Potential for utilizing blended drainage water for irrigating west side, San Joaquin Valley pistachios

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SUMMARY – Pistachios grown on the west side sometimes experience insufficient irrigation during years of drought. Saline drainage water from other crops is a potential supplemental water source for saline tolerant crops in drought years as well as an inexpensive alternative during non-drought years. However, before the pistachio industry starts using previously unacceptable irrigation water the salt tolerance of California's commercial pistachio rootstocks needs assessment. Our results through 1999 demonstrate that six sequential seasons of irrigation with 8 dS/m water produced no significant effect on marketable yield of trees grown on the four major commercial California pistachio rootstocks. Two sequential seasons of irrigation water with 12 dS/m significantly decreased yield as follows. In 1997, trees grown on UCB-1 rootstocks had a 19% decrease in marketable yield and trees on Atlantica rootstocks had a 14% decrease, trees on PGI and PGII rootstocks had no decrease in yield. In 1998, trees grown on UCB-1 rootstocks had a 49% decrease in marketable yield, trees on Atlantica rootstocks had a 19% decrease, trees on PGII an 18% decrease, and trees on PGI a 14% decrease in marketable yield. In 1999, yields dropped sharply as a result of alternate bearing, making yield comparisons useless.

Key words: Pistachio, rootstocks, saline irrigation.

RESUME – *"Potentiel d'utilisation d'eau de drainage mélangée pour l'irrigation des pistachiers de la partie occidentale de la Vallée de San Joaquin". Les pistachiers cultivés dans la partie occidentale souffrent parfois d'une irrigation insuffisante pendant les années de sécheresse. Les eaux de drainage salines provenant d'autres cultures sont une éventuelle source d'eau supplémentaire pour des cultures résistantes à la salinité pendant les années de sécheresse ainsi qu'une alternative non onéreuse pendant les années de non sécheresse. Cependant, avant que l'industrie des pistaches ne commence à utiliser une eau d'irrigation qui était auparavant inacceptable, il est nécessaire d'évaluer la tolérance à la salinité des porte-greffes commerciaux de pistachiers de la Californie. Nos résultats sur l'année 1999 montrent que six saisons séquentielles d'irrigation avec 8 dS/m d'eau ne produisaient pas d'effet significatif sur la production commercialisable des arbres cultivés sur les quatre principaux porte-greffes commerciaux de la Californie. Deux saisons séquentielles d'eau d'irrigation avec 12 dS/m avaient fait baisser le rendement de façon significative, comme suit. En 1997, les arbres cultivés sur porte-greffe UCB-1 présentaient une baisse de 19% du rendement commercialisable, les arbres sur porte-greffe Atlantica avaient une baisse de 14%, et les arbres sur porte-greffe PGI et PGII ne montraient pas de diminution de rendement. En 1998, les arbres sur porte-greffe UCB-1 présentaient une baisse de 49% du rendement commercialisable, les arbres sur porte-greffe Atlantica avaient une baisse de 19%, les arbres sur PGII une diminution de 18%, et les arbres sur PGI une baisse de 14% du rendement commercialisable. En 1999 les rendements avaient baissé brusquement comme résultat de production alternante bearing, rendant ainsi inutiles les comparaisons.*

Mots-clés : *Pistachier, porte-greffes, irrigation saline.*

Procedures

Saline irrigation

In 1997 through 1999, an attempt was made to better determine yield reduction as a function of soil salinity for three sequential seasons by increasing one of the irrigation treatments ECw to 12 dS/m. The ECw 6.0 dS/m irrigation treatment was eliminated and the 2 dS/m irrigation treatment was converted to a 12.0 dS/m irrigation treatment.

Four saline irrigation treatments with ECw values of 0.5, 4.0, 8.0 and 12.0 dS/m were randomly replicated five times across 20 rows within a 400 tree pistachio rootstock trial randomly partitioned into four rootstock sets established at Paramount Farms, Kern County, in 1989. The experiment was conducted on 80 female 'Kerman' trees (5 sets of 20 trees) budded onto four rootstocks: *P. atlantica* (Atlantica), *P. integerrima* (PGI), and *P. atlantica* x *P. integerrima* (PGII and UCB-1). Female trees were established with buds from one female tree, thus differences among trees should be the result of rootstock influence as all the scions are genetically identical. The soil type at this field site, located approximately 15 miles southwest of Kettleman City, CA, has been classified as a fine sandy loam, mixed, thermic Typic Haplargid.

Two high salt concentration nurse tanks one at 0.3 lbs/gal sodium sulfate and the other at 0.2 lbs/gal calcium chloride were used as salt water sources for creating saline treatments. Salt treatments were injected from each high salt concentration nurse tank using an impeller pump into a manifold equipped with flowmeters and then at differential rates into four sets of irrigation lines pressurized at 22 psi with canal water to produce the desired salinity treatment levels as measured with a portable EC meter. One irrigation line, the control treatment which was California Aqueduct canal water, received no salt injection. Each of the five irrigation lines were equipped with water meters to measure seasonal irrigation delivery. Each of the five irrigation lines appeared as headers at each of the twenty rows of trees to provide source outlets for drip irrigation lines to achieve the appropriate salinity treatment replication. Existing irrigation lines were plugged and new 240° fan-jets were installed four feet from trunks of treatment trees with the water outlet pattern being directed back towards the trunk. Irrigations were scheduled using historical evapotranspiration data. Field samples of irrigation water were collected in 400 ml containers over the course of each irrigation in order to determine water quality.

