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Comment and Salinity Field Trial Report

Additional submitted attachment is included below.

I am submitting a salinity field trial report performed by Blake Sanden titled "Large-Scale Utilization of Saline Groundwater for Irrigation of Pistachios Interplanted with Cotton." The trial was initiated in order to expand on Louise Ferguson's earlier work in this area. This twenty-four page report is a public document; there is a peer reviewed paper authored by Blake Sanden based on this trial and report that are expected to be released by the International Society of Horticultural Science in the weeks to come. The Sanden report is followed by comments of my own:

Sanden, B., L. Ferguson, C. Kallsen, B. Marsh, B. Hutmacher. 2013. Large-scale utilization of saline groundwater for irrigation of pistachios interplanted with cotton. 2012 Production Research Reports, CA Pistachio Research Board, Fresno, CA. 24 pp. http://www.acpistachios.org/Industry/research/12-2012.pdf

Large-Scale Utilization of Saline Groundwater for Irrigation of Pistachios Interplanted with Cotton

2012 Progress Report for the California Pistachio Commission
December 31, 2012

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SUMMARY

A nine year field study on the salt tolerance of pistachios on the Westside of the San Joaquin Valley (Ferguson et. al., 2004 and Sanden, 2003), and previous pistachio studies in Iran (Fardooel, 2001) have shown the viability of using saline water with an electroconductivity (EC) up to 8 dS/m for irrigating these trees where the maximum rootzone soil salinity is less than 10 dS/m without a reduction in yield. A rootstock trial in sand tanks at the USDA Salinity Lab in Riverside (Ferguson et al., 2002) showed a significant increase in leaf burn when 10 ppm boron was added to irrigation water but no reduction in the biomass of year old trees. In contrast to these studies, Sepaskhah and Maftoun (1981) found that pistachio nut production under greenhouse conditions was reduced by 38% with a 7-day irrigation interval and 4.5 dS/m water, but when water was not limiting, shoot growth (which should be more sensitive than nut yield) was not reduced until soil salinity reached an EC of 12.5 dS/m.

The salinity and B tolerance of cotton has been reported at similar levels in tank trials (Ayars and Westcott, 1985) and investigated in long-term field trials (Ayars et al., 1993). But despite many small-scale field trials over the last 30 years almost no marginally saline water in the San Joaquin Valley is used for long-term production. Over this same period water costs have increased four to tenfold while acala cotton prices have actually declined to those seen in the early 1960’s. Farmers are looking for less expensive, more secure water supplies and more profitable crops. This project attempts to determine the economic and physiologic viability of establishing a large-scale pistachio orchard interplanted with cotton and irrigated with buried drip tape using marginally saline groundwater.

This most current large-scale trial began March 2004. Twelve 19.5 acre test plots were set up in a 310 acre field to test the use of saline water for commercial-scale cotton production and development of a new pistachio orchard using shallow sub-surface drip tape. The field was well reclaimed (salinity averaged 1.57 dS/m to 3 feet) and had good drainage. From 2004-2009 three different irrigation water salinities replicated four times were applied to these large plots using fresh (Aqueduct), blended (Blend) and saline Well water (average EC of 0.4, 3.2 and 5.1 dS/m and boron @ 0.3, 6 and 11 ppm, respectively). The highest salinity treatment is more than 4 times as saline as most irrigation waters currently used in the SJV. The field was planted to

solid pima cotton in 2004. In 2005, pistachio rootstocks (PG1 and UCB1) were planted in March, 17 feet apart on a 22 foot row spacing and interplanted with four 38 inch rows of pima cotton. Pistachios were budded with a Kerman scion in July. Every winter/early spring all treatments received 6 to 12 inches of fresh water for leaching/preirrigation and cotton germination, followed by 21 to 26 inches of treatment water, depending on seasonal demand. Pistachios received about 18 inches total based on a 9.5 foot wide area (7.8 inches for the 22 foot row spacing). Cotton was not inter-planted starting in 2007 as the grower stopped all his Westside cotton production due to a severe shortage of canal water. The water shortage continues and the trees now shade too much area for profitable cotton production.

The salinity of the well water has been slowly increasing up to 8 dS/m by 2008. So as of August 2007, it was necessary to use additional aqueduct water to return the Well and Blend treatment salinity to 3 and 5 dS/m, respectively. As the drought continued into 2009 with reduced supplies and Emergency Pool water costs as high as $400/ac-ft, the grower could no longer afford to apply aqueduct water to this field. The irrigation system was connected to another well ½ mile to the east with a steady EC of 3.3 dS/m. This water has now been used as the main irrigation supply for the block starting June 2009. In order to maintain the Aqueduct (0.5 dS/m) and Well (5.2 dS/m) treatments 3 miles of two inch mainline and 1 inch manifold lines were installed during the winter of 2009-10 to create 4-row by 20-tree replicated plots (0.687 acres each) that were centered on the two rows of trees that have been intensively monitored from the start of the project. Aqueduct water is supplied via a 0.5 mile length of 3 inch pipe from the turnout to the west of the field. The first pistachio harvest was 2011.

Results: For the first two years of cotton, plant tissue analysis showed a significant 0.5 to 3 fold increase in chloride and boron levels in both cotton and pistachio tissues, but produced no toxicity symptoms. Pima cotton lint yields were nearly 4 bale/acre in 2004, but crashed to about 2 bale/acre in 2005 due to very cool spring conditions that made for poor stand establishment. Yields and plant height were unaffected by salinity. Spring 2006 provided excellent conditions for cotton growth, but excessive salts accumulated in the top 4 inches of the Well treatment beds reduced cotton emergence by 14% (statistically insignificant). Cotton plant height under saline irrigation was significantly reduced early in the season, but this difference was insignificant by the end of July. Comparing aerial imagery and the Normalized Difference Vegetation Index (NDVI) for August 2004 and 2006 (the last year of cotton production) also showed no treatment impacts. But 2006 lint yield from the saline Well treatment was reduced by 275 lb/ac compared to the Aqueduct water. However, the Well treatment yield was still excellent at 3.12 bale/ac. At an average pima price of $1.08/lb, an economic analysis of cotton production and yields for the year prior to and first two years after planting pistachios shows a net return of $2,120 for Aqueduct water @ $120/ac-ft and $2,249 for Well water @ $45/ac-ft for this system.

One of the arguments against interplanting is the potential to reduce the early development of the orchard and, subsequently early yields. Even though this orchard is equipped with a separate irrigation system for the trees that allows continued irrigation after the cotton is cut off, rootstock circumference was barely 3 inches at the end of 2nd leaf. This carry over effect may have been the reason that there was insufficient fruit for a 6th leaf harvest.

Increase in pistachio rootstock diameter and general tree development was unaffected by salinity for both rootstocks for the first three years. PG1 rootstocks showed a significant 7% decrease at the end of 4th leaf while UCB was unaffected. From 10/22/08 to 12/6/12 average trunk circumference increased 1.5 to 2 inches per year for the Aqueduct irrigation, but as of the end of 2009 the trunk circumference for UCB showed a statistically significant 7% reduction for the Well treatment. As of 12/6/12, the end of 8th leaf, **trunk circumference** for both the 3.3 and 5.1 dS/m irrigation water is 7 to 9% less than the 0.5 dS/m irrigation. For the first time, Photoshop pixel estimates of the volume of green foliage down the row also show a significant reduction of 15.7 and 9.3% smaller canopy for the 3.2 and 5.2 dS/m irrigation, respectively, compared to the 0.5 dS/m irrigation water. An NDVI image from 8/14/12 showed a similar result with a statistically significant reduction in canopy cover of 13.0 and 11.7% for the 3.2 and 5.2 dS/m irrigation, respectively, compared to the 0.5 dS/m irrigation water.

Reduction in **pistachio nut yield** was not statistically significant for either the first, second year or combined 2011/2012 harvests due to saline irrigation water, but there was about a 300 to 700 lb/ac decline trend for the 3.2 and 5.2 dS/m treatments when comparing clean split or total inshell nut tonnage to the fresh water irrigation. Split nut % averaged 74% and was unaffected by treatment. The two year biennial yield ranged from 3,202 to 3,938 lb/ac inshell depending on rootstock and irrigation water salinity.

Salinity and sustainability: At the end of 2006, after three seasons of cotton irrigation this program applied about 6,600, 32,500 and 54,000 lb/ac (total) of salt in the Aqueduct, Blend and Well treatments, respectively. By the end of 2012, assuming that irrigation water and salts sub across a 9 foot wide rootzone with the double-line buried drip tape irrigation system, this total is up to 27,162, 159,441 and 227,601 lb/ac of salts deposited or passing through (due to leaching) the wetted rootzone for the same treatments. This equals a maximum increase in EC of 2.1, 12.5 and 17.8 dS/m if averaged over a 9 foot wide by 5 foot deep rootzone with no leaching or precipitation of salt. But salts from drip irrigation don't like to cooperate in this way. As of July 2011 the salinity in the top 0-15 inches is more than twice that of the lower depths for all treatments and is over the ECe tolerance limit of 8.4 dS/m established by Sanden and Ferguson (2004). This is caused by the fact that the 2 drip tapes are buried about 10 to 12 inches deep on either side of the tree; causing the salt to move to the middle of the tree row/crown in our sampling zone. This effect can also create excessive NO3 levels around the crown with certain soils and water quality. This concentration effect increases leaf burn during mid to late season forcing more water to be taken up deeper in the profile. In fact, average soil salinity to a depth of 5 feet between the hoses as of 7/21/12 was greater for the 3.2 dS/m irrigation treatment (soil ECe of 12.7 dS/m) than for the 5.2 dS/m treatment (soil ECe of 8.5 dS/m) due to the fact that a surface drip hose with high flow emitters is centered on the Well Treatment tree rows to supply the additional saline water required to reach the average 5.2 dS/m EC irrigation salinity. This arrangement, coupled with additional osmotic stress in this high EC treatment which potentially reduces tree ET, results in a much greater leaching fraction for this treatment. **But the bottom line is without 6 to 10 inches of effective rainfall or fresh water winter irrigation for efficient leaching at least every two years this system may not be sustainable.**

PROCEDURES

Counting on the salt tolerance of cotton and pistachios, a large-scale grower in the Belridge Water District of NW Kern County started pumping brackish groundwater for an experimental drip tape field in cotton in 2003; with the intent of interplanting pistachios in the following years. Pumping costs for this water are about $45/ac-ft compared to $120+/ac-ft for California Aqueduct water. The regional salinity of this groundwater varies from 3 to 15 dS/m with 8 to 18 ppm boron.

Starting in 2004, twelve 19.5 acre test plots were set up in a randomized complete block design in two adjacent 155 acre fields to test the use of saline water for commercial-scale cotton production and development of a new pistachio orchard using shallow sub-surface drip tape

(SDI). (See Figure 1) With each plot being nearly 20 acres in size, the 240 acres dedicated to this trial is possibly the largest replicated salinity irrigation test ever attempted in the SJV.

Treatments: Irrigation treatments consist of fresh (Aque), blended (Blend) and full strength saline well (Well) water (average EC of 0.5, 2.5 and 5 dS/m and boron @ 0.3, 6 and 11 ppm, respectively). The highest salinity treatment is more than 4 times as saline as almost all irrigation waters currently used in the SJV. Due to contamination of the aquifer by oil field leachate water, the average salinity of the Well water eventually increased to 7.5 dS/m by July 2007. At this time we began blending some Aqueduct water into the Well treatment and increased the amount of Aqueduct water in the Blend treatment to return to the salinity levels at the start of the trial; being 4.5 dS/m for the Well treatment and 2.5 dS/m for the Blend. EC over the last four years we reduced the salinity of the Well treatment (by blending with Aqueduct water) down to 4.5 dS/m starting July 2007. The SDI system allows the grower to meet the much higher cotton water demand while avoiding saturation of the young trees – thus maintaining critical cash flow during the early years of orchard development.

