Irrigation with saline water: effects of soil hydraulic properties on crop response and leaching fraction

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THE DEPARTMENT OF SOIL AND WATER SCIENCES

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Objectives:

The effect of soil hydraulic properties on water and salt balance of an irrigated crop were investigated in order to evaluate the hypothesis that crop response to irrigation water salinity is dependent on the soil in which it grows. Simulations from both analytical and numerical models of crop response to the soil environment were applied to the case of tomatoes irrigated with increasing water salinity in two (loamy sand and clay loam) soils with different saturated hydraulic conductivities and water retention properties. Results were compared to those from a greenhouse lysimeter study.

Model approach I: analytical solution

An analytical model integrating yield, water, soil type and salinity (Shani et al., 2007).

-A simple, accessible model that predicts plant yield and transpiration under user specified environmental, biological and management parameters.

-Based on water and salt balances combined with a water uptake term using hydraulic models and reduction of uptake due to salinity.

-Assumes steady-state conditions and that plant response may be computed from representative values of the water content and salt concentration in the root zone.

Experimental: lysimeter studies

- Drainage lysimeters with highly conductive extension to maintain hydraulic conditions at bottom boundary (Ben-Gal and Shani 2002).
- Tomatoes *Lycopersicon esculentum* Mill cv. 1912)
- Two soils (table below); 4 irrigation water salinity levels; 5 replications
- Irrigation rate = 1.4 x ETp (target leaching fraction D/I = 1.29)
- Irrigation events: 2 per day
- 60 days
- Measurement of drainage amount and salinity, transpiration, growth, yields, soil moisture, soil salinity

Model approach II: numerical solution

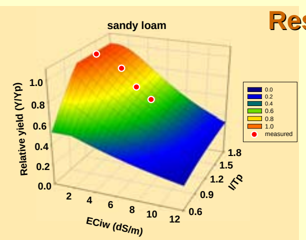
SOWATSAL model: Childs and Hanks, 1975; Hanks and Cui, 1990; Dudley and Shani, 2003.

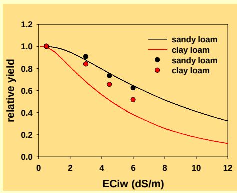
-One-dimensional, second-order, Crank-Nicholson numerical approximations to the Richards equation (with a root extraction term) and an equation of continuity for transport of a conservative solute.

-Simulates crop and root growth and water flux through the upper boundary as transpiration and evaporation.

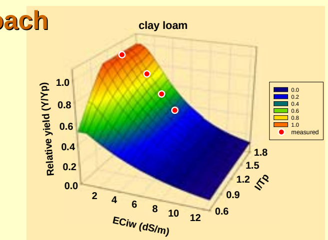
-Root uptake modules account for compensation between dry and wet or salty and less salty layers.

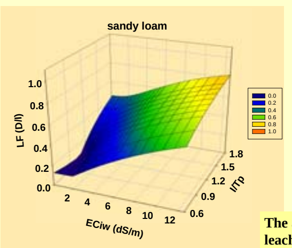
Results: Analytical approach



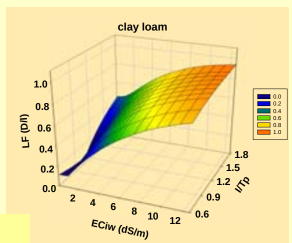


Yield as a function of irrigation water salinity for the case of irrigation amount I/ETp = 1.4. Shown with measured values from the lysimeter experiment





Relative yield and leaching fraction (LF) as a function of relative irrigation amount (I/Tp) and irrigation water salinity (ECiw)



The analytical model predicts lower yields and higher leaching when the clay loam soil is irrigated with saline water compared to the sandy loam soil.