Fertilization, pest, disease, pruning and harvest practices were performed on the rootstock trial block as a whole and are consistent with commercial farming practices. Individual tree trunk growth, yield and yield components were determined on all trees. Soil samples were collected before the irrigation season in April and after the irrigation season in November of each growing season. Additionally, leaf tissue, root tissue, rootstock trunk tissue, and scion trunk tissue were collected for nutritional analysis. Tissue, water and soil analysis were conducted using established laboratory procedures as utilized by the Division of Agriculture and Natural Resources Laboratory in Davis, CA. Yield components were evaluated from 0.75 pound sub-samples from each of the 100 trees.

Tree water status measurement

Tree water status by midday, bagged leaf water potentials was measured prior to each irrigation, when trees should be most stressed. Tree water status was measured by bagging one leaf from each tree of three replications of each rootstock-saline irrigation treatment combination. Bags were constructed from black polyethylene and aluminum foil with the intent of excluding measured leaves from light and micrometeorological environments. Leaves were bagged at 1100 Pacific Standard Time, then removed one hour later for water potential determination using a Scholander type pressure vessel. All leaves were selected based upon similar age and canopy position.

Siting of neutron probe access tubes, replication and measurement of soil water content

Using a measurement of the backscatter of thermalized (slowed) neutrons, the neutron probe determines water content of the soil using a volume about the size of a basketball. For this study, 2" PVC Class 125 pipe access tubes have been installed to allow for repeated measurements of soil water content from 0.5 to 5 feet in one foot increments. One neutron probe access tube has been installed to a depth of 5.5 feet on every tree in the trial in approximately the same location relative to the trunk and the opposing fanjet; about 4 feet east of the trunk, 4.5 feet west of the fanjet and 1.5 feet south of the hose. This places the access tube in an area that represents average to slightly better than average application of irrigation water. This wetted area, and the subsurface redistribution of water, give the tree an active root volume of about 50% of the entire orchard floor. This means that a 1" irrigation over the whole orchard equals about 2" around the site of the neutron probe tube. Likewise, neutron probe readings that show a 2" extraction of water between irrigations represents about 1" of tree water use as transpiration over the whole orchard.

With only one neutron probe access tube per tree there is insufficient monitoring to exactly determine evapotranspiration (ET) for a given tree. The spatial distribution of tree roots and the precipitation pattern of the fanjet result in different rates of water application and subsequent tree uptake throughout the rootzone of a given tree. For this study, to get the most comparative information possible across all treatments, we have measured soil water content to maximize replication across the most trees instead of opting for complete ET estimates using many tubes on only a few trees. The assumption is that the location of the neutron probe tube represents an equal water application and extraction opportunity for each tree – providing a relative comparison suitable for statistical analysis. The results reported have been generated from neutron probe data taken from 3 replications times 4 rootstocks times 4 levels of salinity; a total of 48 tubes.

Photosynthetic gas exchange measurements

A Licor LI-6400 portable photosynthesis system was used to measure gas exchange of individual tree leaves monthly June through August. The reference CO_2 was set at 400 ppm. The PAR (photosynthetically active radiation) level was 1500 microeinsteins. Sample relative humidity was maintained at 55% ± 5%. The flow rate was maintained at 500 micromoles and adjusted as required. Sample leaves were mature and fully expanded and selected for maximum sun exposure and height. The same sample leaves were used each time and measured at the end of the irrigation cycle, immediately prior to the next irrigation. Measurements were made between 09:00 and 15:00 hours.

Results and discussion

Effect of saline irrigation on yield

As can be seen from Table 1, when using marketable yield as an indicator of salinity tolerance, trees grown on all four rootstocks appear tolerant of irrigation water with salinities through 8 dS/m. When irrigation water salinity was higher yield decreased in trees on all four rootstocks. In the first year of irrigation with 12 dS/m water, 1997, there were slight but significant decreases in yield relative to 0.5 dS/m controls in trees grown on Atlantica and UCB-1 rootstocks. This significant decreases in yield were larger, and present in trees grown on all four rootstocks by 1998, after two years of irrigation with 12 dS/m water. Through 1998 the relative salinity tolerance ranking of the four rootstocks is as follows; PGI = PGII > Atlantica > UCB-1. Unfortunately, in 1999 sharp yield decreases produced by alternate bearing rendered the data useless as an indicator of tree productivity as affected by irrigation water salinity.