The field was planted to solid pima cotton in 2004. Pioneer Gold (PG1) rootstocks were planted in March 2005 to an 18 x 22 foot spacing inter-planted with four 38 inch rows of pima cotton. A set of 10 trees in the middle of each 19.5 acre plot, along with the adjacent cotton is used for intensive monitoring and sampling. A total of 23 UCB rootstocks were also planted adjacent to these monitoring areas. Pistachios were budded with a Kerman scion from August 12-19. All plots are irrigated with a total of 8 to 12 inches of fresh (Aqueduct) water (wetted area basis) during the winter and/or cotton germination, followed by 18 to 26 inches of treatment water, depending on seasonal demand. Pistachios receive about 18 inches based on a 9.5 foot wide area between the cotton (7.8 inches for the 22 foot row spacing). Four rows of Pima were again interplanted in 2006. A final fourth season of interplanted cotton for 2007 was canceled due to a 40% reduction of district water and the grower canceling his entire Westside cotton program. Pistachios only were grown for 2008.

Irrigation system: T-Tape TSX 708-12-220, 0.875 inch diameter drip tape with emitters every 12 inches was injected at 9 to 10 inches below field grade in January 2004. Designed for a final tree spacing of 22 feet, the tape was installed under 4 contiguous 38 inch rows followed by a 56 inch skip, 2 more 38 inch rows and a second 56 inch skip (see Figure 1). A separate underground manifold connected to the two hoses with the 56 inch spacing to either side was installed for irrigating pistachios and to allow for separate scheduling from the cotton. At this spacing the cotton receives 1.99 inches/day and the pistachios receive 0.57 inches/day from the two adjacent hoses.

Hose runs are 1280 feet long with the manifold connected at the high side of the field with the outlets connected to a common flush line. Each block has 16 separate pressure regulating subunit valves. Sixty hoses are served by a single cotton manifold tied to each subunit valve that also delivers water to 30 hoses connected to the manifold serving the interplanted pistachios. The grower's booster and filter station are designed can irrigate 8 to 16 subunits at a time (78 to 156 net acres); making for two to four, 24 hour set changes during irrigation. Flow from the well, however, is not sufficient to meet this demand when no additional canal water is blended for irrigation. Therefore, the "WELL" only treatment was irrigated in two sets to maintain pressure uniformity for the first two years after planting trees. Increased WELL water salinity required blending of Aqueduct water after that and this treatment was irrigated as one set. The system is operated @ 15 psi at the subunit regulators, yielding 0.27 gpm/100 feet of drip tape. All irrigations are scheduled for 24, 48 or 72 hour durations due to restrictions on canal water delivery. Randomized, replicated treatments are applied to 19.5-acre plots (2 adjacent subunit valves each, 440 feet wide by 1280 feet long). Valves have been color coded to indicate the appropriate treatment water and are operated by farm staff.

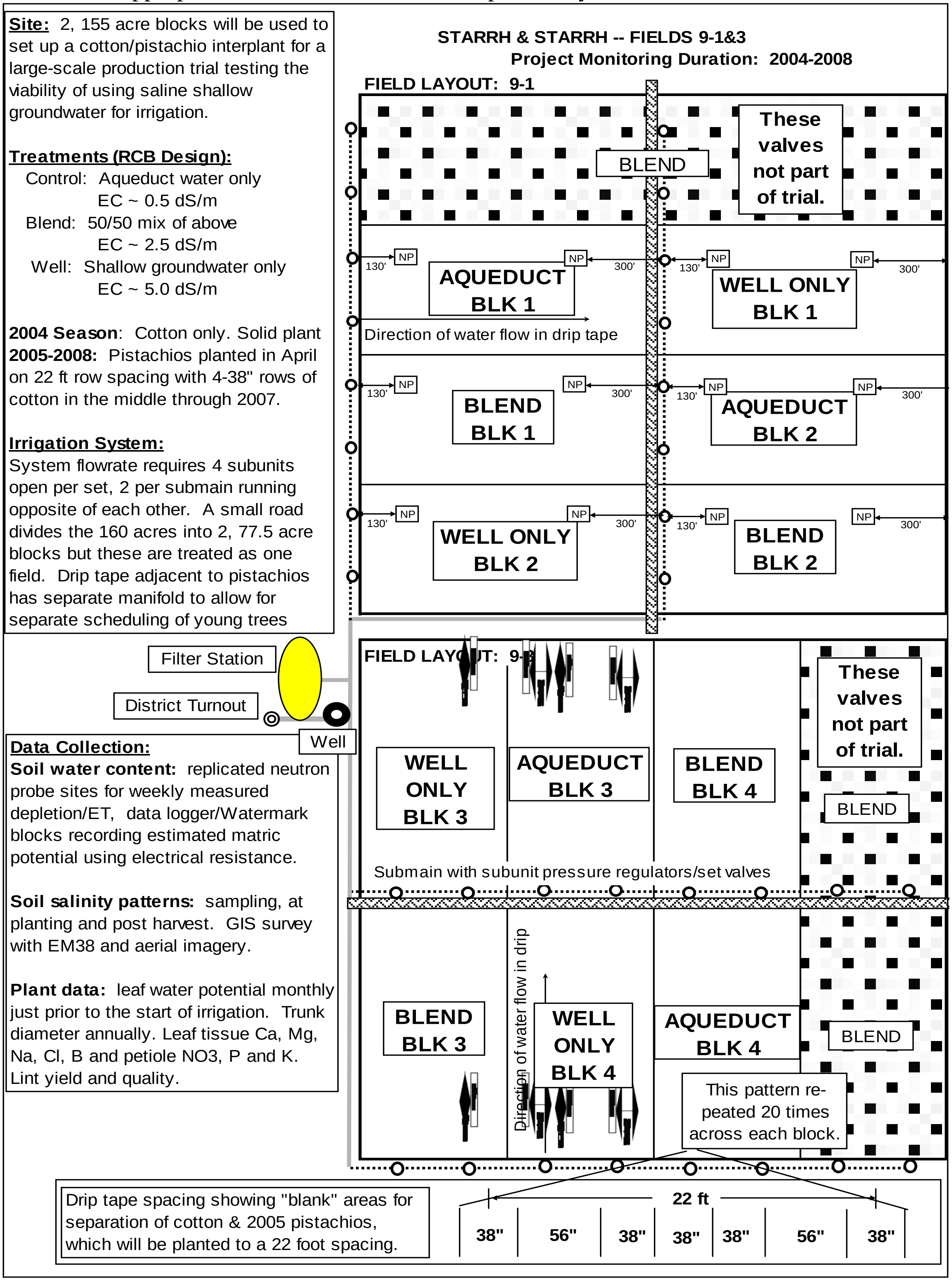


Fig.1. Experimental design and data collection.

The salinity of the WELL water continued increasing up to 8.2 dS/m by 2008 due to lateral flow of oilfield "produced water" leachate contamination in the groundwater. So as of August 2007, it was necessary to use additional aqueduct water to return the Well and Blend treatment salinity to 3 and 5 dS/m, respectively. As the drought continued into 2009 with reduced supplies and Emergency Pool water costs as high as $400/ac-ft, the grower could no longer afford to apply aqueduct water to this field. The irrigation system was connected to another well ½ mile to the east with a steady EC of 3.3 dS/m. This water has now been used as the main irrigation supply for the block starting June 2009. In order to maintain the Aqueduct (0.5 dS/m) and Well (5.2 dS/m) treatments 3 miles of two inch mainline and 1 inch manifold lines were installed during the winter of 2009-10 to create 4-row by 20-tree replicated plots (0.687 acres each) that were centered on the two rows of trees that have been intensively monitored from the start of the project (Figure 2).

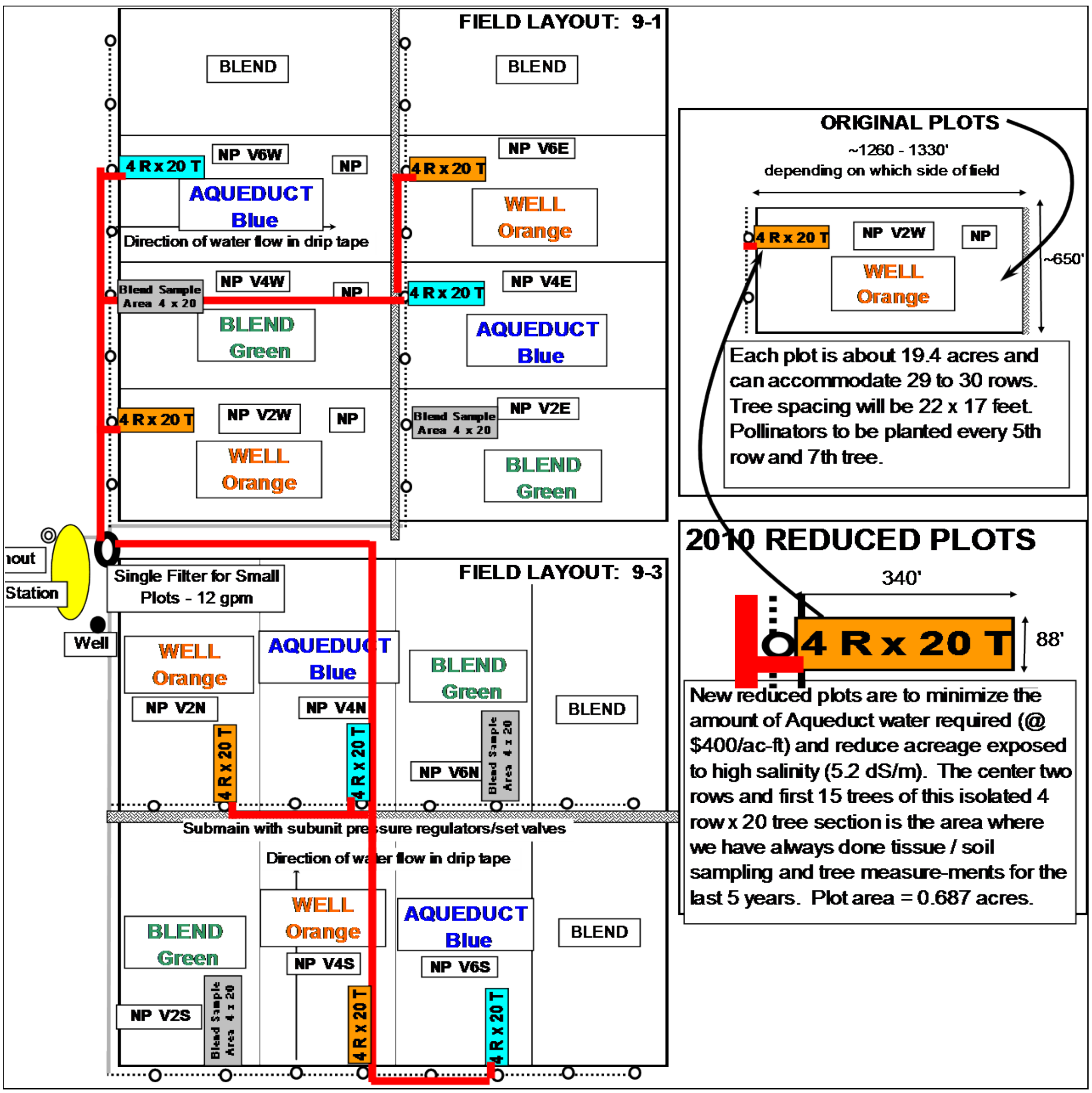


Fig.2. Additional mainlines installed in January 2010 and revised plot size.
Both the 0.5 dS/m and 5.2 dS/m irrigation treatments are delivered through the same two inch mainline with the manifold valves for one treatment being shut off while the other is irrigated. This results in a small amount of cross contamination (<3% of applied treatment water) when changing sets, but was the only practical way to maintain the low and high salinity treatments for this trial.

Monitoring and analyses: *Soil water content and applied water:* For the 2004 cotton season, neutron probe access tubes for weekly measured soil water content were installed in Blocks 1, 2 and 3 to a depth of 6 feet @150 feet from the head and 300 feet from the tail ends of the drip tape. In Block 1, 6 electrical resistance blocks (Watermarks®) are used to estimate matric potential at the 12, 24 and 48 inch depths adjacent to neutron probe access. A Hanson AM400 data logger records these readings every 8 hours. These loggers allow the grower a quick graphic check on moisture status trends over five weeks and help with optimal irrigation scheduling. Small flow meters were installed at the entrance to each replicated run of drip tape adjacent to neutron probe access tubes. For the 2005 season, a similar network of access tubes and resistance blocks was set up for the newly planted pistachios and reinstalled in the cotton after planting. “Tail” end monitoring of soil water was deemed unnecessary for the 2005 season due to the high uniformity of the system and lack of real differences between the head and tail ends. Eliminating these sites allowed for the installation of access tubes in the head end of Block 4 to increase replication.

