# Using Saline Groundwater for Large-Scale Development and Irrigation of Pistachios Interplanted with Cotton

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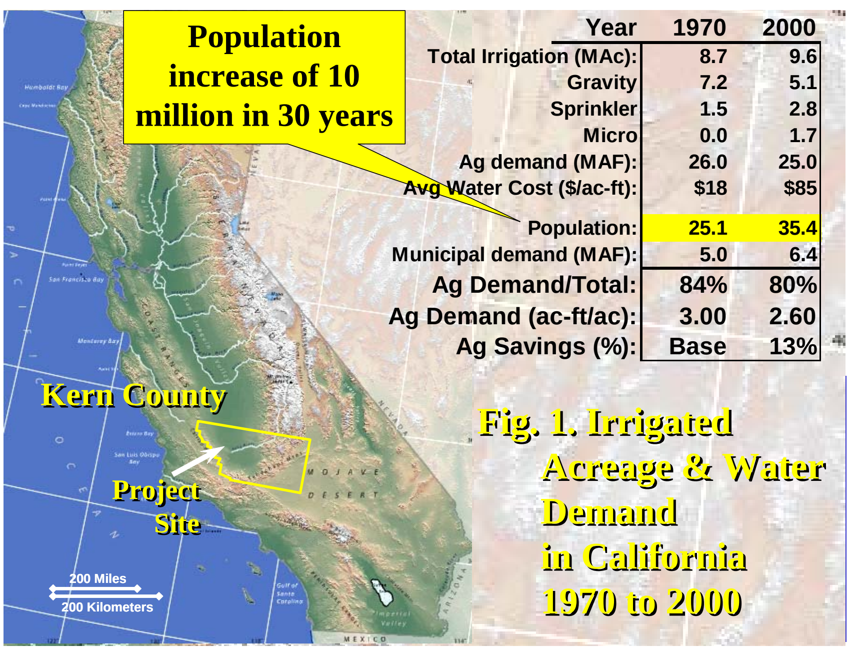
## ABSTRACT

A 9-year small-scale trial (ending 2002) in the southern San Joaquin Valley found that established pistachios can tolerate an irrigation water salinity up to 8 dS/m (similar to cotton) without a reduction in yield.

In 2004, a shallow subsurface drip tape system was installed in two 155 acre fields to irrigate future pistachio tree rows 22 feet apart with 4 rows of cotton interplanted on 38 inch beds. Replicated 19.5 acre blocks were arranged to test plant response to fresh (canal) water, blend and saline well water treatments with EC of 0.5, 3.0 and 5.4 dS/m and boron @ 0.3, 6 and 11 ppm, respectively. Fresh water was used to germinate cotton, which was planted in 2004, 5 and 6. Pistachios were planted in 2005. Cotton yields were unaffected by salinity, until 2006; showing a half bale loss for the well water (3.12 bale/ac) compared to the canal water (3.68 bale/ac). Pistachio growth is unaffected by salinity after 3 years.

## INTRODUCTION

Cotton has long been known as a salt tolerant crop, but despite many small-scale field trials over 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 increased little since the early 1960's. At the same time, the population of California has grown by 10 million people and ag demand has dropped from 26 to 25 MAF mostly due to the adoption of micro (drip) irrigation systems (Figure 1). Farmers are looking for less expensive, more secure water supplies and more profitable crops.




| Year | 1970 | 2000 |
|---|---|---|
| Total Irrigation (MAc): | 8.7 | 9.6 |
| Gravity | 7.2 | 5.1 |
| Sprinkler | 1.5 | 2.8 |
| Micro | 0.0 | 1.7 |
| Ag demand (MAF): | 26.0 | 25.0 |
| Avg Water Cost ($/ac-ft): | $18 | $85 |
| Population: | 25.1 | 35.4 |
| Municipal demand (MAF): | 5.0 | 6.4 |
| Ag Demand/Total: | 84% | 80% |
| Ag Demand (ac-ft/ac): | 3.00 | 2.60 |
| Ag Savings (%): | Base | 13% |

Fig. 1. Irrigated Acreage & Water Demand in California 1970 to 2000

A recently completed nine year field study on the salt tolerance of pistachios on the Westside of the San Joaquin Valley (Ferguson et. al., 2003 and Sanden, 2004), and previous pistachio studies in Iran (Fardooel, 2001) have shown the viability of using saline water up to 8 dS/m for irrigating these trees (Figure 2). 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. 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).