Table 1. Effect of irrigation water salinity level on the marketable yield (kg of dry inshell split nuts per tree) of trees on four different pistachio rootstocks

Rootstock	Irrigation water salinity (dS/m)											
	0.5			4.0			8.0			12.0†		
	1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999
Atlantica	6.0 a	8.4 a	0.2 a	6.1 a	7.6 ab	0.5 a	6.5 a	8.3 a	0.7 a	5.2 B	6.9 b	0.7 a
PGI	7.6 a	11.9 a	1.7 a	8.6 a	9.0 b	3.4 a	8.1 a	10.8 b	2.3 a	7.7 a	10.3 b	0.7 a
PGII	6.5 b	10.8 a	0.3 a	7.8 a	10.9 a	0.4 a	8.1 a	10.8 a	1.2 a	6.7 b	9.0 b	1.2 a
UCB-1	6.3 b	11.9 a	0.5 a	8.2 a	12.3 a	0.8 a	8.8 a	10.9 a	0.4 a	5.1 c	6.1 b	0.3 a

†12 dS/m irrigation was only applied for 1997 through 1999 seasons.
[a,b,c]Values within a rootstock row for a given year followed by the same letter are not significantly different.

A preliminary, parallel salinity tolerance tank trial was conducted in 1999. The objective was to corroborate this field trial in terms of salinity limits and rootstock tolerance ranking. The rationale for conducting this trial was to counter the possibility, in the field trial, that tree roots were proliferating outside the saline irrigation zone, thus producing invalid, positive salinity tolerance limits. This preliminary tank trial corroborated the salinity tolerance limit of 8 dS/m. However, the salinity tolerance of the rootstocks in the tank trial ranked in the opposite order. From most to least tolerant they ranked Atlantica > UCB-1 > PGI. PGII was dropped from the tank trial as no longer commercially viable.

We suspect experimental conditions are producing the apparent conflict in rootstock ranking of salinity tolerance. As the discussion below demonstrates even though the cumulative applied water for all four saline irrigation treatments closely approximated California Irrigation Management Information Systems (CIMIS) ET there were significant, and increasing, differences in cumulative seasonal transpiration and percent available soil moisture through the season among the four salinity treatments. Consistently, as salinity level rose, water extraction and evapotranspiration by the trees decreased. This suggests that, even through the appropriate amount of water was applied for budget irrigation, the differential soil salinities were preventing efficient water extraction, resulting in decreased cumulative seasonal transpiration. Interestingly, these differences were not reflected in tree water status as measured by midday tree water potential readings. An attempt to further define tree function by measuring photosynthetic efficiency produced no significant differences either.

Effect of saline irrigation treatments on soil water content, plant stress and tree water use

The following discussion addresses only different salinity level impacts averaged over all rootstocks. This provides 12 replicates of soil water content data for each salinity level. For the sake of clarity, the following figures show the mean value for each salinity level over the season. A full statistical analysis will be performed at a later date.

Irrigations during the season were scheduled using normal year CIMIS potential evapotranspiration (ET_0) multiplied by pistachio crop coefficients determined in a previous study by Goldhamer *et al.* (1985). Because coverage of the orchard floor is about 50% in this young orchard, crop ET was further discounted to 90% of a mature orchard (Snyder *et al.*, 1989). Irrigation was timed to match this demand with the same depth applied to all salinity treatments. Separate flowmeters record the application depth for each treatment. Figure 1 shows pistachio ET for the 1999 season calculated by using the real time 1999 CIMIS ET_0 at the Shafter Field Station multiplied by the appropriate crop coefficient for that time of year along with individual treatment irrigation depths. CIMIS ET_0 from the Shafter Field Station was used instead of Lost Hills or Dudley Ridge due to the quality of data and weather station siting. In general, application depths matched calculated ET fairly well. Total application in the higher salinity treatments appears to be slightly less than the 0.7 dS/m treatment; probably due to some precipitation of calcite around fanjet nozzles and, I suspect, some decline in meter accuracy due to some marginal calcite precipitation in the meters. Pressure to the hoses in all treatments was identical. Ignoring possible meter inaccuracies, the low salinity treatment received 102% of calculated ET and the 12 dS/m treatment received 85%.

Midday bagged leaf water potentials showed no real difference in apparent stress between any salinity level (Fig. 2). This appears to support the idea that irrigation scheduling was appropriate for all treatments and that plant stress and transpiration was unaffected by salinity. Bagged leaf water potential is an indicator of overall trunk water potential. Theoretically, identical water potential measurements in different trees should indicate identical levels of stress for the whole tree and provide the energy to drive similar rates of transpiration. This may not be the case for pistachio physiology. Preliminary data from first year tank trials on grafted pistachio rootstocks at the USDA Salinity Lab in Riverside showed significant differences in the stomatal conductance of leaves as salinity increased. The stomates are going to be one of the main controlling factors in determining actual transpiration. Stomatal conductance may track more closely with *unbagged* leaf water potential and provide better correlation with average tree stress and transpiration at higher salinity levels.