Soil and water salinity: Replicated soil samples were taken at germination and post harvest each year in cotton from the area adjacent to access tube locations from the 0-6, 6-18, 18-36 and 48-60 inch depths and analyzed by the ANR Lab at UC Davis for EC, Ca, Mg, Na, Cl, HCO3, and B. Treatment water samples are collected in June and the end of August (near irrigation cutoff) and analyzed for the same constituents. In addition, weekly to biweekly (June – Aug) the EC of treatment water samples are checked with a portable EC meter in our Kern County office. For each treatment, a transect of closely spaced samples taken at the time of cotton emergence (about one week after the end of irrigation) and perpendicular to the drip tape will be used to characterize EC and B patterns at the time of stand establishment for each treatment. A similar transect has been done yearly for pistachios but with wider spacing. To improve the characterization of an “average” transect, individual samples representing the same distance from the drip hose(s) are obtained by compositing separate samples from 3 separate transects along 50 to 100 feet of the same drip hose near, but not adjacent to, a “head” access tube. Starting in 2008 only mid-season soil samples are taken to coincide with pistachio leaf tissue sampling.

Plant data: Leaf water potential (LWP) was measured biweekly once cotton plants were about 12 inches high. Petiole NO3, P, K, Na, Cl and B was determined for the end of June and again just before defoliation in September. Foliage was rated visually for leaf burn. Plant mapping was done in July and just before defoliation. Cotton lint was determined using a 2-row and 4- row commercial picker harvesting over the 1280 foot length of the row and weighed in a separate “boll buggy”. Lint quality was be determined by subsampling each plot and using HVI automated classing. Starting in 2006, LWP and N, P, K, Na, Cl and B will be determined for the Kerman scion that was budded into all trees 8/12-19/05. Trunk circumference in pistachios is measured annually at the end of the season. Three extra trees per plot were planted in 2005 and will be sacrificed at the end of the experiment to determine shoot, scaffold and trunk weights and B accumulation in the woody tissue. Replicated Photoshop pixel counts of total “down the row” green foliage have been made starting 2007. The first pistachio harvest was 9/23/11. A standard catch-frame harvester and receiver were used with nuts off-loaded into bins for weighing on a platform scale. Harvest weights and nut quality were determined from the two intensively monitored rows for a total of 30 normally spaced PG1 rootstocks and 10 normally spaced UCB rootstocks. An additional 1.25 “equivalent” trees were credited to each of the varietal totals as an estimate of additional bearing canopy from the 3 close-planted trees. Fifteen pound subsamples for each plot and variety were submitted to Paramount Farms processing unit for turnout and quality analysis.

GIS / ECa / Aerial survey: Both fields were surveyed for ECa (apparent soil salinity) using a tractor mounted dual dipole EM38 from the USDA Salinity Lab in Riverside, CA with GPS (Section 9-1, on May 14,26-27 and field 9-3, May 5-6). GPS way points for anchoring aerial imagery and field mapping were done with HGIS and a hand-held NavMan GPS unit mounted to an IPAQ pocket PC. This data was compared to field aerial imaging analysis (Ag Recon of Davis, CA) shot on 7/29/04. Reflectance is digitally recorded for three different band widths: visible red light (VIS 0.4 to 0.7 µm), near infrared (NIR, 0.7 to 1.1 µm) and far (thermal IR, 6 to 15 µm) infrared. The relative intensity of thermal IR and the Normalized Difference Vegetation Index (NDVI = (NIR — VIS)/(NIR + VIS)) was calculated for each plot where 1 pixel equals a 2 meter diameter. As plots are 440 feet wide by 1280 feet long (6.71 x 390.1m) this equals 1308 pixels per plot – providing a much greater number of pixels for analysis than is often available for replicated studies. Aerial NDVI was again measured 8/14/06 and 8/14/12. The final ECa survey is planned for 2013.

Data analysis: All data was tested for significance using a 2-way ANOVA for a completely randomized block design using Stat Graphics software. Some tables are presented with a Fisher’s least significant difference (LSD0.05) means separation. Adobe Photoshop was used to analyze average plot gray-scale pixel intensity of a modified NDVI calculation of spectral data for significant differences between treatments and field variability. In a similar manner, average plot values of the vertical electromagnetic conductance (EMv in milliSeimens/meter) were calculated from filled contours generated from the EM38 survey and regressed against mean values of plot NDVI.

Results and Discussion

As the well water quality in this trial has degraded over time we have attempted to maintain the original salinity treatment targets by adjusting the Blend and Well treatments to the appropriate EC using a small field EC tester. The average water quality is given in Table 1.

Table 1. Average treatment water quality from 2004-2012

WATER SOURCE	pH	EC	SAR	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	Cl (meq/l)	B (ppm)	HCO3 (meq/l)	CO3 (meq/l)	NO3-N (ppm)	SO4 (meq/l)
Aqueduct	7.9	0.5	2.4	1.1	1.0	2.4	2.1	0.2	1.3	<0.1	0.5	0.7
Blend	7.7	3.7	4.4	13.6	8.0	14.4	19.5	8.0	1.9	<0.1	1.7	9.9
Well	7.8	5.1	5.4	21.3	11.1	21.9	32.7	11.5	1.7	<0.2	4.5	19.6
Well 9-3 high EC	*7.8*	*8.89*	*7.0*	*40.3*	*19.1*	*37.7*	*66.3*	*19.2*	*2.0*	*<0.1*	*12.0*	

Despite the high salinity of this water, it is atypical of most Westside saline waters in that the calcium and sodium are about equal in ionic strength. This ratio is usually more in the range of three to five times the sodium to calcium. Therefore, this water may provide some buffering effect against sodium ion toxicity that may not be found in sodium dominated waters of the same salinity.

Cotton yields for 2004 were virtually the same for all treatments (3.4 bale/total acres, 3.9 bale/ac based on a 38" row, with the Well Treatment producing just over 4 bale/planted ac, Table 2). Pistachios (PG1 rootstock with a small-scale subplot of UCB in each plot) were planted

Table 2. Summary of plant tissue data, cotton height/lint yield,								Rootzone	[1]Cotton Ht,	Lint or	[2]Total Salts
	N (p	NH4-N (ppm)	PO4-P (ppm)	K (%)	Na (ppm)	Cl (%)	B (ppm)	EC_e to 5 ft (dS/m)	Pistachio Circum (inch)	Inshell Yield (lb/ac)	Applied in Irrigation (lb/ac)
2004 Petioles 8/27/04					**Cotton 2004**			**10/6/04**	**9/14/04**	**10/6/04**	**Cotton'04**
Aque	#	75	368	1.84	570	**2.58**	**34**	**2.71**	42.2	**1933**	2,343
50/50	#	95	463	1.73	712	****3.23**	**37**	***4.08**	*35.8	**1928**	11,390
Well	#	108	413	1.72	574	***3.00**	**37**	***4.68**	38.8	**2016**	21,444
2005 Petioles 9/15/05					**Cotton 2005**			**10/18/05**	**9/15/05**	**10/19/05**	**Cotton'05**
Aque	#	53	760	2.06	605	**2.71**	**42**	**1.42**	41.6	**954**	2,305
50/50	#	40	573	1.79	539	***3.13**	**46**	**3.71**	43.1	**1129**	10,144
Well	#	85	593	1.91	546	****3.38**	****50**	***4.74**	42.1	**999**	16,975
	Rootstock Leaves 9/15/05 Pistachio 2005							**10/18/05**	**10/19/05**		**Pistach'05**
Aque		160	580	1.02	222	**0.27**	**194**	**2.87**	2.31		1,742
50/50		128	545	1.06	220	**0.27**	****492**	**4.12**	2.17		8,570
Well		148	500	1.08	314	****0.38**	****673**	***4.44**	2.18		14,782
2006 Petioles 9/21/06					**Cotton 2006**			**10/30/06**	**9/21/06**	**10/27/06**	**Cotton'06**
Aque	#	55	635	2.15	885	1.95	48	**1.01**	44.9	**1835**	1,967
50/50	#	65	495	1.90	937	1.91	55	***3.61**	45.0	**1615**	11,046
Well		63	413	1.97	1143	2.21	*56	****4.63**	40.9	***1560**	15,832
	Kerman Leaves 10/31/06				**Pistachio 2006**		**Rootzone ECe to 5'**				
		N (%)	**P (%)**	**K (%)**	**Na(ppm)**	**Cl (%)**	**B(ppm)**	**10/30/06**	**Circum (in)**		**Pistach'06**
Aque		1.19	0.08	2.67	171	0.52	531	**2.65**	2.58		1,022
Blend		1.36	0.08	2.83	140	*0.58	**954	**4.34**	2.55		8,994
Well		*1.55	0.09	2.99	201	*0.62	**1096	***4.61**	2.49		11,104
	Kerman Leaves 8/26/08 (PG1)					**Pistachio 2008**		**4/25/08**	**10/22/08**		**Pistach'08**
Aque		2.29	0.13	2.91	80	0.12	301	**2.60**	7.81		1,553
Blend		2.36	0.13	2.87	84	0.12	684	***4.69**	7.55		8,185
Well		2.33	0.13	3.15	79	0.15	**870	****5.64**	*7.23		13,296
	Kerman Leaves 8/26/08 (UCB1)					**Pistachio 2008**		**11/11/08**	**10/22/08**		
Aque		2.32	0.13	2.41	83	0.14	269	**2.84**	7.83		
Blend		2.41	0.13	*2.73	75	0.13	**606	***5.05**	7.66		
Well		2.37	0.13	2.50	68	0.14	**733	****6.44**	7.49		
	Kerman Leaves 7/21/10 (PG1)					**Pistachio 2010**		**7/21/10**	**11/11/10**		**Pistach'10**
Aque		2.30	0.12	2.09	115	0.24	274	**5.62**	15.0		
Blend		2.34	0.12	2.32	106	0.25	**563	***8.55**	14.5		
Well		2.33	0.12	2.21	132	0.27	**610	***7.82**	*14.0		
	Kerman Leaves 7/21/10 (UCB1)					**Pistachio 2010**			**11/11/10**		
Aque		2.41	0.13	1.75	99	0.16	248		15.2		
Blend		2.44	0.13	1.89	92	0.16	**479		*14.4		
Well		2.53	0.13	1.84	99	0.18	**516		*14.3		
	Kerman Leaves 7/29/11 (PG1)					**Pistachio 2011**		**7/21/11**	**11/27/11**	**PG1 (lb/ac)**	**Pistach'11**
Aque		2.41	0.13	2.21	159	0.29	455	**6.96**	17.1	**2159**	
Blend		2.54	0.12	2.32	151	0.28	**845	***12.68**	*15.9	**1983**	
Well		2.55	0.13	2.30	113	0.27	**818	**8.49**	*15.5	**1902**	
	Kerman Leaves 7/29/11 (UCB1)					**Pistachio 2011**			**11/27/11**	**UCB (lb/ac)**	
Aque		2.51	0.13	2.00	161	0.25	328		17.9	**1949**	
Blend		2.52	0.13	2.23	160	0.24	**724		*16.4	**1901**	
Well		2.66	0.13	2.03	109	0.24	**637		*16.3	**1808**	

*Significantly different from Aqueduct @ 0.05, **Significant @ 0.01

[1]Cotton height @ irrigation cuttoff. [2]Cotton cover = 12.7 feet/tree row Pistachio drip subbing = 9.5 feet/tree

NOTE: 2012 laboratory analyses not yet completed by UCD lab.

March 2005 on 22 foot centers with a reduced, 4-38 inch row cotton planting in between tree rows. Tree growth was good and unaffected by salinity. Cotton yields for 2005 were poor (2.1 bale/ac) due to a cold spring and excessive heat in July/August, but increase in pistachio trunk circumference was excellent. Cotton yields and tree growth were unaffected by salinity.

Plant tissue analysis showed a significant 0.5 to 3 fold increase in chloride and boron levels in both cotton and pistachio for 2005 and 2006 (Table 2), but produced no toxicity symptoms in 2005. From 2006 on only boron has been consistently higher in Kerman leaves irrigated with saline water. Marginal leaf burn has slowly increased in severity (up to ½ inch of outer leaf boundary necrosis) since 2006. By the end of 2007 scaffold development was essentially the same for all treatments and rootstocks.

