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Highlights of an Experimental Study on the Vulnerability of a Soil-Crop System to Drought and Saline Water

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Climate change, if it occurs as projected, might have significant implications for agricultural and water resources. Among them soil moisture changes, which reflect changes in agricultural water availability, are of special concern due to their direct impact on crop growth. In this situation drought and salinity can be considered as related stressors and influence the productivity of agricultural systems. The present work is a review of the results of 7 years experiments in areas where the sea water intrusion affects the soil hydrological physical properties and the crop production.

Methodology

On two sites, Torre Lama (TL) and Vitulazio (VT), at each spring soil samples were taken at different depths to determine the ECe and ESP, moreover from the top soil layer samples were taken to determine the index of aggregates water stability in water (IASW). Undisturbed soil samples were taken too in different years on each sites to determine the hydrological parameters h(θ), and the soil porosity by image analysis. The impact of the different soil hydrological properties on the temporal variability of soil water content was evaluated for a range of meteorological conditions, in particular for a dry, wet and normal climatic year. At VT the yield response of sunflower, sweet pepper and eggplant growth under saline water irrigation was tested. Treatments consisted in a factorial combination of 3 treatments (T025, T05, T1) irrigated with water to a concentration of 0.25, 0.5 and 1% of NaCl and a control (T0) irrigated with fresh water.

Results

Soil properties and hydrology. At both sites, for the 20 cm depth, the ECe measured each year in spring shows, only for the treatments with 10 gl^{-1} in the irrigation water determined a progressive soil salinization. ECe measured each year in spring increased significantly for all the treatments evaluated in both sites (VT and TL). The ESP (VT) increases with the saline concentration of the irrigation water in the layer of 0-20 cm and gradually decreases with depth where the ESP is higher than in the other layers.. Same trend was observed for TL. Irrigation with saline water led to an increase of ESP and a degradation of the soil physical properties that were estimated indirectly by measuring IASW. For the layer 0-0.15 m layer IASW was inversely correlated to the ESP values at VT and TL sites. In the latter site soil structure degradation occurred also in the deepest layers.

At TL the h(θ) curve of the 1% saline water treatments had lower values of θ than the 0% treatments at the same pressure head, while at VT, the total porosity for the I_0 is around 0.55 against 0.58 of the I_1, in contrast with what was observed for the TL (Fig.1). Such difference could be due to the shorter duration of saline water application at VT (2-yr) than at TL (5-yr). Moreover, the difference between TL and VT might depend from the type of clay minerals: at VT there is an abundance of smectite-type clay, while at TL illite-type. Despite these differences in total porosity of the two sites, the soil water retention capacity (WRC), calculated between 100 cm and 10^4 cm pressure head, showed a similar trend at the two sites. At TL for all the irrigation treatments, the control had lower WRC-values than the saline treatments (e.g 0% T_2 20-30 cm WRC = 30.8 mm vs. 1% T_2 20-30 cm WRC = 74 mm). At VT, even if the total porosity was different than TL, the calculated AW showed the similar trend (I_0 at VT had WRC = 128 mm vs. 178 mm of I_1). The total porosity at TL changed from about 29% (I_0) to 20% for the I_1, while at VT site values ranged from 21 to 15%for I_0 and I_1, respectively.