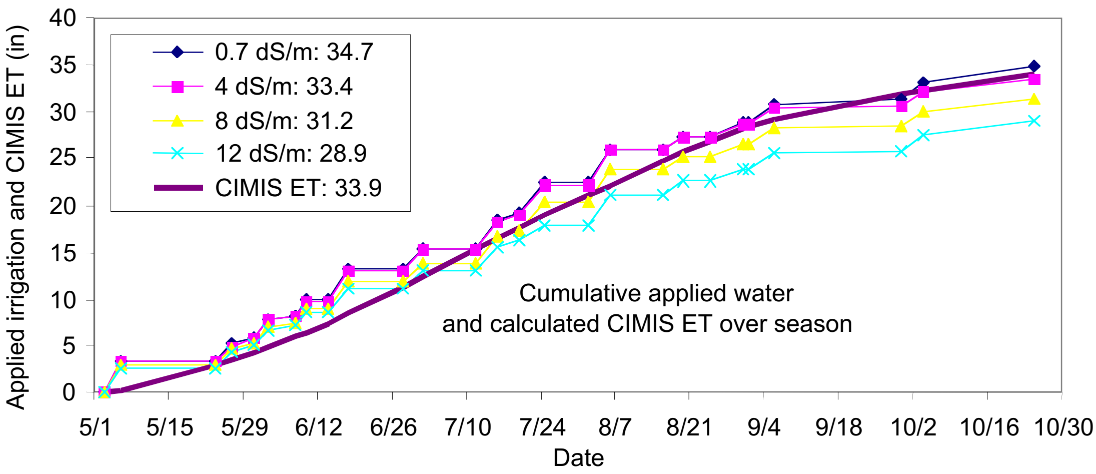

Fig. 1. Cumulative seasonal applied irrigation water to all treatments and calculated pistachio ET using 1999 CIMIS ET_0 as measured at the Shafter Field Station multiplied by crop coefficients described by Goldhamer (1987).

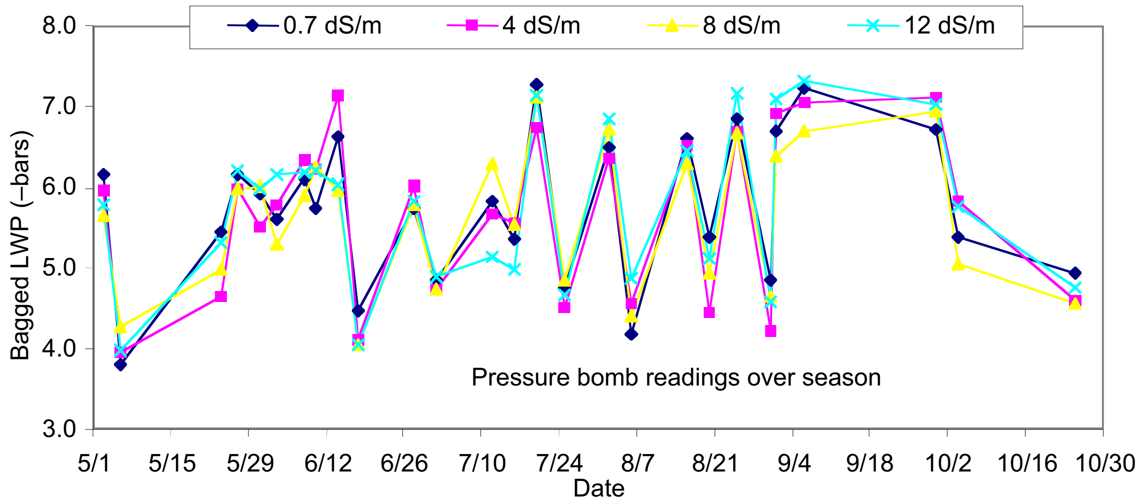

Fig. 2. Midday bagged leaf water potentials over season.

Figure 3 reveals major differences in rootzone soil water content beginning in July with the 12 dS/m treatment remaining at or above field capacity for the entire season and the fresh water treatment (0.7 dS/m) declining to 40% after harvest. The 4 dS/m treatment remained around 80% field capacity at season's end. This corroborates the idea that the bagged leaf water potential is not providing an accurate indication of tree water use. It also indicates that the depth of irrigation in the low salinity treatment was insufficient to meet all the ET demand for these trees; causing excessive extraction of available soil water. The maintenance of near 100% field capacity in the higher salinity treatments means that some leaching is occurring in these treatments.

It is possible that the more negative soil matric potential (the soil holding the water more tightly) caused by lower available soil water in the 0.7 dS/m treatment could cause a similar bagged leaf water potential resulting from the osmotic stress caused by the salt in the 8 and 12 dS/m treatments. But it is clear that this measurement is inadequate for estimating the very large differences that were found this season in actual tree transpiration (Fig. 4).