Comparison of digital aerial analysis of the Normalized Difference Vegetation Index (NDVI, Figure 3) for August 2004 and 2006 showed a very slight decrease in NDVI with increasing salinity that was not statistically significant. However, correlation of the average NDVI and season end rootzone salinity to five feet in 2004 (the solid cotton planting) was highly significant (Figure 4). Final 2006 cotton yields showed a half bale loss for the Well compared to the Aqueduct treatment (3.12 and 3.68 bale/ac, respectively). Pistachio development was unaffected by salinity, but due to small caliper rootstocks at planting and extremely high July temperatures, a significant number of trees needed to be rebudded in Fall 2005 and only 40% of the PG1 and 4% of the UCB trees had a full set of Kerman scaffolds by the end of 2006. UCB rootstocks were significantly larger than the PG1 rootstocks.

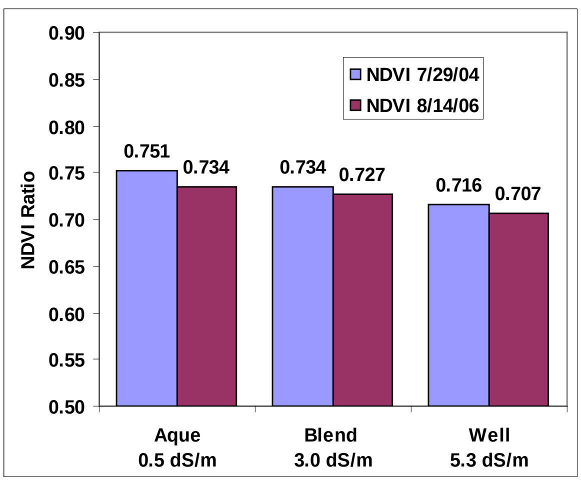


Fig. 3. Normalized Difference Vegetation Index (NDVI) for 2004 solid cotton and 2006 cotton/pistachio interplanting.

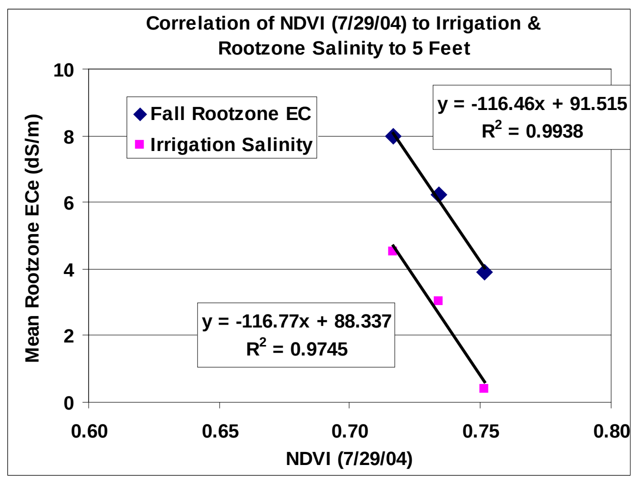


Fig. 4. Correlation of average treatment NDVI with irrigation and season end rootzone salinity.

On 8/14/12 a four color aerial digital image of the field was captured near solar noon with a 1 foot pixel resolution. Calculated % cover using a digital image assay program (Envy) revealed a reduction of 13.0 and 11.7% for the 3.2 and 5.2 dS/m treatments compared to the Aqueduct fresh water treatment. Likewise the full plot (2 rows by 20 trees) NDVI was reduced by 10.1 and 8.9% and the canopy only NDVI was reduced by 4.0 and 4.0% for the same respective treatments (Figure 5). All reductions are significant with a 90% probability.

PG1 rootstock circumference for the Well treatment was a significant 7% less than the rootstock circumference for the Aqueduct treatment in 2008, but not significantly different in 2009. In 2009, however, UCB rootstock circumference in the Well treatment was significantly less by 7% compared to the Aqueduct (Figure 5). One of the arguments against interplanting is

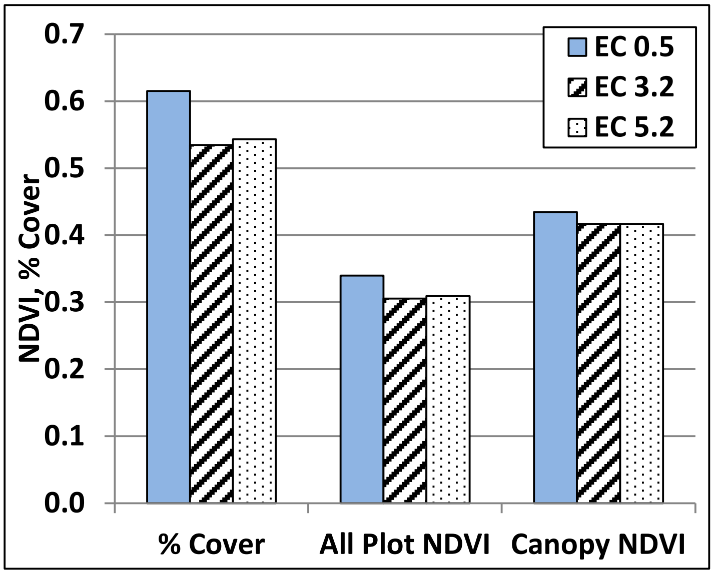


Fig. 5. NDVI and % cover from 4 color digital aerial imagery captured at a 1 foot pixel resolution 8/14/12.

the potential to reduce the early development of the orchard and, subsequently early yields. Even though this orchard is equipped with a separate irrigation system for the trees that allows continued irrigation after the cotton is cut off, rootstock circumference was barely 3 inches at the end of 2nd leaf. This carry over effect may have been the reason that there was insufficient fruit for a 6th leaf harvest. Increase in pistachio rootstock diameter and general tree development was unaffected by salinity for both rootstocks for the first three years. PG1 rootstocks showed a significant 7% decrease at the end of 4th leaf while UCB was unaffected. From 10/22/08 to 11/27/12 average trunk circumference increased 1.5 to 2 inches per year for the Aqueduct irrigation, but as of the end of 2009 the trunk circumference for UCB showed a statistically significant 7% reduction for the Well treatment. Currently, the end of 8th leaf, **trunk circumference** for both the 3.3 and 5.1 dS/m irrigation water is 7 to 9% less than the 0.5 dS/m irrigation (Figure 6).

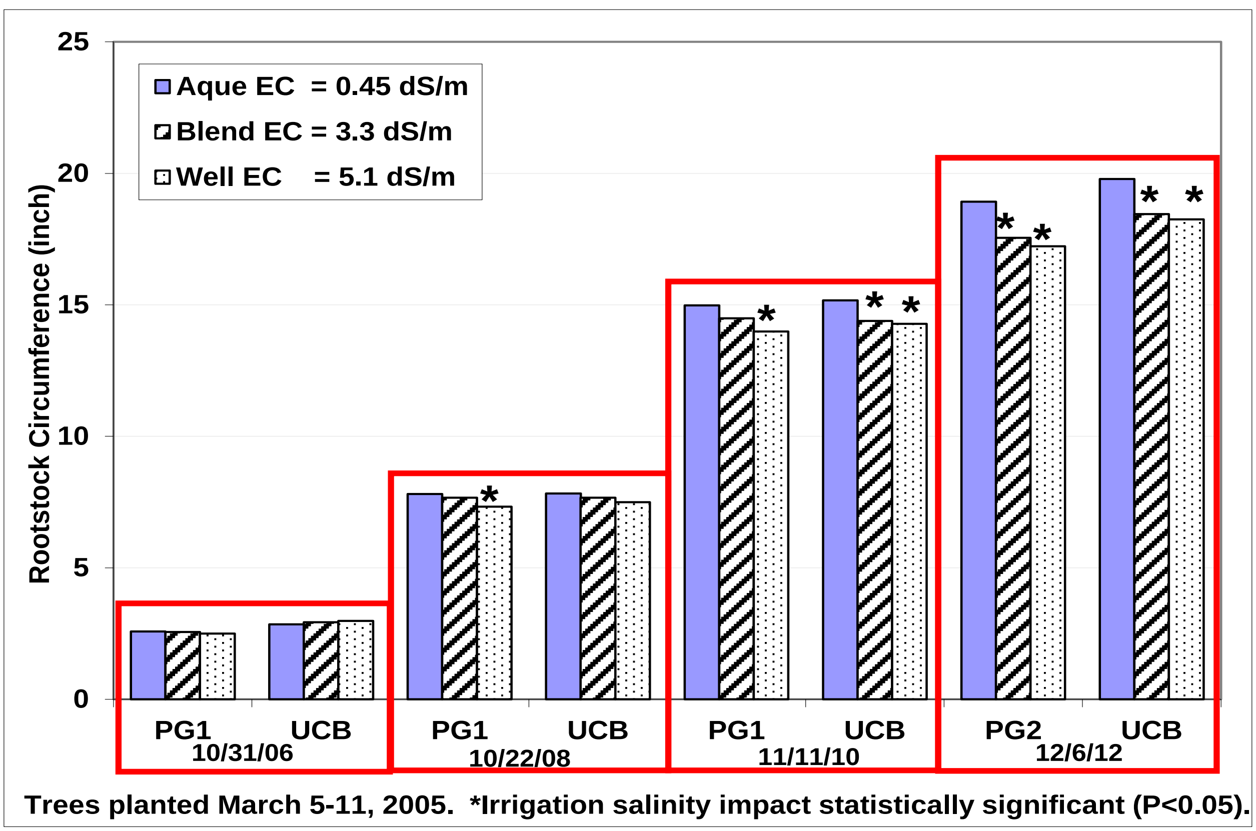


Fig. 6. Change in pistachio rootstock circumference over 8 years.

In 2007 a method was designed using Adobe Photoshop® to isolate and count pixels of leaves in the pistachio canopy. Thus, provided a very quick, inexpensive quantitative estimate of the comparative canopy development for all treatments. July 24, 2012 Photoshop pixel counts of the volume of green foliage down the row showed a statistically significant reduction of 15.7 and 9.3% smaller canopy for the 3.2 and 5.2 dS/m irrigation, respectively, compared to the 0.5 dS/m irrigation water. (Figures 7 and 8). This reduction agrees with the aerial imagery canopy estimate.

			Leaf Pixels	Mean Green
Aque		V 6 W	3,439,015	69.49
Blnd	Rep1	V 4 W	3,075,481	62.96
Well		V 6 E	3,062,096	64.94
Aque		V 4 E	3,469,259	62.73
Blnd	Rep2	V 2 E	3,068,868	74.51
Well		V 2 W	3,168,785	48.79
Aque		V 4 N	3,372,243	64.91
Blnd	Rep3	V 2 S	2,257,142	57.61
Well		V 2 N	3,147,678	58.76
Aque		V 6 S	2,977,761	60.89
Blnd	Rep4	V 6 N	2,771,255	59.26
Well		V 4 S	2,650,309	52.64

AVERAGE LEAF PIXEL TOTALS

	Leaf Pixels	% of Aque	Mean Green
AQUEDUCT	3,314,570	**100.0%**	64.51
BLEND	2,793,187	**84.3%**	63.59
WELL	3,007,217	**90.7%**	56.28

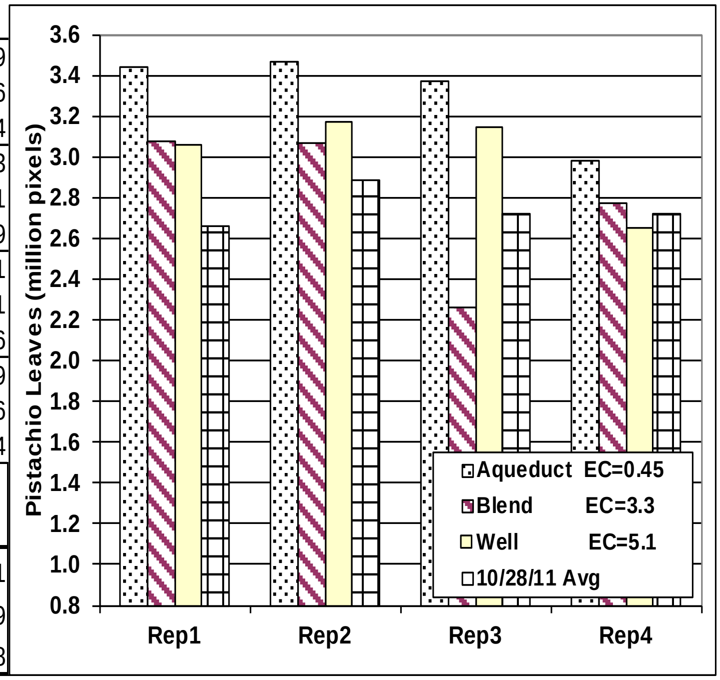


Fig. 7. Comparison of leaf pixel totals by treatment and replication (10/28/11 and 7/24/12, Camera Aspect 16wide:4tall, PicSize 5.5MB) and 2004-12 average water quality.