Emphasizing the need for alternative water supplies, State Water Project allocations to Westside irrigation districts went to zero in 1990 due to extended drought; unleashing California's infant water market with the establishment of "Emergency Pool" water that could be bought for $100/ac-ft. Given the salt tolerance of cotton and other rotation crops on the Westside (such as processing tomatoes), some studies investigated utilizing fresh water blended with drainage from tile systems as a means of boosting available water supplies for furrow irrigation (Ayars et al., 1993, Sheenan et al., 1995). This approach generated some interest, since yields were maintained at similar levels to fresh water irrigations, but required a high degree of management with the possibility of long-term residual salinity problems that growers did not want to deal with.

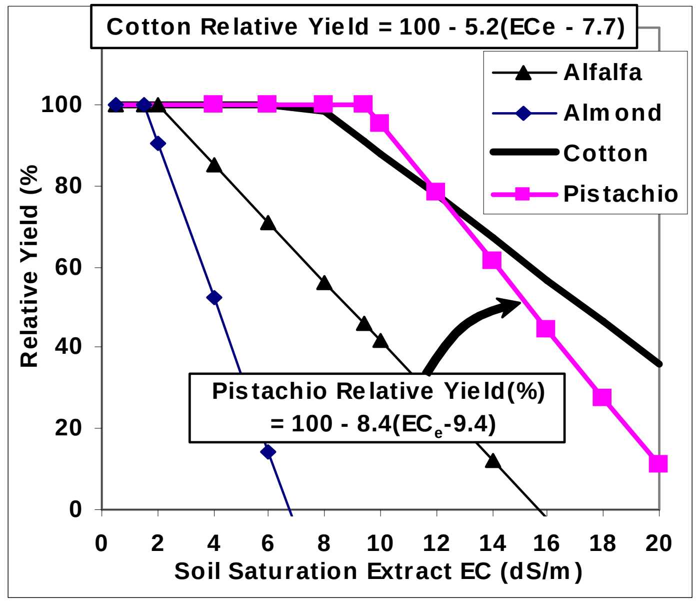


Fig 2. Comparison of salt tolerance thresholds and relative yield for various crops (Sanden, et.al., 2004)

At the same time water supplies have decreased and costs have soared, subsurface drip irrigation (SDI) systems using improved, thin-walled drip tape have become cheaper and more profitable than the earlier prototypes of the mid 1990's (Fulton et al., 1991), with capital costs as low as $800/acre for grower installed systems. With a much lower energy requirement than sprinklers, greater uniformity and reduced loss to evaporation (a total savings of 6 to 8 inches) this type of system becomes the most cost effective in this setting. All these factors have combined to make the time right for developing irrigation system management approaches that can use hybrid fresh and saline water supplies to irrigate salt tolerant crops.

## PROJECT OBJECTIVES

- Assess the viability of large-scale cotton production and pistachio interplanting using saline groundwater (up to EC 5 dS/m and B @ 10 ppm) and optimal irrigation scheduling with SDI.
- Determine crop ET as a function of salinity using simple water and chloride balance.
- Maintain acceptable soil salinity levels for cotton stand establishment/production and maximum growth of young pistachios.
- Compare total project profitability under SDI using 3 different levels of salinity: saline water, non-saline CA Aqueduct water and a 50/50 blend. Compare the economics of drip tape SDI with typical Belridge Water District cotton production using sprinklers.