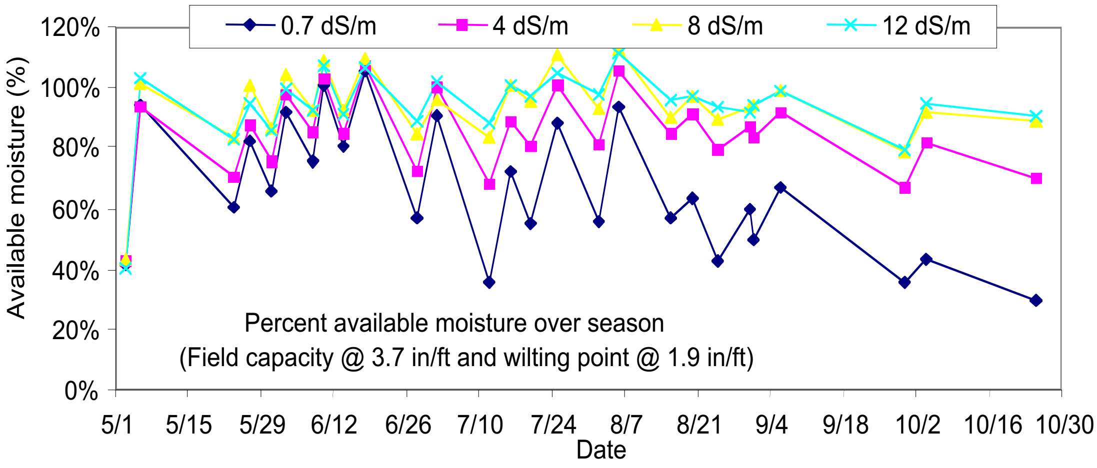

Fig. 3. Percent available water for all treatments from 0.2 to 5.2 foot depth. Calculated using field capacity at 3.7 in/ft, 18.5 inches total over 5 feet, and wilting point of 1.9 in/ft, 9.5 inches total over 5 feet. Total available water at 100% = 9.0 inches.

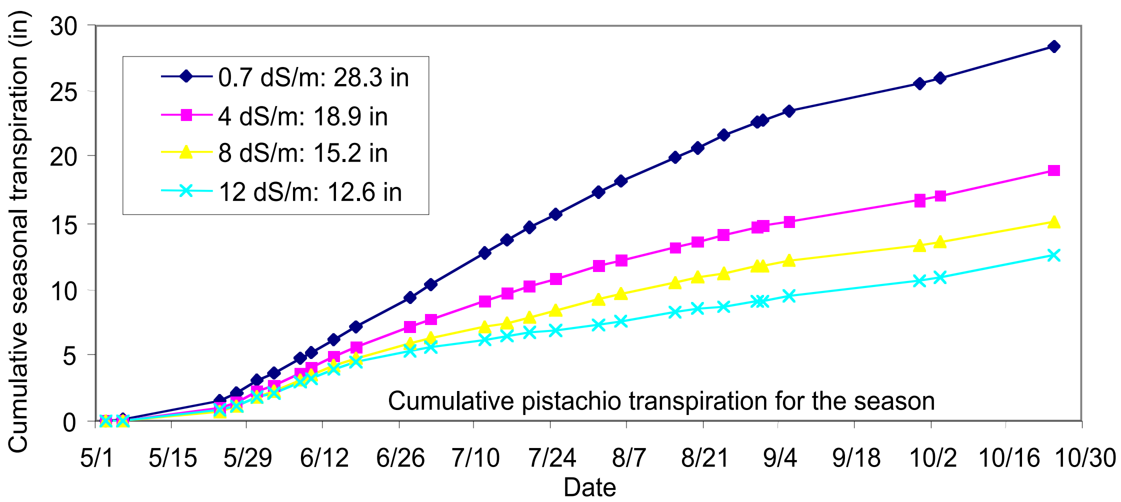

Fig. 4. Comparative seasonal transpiration for all treatments as determined by soil water content depletion between irrigations.

Actual comparative treatment transpiration was calculated by measuring the soil water depletion in between irrigations. Since the wetted volume from the fanjets is only 50% of the entire orchard floor, net depletion of soil water in the area of the neutron probe tubes is then multiplied by 0.5 to estimate transpiration over the whole orchard floor. Thus, a 3 inch average depletion would mean 1.5 inches of transpiration. Water consumption in Fig. 4 is reported as transpiration and not evapotranspiration because the neutron probe is incapable of accurately measuring water content changes in the top three inches of soil; the zone from which most evaporative water loss will occur. This means that the depletion measured between irrigations is either extraction by the tree (transpiration), or leaching. Nearly all measurements of depletion for this season consisted solely of transpiration as we waited two to five days after an irrigation before making the initial soil water content measurement, with the subsequent measurement immediately before the next irrigation.

This depletion measured by the neutron probe is multiplied by 0.5 and then divided by the actual CIMIS ET_0 for that same period. This calculated crop coefficient value (K_c) for each treatment is then multiplied by the CIMIS ET_0 during the following irrigation interval to estimate the treatment transpiration during that period. This provides a continuos cumulative estimate of crop transpiration over the season.

