Seminar

Manejo del riego y suelo en el cultivo del palto

27-28 de Septiembre de 2006

Gobierno de Chile
Ministerio de Agricultura

Instituto de Investigaciones Agropecuarias (INIA)
Institute of Agricultural Research

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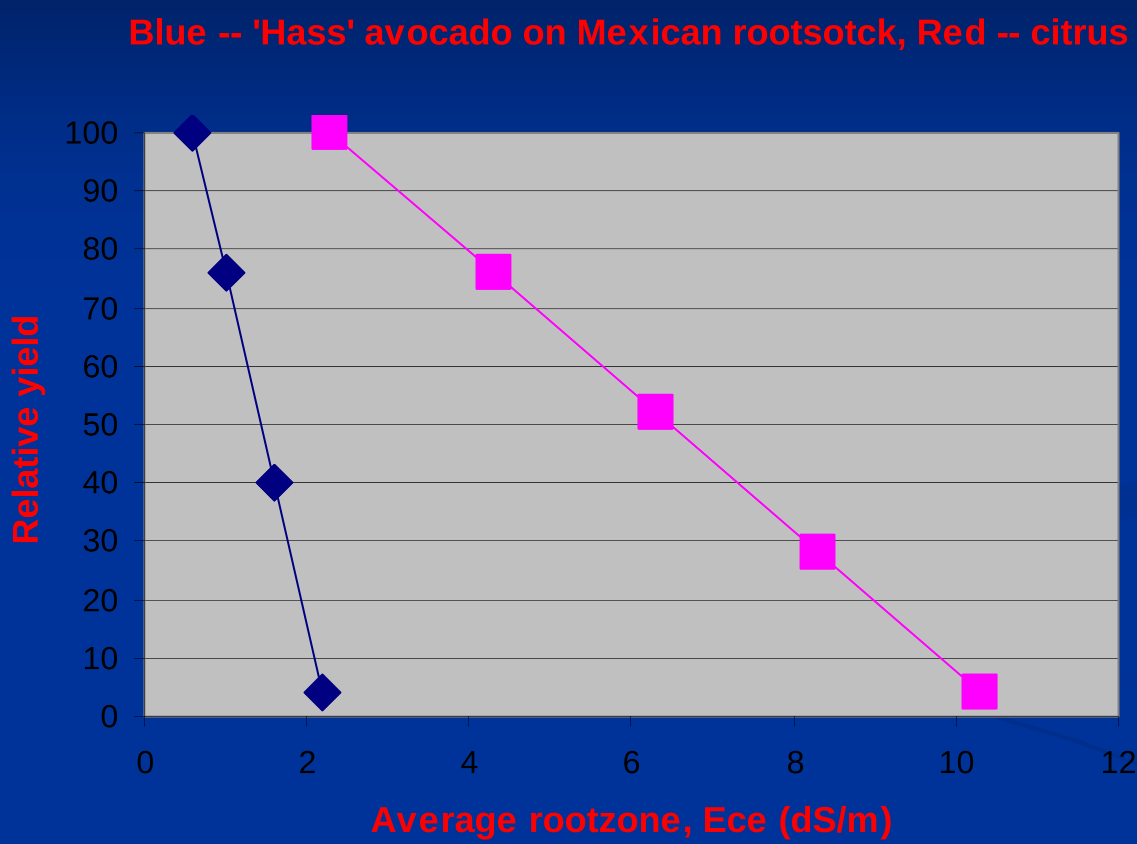
Plant response to salinity

Requires energy to make osmotic adjustments

J. Oster
University of California



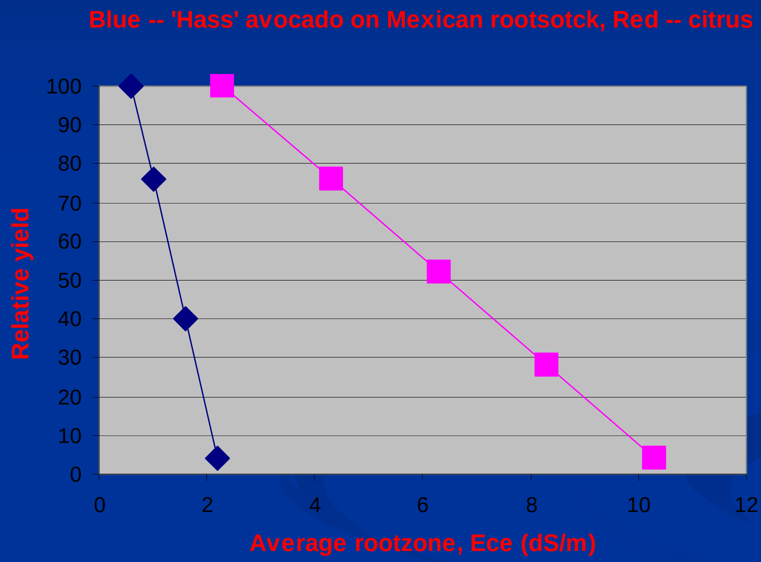
Blue -- 'Hass' avocado on Mexican rootsotck, Red -- citrus
Relative yield
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
Average rootzone, Ece (dS/m)

PLANT SYMPTOMS

– not visible – reduced growth, ET, and yield

leaf necrosis – tip burn, curled leaves –stunted seedlings

leaf drop – nude tree -dead plants



Plant physiology

- I'm a soil scientist

Plant physiology

para mi

un gran 'lomo de toro'

Anoxia – salinity interactions

Eucalyptus c.

Membrane selectivity at root-soil interface is lost

Avocados: 'Hass' seedling experiments at UCR on clonal rootstock 1998 - 2002

Osmotic or specific ion?

Osmotic adjustment via organic osmolytes
or increased salt content of leaves

Salt effects on stomatal conductance

K/Na, Ca/Na, Cl ?

Salinity-fertility interactions?

Root growth, or top growth, or both?

Does salinity trigger a specific signal for ABA
synthesis [sensitive v/v insensitive clonal
rootstock]

Rootstocks?

Avocados: 'Hass' seedling experiments at UCR

Osmotic or specific ion?
Osmotic adjustment via organic osmolytes or increased salt content of leaves
Salt effects on stomatal conductance
K/Na, Ca/Na, Cl ?
Salinity-fertility interactions?
Root growth, or top growth, or both?
Does salinity trigger a specific signal for ABA synthesis [sensitive v/v insensitive clonal rootstock]
Rootstocks?