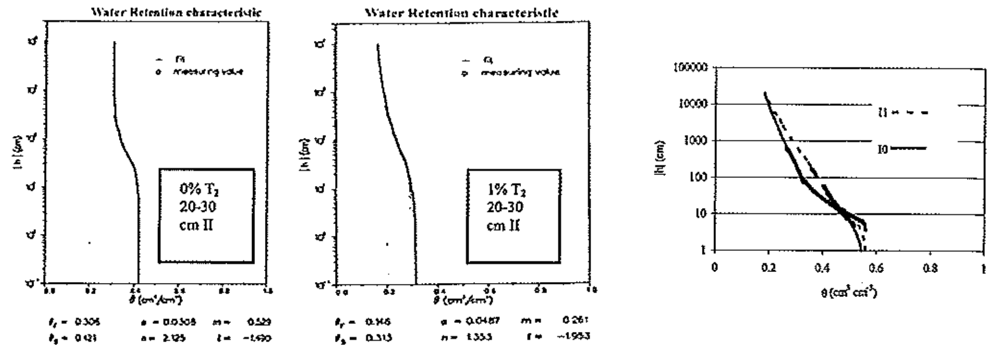

Figure 2 Water retention characteristics: (on left) TL site treatments 0% and 1% with 2-day frequencies in layer 20-30 cm.; (on right) Water retention characteristics VT site for treatment I0 and I1 in the layer 0-10 cm.

The numerical experiments showed that the differences in $h(\theta)$ and $K(h)$ (unsaturated capillary conductivity) of I_0 and I_1 led to higher available water (AW) for I_1 against the I_0 treatment through the year: In the dry year fewer days with AW< 124 mm respectively 119 mm were obtained for I_1, i.e. 105, than for I_0, i.e. 152 In the wet year the number of days for the same cases was 46 for I_1 and 67 for I_0.

Crop. The Maas and Hoffman analysis was applied to sunflower yield to give a slope of 5.88 (m dS^{-1}), while the 50% yield reduction was reached at ECe = 9.2 dS m^{-1} level. These results indicate that this species is moderately tolerant to salinity; therefore it could be cropped in environments affected by salinity problems. Sweet pepper yield decreased with ECe > 1.23 dS m^{-1} while the 50% of yield loss was reached at ECe = 5.11 dS m^{-1} and it was zero at ECe 8.99 dS m^{-1}, thus characterizing this species as moderately sensitive to salinity. Eggplant was also moderately sensitive to salinity since the relative yield decreased with ECe > 1.11 dS m^{-1} with a slope of 9.84 ((m dS^{-1})).

Table 1 Absolute and relative difference in crop yield, Y (t ha^{-1}) observed between a drier and a wetter year, ($Y_{dry} - Y_{wet}$); relative differences are given as % of mean yield over the drier and wetter year.

Irrigation level	NaCl content	Sunflower '96 - '95		Sweet pepper '97 - '98		Eggplant '01 - '00	
		t ha^{-1}	*%*	*t ha^{-1}*	*%*	*t ha^{-1}*	*%*
100%	0%	0.56	12	0.70	3	4.92	7
100%	0.25%	0.57	13	7.49	45	-6.68	-11
100%	0.50%	0.47	11	8.03	58	-17.12	-40
100%	1%	0.39	10	1.75	50	-7.52	-41
40%	0%	0.47	11	5.18	71	18.89	59
40%	0.25%	0.54	13	4.12	72	16.41	59
40%	0.50%	0.66	15	3.35	76	18.96	66
not irrig.	-	0.38	9	0.37	19	6.07	54

Taking all yield observations together (Table 1) for all crops grown during two subsequent years and comparing changes in yield with changes in the value (P – ET0) over the period June through August, we obtained a somewhat contradictory result. Sunflower was grown in 1995, (P – ET0) = -238.7 mm, and 1996, (P – ET0) = -337.8 mm. Sweet pepper in 1997, (P – ET0) = - 432.6 mm, and 1998, (P – ET0) = - 425.7 mm . Eggplant in 2000, (P – ET0) = - 431.6 mm, and 2001, (P – ET0) = - 485.6 mm. For almost all irrigation and saline treatments yield was higher in the drier than in the wetter year (Table 1).

On the one hand these results call for caution: differences in net water demand (P – ET0) between 1997 and 1998, when sweet pepper was grown, were negligible. Overall, however, yield was higher in the drier year of each pair. Exceptions were the saline treatments of the eggplant crop: here full irrigation implies a very high salt load, especially in a dry year, which may explain the results.

Conclusions

The question of vulnerability of a soil – crop system requires taking into account the positive effects of saline water on the water retention capacity of soils and of the yield response to relatively small changes in water availability.