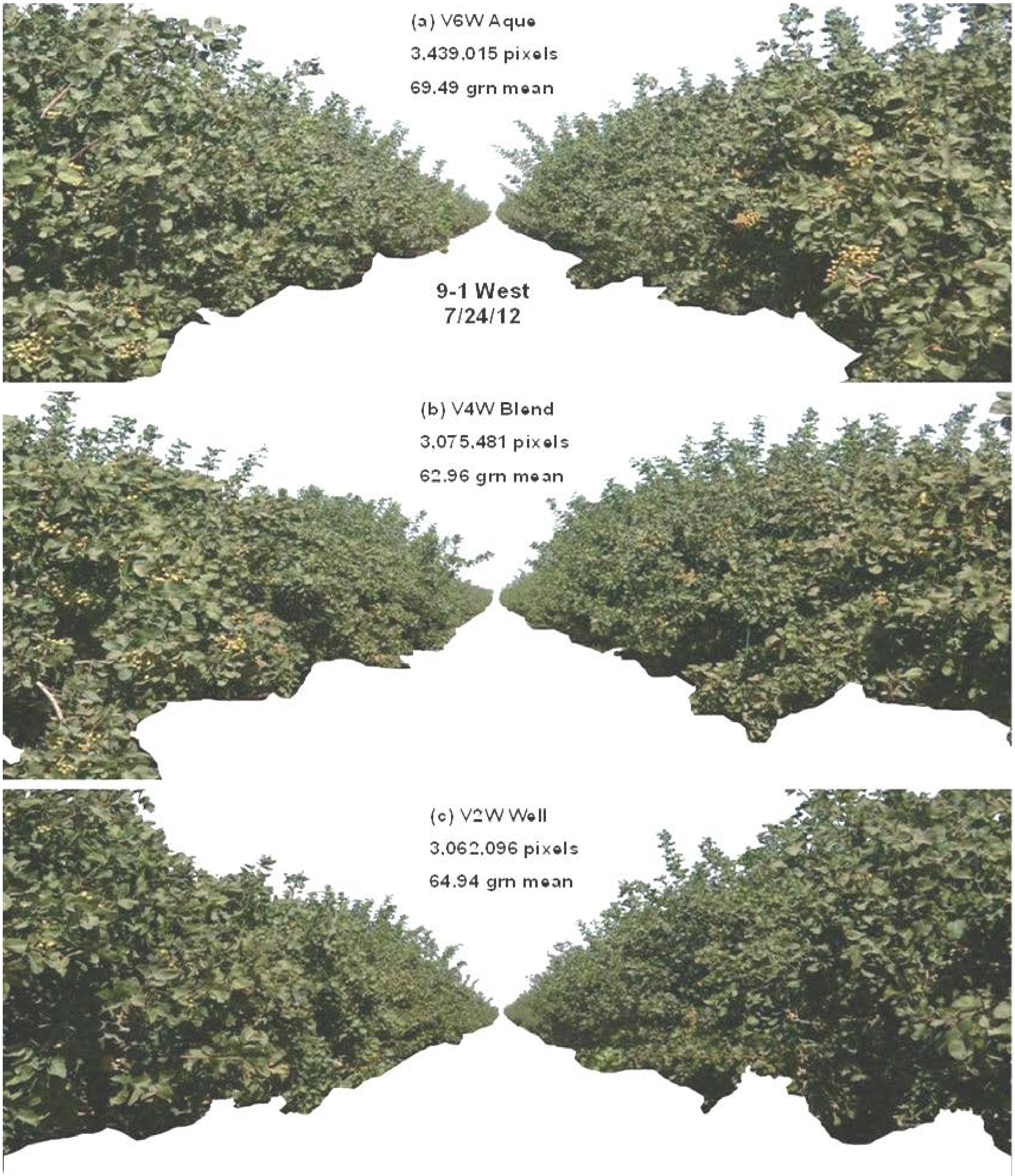


Fig. 8. Canopy leaf pixels isolated from color digital pictures on 7/24/12. Above images created using pictures taken with a Panasonic Lumix DMC-FZ30 and aspect ratio of 16wide:4tall, picture size of 5.5MB, JPEG quality high (7 dots). Image processed with Adobe Photoshop® by first selecting and excising bare soil using "Magic Wand" (Tolerance 50) and then selecting green foliage (Tolerance 50). Total foliage pixel count and "Average Green" (0 is total green, 256 total white) is obtained by selecting "Histogram" from the "Image" pull-down menu.

Applied water, including winter rainfall, more than doubled between 2009 and 2011 (Table 3). Winter and spring rains totaling nearly 9 inches were a welcome relief after three years of drought. Without the benefit of the heavy rains of December 2010 the neutron probe soil water content readings (Figure 10) showed that total stored soil moisture to a six foot depth started the spring 2012 season at about 75% available and later exceeded field capacity (100%) during the middle of the season for the Well treatment – indicating the potential for significant leaching. This indeed was the case for the Well (5.2 dS/m) treatment given the mid-season soil salinities we measured, but according to in-field flow meters this was about 11 inches less water than the Blend (3.2 dS/m) treatment received, which never really showed water content readings exceeding 100% available. This would indicate virtually no leaching, which does corroborate the measured soil salinity for this treatment. Indeed, midday stem water potential measurements indicated that the Blend treatment experienced the greatest stress over the summer even though it received the most water (Figure 9). Osmotic stress due to increased rootzone salinity in the blend and well treatments undoubtedly contributed to this stress. But it is unclear as to why the Aqueduct treatment appeared to show less stress as SWP while receiving almost 10 inches less water. All these factors contributed to significant marginal leaf burn as soil salts concentrated in all treatments and contributed to the decrease in rootstock growth in the saline irrigation treatments. Most irrigations were 48 hours in duration with penetration to four to five foot depth. Total inches of applied water, including preirrigation and rainfall, and the calculated mass of salts applied is listed in Table 3.

Table 3. Total irrigation and rainfall (total acreage) and cumulative salt loading for pistachios.

Irrigation Treatment (*avg dS/m)	2004 Irrig (in)	Cotton Salt (lb/ac)	2006 Irrig (in)	Salt (lb/ac)	2008 Irrig (in)	Salt (lb/ac)	2010 Irrig (in)	Salt (lb/ac)	2012 Irrig (in)	Salt (lb/ac)	TOTAL Irrig (in)	Salt (lb/ac)	[2]EC+ Max (dS/m)
Aque (0.45)	32.3	2,343	8	1,022	9	1,553	27	3,120	33	5,584	**182.5**	**27,162**	**2.1**
Blend (3.25)	33.1	11,390	9	8,994	9	8,185	24	19,792	45	39,703	**197.4**	**159,441**	**12.5**
Well (5.01)	33.1	21,444	8	11,104	10	13,296	28	37,647	33	49,091	**186.0**	**227,601**	**17.8**

*Average EC for respective treatments over length of trial.

[1]Irrigation inches for total tree spacing, salt totals (lb/ac) calculated for a 9.5 foot wide subbing area centered on the tree row. Assumes 640 ppm soluble salt = 1 dS/m and a 5 ac-ft depth of soil = 20 million lbs.

[2]Maximum increase in soil saturated paste EC for a 5 foot rootzone with no precipitation of salts and no leaching past the 5 foot depth.

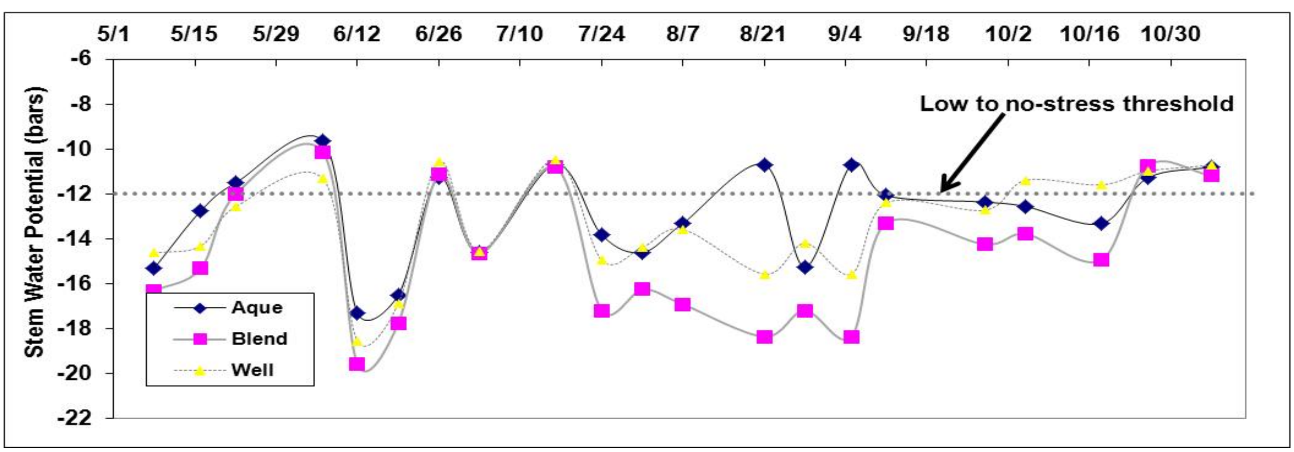


Fig. 9. 2012 midday stem water potential measurements for all treatments using shaded bagged leaves in a PMS pressure chamber.