Transpiration for the low salt treatment, at 28.3 inches, when subtracted from the 34.7 inches applied, leaves 6.4 inches for evaporation and leaching. Given the soil moisture status shown in Fig. 3 we can assume that leaching in this treatment was minimal. If we assume that about 6 inches of irrigation went to evaporation over the season and transpiration in the 12 dS/m treatment was only 12.6 inches with applied water to this treatment at 28.9 inches, then about 10 inches of water went to leaching. This is not at all bad in that a high leaching fraction is essential for these salt loads to minimize buildup in the rootzone.

It has taken several years to bring the rootzone of these different treatments into a somewhat steady-state salinity level that resulted in this type of water uptake for 1999. With poor conditions during pollination and the poor fruit set of the crop it is impossible to say what long-term effect this restricted transpiration will have on future yields. Carbohydrate production is absolutely dependant on crop transpiration for the uptake of CO_2. The leaves on pistachio trees in the higher salt treatments did not visually appear more stressed than the low salt. Future availability of carbohydrates, however, will be affected in some manner.

Effect of saline irrigation treatment on photosynthetic efficiency

Because midday bagged leaf water potentials did not demonstrate any significant difference in tree water status, gas exchange measurements, more accurate indicators of tree stress, were attempted. The results are give in Tables 2-10. Tables 2-7 give the photosynthetic rate, stomatal conductance, transpiration, leaf internal CO_2, the ratio of leaf internal CO_2 to ambient CO_2 and the ratio of photosynthesis to stomatal conductance for the four rootstocks at the five salinity levels monthly June through August. Tables 8 and 9 give the averages of the same four measurements and two ratios for the entire season. Table 10 gives the monthly and average seasonal water use efficiency (photosynthesis/transpiration) for the season. As with the bagged midday leaf water potentials there are few significant differences within each rootstock among the five salinity treatments. By these measurements the trees are not displaying any stress. This is consistent with the appearance of leaves of trees on all four rootstocks at all five salinity levels, and with the results of bagged midday leaf water potential measurements. However, this is not consistent with the calculated transpiration levels at each salinity level. The calculated transpiration levels given in Fig. 4 are generally those associated with stressed trees. Perhaps the lack of crop, due to alternate bearing, renders the trees more able to withstand decreased water uptake. This work will be repeated in 2000. Perhaps the presence of crop will precipitate measurable differences in tree water status at salinities above 8 dS/m, the salinity level at which decreases in crop manifested in 1998.

Conclusions and practical applications

In summary, 1994 through 1998 results of this field trial have demonstrated irrigation water salinity above 8 dS/m can significantly decrease yield of pistachios grown on all four rootstocks tested. Based on this field trial, which used marketable yield as an indicator of salinity tolerance, the rootstocks ranked as follows, from least to most saline tolerant: UCB-1, Atlantica, PGII and PGI. However, the lack of measurable credible yields in 1999, due to severe alternate bearing make this data incomplete.

There are two major conclusions, in addition to the results discussed above, to be drawn from the 1999 field trial results. First, the field trial must be continued through 2000, or longer, if 2000 yields are not more credible and measurable than those of 1999.

Acknowledgements

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Table 2. Summary of photosynthesis, stomatal conductance and transpiration survey of pistachio trees at Lost Hills in June 1999. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	Photosynthesis (mol $CO_2/m^2/s$)				Stomatal conductance (mol/m^2/s)				Transpiration (mmol/m^2/s)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	26.8 a	24.1 a	22.1 b	20.4 a	0.51 a	0.46 a	0.45 a	0.37 a	9.22 a	9.18 a	9.06 a	7.77 b
4.0	23.0 a	24.2 a	27.1 a	24.8 a	0.40 a	0.47 a	0.63 a	0.58 a	9.08 a	9.80 a	11.1 a	11.3 a
8.0	23.3 a	21.2 a	24.0 ab	22.6 a	0.42 a	0.44 a	0.49 ab	0.49 a	8.73 a	9.32 a	9.36 a	9.54 ab
12	23.5 a	24.8 a	23.3 ab	25.9 a	0.40 a	0.45 a	0.43 b	0.57 a	8.86 a	9.14 a	9.09 a	10.4 ab
LSD	5.44	3.94	4.00	6.13	0.18	0.17	0.18	0.30	1.93	2.06	2.27	3.12

[a,b]Means with same letter in column are not significantly different (= 0.05).

Table 3. Summary of leaf internal CO_2 (C_i), ratio of internal CO_2 to ambient CO_2 (C_a), and ratio of photosynthesis (A) to stomatal conductance (g_s) survey of pistachio trees at Lost Hills in June 1999. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	Leaf internal CO_2 (C_i) (mol CO_2/mol)				C_i/C_a (mol/m^2/s)				A/g_s (mol/mol)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	249 a	254 a	268 a	253 a	0.68 a	0.69 a	0.72 a	0.68 a	56.4 a	55.4 a	49.1 ab	59.9 a
4.0	244 a	258 a	266 a	268 a	0.67 a	0.70 a	0.74 a	0.74 a	60.7 a	51.8 a	44.3 b	44.2 a
8.0	254 a	269 a	265 a	266 a	0.67 a	0.73 a	0.72 a	0.72 a	55.1 a	48.1 a	48.5 ab	49.2 a
12	247 a	251 a	253 a	268 a	0.69 a	0.69 a	0.69 b	0.74 a	59.0 a	55.6 a	56.5 a	45.6 a
LSD	12.4	20.1	8.99	26.8	0.043	0.061	0.029	0.083	10.1	14.1	8.70	19.2

[a,b]Means with same letter in column are not significantly different (= 0.05).