Key mechanisms of salt injury:

None of the above?
Some of the above?
All of the above?

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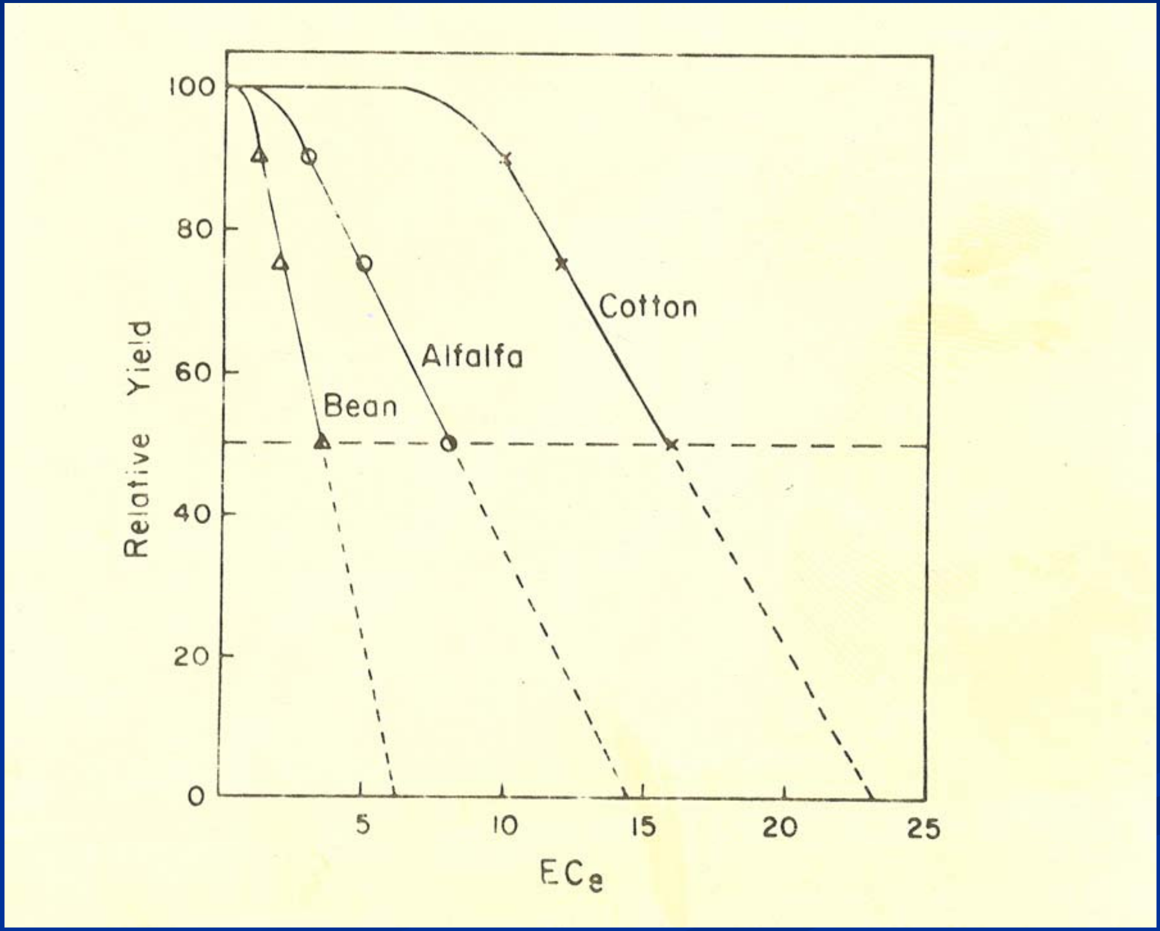
Limiting soil salinities within the rootzone

- There is an upper limit of salinity within the rootzone to which roots can absorb water (Bernstein and Francois. 1973. SSSAJ 27: 931-943; van Schilfgaarde et al. 1974. J. Irr. Dr. Div, Proc. Am Soc. Civil Eng. 100 No. IR3: 321-338).

- "In the soil layers where water loss through transpiration predominates, the maximum level of salt accumulation possible is that against which roots can still absorb water. Controlled leaching will assure that this concentration is present at the bottom of the root zone. Reducing the intensity of leaching cannot result in higher salt concentration, but in the salt accumulating at shallower depths, causing ever-decreasing rooting depth. Thus, the maximum level to which salts can accumulate in the soil depends on the salt tolerance of the crop in question, rather than on the leaching fraction (LF)." Shalhevet, 1994. Agr. Water Management 25: 233 – 241.

The lower the salt tolerance of the plant, the lower the limiting salinity



Limiting salinities correspond to relative yield of zero

ECiw was 0.5 dS/m with winter rain averaging 240 mm/y. Fertilizer – calcium nitrate applied in three splits in Feb., Mar. and Aug.

Table 4.—Electrical conductivity, millimhos/cm, of saturation extract of 0–30-inch soil horizon, 1956.

Treatment		Irrigation treatment (Maximum soil suction)		
		1/2 bar millimhos/cm	1 bar millimhos/cm	10 bars millimhos/cm
Zero-N	Jan.–Mar.	0.63	0.72	0.49
	Apr.–June	0.70	0.65	0.64
	July–Sept.	0.93	0.91	0.72
	Oct.–Dec.	1.10	0.65	0.62
	Average	0.84	0.73	0.62
Low-N (0.6 kg N/tree-y)	Jan.–Mar.	0.88	1.28	0.88
	Apr.–June	1.04	0.87	1.01
	July–Sept.	1.09	0.86	0.86
	Oct.–Dec.	0.66	0.86	0.73
	Average	0.92	0.97	0.87
High-N (1.4 kg N/tree-y)	Jan.–Mar.	1.29	1.48	1.59
	Apr.–June	1.57	2.12	1.71
	July–Sept.	1.80	1.94	3.13
	Oct.–Dec.	1.52	1.99	2.34
	Average	1.55	1.88	2.19

Bingham and Richards. 1958. Am. Soc. Hort. Sci. 71:304 - 309

ECiw was 1.1 dS/m with winter rain (~ 400 mm/y)

Table 18: Average Soil Salinity [$EC_e \times 10^3$] in 0 to 3 Foot Depth, 1970—1976