	Sandy loam	Clay loam
Sand (%)	80	38
Silt (%)	12	30
Clay (%)	7	32
K_s (mm d^{-1})	3600	600
δ	4.91	10
η	2.7	2.5
β	0.55	0.25
θ_s (V/V)	0.41	0.5
θ_r (V/V)	0.06	0.04
ψ_w (mm)	-200	-300

Tomatoes

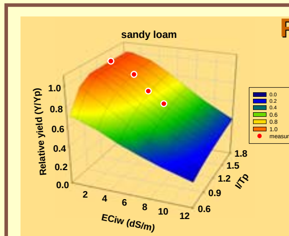
$h_{root} = \psi_{root} = -6000$ mm

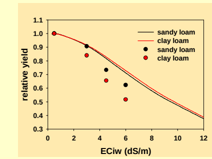
$EC_{50} = 4.5$ dS/m

Climate

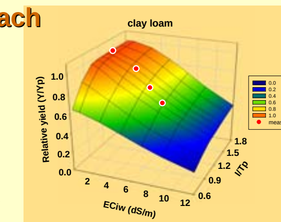
Tp = 5 mm/day

Results: Numerical approach

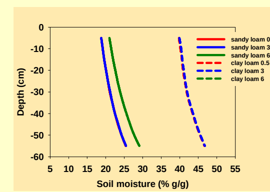




Yield as a function of irrigation water salinity for the case of irrigation amount I/ETp = 1.4. Shown with measured values from the lysimeter experiment

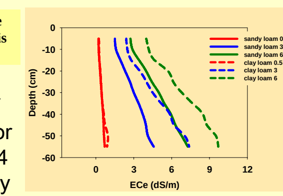


Relative yield as a function of relative irrigation amount (I/Tp) and irrigation water salinity (ECiw)



The numerical model predicts equal yields for the different soils even though predicted soil salinity is higher in the heavier soil.

Profiles of soil moisture and of saturated paste salinity (ECe) for the modeled case of I/ETp = 1.4 and three irrigation water salinity levels



Summary:

-As expected, yield and transpiration were reduced from optimum levels as irrigation water salinity increased and increasing the leaching fraction reduced soil water salinity and allowed greater transpiration (yield).

-Both the analytical and numerical models accurately predicted increased average and total soil salinity for soils with lower hydraulic conductivities.

-The analytical model assumes single representative values of salinity and of moisture for the root zone, and predicted decreased water uptake and biomass production resulting from irrigation water salinity accordingly. In contrast, the numerical model predicted that moisture sufficient to supply transpiration requirements was extracted from areas of relatively low salinity in leached upper layers, and that plant response was a function of that salinity alone.

-The analytical model under-predicted yield at high salinities for the heavier soil. That may be a result of using representative values of soil water content and salinity as discussed above.

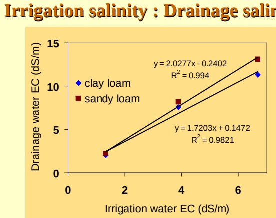
-The numerical model over-predicted yield at high salinities for both soils and did not predict differences due to soil. That may be a result of exaggerated capacity for selective water uptake.

-To achieve equal yields – leaching fractions or storage of salts in the lower root zone may need to be greater in heavier compared to lighter soils.

-Compared to those grown in the heavier soil, tomatoes in the loamy sand showed lower sensitivity to increasing irrigation water salinity. Thus, lighter soils appear to be more appropriate for irrigation with saline water compared to heavier soils.

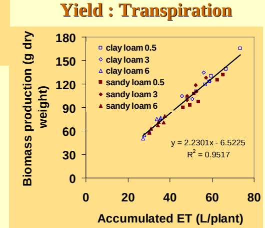
Results: Lysimeter study

Irrigation salinity : Drainage salinity

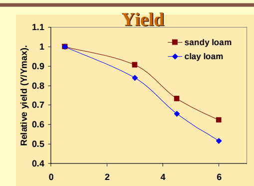


Relationships measured between salinity of irrigation and drainage waters and between yield and transpiration

Yield : Transpiration

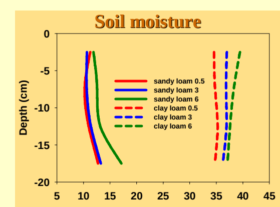


Yield

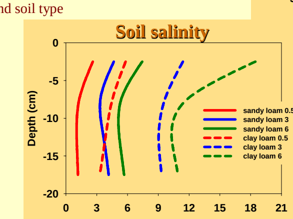


Biomass production as a function of irrigation water salinity and soil type

Soil moisture



Soil salinity



Water content and salinity for soil profiles of lysimeters after 60 days of tomato growth and irrigation with three different water salinity levels in two soils.

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