab	40.5 ab	7.3 ab

[1]Injury scale of 0 to 10, where 0 is no injury and 10 is dead.

*Tukey's HSD used to calculate means separations. Values within a column with the same letters are not statistically different ($P \leq 0.05$).

Appendix A: Analysis of irrigation efficiency of drip and furrow-irrigated melons and Sudangrass

Melon Trial Using Drip Irrigation System

Soil temperature sensors (at 6-in depth) and tensiometers (at 6-, 12-, 18-, and 24-in depths) were installed in uncovered and covered with plastic mulch beds. Sensors recorded data every hour. This data was averaged for daily analysis (Table 1 and 2). Data was collected from June 3 to July 12, 2016.

Average daily soil temperature recorded at 6 in depth was about 2 ^{o}F higher in uncovered bed than bed covered with plastic mulch. Soil temperature fluctuations were lower in covered bed.

Soil water tension (SWT) sensors installed in uncovered bed ranged from 0.00 cb to 46.58 cb with median values close to 14 cb. Daily variations of SWT sensors in uncovered bed were very similar. In general, SWT data recorded in covered bed showed higher values and variability.

Table 1. Average daily soil temperature (ST) and soil water tension (SWT) values at different depths installed in uncovered bed.

Statistic	ST at 6 in (^{o}F)	SWT at 6 in (cb)	SWT at 12 in (cb)	SWT at 18 in (cb)	SWT at 24 in (cb)
Average	87.36	15.30	14.14	17.92	16.89
Median	87.23	14.96	12.98	14.52	14.56
Standard deviation	3.43	10.04	7.58	12.32	8.63
Coefficient of variation	0.04	0.66	0.54	0.69	0.51
Maximum	92.63	37.42	35.25	46.58	31.33
Minimum	81.88	0.00	0.00	0.00	5.67
Lower quartile	84.00	9.43	9.72	10.68	9.12
Upper quartile	90.66	20.15	17.44	23.47	24.61

Table 2. Average daily soil temperature (ST) and soil water tension (SWT) values at different depths installed in covered bed with plastic mulch.

Statistic	ST at 6 in (^{o}F)	SWT at 6 in (cb)	SWT at 12 in (cb)	SWT at 18 in (cb)	SWT at 24 in (cb)
Average	89.54	14.34	17.04	28.08	23.71

Statistic	ST at 6 in (ºF)	SWT at 6 in (cb)	SWT at 12 in (cb)	SWT at 18 in (cb)	SWT at 24 in (cb)
Median	89.63	12.88	15.52	18.63	18.06
Standard deviation	2.25	10.36	10.81	23.95	21.98
Coefficient of variation	0.03	0.72	0.63	0.85	0.93
Maximum	94.10	39.00	48.70	69.50	84.96
Minimum	85.58	0.00	0.04	0.00	0.00
Lower quartile	87.88	6.32	9.48	10.10	9.38
Upper quartile	91.18	19.34	22.93	47.17	28.60

Figures 1 and 2 show soil water tension (SWT) and irrigation data collected in this study. Recommended SWT values for melons range from 30 to 40 cb. SWT sensors installed at 6- and 12-in followed very well the irrigation patterns. SWT sensors at 18- and 24-in only followed the irrigation pattern for the largest irrigation (1.5 in). It appears that small and frequent irrigations (about 0.5 in) did not reach too quickly the deeper soil profile. In general, most of the time recorded SWT values were below the recommended threshold. This means that melons did not suffer for water stress for the recorded period.