Table 4. Summary of photosynthesis, stomatal conductance and transpiration survey of pistachio trees at Lost Hills in July 1999. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	Photosynthesis (mol $CO_2/m^2/s$)				Stomatal conductance ($mol/m^2/s$)				Transpiration ($mmol/m^2/s$)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	22.6 a	20.0 a	19.6 a	18.7 a	0.42 a	0.36 a	0.42 a	0.34 a	7.31 a	6.59 a	7.31 ab	6.26 a
4.0	20.3 a	21.7 a	23.3 a	21.8 a	0.38 a	0.44 a	0.47 a	0.46 a	7.00 a	7.46 a	8.06 a	7.51 a
8.0	22.7 a	19.1 a	22.8 a	19.0 a	0.42 a	0.44 a	0.47 a	0.36 a	7.58 a	7.56 a	7.85 ab	6.79 a
12	19.7 a	19.6 a	19.1 a	21.0 a	0.34 a	0.37 a	0.40 a	0.40 a	6.42 a	6.60 a	6.71 b	6.97 a
LSD	6.68	4.91	4.96	5.17	0.17	0.16	0.11	0.14	1.93	2.06	1.34	1.55

[a,b]Means with same letter in column are not significantly different (= 0.05).

Table 5. Summary of leaf internal CO_2 (C_i), ratio of internal CO_2 to ambient CO_2 (C_a), and ratio of photosynthesis (A) to stomatal conductance (g_s) survey of pistachio trees at Lost Hills in July 1999. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	Leaf internal CO_2 (C_i) (mol CO_2/mol)				C_i/C_a ($mol/m^2/s$)				A/g_s (mol/mol)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGII	PGI	UCB-1
0.75	259 a	259 a	277 a	257 a	0.70 a	0.69 a	0.74 a	0.68 a	55.9 a	58.1 a	47.8 a	60.9 a
4.0	265 a	270 a	268 a	272 a	0.71 a	0.73 a	0.73 a	0.73 a	53.9 a	50.0 a	49.3 a	48.3 a
8.0	257 a	280 a	270 a	268 a	0.70 a	0.75 a	0.73 a	0.71 a	56.8 a	45.9 a	48.6 a	53.9 a
12	257 a	267 a	268 a	264 a	0.69 a	0.72 a	0.72 a	0.71 a	60.2 a	53.8 a	53.4 a	54.1 a
LSD	17.4	23.7	11.0	19.9	0.047	0.066	0.029	0.057	11.3	15.5	6.35	12.7

[a]Means with same letter in column are not significantly different (= 0.05).

Table 6. Summary of photosynthesis, stomatal conductance and transpiration survey of pistachio trees at Lost Hills in August 1999. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	Photosynthesis (mol $CO_2/m^2/s$)				Stomatal conductance ($mol/m^2/s$)				Transpiration ($mmol/m^2/s$)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	14.9 a	13.4 b	16.2 a	9.50 b	0.30 a	0.21 c	0.32 a	0.16 b	8.32 a	6.55 c	8.86 a	5.60 b
4.0	16.2 a	19.6 a	19.2 a	18.6 a	0.31 a	0.45 a	0.43 a	0.40 a	8.60 a	10.5 a	9.98 a	9.74 a
8.0	17.4 a	13.8 b	16.7 a	14.4 ab	0.35 a	0.35 ab	0.42 a	0.32 a	9.09 a	8.96 ab	10.0 a	8.51 a
12	17.4 a	15.5 b	15.8 a	14.4 ab	0.35 a	0.28 bc	0.35 a	0.38 a	8.76 a	7.82 bc	8.91 a	8.52 a
LSD	5.37	2.71	3.94	5.98	0.14	0.12	0.15	0.17	2.26	1.86	2.56	1.97

[a,b,c]Means with same letter in column are not significantly different (= 0.05).

Table 7. Summary of leaf internal CO_2 (C_i), ratio of internal CO_2 to ambient CO_2 (C_a), and ratio of photosynthesis (A) to stomatal conductance (g_s) survey of pistachio trees at Lost Hills in August 1999. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	Leaf internal CO_2 (C_i) (mol CO_2/mol)				C_i/C_a ($mol/m^2/s$)				A/g_s (mol/mol)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PG II	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	268 a	241 b	266 b	264 a	0.72 a	0.64 b	0.71 b	0.69 a	50.7 a	69.2 a	51.4 a	58.9 a
4.0	264 a	272 a	265 b	272 a	0.71 a	0.74 a	0.72 ab	0.74 a	52.9 a	43.8 b	48.2 a	46.5 a
8.0	263 a	288 a	284 a	277 a	0.71 a	0.77 a	0.77 a	0.74 a	51.8 a	40.9 b	40.1 a	46.1 a
12	265 a	261 ab	274 ab	285 a	0.72 a	0.70 ab	0.73 ab	0.76 a	50.2 a	55.3 ab	46.9 a	41.7 a
LSD	14.1	28.4	15.7	31.9	0.037	0.077	0.029	0.084	8.59	17.7	11.6	19.0

[a,b]Means with same letter in column are not significantly different (= 0.05).