## PROCEDURES

**Irrigation system and treatment replication**: Two, 155 acre blocks were designed for irrigation with TSX 708-12-220, 0.875 inch diameter drip tape injected at 10-12 inches below field grade using a 38 inch row spacing with two 54 inch skips every 22 feet between the tape used for future pistachio rows and the 4 adjoining 38 inch rows for cotton.. A separate underground manifold connected to the two hoses that irrigate the pistachio rows was installed to allow for separate scheduling. Hose runs are 1280 to 1300 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. The grower's booster and filter station are designed to irrigate 8 subunits at a time (~78 net acres); making for 4 set changes to irrigate

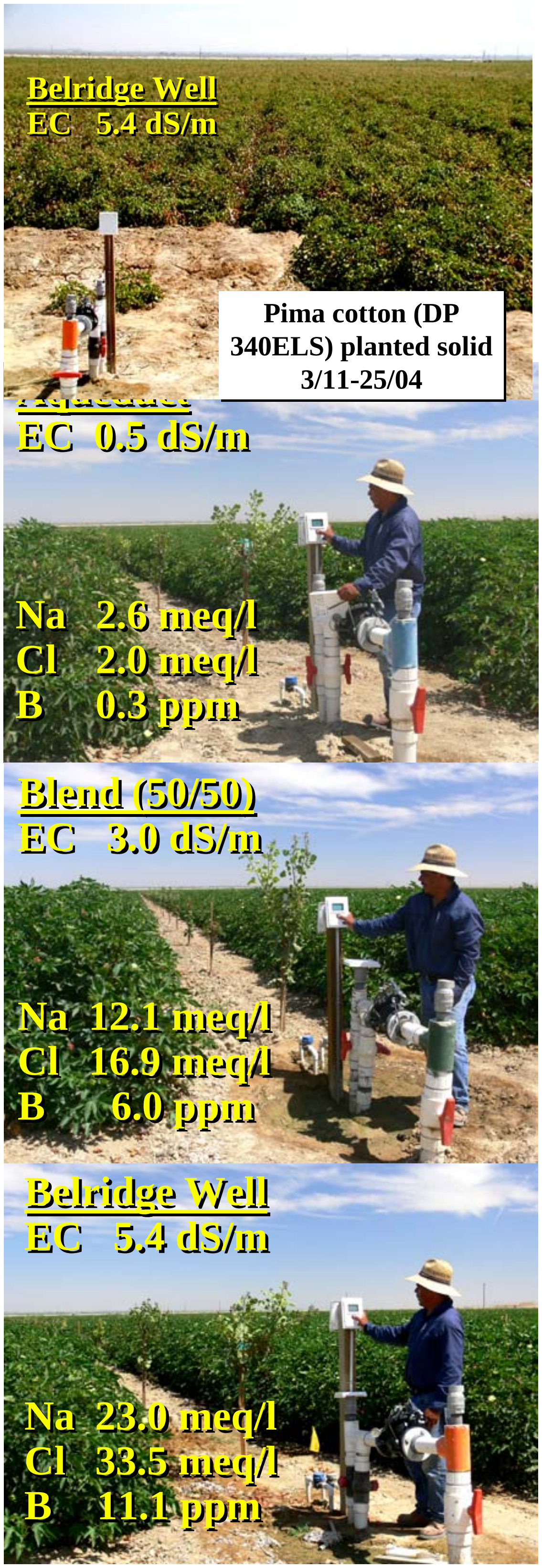



Fig 3. Solid planted cotton (Well treatment) July 2004 and comparison of irrigation treatments with third year of cotton and two year old pistachios (8/17/06).

310 acres. Treatments are applied to a total of twelve 19.5-acre plots (2 subunit valves each) arranged in a randomized complete block design with four replications.

**Treatments:** Aqueduct water (a 6 to 12 inch depth) is used for winter recharge of the rootzone and the germination irrigation for optimal cotton stand establishment and leaching in pistachios in all subunits. Subsequent irrigations are applied using 24 hour sets (2 inches) as required over the season using the following treatments:

**Control:** Aqueduct water only: EC ~ 0.5 dS/m

**Blend:** 50/50 mix Aqueduct and Well: EC ~ 3.5 dS

**Well:** Groundwater only: EC ~ 5.5 dS/m

**2004 Season**: Delta Pine 340 ELS pima cotton was planted over the entire field 3/11-25/04 (Figure 3, top).
**2005-2006:** Pistachio Pioneer Gold (PG1) rootstock was planted 3/5-11/05 with DP340 ELS pima interplanted 3/25-4/15/05. Pistachios were planted to a 17 x 22 foot spacing with 4-38" rows of cotton in between tree rows. Sub-blocks of 20 UCB1 rootstocks were planted in each plot to compare the vigor of both varieties under varying salinity. Separate orchard manifolds feed two drip tape hoses placed 19 inches from the tree trunk allow for optimal irrigation scheduling for trees in order to satisfy ET and some leaching even after cotton irrigation ceases. Phytogen 810RR pima was interplanted 4/12-14/06 (Figure 3, left).
**2007:** Pistachios only using the 2 adjacent drip tape hoses. Cotton was to be planted a 4$^{th}$ year, but severe reductions in irrigation district allocation forced the grower to cancel his Westside cotton program.