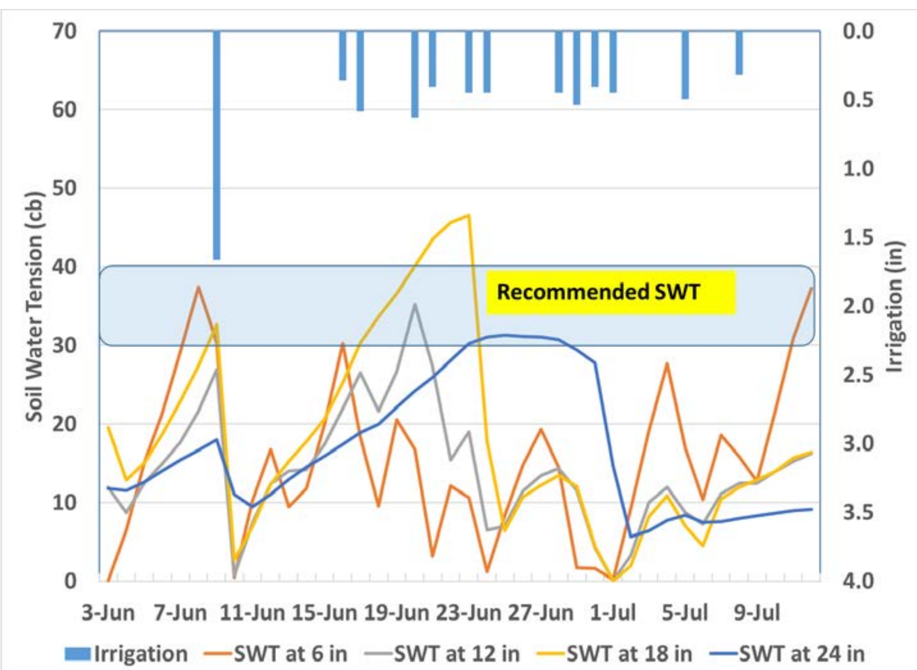

Figure 1. Average daily soil water tension SWT) data at different depths with drip irrigation system in uncovered bed. Total irrigation values displayed on the top.

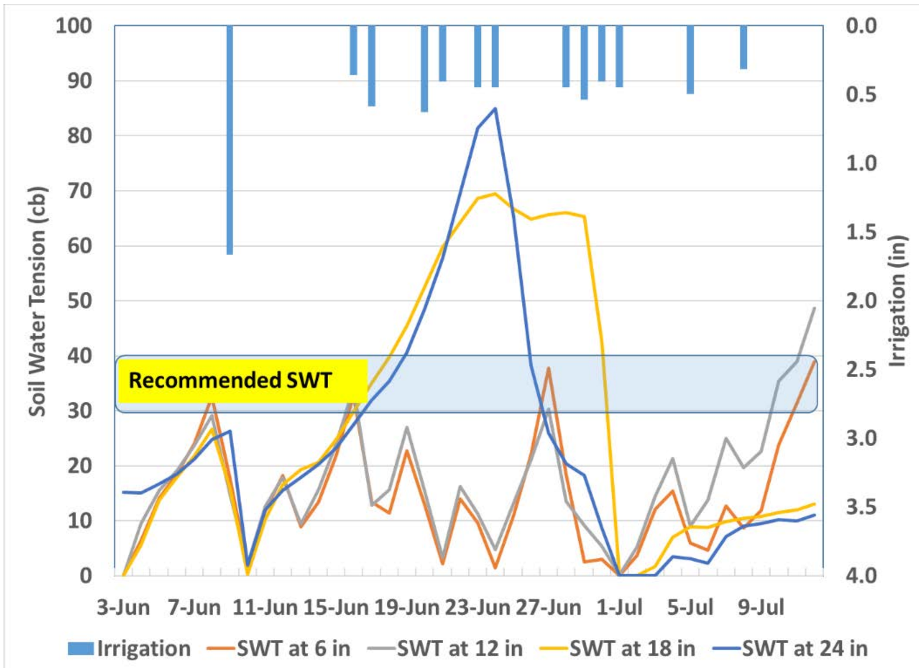

Figure 2. Average daily soil water tension (SWT) data at different depths with drip irrigation system covered with plastic mulch. Total irrigation values displayed on the top.

Total crop evapotranspiration (crop water needs from planting to last irrigation) was computed at 23.20 in using data from the California Irrigation Management Information System station based at the Desert Research an Extension Center (Meloland station) and crop coefficients (Kc) developed by the Food and Agriculture Organization (Kc values ranged from 0.59 to 0.95). Total drip irrigation measured was 16.87 in. We can see that drip irrigation supplied about 73% of melon water needs (16.87 in/23.20 in).