		SPRINKLER	DRIP
1970	Fall	1.4	1.8
1971	Spring	1.3	1.2
1971	Fall	2.9	3.6
1972	Spring	2.0	1.8
1972	Fall	3.2	2.8
1973	Spring	2.0	2.0
1973	Fall	2.4	2.1
1974	Spring	3.2	1.9
1975	Spring	1.5	1.2
1976	Spring	1.7	1.3

Gustafson et al. Drip irrigation of avocados, Calif. Avocado Soc. 1979 yrbk 63:95-134 available at www.avocadosource.com

ECiw: 0.5 – 0.8 dS/m

Rain: ~600 mm/y

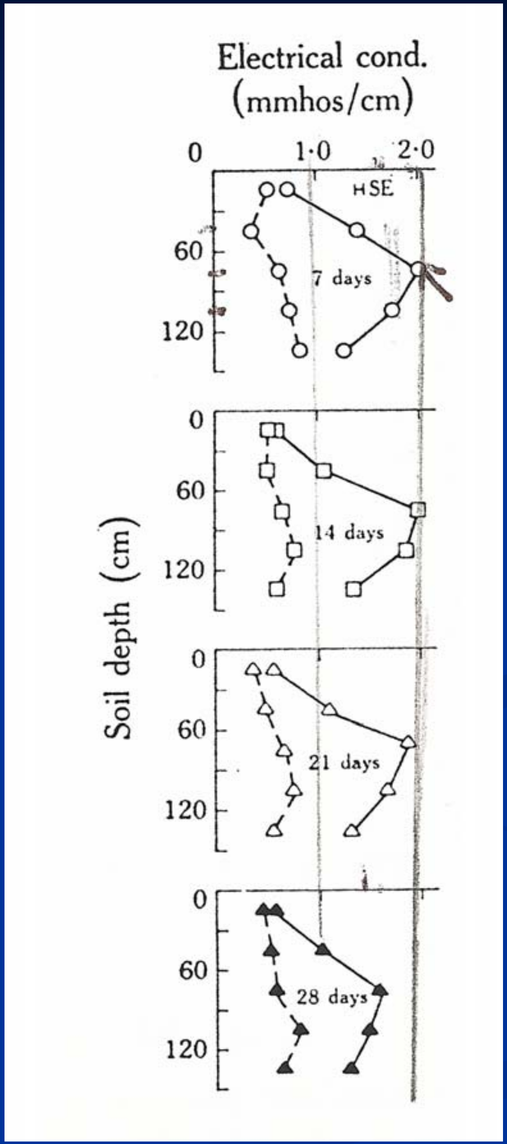
Applied water

7 days; 890 mm/y

14 days; 740 mm/y

21 days; 670 mm/y

28 days; 590 mm/y



Left line: Spring 1968

Right line: Autumn 1974

Kalmar and Lahav. 1977. Aust. J. Agric. Res. 28:859-868

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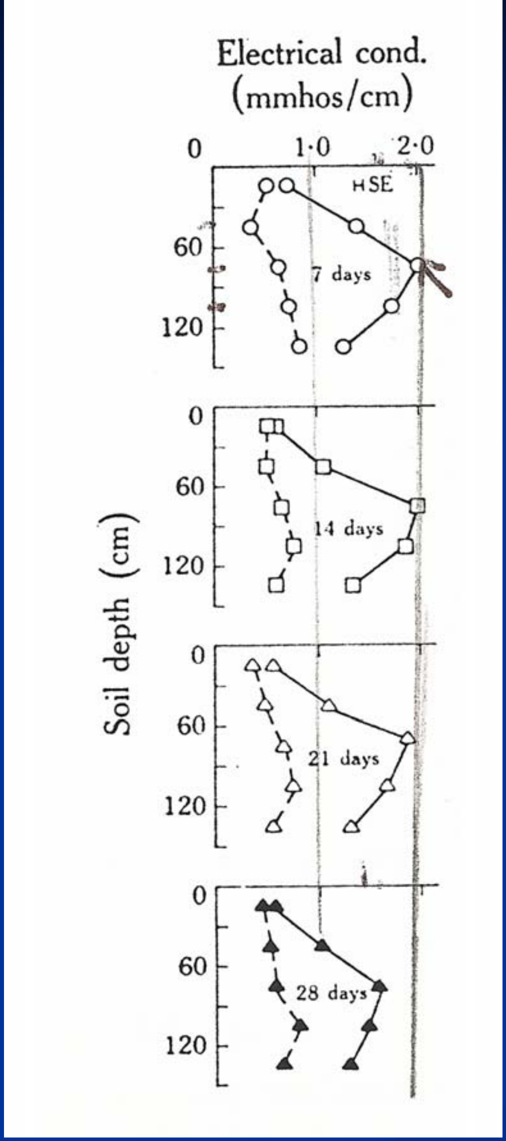
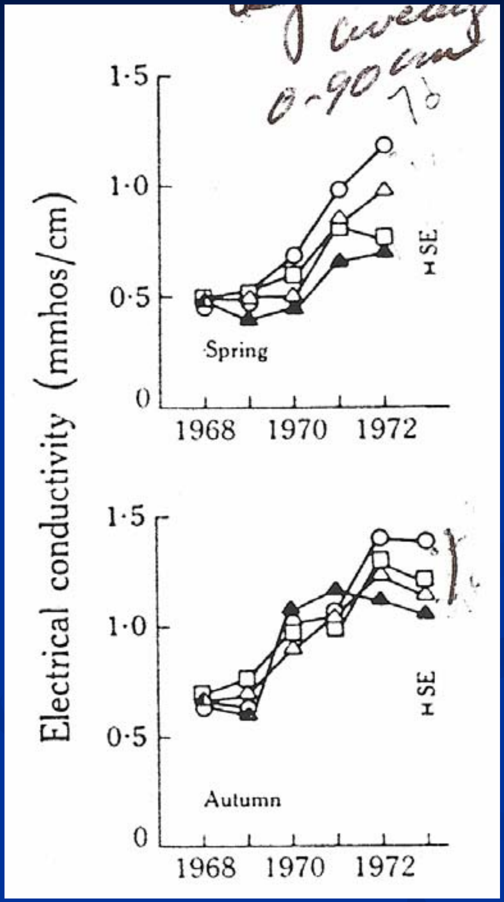




Kalmar and Lahav. 1977. Aust. J. Agric. Res. 28:859-868

Photo of Covey Lane taken in 2000 or 2001.