**Data Collection and Analysis -- Soil water content and applied water:** One neutron probe access tube for weekly measured water content depletion/ET estimation was installed in each plot, 150 feet from the head and, in Block 1 only, 250 feet from the tail ends of the drip tape. In one block for each treatment, matric potential at the 12, 24 and 48 inch depths adjacent to neutron probe access tubes was monitored using a Hanson AM400 data logger with six electrical resistance blocks (Watermark®). Small flow meters were installed at the entrance to each replicated run of drip tape in both cotton and pistachios.

**Soil and water salinity:** Replicated soil samples were taken each year from the area adjacent to access tubes from 0-6, 6-18, 18-36 and 48-60 inch depths at planting and post harvest and analyzed for EC, Ca, Mg, Na, Cl, HCO3, and

B. Treatment water samples were collected over the season. A transect of closely spaced samples perpendicular to the drip tape was used to characterize salinity patterns at the time of stand establishment.

**Plant data:** Replicated measurements of cotton leaf water potential were taken biweekly during the season. Pistachio trunk diameter was measured at the end of the season. Leaf tissue was analyzed for Ca, Mg, Na, Cl, B, N, P, K (pistachio) and petiole NO3, P, K and B (cotton) mid-season. Cotton lint yield and quality were monitored for all plots.

**Data analysis:** All data was tested for significance using 2-way ANOVA for a completely randomized block design.

## RESULTS AND DISCUSSION

2004 cotton yield was excellent at around 4 bale/ac (Table 1). In 2005, all cotton yields were disappointing at around 2 bale/acre due to a very cold spring. Yields were unaffected by irrigation water salinity. Comparison of digital aerial analysis of the Normalized Difference Vegetation Index (NDVI) for August 2004 and 2006 showed no treatment impacts on crop vigor across the field. However, 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). Again, cool spring temperatures combined with significant increased seedbed salinity in the Well treatment (ECe of 8 to 11, Figure 4) reduced plant population and early season vigor.

Table 1. Plant tissue nutrients, selected salts, growth characteristics, yield and applied salts for cotton and pistachio.

| PLANT TISSUE ANALYSIS | Na (ppm) | Cl (%) | B (ppm) | Root-zone $EC_e$ to 5 ft (dS/m) | [1]Cotton Ht, Pistachio Circum (inch) | Cotton Lint Yield (lb/ac) | [2]Total Salts Applied in Irrigation (lb/ac) |
|---|---|---|---|---|---|---|---|
| **2004** | **Cotton Petioles 8/27** | | | **10/6/04** | **9/14/04** | **10/6/04** | **Cotton'04** |
| **Aque** | 570 | 2.58 | 34 | 2.71 | 42.2 | 1933 | 2,343 |
| **50/50** | 712 | **3.23 | 37 | *4.08 | *35.8 | 1928 | 11,390 |
| **Well** | 574 | *3.00 | 37 | *4.68 | 38.8 | 2016 | 21,444 |
| **2005** | **Cotton Petioles 9/15** | | | **10/18/05** | **9/15/05** | **10/19/05** | **Cotton'05** |
| **Aque** | 605 | 2.71 | 42 | 1.42 | 41.6 | 954 | 2,305 |
| **50/50** | 539 | *3.13 | 46 | 3.71 | 43.1 | 1129 | 10,144 |
| **Well** | 546 | **3.38 | **50 | *4.74 | 42.1 | 999 | 16,975 |
| | **Pistachio Leaves 9/15** | | | **10/18/05** | **10/19/05** | | **Pistach'05** |
| **Aque** | 222 | 0.27 | 194 | 2.87 | 2.31 | | 1,742 |
| **50/50** | 220 | 0.27 | **492 | 4.12 | 2.17 | | 8,570 |
| **Well** | 314 | **0.38 | **673 | *4.44 | 2.18 | | 14,782 |
| **2006** | **Cotton Petioles 9/21** | | | **10/30/06** | **9/21/06** | **10/27/06** | **Cotton'06** |
| **Aque** | 885 | 1.95 | 48 | 1.01 | 44.9 | 1835 | 1,967 |
| **50/50** | 937 | 1.91 | 55 | *3.61 | 45.0 | 1615 | 11,046 |
| **Well** | 1143 | 2.21 | *56 | **4.63 | 40.9 | *1560 | 15,832 |
| | **Pistachio Leaves 10/31** | | | **10/30/06** | **10/19/06** | | **Pistach'06** |
| **Aque** | 171 | 0.52 | 531 | 2.65 | 2.58 | | 1,022 |
| **50/50** | 140 | *0.58 | **954 | 4.34 | 2.55 | | 8,994 |
| **Well** | 201 | *0.62 | **1096 | *4.61 | 2.49 | | 11,104 |
| **2007** | **Pistachio Leaves 6/19** | | | | **10/18/07** | | **Pistach'07** |
| **Aque** | 99 | 0.24 | 167 | | 4.65 | | |
| **50/50** | 108 | 0.28 | **315 | | 4.59 | | |
| **Well** | *133 | 0.30 | **384 | | 4.45 | | |