Melon Trial Using Furrow Irrigation System

Soil temperature sensors and tensiometers were installed following the same methods as in the drip irrigation trial. Tables 3 and 4 show average daily soil temperature (ST) and soil water tension (SWT) values at different depths. SWT sensors at 6- and 12-in installed in the uncovered bed had several malfunctions and data were disregarded. Soil temperature values and patterns were similar to those recorded in the drip irrigation trial. In general, SWT data from the furrow irrigation systems were lower than the trial using drip irrigation.

Table 3. Average daily soil temperature (ST) and soil water tension (SWT) values at different depths installed in uncovered bed.

Statistic	ST at 6 in (ºF)	SWT at 6 in (cb)	SWT at 12 in (cb)	SWT at 18 in (cb)	SWT at 24 in (cb)
Average	86.83	N/A	N/A	9.73	6.52
Median	88.67	N/A	N/A	10.56	7.31
Standard deviation	5.09	N/A	N/A	5.35	3.91
Coefficient of variation	0.06	N/A	N/A	0.55	0.60
Maximum	95.24	N/A	N/A	18.25	13.92
Minimum	78.67	N/A	N/A	0.00	0.00
Lower quartile	81.58	N/A	N/A	8.11	4.84
Upper quartile	90.60	N/A	N/A	12.31	9.48

Table 4. Average daily soil temperature (ST) and soil water tension (SWT) values at different depths installed in covered bed with plastic mulch.

Statistic	ST at 6 in (ºF)	SWT at 6 in (cb)	SWT at 12 in (cb)	SWT at 18 in (cb)	SWT at 24 in (cb)
Average	86.37	15.96	13.00	15.21	6.53
Median	86.83	16.15	12.58	14.68	7.56
Standard deviation	4.00	7.85	7.12	10.43	4.20
Coefficient of variation	0.05	0.49	0.55	0.69	0.64
Maximum	91.75	31.42	32.50	45.75	11.33
Minimum	80.13	0.00	0.00	0.00	0.00
Lower quartile	82.69	11.06	9.92	10.33	3.77
Upper quartile	90.31	21.57	15.36	20.28	10.42

From June 3 to July 12, 2016, five irrigations were scheduled ranging from 2.22 in to 9.76 in (Figures 3 and 4). These irrigations wetted well the soil profile until 24-in depth. From this data, we can infer that small amounts of water were lost via deep percolation (water below plant roots) as SWT data did not reach very low values (near zero) for long periods of time. We noticed that a considerable amount of water left the field via runoff. We could not quantify how much water was lost via runoff but our best guess is about 50% of water was lost. In general, most of the time recorded SWT values were below the recommended threshold. This means that melons did not suffer for water stress for the recorded period.

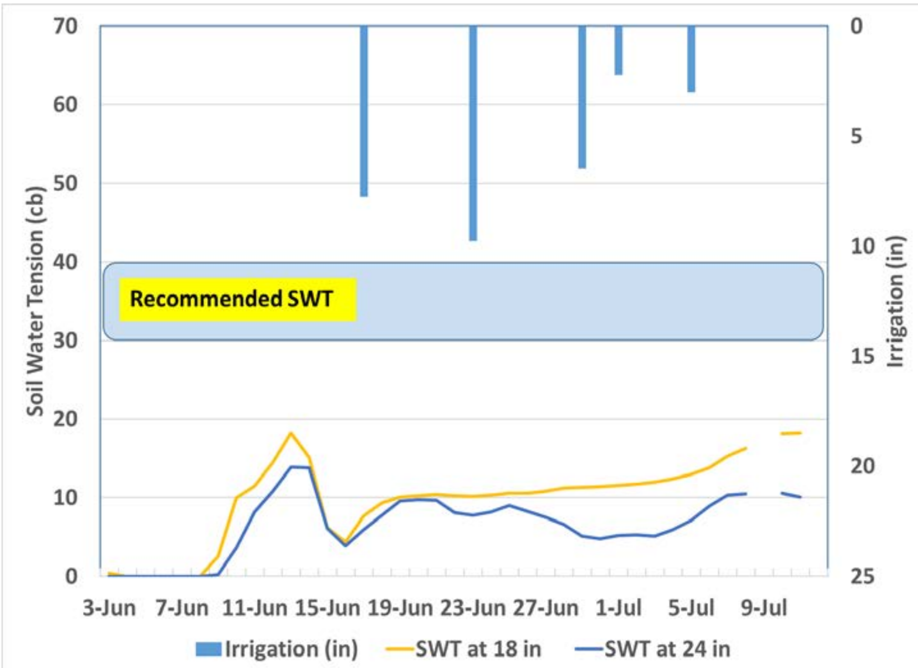

Figure 3. Average daily soil water tension SWT) data at different depths with furrow irrigation system in uncovered bed. Total irrigation values displayed on the top.