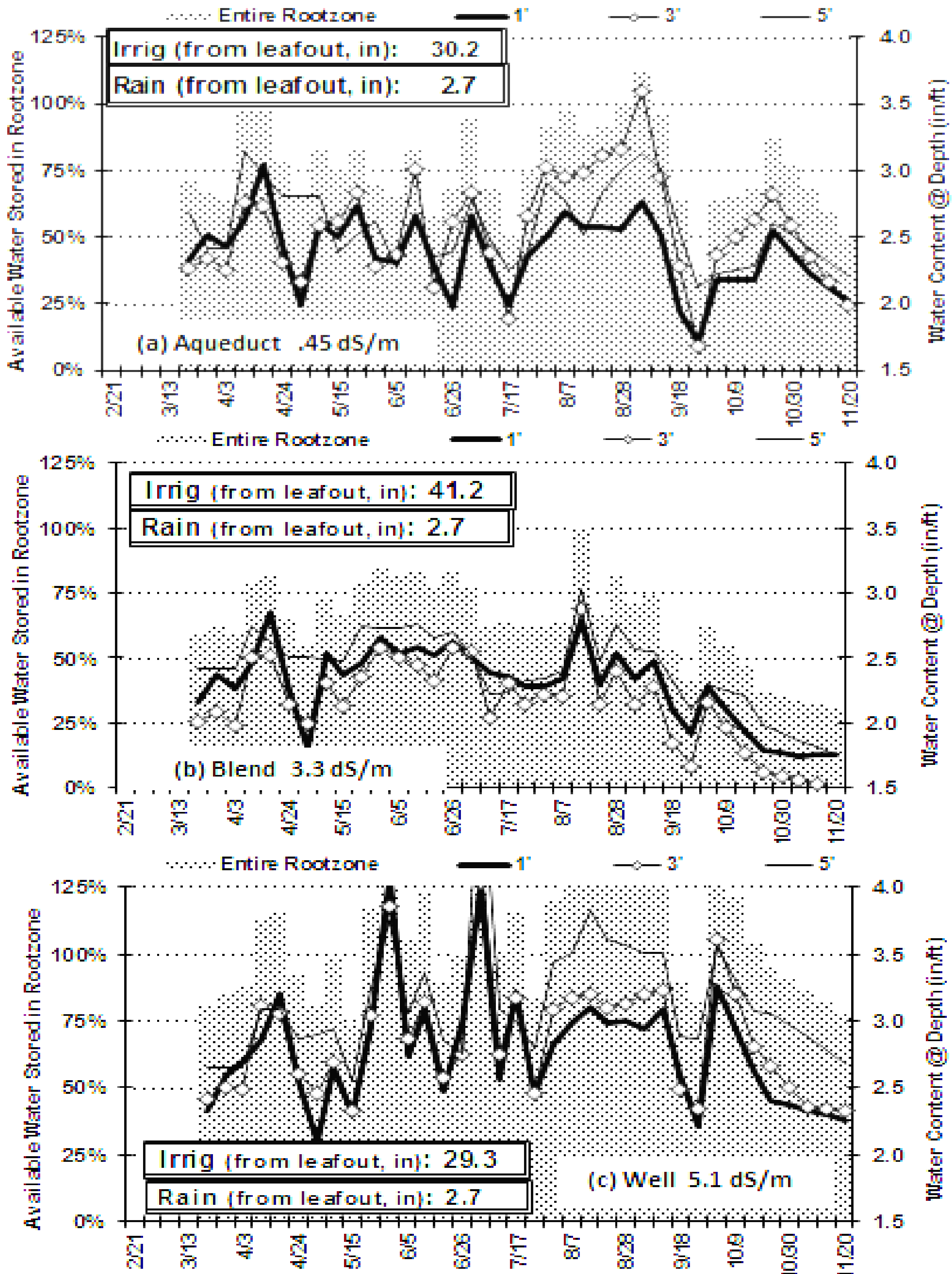


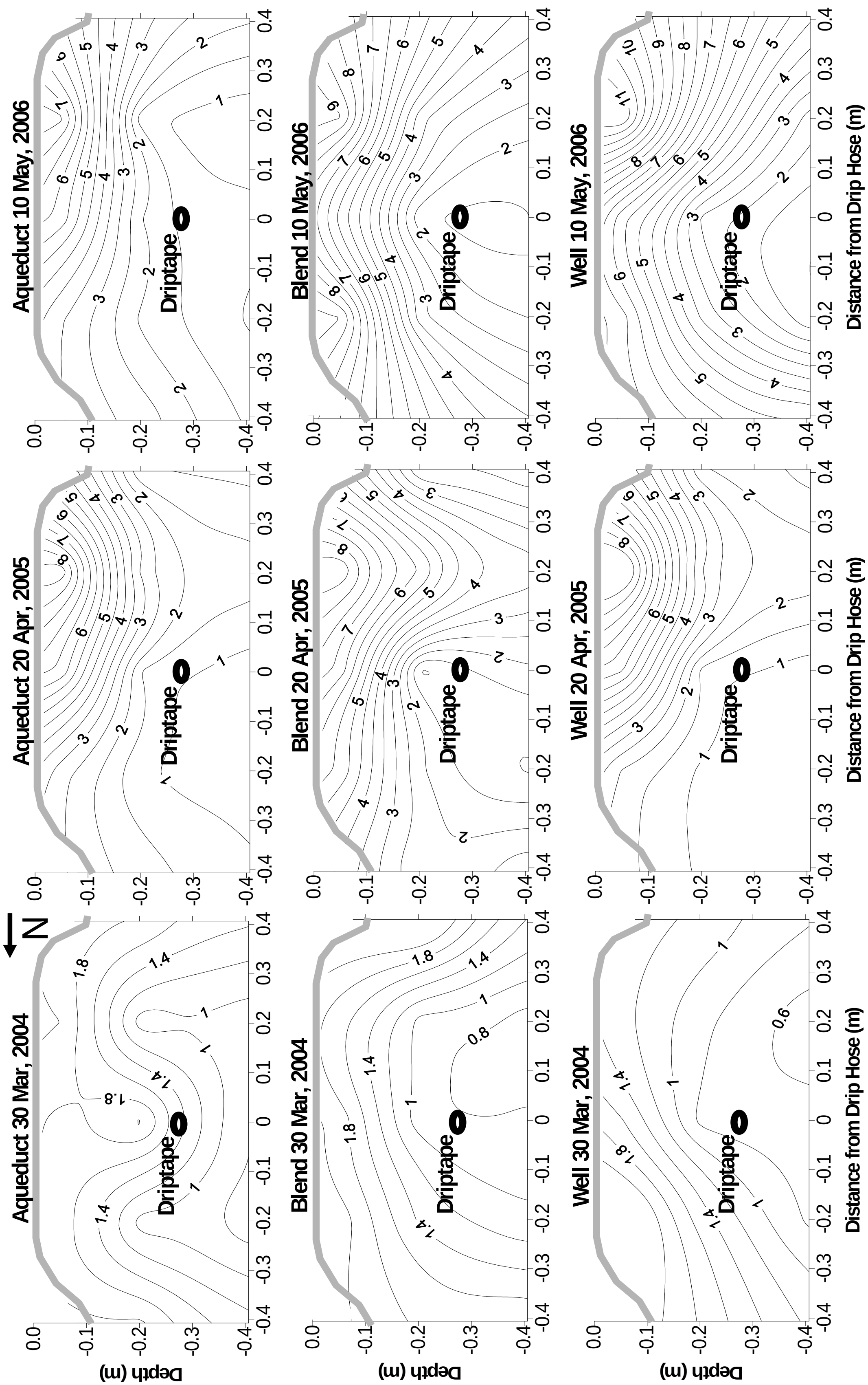
Fig. 10. Weekly neutron probe measurements of soil water content for the Aqueduct (a), Blend (b) and Well (c) treatments. Cross-hatched area indicates integrated water content to 6 feet as %Available Water (3.1 in/ft as 100%, 1.1 in/ft as 0%). Total water content for the 1, 3 and 5 foot depths indicated on right hand axis.

Salinity and sustainability: At the end of 2006, after three seasons of cotton irrigation these treatments applied about 6,600, 32,500 and 54,000 lb/ac (total) of salt in the Aqueduct, Blend and Well treatments, respectively. By the end of 2012, assuming that irrigation water and salts sub across a 9 foot wide rootzone with the double-line buried drip tape irrigation system, this total is up to 27,162, 159,441 and 227,601 lb/ac of salts deposited or passing through (due to leaching) the wetted rootzone for the same treatments. This equals a maximum increase in EC of 2.1, 12.5 and 17.8 dS/m if averaged over a 9 foot wide by 5 foot deep rootzone with no leaching or precipitation of salt (Table 3). But salts from drip irrigation don't like to obey simple mass balances. As of July 2011 the salinity in the top 0-15 inches is more than twice that of the lower depths for all treatments and is over the EC tolerance limit of 8.4 dS/m established by Sanden and Ferguson. This is caused by the fact that the 2 drip tapes are buried about 10 to 12 inches deep on either side of the tree; causing the salt to move to the middle of the tree row/crown in our sampling zone. This effect can also create toxic NO3 levels around the crown with certain soils and water quality. This concentration effect increases leaf burn during mid to late season forcing more water to be taken up deeper in the profile. In fact, average soil salinity to a depth of 5 feet between the hoses as of 7/21/12 was greater for the 3.2 dS/m irrigation treatment (soil ECe of 12.7 dS/m) than for the 5.2 dS/m treatment (soil ECe of 8.5 dS/m) due to the fact that a surface drip hose with high flow emitters is centered on the Well Treatment tree rows to supply the additional saline water required to reach the average 5.2 dS/m EC irrigation salinity. This arrangement, coupled with additional osmotic potential in this high EC treatment that potentially reduces tree ET, results in a much greater leaching fraction for this treatment.

In-season ECe in the top three feet is much higher as water and salts sub up from the buried drip-tape at the 10 to 12 inch depth due to tree water demand and surface evaporation. With the high level of calcium found in this water we are probably precipitating some lime during drying cycles. For cotton, with a drip hose every 38 inches, contours of soil ECe generated from samples taken after emergence (Figure 11) showed that water and salts distribute fairly evenly over the profile of this fine sandy clay loam with excellent lateral subbing. The lowest soil salinity is directly beneath the tape. The highest concentration is on the south side of the bed due to sun angle.

In contrast, contours of pistachio soil ECe (Figure 12) take on a concentric pattern around the tree as water is applied by two buried drip tapes about 19 inches on either side of the tree and these young trees will have the greatest root concentration within a two to three foot radius of the trunk. As the trees take up water, along with the evaporation from this wetted zone, the salts concentrate around the crown of the tree. Over the last 7 years, continuing root development creates a gradient that pulls salts and water farther away from the trunk and evens out the salinity pattern over the 4 foot wide zone shown by the transect contours.

Table 4 shows even less increase as an average to five feet, but also provides an indication of the cause for this result. Total soil B in the top two feet of soil as determined by nitric acid digestion in 2004 showed that most of the native B in this soil is in an unavailable "adsorbed"/ insoluble phase at a concentration of 17 to 20 ppm. A similar digestion performed on all sample sites Fall 2007 showed total B to two feet at 27 to 28 ppm regardless of treatment. Theoretically, there should have been a significant increase in total B for the Well treatment over total B in the Aqueduct treated plots, but these results show the highly variable nature of native B concentrations within many of these Westside soils and the huge potential to sequester irrigation water B into the soil matrix. Still, this ability may provide only marginal help to safeguard the



. Contours of saturation extract **soil salinity (ECe, dS/m)** in **cotton** beds (0.96m, 38 inches) at emergence after spring recharge and post-plant irrigation of 200 mm (8 inches) low salinity canal water (Aqueduct, 0.5 dS/m). Kerman rootstock planted 5-11 March, 2005 following cotton and irrigated with the same treatment waters.

Fig. 11. Cotton bed contours of soil saturation extract salinity (ECe) at emergence.

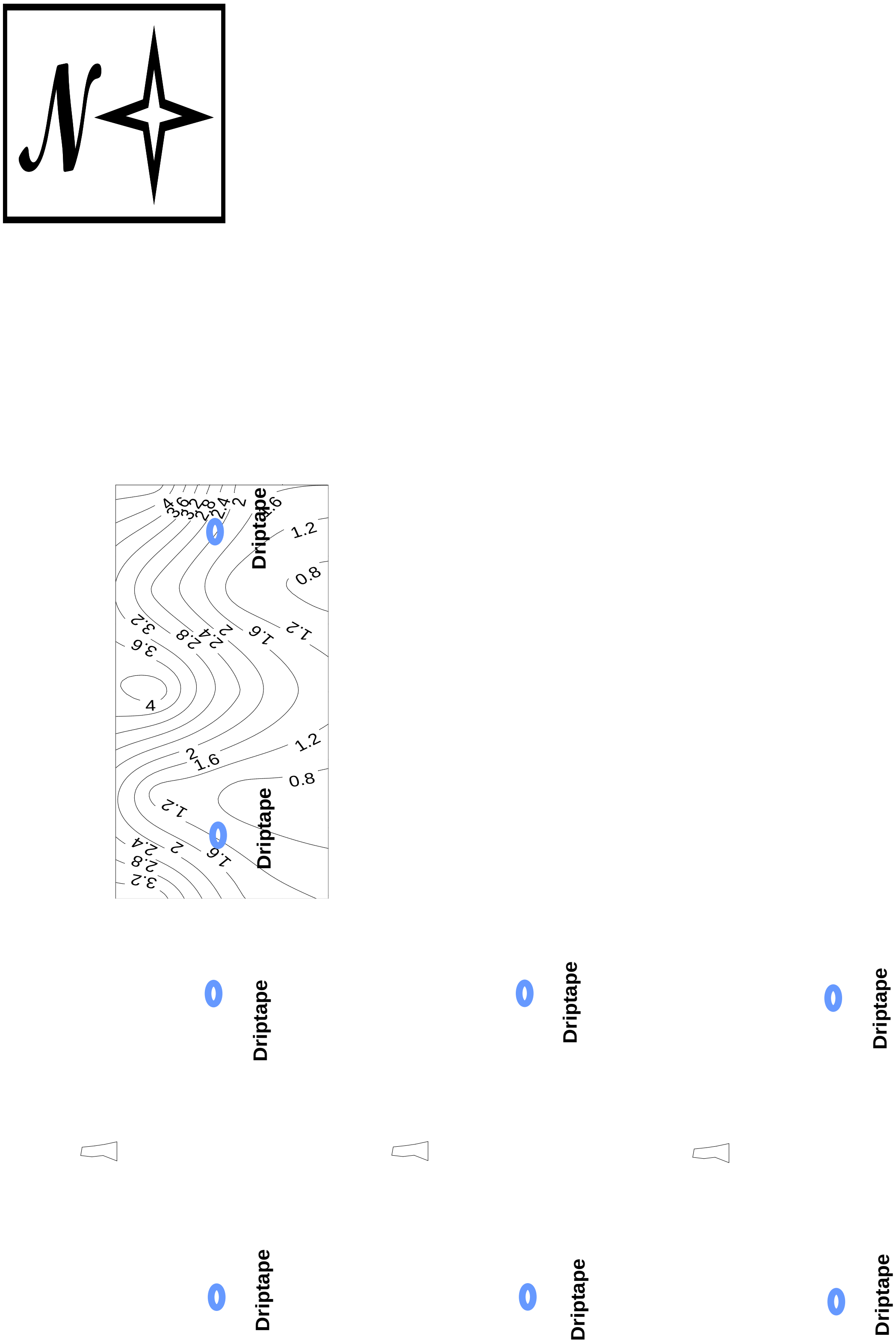
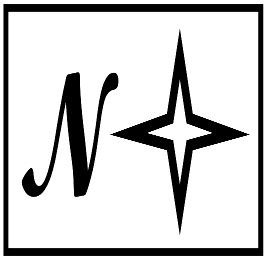


Fig. 12. Pistachio berm contours of soil saturation extract salinity (ECe) over 5 years. (Note increased scale for 2011, spanning 2.8 m (9 feet) across the row.) **NOTE:** 2012 laboratory analyses not yet completed by UCD lab.