Oster, Stottlemyer and Arpaia. Salinity and water effects on 'Hass' avocado yields. ASHS Submitted. O.S. A 2006 ?

Covey Lane Experiment (1992 – 1997)

- Location: 20-km N of Escondido Calif.
- Soil: Coarse sandy loam; pH 6; 16 % slope; southern exposure
- Climate: ETo, 1390 mm/y; rainfall, 460 mm/y; wind speed, 1.7 m/s.
- Average daytime temperature:
  - August: 24 centigrade
  - December: 13 centigrade

Covey Lane

- 10 – 15 year-old 'Hass' on Mexican seedling rootstock
- Tree spacing 8.6 x 8.6 m (135 trees/ha)
- One microsprinkler per tree.
- Randomized complete block design with six blocks, each including one replicate of all irrigation treatments (3 x 3) for a total of 54 plots
- One or two trees located at the center of the plots designated as record trees.
- Record trees topped to 5.4 m in July 1992 and whitewashed.

Covey Lane

- Water treatments started Sept. 1992.
- Water quality: 1.0 dS/m; Cl, 2.7 mmol/L (96 mg/L).
- Water treatments: three amounts of applied water (AW) applied at three irrigation frequencies (F).

    AW1: 0.9 times estimated crop water requirement (ETc)

        water applied once (F1), twice (F2) and seven (F7) times per week.

    AW2: 1.1 times ETc (same F trtmts as AW1)

    AW3: 1.3 time ETc (same F trtmts as AW1)

Data collected at Covey Lane

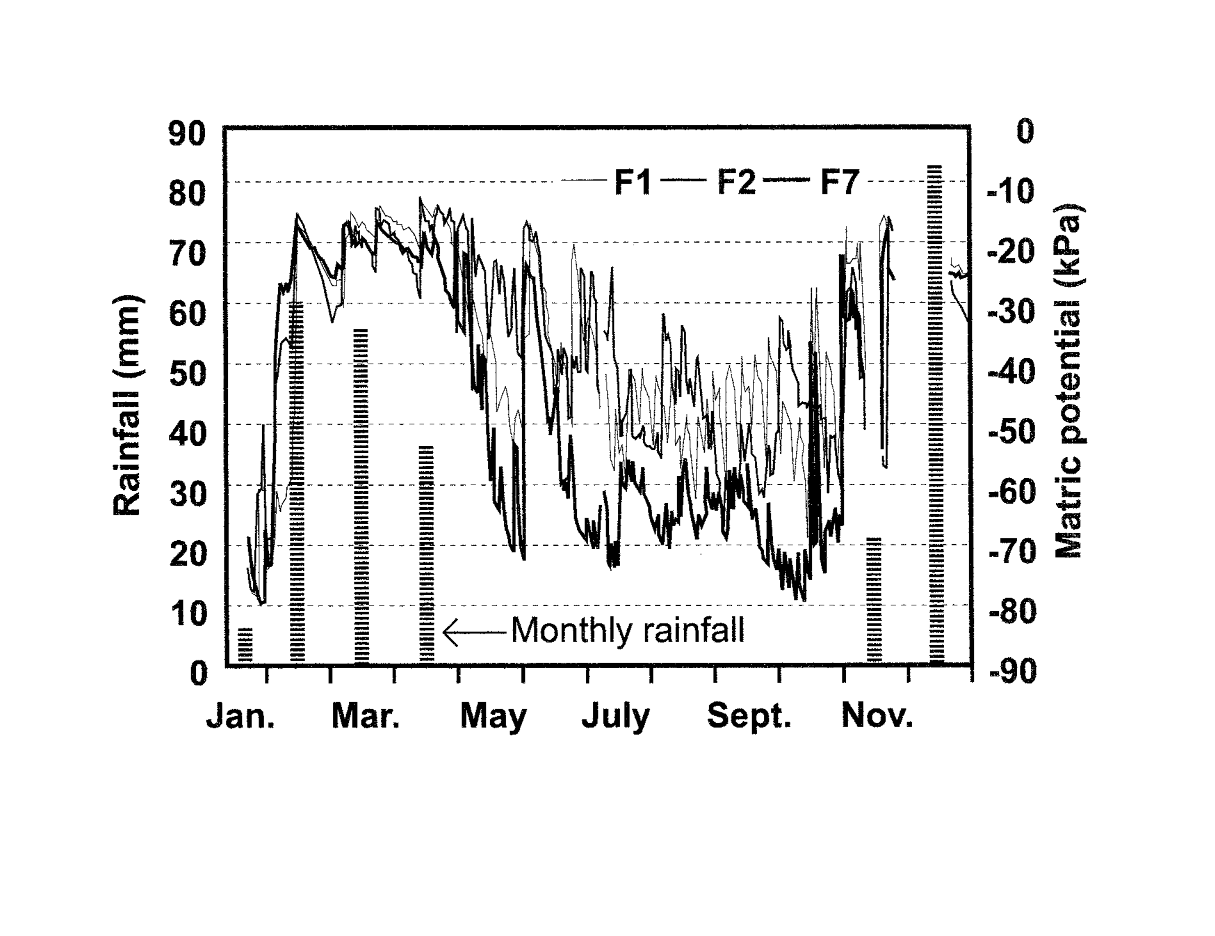
- Yields of record trees
- Tree growth
- Root distribution
- Leaf and root composition
- Electrical conductivity of saturation extract (ECe) and of the soil water (ECsw) in a below the rootzone
- Soil-water matric potential
- On-site pan evaporation
- Irrigation water quality

Crop coefficients, Kc, used at Covey Lane. The values in parenthesis were only used in 1996.	
Month	Kc
Jan.	0.40
Feb.	0.50
Mar. and April	0.55
May	0.60
June and July	0.65
Aug.	0.60 (0.65)
Sept.	0.55 (0.60)
Oct., Nov. and Dec.	0.55

Table 2. Summary of the applied, target and components of applied water for the three targeted water treatments (AW1, AW2, and AW3) and the weighted average electrical conductivity (ECiw*) and Cl concentration (Cliw*) of the irrigation water and rain.