*Significantly different from Aqueduct @ 0.05, **Significant @ 0.01
[1]Cotton height @ irrigation cuttoff.
[2]Cotton cover = 12.7 foot width/tree row Pistachios = 9.3 foot width/tree row

Plant tissue analysis showed a significant 0.5 to 3 fold increase in chloride and boron levels in both cotton and pistachio (Table 1), but produced no toxicity symptoms in 2005. Some marginal burn was seen in the Well treatment in 2006. In 2007, some marginal leaf burn could be seen in all treatments, but did not seem to impact scaffold development or rootstock circumference. Due to small caliper rootstocks at planting and extremely high July 2005 temperatures, a significant number of trees needed to be rebudded Fall 2005 so that only 40% of the PG1 and 4% of the UCB trees had a full set of Kerman scaffolds by the end of 2006.

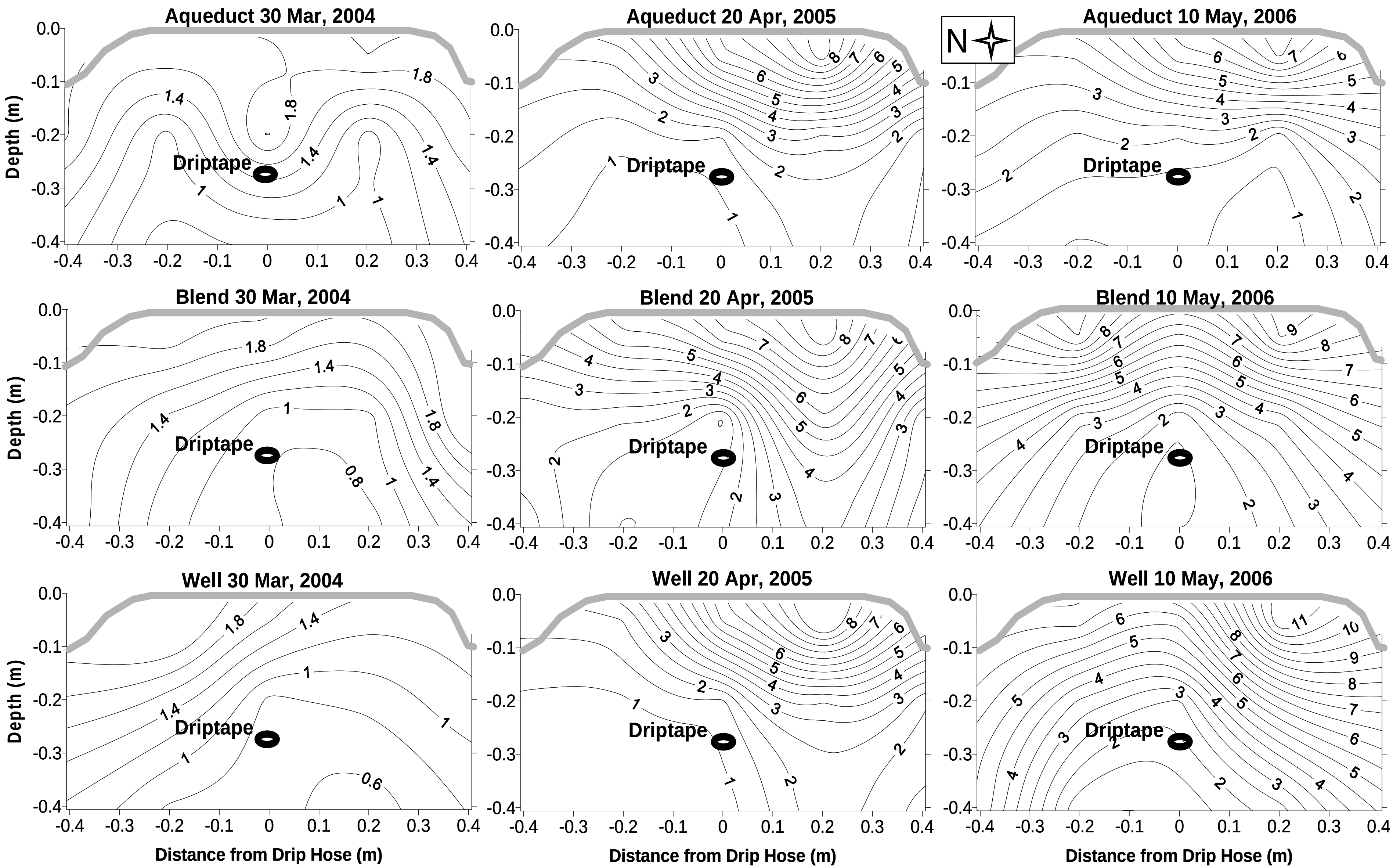



Fig. 4. Contours of saturation extract **soil salinity (ECe, dS/m)** in **cotton** beds (0.96m, 38 inches) at emergence after spring recharge and post-plant irrigation of 200 mm (8 inches) low salinity canal water (Aqueduct, 0.5 dS/m). Kerman rootstock planted 5-11 March, 2005 following cotton irrigated with the same treatment waters.

UCB rootstocks, however, were significantly larger than the PG1 rootstocks, but this difference has disappeared as of the end of this third season of 2007 (Figure 5). Scaffold development is complete on all trees (save a few replants), but the orchard as a whole is behind on development of tertiary branches stemming from the primary scaffolds. This is partially the result of two years of interplanted cotton, and the main reason why interplanting new orchards is rarely seen anymore. However, pistachios do not come into commercial bearing until their 7th year; allowing more time for this orchard to "catch up".