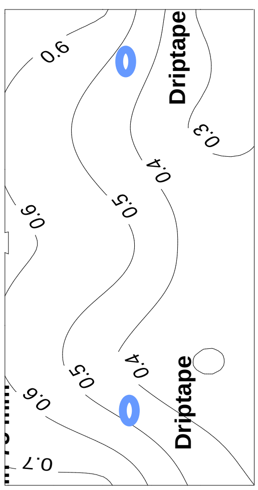
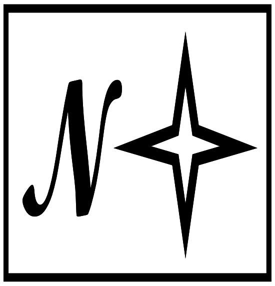


Fig. 13. Pistachio berm contours of soil saturation extract boron over 5 years. (Note increased scale for 2011, spanning 2.8 m (9 feet) across the row.) 2012 data has not been processed. **NOTE:** 2012 laboratory analyses not yet completed by UCD lab.



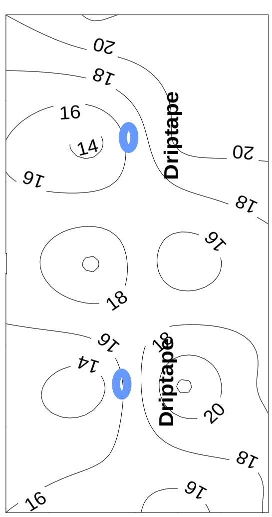


Fig. 14. Pistachio berm contours of total boron from nitric acid extraction after 7 years of irrigation at the indicated average B concentration. (Note increased scale for 2011, spanning 2.8 m (9 feet) across the row.) **NOTE:** 2012 laboratory analyses not yet completed by UCD lab.

Table 4. Average saturation extract rootzone soil salts from 4 continuous samples to 5 feet for spring and fall (2004-8, mid-season only starting 2009) pistachio soil samples taken from replicated monitoring sites corresponding to neutron probe water content measurement. 2012 data has not been processed. (**NOTE:** 2012 laboratory analyses not yet completed by UCD lab.)

	SP %	pH	EC dS/m	Ca (SP) meq/l	Mg (SP) meq/l	Na (SP) meq/l	Cl (SP) meq/l	HCO3 meq/l	B (SP) ppm	
WEIGHTED AVERAGES TO 5 FEET Soil sampled 3/23/04										
Aque	44	7.8	2.07	11.7	2.1	9.1	5.7	1.9	1.1	Nitric
Blend	47	7.8	2.53	13.0	2.3	11.4	7.0	1.9	1.1	Acid
Well	46	7.7	2.10	14.2	1.9	9.3	4.9	1.9	0.8	Total B
WEIGHTED AVERAGES TO 5 FEET Soil sampled 10/7/04										(ppm)
Aque	45	7.8	2.71	11.3	2.5	13.0	9.9	1.8	1.7	17.6
Blend	47	7.7	4.08	21.6	4.2	16.4	18.2	1.4	2.0	
Well	47	7.7	4.68	25.8	5.4	17.2	23.6	1.3	2.7	20.7
WEIGHTED AVERAGES TO 5 FEET Soil sampled 4/10/05										
Aque	44	7.7	3.22	16.3	3.3	15.2	11.9	1.4	1.7	
Blend	48	7.6	4.47	27.6	5.7	17.6	21.3	1.2	1.3	
Well	47	7.6	4.52	29.2	5.5	14.6	23.2	1.1	1.5	
WEIGHTED AVERAGES TO 5 FEET Soil sampled 10/18/05										
Aque	44	8.0	2.88	16.1	3.7	10.8	11.7	1.5	1.5	
Blend	47	7.9	4.12	25.3	5.3	14.1	20.0	1.8	1.5	
Well	47	7.9	4.43	28.1	6.0	14.5	24.2	2.5	1.7	
WEIGHTED AVERAGES TO 5 FEET Soil sampled 5/10/06										
Aque	46	7.9	2.15	10.5	2.2	9.4	5.4	2.8	1.6	
Blend	51	7.7	4.18	27.6	5.1	14.1	16.1	2.0	1.3	
Well	48	7.7	3.99	25.4	5.2	12.5	17.5	2.0	1.5	
WEIGHTED AVERAGES TO 5 FEET Soil sampled 10/30/06										
Aque	44	7.8	3.59	20.5	5.9	13.1	15.9	2.0	1.3	
Blend	48	7.7	5.84	39.7	9.6	17.0	32.3	1.6	1.5	
Well	45	7.7	6.06	39.8	9.5	18.4	35.1	1.7	2.0	
WEIGHTED AVERAGES TO 5 FEET Soil sampled 4/27/07										
Aque	41	7.8	2.55	13.3	3.2	10.3	6.3	2.5	1.4	Nitric
Blend	47	7.7	3.91	24.3	4.7	13.4	17.5	1.6	1.4	Acid
Well	46	7.7	3.99	23.2	5.0	14.2	19.3	1.6	1.9	Total B
WEIGHTED AVERAGES TO 5 FEET Soil sampled 10/18/07										(ppm)
Aque	40	7.8	3.23	17.9	4.3	12.5	10.7	3.1	1.6	27.8
Blend	45	7.7	4.68	29.8	6.0	16.0	24.0	2.1	2.1	28.6
Well	42	7.6	6.53	42.7	9.3	20.8	36.3	2.2	2.6	26.9
WEIGHTED AVERAGES TO 5 FEET Soil sampled 4/25/08										
Aque	42	7.9	2.60	13.4	3.3	10.7	8.2	2.4	1.2	
Blend	47	7.6	4.69	32.5	5.9	15.3	22.8	1.8	1.5	
Well	46	7.7	5.74	37.2	7.9	19.9	35.4	1.7	2.1	
WEIGHTED AVERAGES TO 5 FEET Soil sampled 11/24/08										
Aque	41	7.8	2.84	16.1	3.9	9.0	10.6	2.0	0.6	Nitric
Blend	46	7.8	5.05	28.2	7.7	17.3	29.0	1.6	2.6	Acid
Well	43	7.7	6.44	35.6	9.8	23.2	42.9	1.5	3.8	Total B
WEIGHTED AVERAGES TO 5 FEET Soil sampled 7/30/09										(ppm)
Aque	43	7.7	3.52	19.8	5.3	10.8	13.1	1.9	0.8	18.6
Blend	45	7.6	7.07	42.5	9.4	23.3	39.1	1.6	2.3	21.6
Well	45	7.7	6.89	41.8	9.3	22.7	40.0	1.5	2.7	21.8
WEIGHTED AVERAGES TO 5 FEET Soil sampled 7/21/10										(ppm)
Aque	45	7.7	5.62	37.0	8.0	16.2	26.0	1.4	0.7	17.8
Blend	47	7.7	8.55	52.1	11.5	29.9	53.1	1.3	2.6	21.4
Well	47	7.7	7.82	43.8	10.4	31.8	51.7	1.3	4.6	24.7
WEIGHTED AVERAGES TO 5 FEET Soil sampled 7/21/11										(ppm)
Aque	41	7.8	6.96	45.5	10.0	23.9	35.2	1.7	1.7	24.8
Blend	42	7.6	12.68	85.3	18.4	47.6	86.7	1.7	4.7	32.3
Well	41	7.7	8.49	50.9	12.1	36.5	53.2	1.3	5.7	34.9

tree from uptake of excess B as confirmed by the noticeable leaf burn and tissue levels of excess B in the Well treatment (Table 2). Until 2009, contours of **soil saturation extract boron** (Figure 13) showed only a moderate increase of 2 to 3 ppm in the Well treatment compared to the Aqueduct treatment rootzone, despite the very high irrigation water concentration of 8 to 11 ppm. But 2009 may represent a partial "time bomb" threshold where much of the exchange sites are now saturated with B and thus release more into solution. The saving grace is that the 2010 (data not shown) and 2011 contours (Figure 13) show a partial stabilization of soluble B in this 2 to 4 ppm range for most of the rootzone. Figure 14 illustrates the nitric acid extract estimate of total B in the profile. There does not appear to be much of an increase in the saline irrigation treatments between 2009 and 2011. The reason for this is unclear.

Without 6 to 10 inches of effective rainfall or fresh water winter irrigation for efficient leaching every one to two years the use of 4.5 to 6 dS/m EC irrigation water may not be sustainable. Compounding this problem is the continuing increase in salinity of the groundwater, a not uncommon problem in areas plagued by poor groundwater quality. A regression of all EC data for the well water used for the first five and one-half years of this study indicates a steady increase in EC by about 1 dS/m every 500 days. We are lucky that the well just one-half mile to the east has not been degraded in the same fashion. Time will tell.

Cotton economic analysis: The irrigation requirement of pistachios for the first 4 years under drip irrigation is equal to about one season of cotton irrigation requirement. For the Well treatment in this trial, we used 10.3 inches of fresh water for winter pre-irrigation and 40 inches of well water during the seasons. At an average price of $160/ac-ft for Aqueduct water from 2005-2009 and a Well water price of $50/ac-ft this is a savings of $367/ac. **Table 5** (following) breaks down the economics of the cotton production for the Aqueduct and Well treatments by year. At an average pima price of $1.08/lb, this analysis of cotton production and yields for the year prior to and first two years after planting pistachios shows a net return of $2,120 for Aqueduct water @ $120/ac-ft and $2,249 for Well water @ $45/ac-ft for this system.

Table 5. Economic analysis for Net Return from three years of cotton production for both Aqueduct and Well water treatments.

Cotton	[1]Yield (lb/ac)	[2]Gross $/ac	[3]AQUE Treatment Irrig (in)	Salt (lb/ac)	Net Return	[4]WELL Treatment Aque (in)	Well (in)	Salt (lb/ac)	Net Return
2004	1959	$1,861	32.3	2,343	**$877**	6.1	27.0	21,444	**$1,038**
2005	1028	$1,233	31.8	2,305	**$254**	9.0	21.0	16,975	**$403**
Aque'06	1835	$2,019	36.8	1,967	**$990**				
Well'06	1560	$1,716				17.8	18.5	15,832	**$808**
Total	**4821**	**$5,112**	100.9	6,615	**$2,120**	32.9	66.5	54,251	**$2,249**
[5]Pistachios 2005-2008			39.4	8,050	--	10.3	40.0	92,267	**$367**

[1]Average field yield of all treatments for 2004 & '05 cotton as there was no treatment difference. 2006 yields and returns separated due to treatment effect.