Irrigation Treatment	AW1	AW2	AW3
Average applied, including rainfall (mm/year)	1080	1220	1380
Average target, mm/year	720	880	1040
Excess irrigation, mm/year	360	340	340
Fraction rainfall	0.36	0.32	0.28
ECiw* corrected for rain, $dS \cdot m^{-1}$ [y]	0.64	0.68	0.72
Cliw* corrected for rain, $mmol \cdot L^{-1}$ [y]	1.7 (60 mg/L)	1.8	1.9

Effects of irrigation frequency on soil-water matric potential at the 30-cm depth during 1996 in the AW2 treatment (1.1 times the estimated crop water requirement.)



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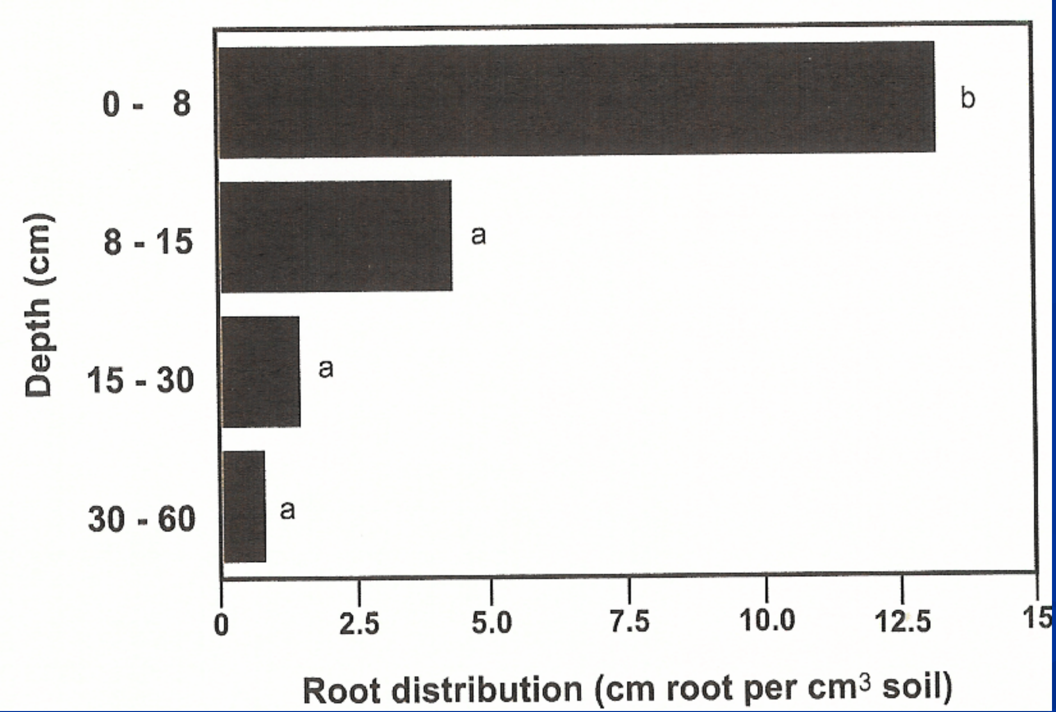
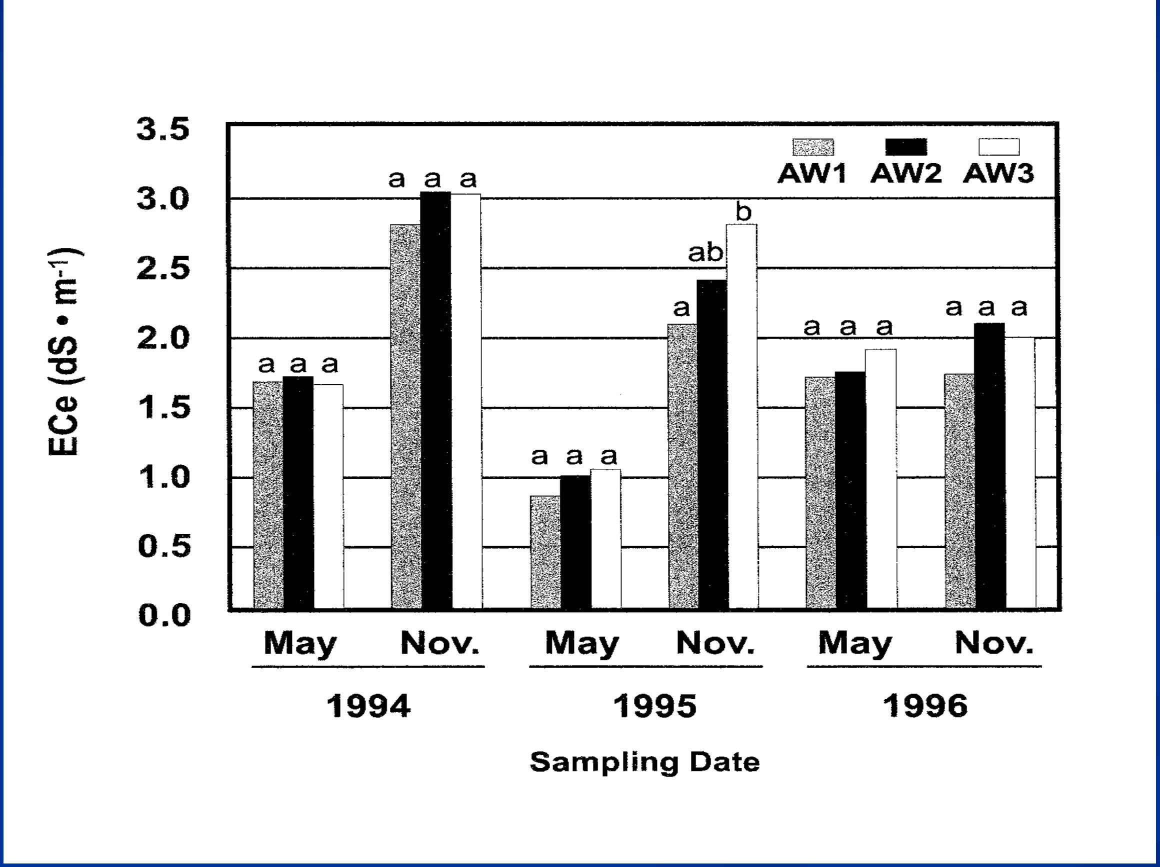
Root distribution with depth



Influence of applied water treatment, AW, on the average ECe at a soil depth of 0 – 120 cm. The irrigation amounts were 0.9 (AW1), 1.1 (AW2) and 1.3 (AW3) times the estimated crop water requirement.