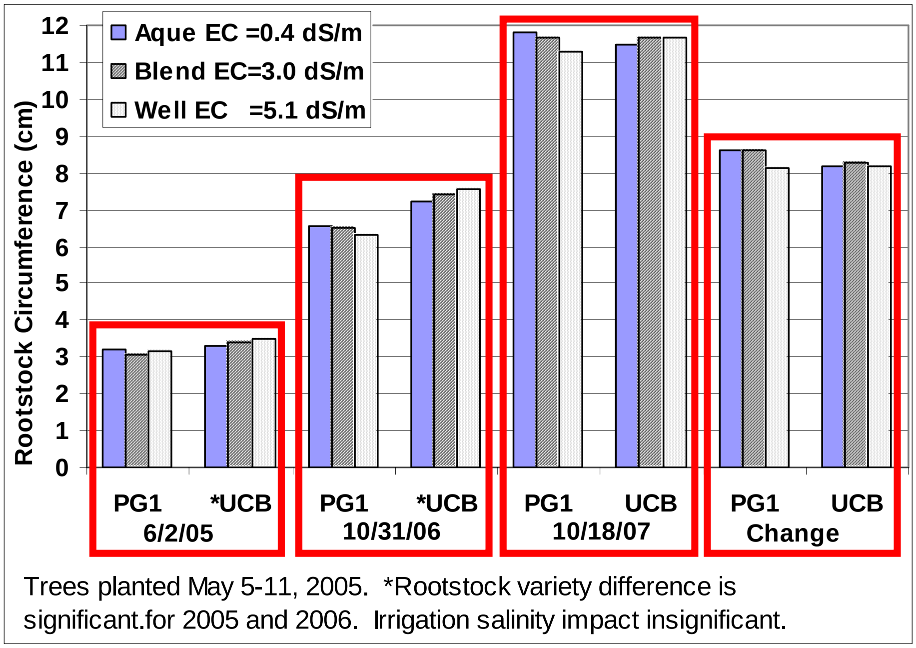



Fig. 5. Mean circumference for PG1 and UCB rootstocks from 40 trees (10 per plot) for all treatments and net increase after three seasons.

After three seasons of cotton irrigation this program results in about 6,600 lb/ac applied salt in the Aqueduct treatment and about 54,000 lb/ac in the Well treatment (Table 1). The final salt load in the 9 foot band along the pistachio drip tape after 3 years will be about 4,000 and 40,000 lb/ac for the Aqueduct and Well treatments, respectively. Total salt loads applied to pistachios would only be half of this if cotton had not been interplanted for the first two years as the cotton pulled substantial amounts of water from the pistachios. Net leaching from the pistachio rootzone is estimated at 5 to 20%.

The current trial is scheduled to run through 2008. Given sufficient funding, the pistachios will be monitored at least until 10 years of age (2014).

## CONCLUSIONS AND PRACTICAL APPLICATION

The final verdict is not yet in on the long-term viability of this project. In addition, only sites with sufficient drainage allowing a 15 to 25% leaching fraction will be suitable for this strategy. But if proven successful, the eventual savings in water costs will be about $120/acre for mature tree ET. This equals $37,000/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. At this writing there are about 4,000 additional acres of pistachios planted or scheduled for 2007 in Buttonwillow and NW Kern County on saline ground with marginal well water that would not have been developed three years ago. Between marginal groundwater and blended drain water there is more than 150,000 ac-ft/year of additional "alternative" water supply on the Westside that appears suitable for pistachios. 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.

## LITERATURE CITED


Ayars, J.E., R.B. Hutmacher, R.A. Schoneman, S.S. Vail, T. Pflaum. 1993. Long term use of saline water for irrigation. Irrigation Science 14(1):27-34.

Ayers, R.S. and D.W. Westcott. 1985. Water quality for agriculture. United Nations FAO Irrig & Drainage Paper No. 29, Rev.1.

Fardooel, A.R. 2001. Evaluation of salt and drought resistance of two pistachio species (Pistacia chin-up and P. musica) in terms of growth and ecophysiological characteristics. Ph.D. dissertation. University of Ghent, Belgium.

Ferguson, L., B. Sanden, S. Grattan, 2003. Salinity tolerance of pistachio rootstocks. Annual Report, UC Salinity/Drainage Program Water Resources Center and Prosser Trust, 2002-2003, pp. 13-27.

Ferguson, L., P.A. Poss, S.R. Grattan, C.M. Grieve, D. Want, C. Wilson, T.J. Donovan and C. T. Chao. 2002. Pistachio rootstocks influence scion growth and ion relations under salinity and boron stress. J. Amer. Soc. Hort. Sci. 127(2):Pp.194-1999.

Fulton, A.E., J.D. Oster, B.R. Hanson, C.J. Phene, and D.A. Goldhamer. 1991. Reducing drainwater: Furrow vs. subsurface drip irrigation. California Agriculture 45(2):4-7, March/April 1991.

Sanden, B.L., L. Ferguson, H.C. Reyes, and S.C. Grattan. 2004. Effect of salinity on evapotranspiration and yield of San Joaquin Valley pistachios. Proceedings of the IVth International Symposium on Irrigation of Horticultural Crops, Acta Horticulturae 664:583-589.

Shennan, C., S.R. Grattan, D. M. May, C. J. Hillhouse, D. P. Schactman, M. Wander, B. Roberts, S. Tafoya, R. G. Burau, and L. Zelinski. 1995. Feasibility of cyclic reuse of saline drainage in a tomato-cotton rotation. J. Environ. Qual. 24 (3):476-486.