[2] Pima price for 2004 - $0.95, 2005 - $1.20, 2006 - $1.10

[3]Total applied water, salts and net return based on irrigation + system depreciation cost of $261/ac, $400/ac other cultural/harvest costs and water cost of $120/ac-ft of CA Aqueduct water.

[4]Above costs apply except WELL water was $45/ac-ft. The indicated depth of Aqueduct water was used for spring pre-irrigation and germination of cotton.

[5]Total applied water and salt load (based on a 9.5 foot wide wetted area) from planting to the end of 4th year. The $186 net return equals money saved using the less expensive WELL water @ an average $50/ac-ft and district water at $160/ac-ft.

Nut yields: Sufficient fruit load in 2011 (7th leaf) merited harvesting and averaged 2,015 and 1,886 lb/ac total inshell for PG1 and UCB, respectively. Total nut yield, or any other harvest component, was not statistically significantly reduced by saline irrigation water, but there was about a 200 lb/ac decline trend for the 3.2 and 5.2 dS/m treatments when comparing PG1 clean split or total inshell nut tonnage to the fresh water irrigation. Split nut % averaged 71% of total dry nut weight and 84% of total inshell. Only 3 replications were used for this analysis in 2011 as there was massive fruit drop of set clusters in the fourth rep which is closest to a nearby environmental cleanup facility, which may have been related to some sort of chemical release. Of course this replication yielded the most fruit by far for 2012 – virtually making it equal to other replications when combining the biennial yields for the 7th and 8th leaf harvests.

Reduction in **pistachio nut yield** was not statistically significant for the combined 2011/2012 harvests due to saline irrigation water, but there was about a 300 to 700 lb/ac decline trend for the 3.2 and 5.2 dS/m treatments when comparing clean split or total inshell nut tonnage to the fresh water irrigation (Fig.15). Split nut % averaged 74% and was unaffected by treatment.

	Clean Splits		Closed Shell		Total Inshell		Blanks	
	PG1	UCB	PG1	UCB	PG1	UCB	PG1	UCB
0.45 dS/m	3414	3230	390	573	3938	3928	477	374
3.3 dS/m	2868	3044	465	521	3422	3672	503	341
5.1 dS/m	2739	2882	357	527	3202	3514	362	358

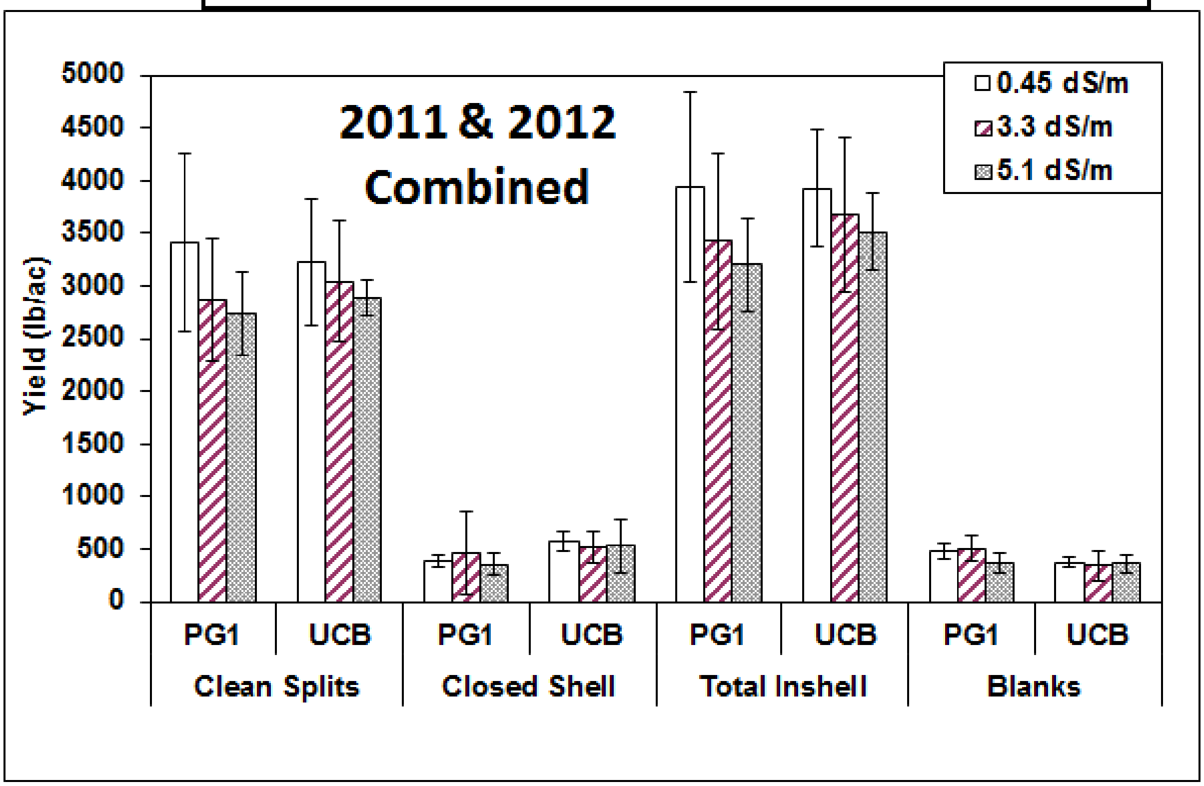


Fig. 15. 2011-2012 pistachio yield components by treatment and variety with standard error bars.

CONCLUSIONS AND PRACTICAL APPLICATIONS

Cotton income plus saved water costs are about $6200/ac since the inception of the project. However, cotton plantings may have contributed to slower tree development and insufficient fruit load for a 6th leaf harvest. The 5.2 dS/m EC treatment has added 200,000 lb/ac more salt than the California Aqueduct water. Soluble B has increased more than three-fold in the 3.2 and 5.2 dS/m irrigation treatments and is rapidly overloading the adsorption complex. Average long-term rootzone salinity of 5 to 8 dS/m may reduce tree stature and yield of pistachios.

On the up side, utilizing these saline waters on the Westside probably allows for up to an additional 100,000 acres of pistachio development that would not be possible given current fresh water supplies. To this one grower, the eventual savings in annual water costs can exceed $200/acre/year for mature tree ET. This equals $62,000/year for the 310 acre orchard. This doesn’t even take into account the fact that planting this acreage would be impossible without using the “substandard” water.

If sufficient fresh water was available for less than $150/ac-ft this would be the safest irrigation supply, but if long-term allocations to the Westside are greatly reduced on the average, then the use of saline drain water up to an EC of 5 to 6 dS/m allows for continued production with occasional leaching and probably some long-term yield impact. At this time there are probably 60,000 additional acres of pistachios planted along the Westside since 2004 that would not have been developed five years ago without our current understanding of pistachio salt tolerance. Between marginal groundwater and blended drainwater there is more than 250,000 ac-ft/year of additional “alternative” water supply on the Westside that is at least partly suitable for pistachios. Pistachio growers in Westlands Water District already rely on this water. The aggregate value of this water and the potential development of 30 to 40,000 acres of pistachios replacing cotton and wheat rotations could easily exceed a benefit of $30 million/year over the value of the field crops.

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The commentary below is based on field data and observation that I have accumulated as a part time field technician in Blake Sanden's trial and as a farmer, consultant, and farm manager in the southern San Joaquin Valley. As noted in Blake Sanden's salinity report, the well water in his most saline treatment had crept up to 8.2 dS/m by 2008. He was able to maintain his 5.1 dS/m treatment by blending the 8.2 dS/m water with Aqueduct water in the .5 dS/m range. By the conclusion of the 2013 growing season we had seen well EC's as high as 10.57 dS/m but were always able to maintain a field EC in the 5.1 dS/m range through a combination of blending other wells and aqueduct water. The rise to 10.57 dS/m was not a constant slope and periodic dips back in to the 5.1 dS/m range caused us to constantly monitor and change our blending rates. The 2013 growing season was a typical example of what we have documented over the last 5 years. At the beginning of the 2013 season we had well EC's of 9.4 dS/m, by mid-summer we had dropped to 5.2 dS/m and by years end the well was pumping at about 4.3 dS/m. These fluctuations occurred while pumping a maximum 100 acre feet of water from the well over a 10 month period. In fairness, there is a well about 1/3 of a mile away that pumped a maximum of 900 to 1200 acre feet at about 3 dS/m that could have some influence on the higher EC well. Sanden's experiment sets the bar for minimum brackish water salinity for economic farming viability quite high and leaves one with serious doubts as to the volume of water available even at these high levels. It should be noted that a similar opportunity to blend wells of low and elevated salinities (although not as high as Sanden's trial) is available throughout the Buena Vista Water Storage District and there is an adequate supply of low EC, Kern River/California Aqueduct, water available for both the blending and leaching of the saltier water. It should also be noted that the composition of salts that conduct electric current over a given range greatly influence a waters agricultural viability. Water in the Buena Vista area is often calcium dominated which allows for higher EC water to be used to achieve economic farming viability. TDS levels alone are not adequate to assess the viability of the Buena Vista water, a complete water quality analysis would be necessary. Evidence of this can be provided if necessary.

A visual observation of the proposed well field B south of Seventh Standard road and east of the Kern River slough shows productive alfalfa, wheat, pistachios, cotton, grapes, and corn. The variety of crops grown in the area rivals that of any other area in our water district. Visual observation alone cannot confirm economic success and productivity, but as a consultant, farmer, and farm manager of these same crops in the Buena Vista Water Storage District and other areas, I do not see any obvious signs of significant yield reduction in the crops grown nearest to the proposed well field B. Most of our limitations for crop varieties in the Buena Vista area are due to soil composition and local climate. Even with an unlimited supply of the least saline water available, I cannot see how you could achieve consistent economic viability with many other crops. In 2013 the Buena Vista Water Storage District supplied its farmers with one of the smallest district water runs in history. This year we only received .7 acre feet of Kern River/California Aqueduct water. Alfalfa has a yearly water requirement of at least 4-5 acre feet when ET is combined with leaching and drainage in our area. This means that by September of 2013 alfalfa growing at the proposed well site B would have had between 2.5 and 4 feet of applied well water. The alfalfa that I have seen growing without obvious salinity issues at the proposed well field has a soil salt tolerance in the 4-5 dS/m range. Typical soil salinity is about three times that of applied water EC with a ten percent leaching fraction. This would mean that the average water EC for the 2013 growing season for this area would be in the 1.3-1.7 dS/m range. Subtracting .7 acre feet of district water at .5 dS/m puts estimated well EC for the viewed alfalfa field at approximately 2 dS/m. While I do not expect all soil or well water salinities in this area to fit into this exact range, I would expect both to be much closer to this range than any other that would constitute the need for a remediation program like the one proposed by HECA. I think it would be in the Buena Vista Water Storage District's best interest to protect our water for agricultural use. If the numbers are even close to the ones derived through visual observation and scientifically calculated salt tolerance thresholds, the area would be completely suitable for a pistachio development and one should expect little or no yield reductions due to salinity. A fully productive pistachio orchard yielding 3,000lbs and fetching $2.43/lb nets about $3,609/acre according to U.C. Davis cost return studies. Although no statistical differences have been shown to date in Sanden's pistachio salinity trial, the highest yield difference between the low salt and high salt treatment has been about 20%. Even with a 20% yield loss from a 3,000lb base line the yearly net profit on pistachios at $2.43/lb would be $2,153/acre. The 2012 pistachio price settled out at about $2.85/lb and we are told to expect the same in 2013. Although not yet published, preliminary 2013 data seems to show that the highest yield losses can be minimized with rootstalk variety selection. I do not believe there is crop fit to grow in our area even with the highest water quality available that can rival this level of economic viability. It would appear that smart farmers in our area have already come to these same conclusions because there are multiple pistachio orchards being developed near well site B.

Originally The Buena Vista Water Storage District had proposed an alternate well field referred to as well field A. Although there is some brackish perched water in the northern part of the district in field A, visual observation, years of farm management, and data collected during scientific research supports the district's conclusions that there is not an adequate supply of brackish water in the area to support the needs of the HECA plant, especially when coupled with the district's plans to line canals near the well field and the development of modern farming technology, primarily drip irrigation. Evidence and explanations to support these claims can be provided but at this time does not appear to be necessary.

Beau Antongiovanni