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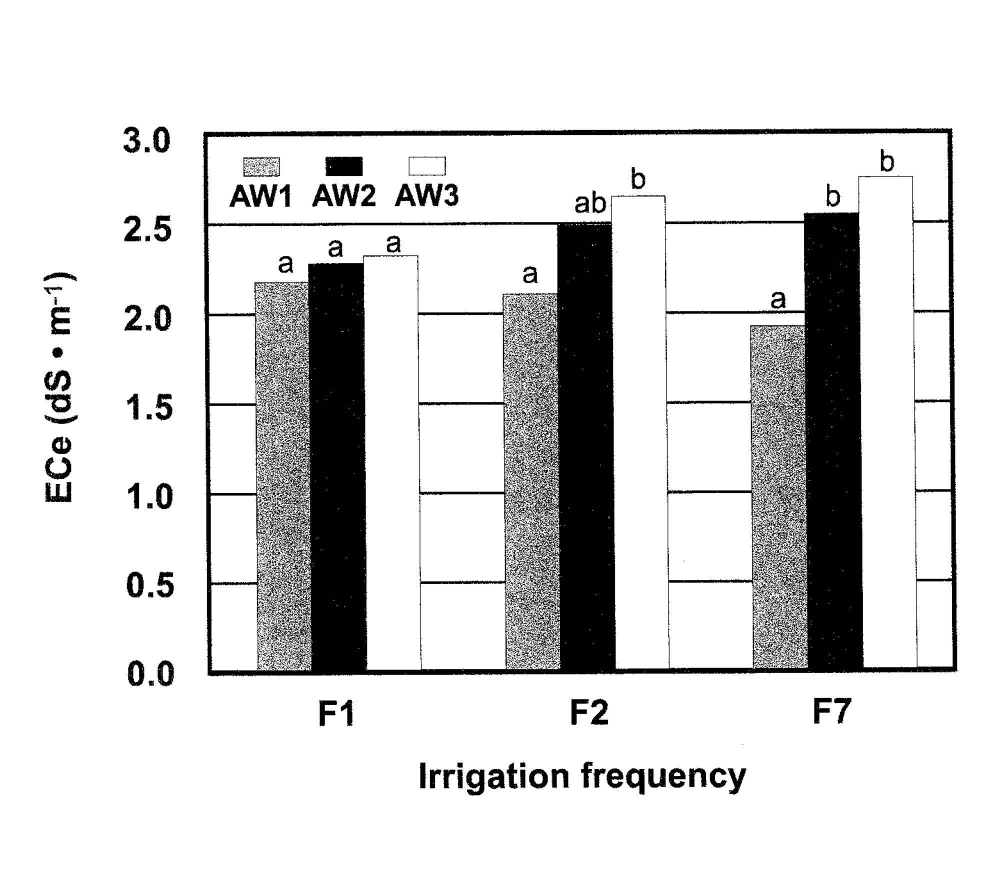
AW x F interaction – average ECe of the 0 – 120 cm depth interval measured in Nov.



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Soil water salinities (1993 – 1997). 779 samples obtained at the 30 cm; 797 at 60 cm, and 221 at 120 cm).

- Applied water effects were inconsistent and small for average ECsw in the 30 to 120-cm depth interval:
  - AW1: 3.5 dS/m (a b)
  - AW2: 3.2 dS/m (a)
  - AW3: 4.0 dS/m (b)

Numbers followed by the different letters are significantly different ($P < 0.055$) [Tukey pairwise comparison]

Soil water salinities (1993 – 1997. 779 samples obtained at the 30 cm; 797 at 60 cm, and 221 at 120 cm).

- ECsw for the three depths were similar:
  - 30 cm: 3.3 dS/m (a)
  - 60 cm: 3.8 dS/m (b)
  - 120 cm: 3.6 dS/m (a b). There were no significant differences among the means for the significant interaction, AWxFxD, at the 120 cm depth.
- Both the 60 and 120 cm depths were below the rootzone. The average ECsw of these two depths, 3.7 dS/m, was used to calculate the leaching fraction.

Leaching fraction

- $Vdw \times ECdw = Viw \times ECiw^{x}$
  - where $ECiw^{x}$ is the weighted average EC of the irrigation water and rain water used to meet the crop water and leaching needs.
- $LF = Vdw/Viw = ECiw^{x}/ECdw$
  - where ECdw is the salinity of the soil water below the rootzone at the field water content.
- LF covey Lane = 0.68/3.7 = 0.18
  - LF was the same for all AWxF treatments

Crop yields

- Crop yields increased for the crop seasons ending in 1993, 1994, and 1995. Crop yields for 1996 and 1997 were the same.
- Crop yields for F7 did not increase during the five crop seasons, whereas they did increase for F1 and F2.
- Crop yields increased with increasing AW.
- **Production function methodology** was used to determine the coefficients that fit the yield data obtained in 1996 and 1997 for the F1 and F2 treatments.
  - AW1: 28 kg/tree (a)
  - AW2: 46 kg/tree (ab)
  - AW3: 71 kg/tree (b)

  AW2 and AW3 where significantly different at a $P < 0.08$.

Chloride levels in leaves

- AW1: 0.43 % (a)
- AW2: 0.41 % (a)
- AW3: 0.39 % (b)

- F1: 0.38 % (a)
- F2: 0.43 % (b)
- F3: 0.44 % (b)

'Hass' on three different clonal rootstocks:

No leaf damage: 0.46 %

Slight leaf damage: 0.64 %

Mickelbart and Arpaia. 2002. J. Amer. Soc. Hort. Sci. 127:649 - 655

6-yr-old 'Hass" leaves on Mexican seedling rootstock:

Slight leaf damage: 0.48 %

Bingham et al., 1968. Soil Sci. Soc. Amer. Proc. 32:249 -252.

Production Function (Letey et al., 1985. Soil Sci. Soc. Amer. J. 49:1005-1009.

- This function combines three relationships: yield and evapotranspiration, yield and average root zone salinity, and average root zone salinity and leaching fraction. It has five coefficients:
  - AWt: threshold amount of applied water
  - AWm: amount of applied water that results in maximum yield where root zone salinity is zero.
  - Ym: maximum yield where rootzone salinity is zero.
  - ECt: Threshold salinity above which yield decline occurs
  - Sd: % decline in yield per unit salinity above the threshold.