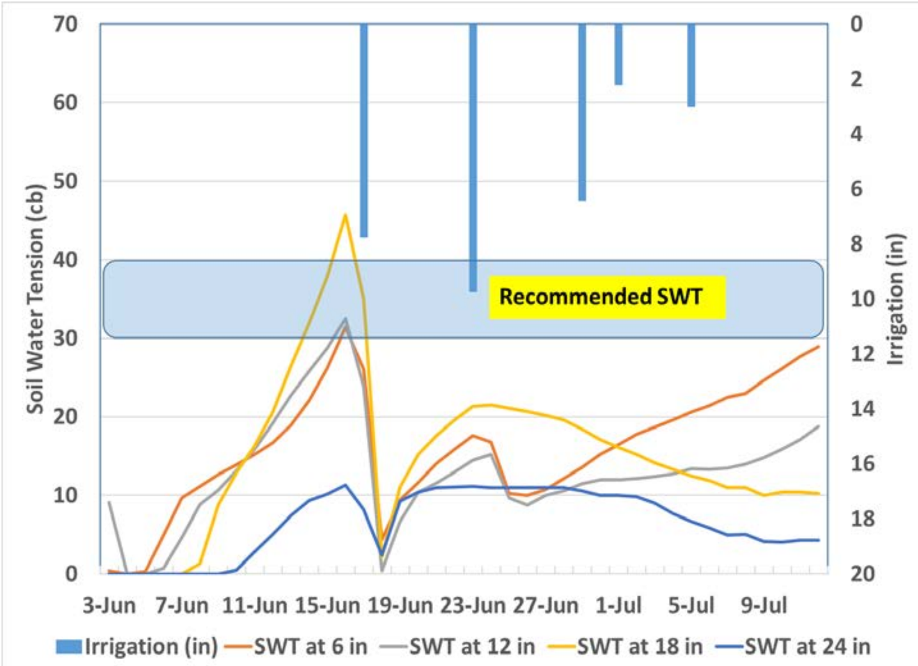

Figure 4. Average daily soil water tension (SWT) data at different depths with furrow irrigation system covered with plastic mulch. Total irrigation values displayed on the top.

Total furrow irrigation measured was 82.01 in. Assuming a 50% irrigation efficiency, total water available for melons was 41 in. Total crop evapotranspiration was 23.20 in. In this trial, melons had available 77% more of the water needed.

Effects of Irrigation Systems on Yield

Results of melon yield response to irrigation system are shown in table 5. This table show results of total yield (Kg) by total amount of water applied (ft) by treatment and irrigation system. Drip irrigation plots used 1.4 ft vs 6.8 ft in furrow irrigation trials. All treatments under drip irrigation had better water efficiency (yield per unit water) than furrow irrigated trials.

Table 5. Melon yield response to water by irrigation system.

Treatment #	Drip Irrigation (Kg/ft)	Furrow Irrigation (Kg/ft)
Curbit	61.8	18.5
Curbit (split)	41.1	19.0
Dual Magnum	68.0	20.3
Dual Magnum (split)	90.5	20.5
Prefar	49.3	24.5
Prefar (split)	54.1	20.6
Sandea	50.7	28.6
Sandea (split)	58.9	22.2
Zeus	48.7	16.2

Treatment #	Drip Irrigation (Kg/ft)	Furrow Irrigation (Kg/ft)
Zeus (split)	54.0	13.9
Control	48.1	12.9
Mulch	44.4	14.9
Average	55.8	19.3
minimum	41.1	12.9
Maximum	90.5	28.6