Table 8. Average of photosynthesis, stomatal conductance and transpiration survey of pistachio trees at Lost Hills performed in June, July and August 1999. Values are means and least significant differences (LSD) of 4 replications at three different times

Salinity (dS/m)	Photosynthesis (mol $CO_2/m^2/s$)				Stomatal conductance ($mol/m^2/s$)				Transpiration ($mmol/m^2/s$)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	21.4 a	19.2 b	19.3 b	16.2 b	0.41 a	0.34 b	0.40 ab	0.29 b	8.28 a	7.44 b	8.42 a	6.54 b
4.0	19.8 a	21.8 a	23.2 a	21.7 a	0.36 a	0.45 a	0.51 a	0.48 a	8.22 a	9.25 a	9.71 a	9.52 a
8.0	21.1 a	18.1 b	21.1 ab	18.7 ab	0.40 a	0.41 ab	0.46 ab	0.39 ab	8.47 a	8.61 ab	9.09 a	8.28 a
12	20.2 a	19.9 ab	19.4 b	20.4 ab	0.36 a	0.37 ab	0.38 b	0.45 a	8.01 a	7.85 b	8.24 a	8.65 a
LSD	4.50	2.06	3.41	4.40	0.12	0.10	0.12	0.16	1.41	1.23	1.62	1.65

[a,b]Means with same letter in column are not significantly different (= 0.05).

Table 9. Summary of average leaf internal CO_2 (C_i), ratio of internal CO_2 to ambient CO_2 (C_a), and ratio of photosynthesis (A) to stomatal conductance (g_s) survey of pistachio trees at Lost Hills taken in June, July and August 1999. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	Leaf internal CO_2 (C_i) (mol CO_2/mol)				C_i/C_a ($mol/m^2/s$)				A/g_s (mol/mol)			
	Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	259 a	251 b	270 a	258 a	0.70 a	0.68 b	0.73 b	0.69 a	54.3 a	60.9 a	49.4 a	58.9 a
4.0	258 a	267 a	266 a	270 a	0.69 a	0.72 ab	0.73 a	0.74 a	55.8 a	48.5 b	47.3 a	46.5 a
8.0	258 a	279 a	273 a	270 a	0.70 a	0.75 a	0.74 a	0.73 a	54.6 a	45.0 b	45.7 a	46.1 a
12	257 a	260 ab	265 a	272 a	0.69 a	0.70 ab	0.71 a	0.74 a	56.4 a	54.9 ab	52.3 a	41.7 a
LSD	9.24	19.6	9.93	21.6	0.028	0.054	0.028	0.060	6.92	12.0	7.42	19.0

[a,b]Means with same letter in column are not significantly different (= 0.05).

Table 10. Summary of water use efficiency (photosynthesis/transpiration) survey of *P. vera* trees budded on four different pistachio rootstocks at Lost Hills in June, July, August 1999 and average of the three months. Values are means and least significant differences (LSD) of 4 replications

Salinity (dS/m)	June				July				August				Average			
	Rootstock				Rootstock				Rootstock				Rootstock			
	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1	Atlantica	PGI	PGII	UCB-1
0.75	2.83 a	2.57 a	2.43 a	2.77 a	3.21 a	3.11 a	0.72 a	0.68 a	1.79 a	2.14 a	1.86 ab	1.74 a	2.61 a	2.60 a	2.34 a	2.57 a
4.0	2.44 b	2.43 a	2.43 a	2.15 b	2.98 a	2.95 a	0.74 a	0.74 a	1.89 a	1.87 ab	1.94 a	1.88 a	2.44 a	2.41 a	2.44 a	2.33 a
8.0	2.65 ab	2.23 a	2.56 a	2.45 ab	3.18 a	0.73 a	0.72 a	0.72 a	1.91 a	1.56 b	1.67 b	1.69 a	2.58 a	2.18 a	2.41 a	2.35 a
12	2.61 ab	2.70 a	2.61 a	2.49 ab	3.26 a	0.69 a	0.69 b	0.74 a	2.02 a	2.00 a	1.80 b	1.67 a	2.63 a	2.59 a	2.46 a	2.45 a
LSD	0.29	0.49	0.43	0.59	0.40	0.57	0.34	0.54	0.23	0.37	0.23	0.66	0.23	0.37	0.24	0.50

[a,b]Means with same letter in column are not significantly different (= 0.05).

References

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