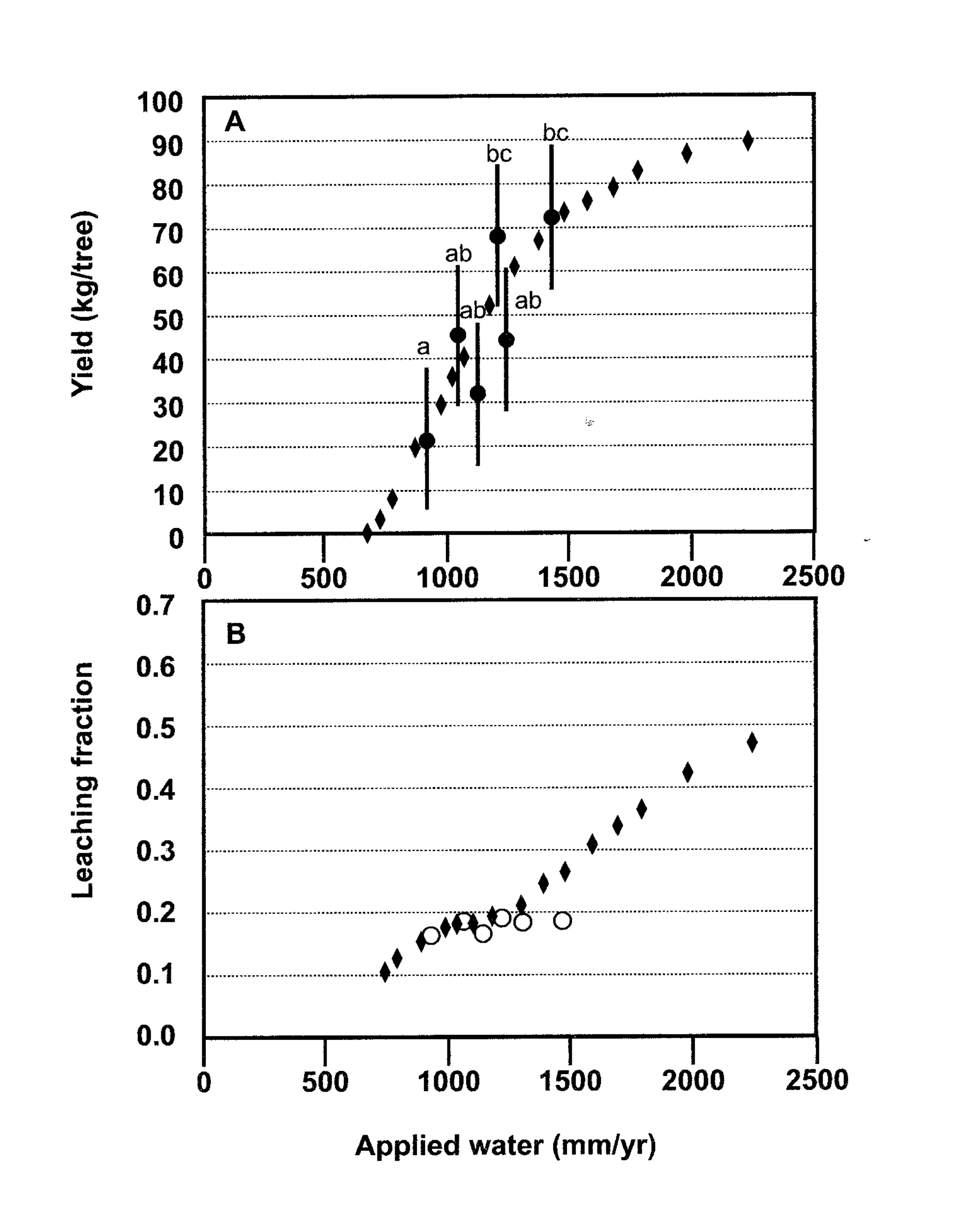
Production Function

Concept:

"Irrigating with saline water will cause some degree of salinization of the soil. This, in turn, will cause a decrease in crop yield relative to yield under non-saline conditions. This reduced yield ought to be associated with a decrease in plant size and a decrease in seasonal ET. But, as ET goes down, effective leaching will increase, mitigating the initial effect of the saline irrigation water. For any given amount and salinity of irrigation water, there will be some point at which values for yield, ET, leaching, and soil salinity all are consistent with one another. The yield at this point is the yield to be associated with a given irrigation water quantity and salinity." Solomon, K.H., 1985. Water-salinity-production functions. Trans ASAE, 28: 1975-1980.

A. Projected and measured yield as influenced by amount of applied water

B. Projected and calculated leaching fractions as influenced by the amount of applied water.



O. S. A. 2006 ?

ECiw*,

0.68 dS/m

Production function coefficients

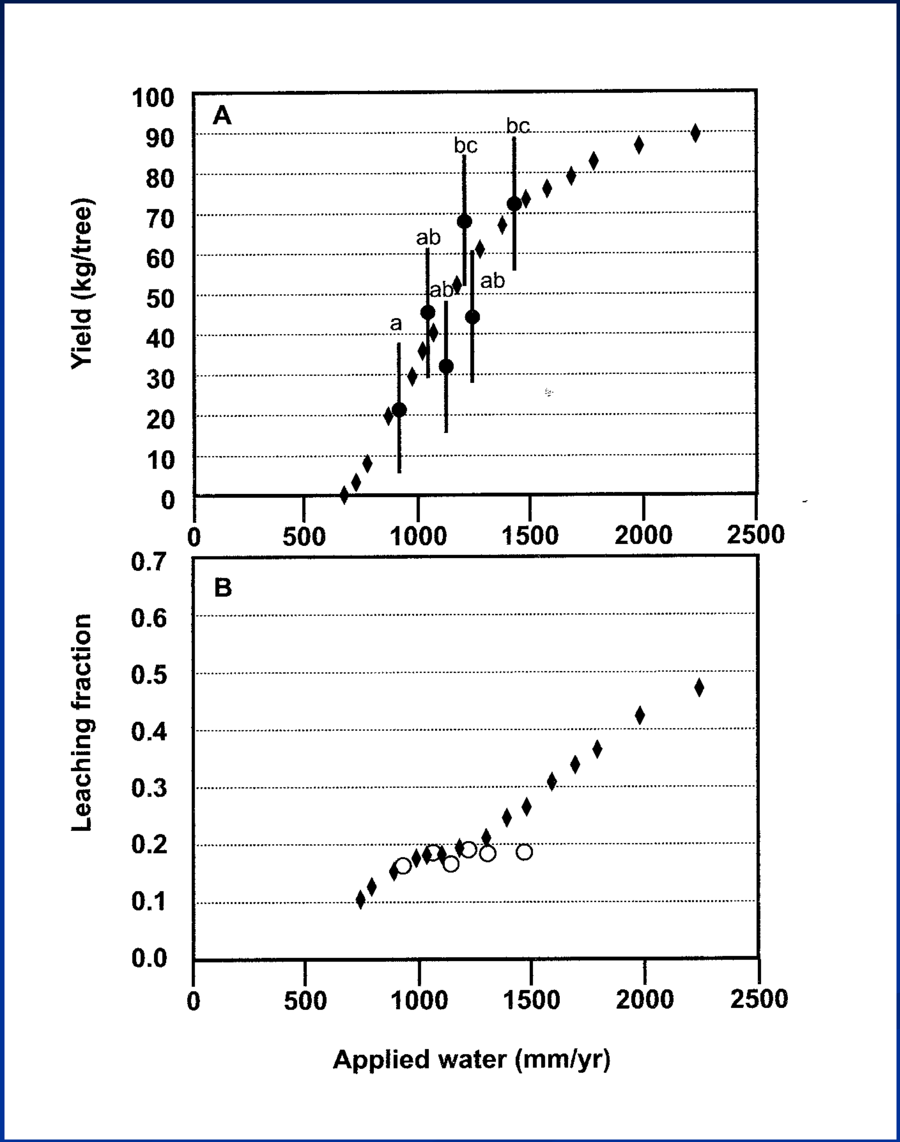
ECt, 0.57 dS/m,

Sd, 63 % per dS/m,

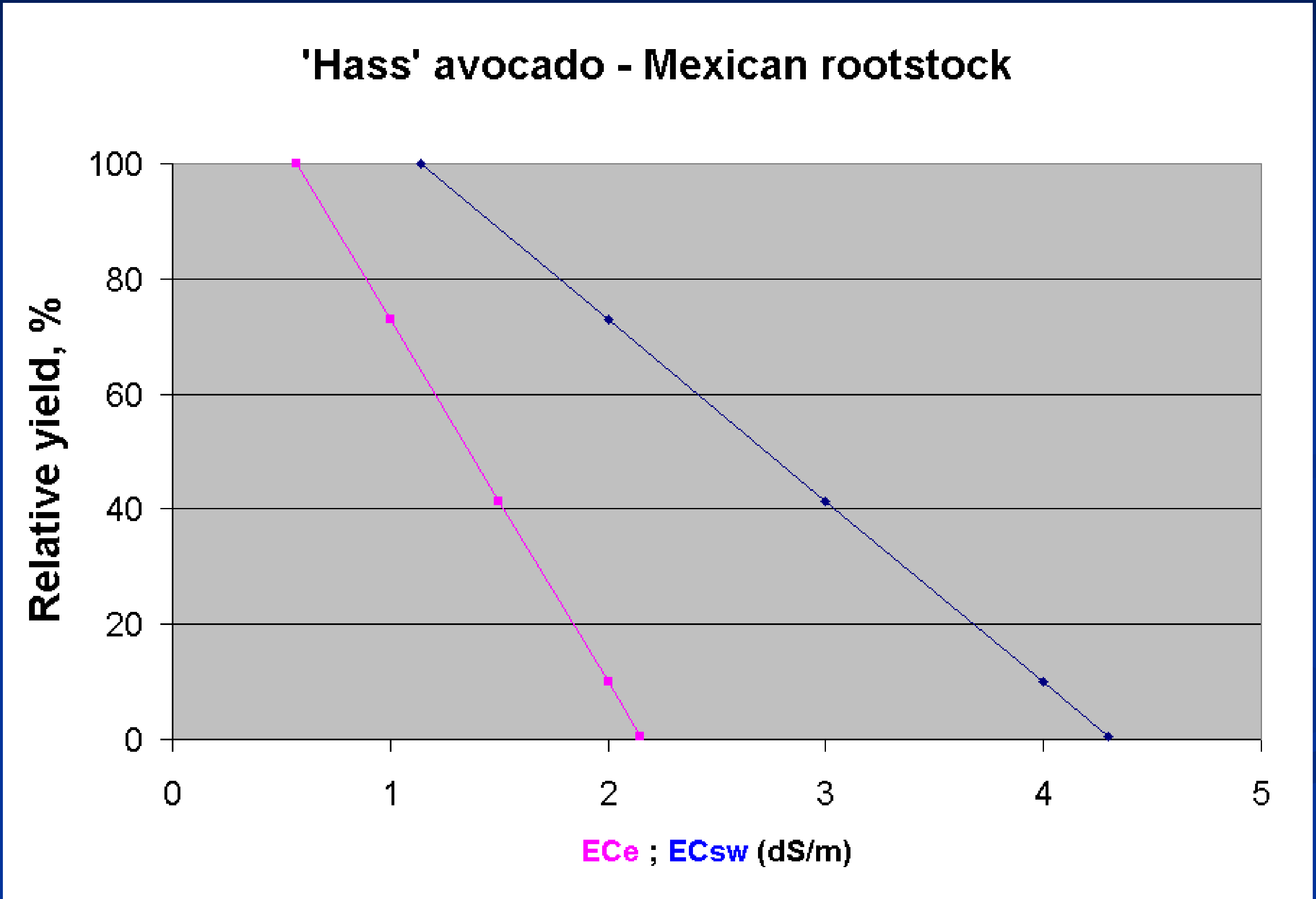
Ym, 94 kg/tree,

AWt, 620 mm/y,

AWm, 1200 mm/year



Limiting salinity for 'Hass' avocado on Mexican seedling rootstock.



Conclusions

- Different amounts of applied water had little effect on average rootzone salinity; neither did they result in Cl levels in leaves that are associated with leaf injury
- Yields increased with increasing applied water because trees evapotranspired more water before the ECsw reached a level of about 4 dS/m, which restricted water uptake.

Conclusion

- 'Hass' avocado on Mexican rootstock is the most salt sensitive crop species:
  - Threshold salinity: ~0.6 dS/m
  - Yield decline per unit increase in salinity: ~60 %/(dS/m)

- Because of the high senstivity to salinity and anoxia, maximum crop yields likely cannot be achieved when the weighted-average irrigation water salinity is greater than about 0.5 dS/m.