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Effects Of Irrigation With Saline Water, And Soil Type On Germination And Seedling Growth Of Sweet Maize (*Zea Mays L.*)

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ABSTRACT

Germination and early growth of maize Sweet Maize (Zea mays L.), var. (SEL. CONETA) under irrigation with saline water were investigated in a pot experiment with different soil types. Seven salinity levels of irrigation water up to 12 dS/m were used on a Clay soil (C) and a Sandy-Loam (SL). Emergence of maize was delayed under irrigation with saline water, and the final percentage of germination was reduced only at 8 dS/m or above. Seedling shoot and root growth were reduced starting at 4 dS/m of irrigation water. Salts accumulated more in the C soil but reductions in final germination rate and seedling growth were larger in the SL soil, although differences were not always significant. Data indicate that germination is rather tolerant to salinity level in var. SEL. CONETA whereas seedling growth is reduced at moderate salinity levels, and that soil type affects plant performance under irrigation with saline water.

***Key words: Germination, Maize, Saline irrigation, soil type*.**

INTRODUCTION

Soil salinity is one of the most important problems affecting soils in Mediterranean regions (1). It is caused by a rising water table, or the misuse of the irrigation water. Irrigated agriculture in arid and semiarid regions of the world has resulted in salinity and waterlogging problems that threaten land sustainability (2). Soils of these regions may be classified as saline, alkali, and saline-alkali based on pH electrolytic conductivity of the saturated paste extract (ECe), and exchangeable sodium percentage (ESP). Which are in turn affected by chemical properties of irrigation water. Richards (3) indicated that, increasing the SAR values in irrigation water remarkably increased the relative soluble Na^+ and decreased the soluble Ca^{++} and Mg^{++} in the soils. Change (4) found that the effect of $Na^+ : Ca^{++}$ ratio in saline water is more important than the total amount of sodium or calcium in irrigation water. Jain et al (5) reported that, in field experiment continued for three years, irrigation water of EC 4.8 dS/m (SAR 32) did not cause appreciable accumulation of salts in 0-60 cm depth of sandy soils. Also, Jean and Rhoades (6) reported that, there was no specific trend in the soil electrical conductivity values relative to SAR in saline solution, but electrical conductivity of soil solution are essentially parallel to the SAR excess at any fixed value of electrical conductivity of soil extract.

Hausenbuiller *et al* (7) studied the effect of various $Na^+ : Ca^{++}$ ratio in synthetic irrigation water on soil properties. They found that removal of exchangeable Ca^{++} by percolating water occurred even when the soluble Na^+ percentage in the added water was only 50. Reduction in the added Ca^{++} through precipitation apparently rose to effective Na^+ percentage in the percolating water to critical levels.

The use of saline water for irrigation therefore requires the selection of appropriately salt tolerant crops, improvements in water management, the adoption of advanced irrigation technology and the maintenance of soil physical and chemical properties [8].

The evaluation of sensitivity of a crop to irrigation with saline water is a complex issue. For some crops sensitivity varies from one growth stages to the other. Many salt sensitive species germinate in the presence of the high concentrations of salt e.g. corn [9], tomato [10] and rice [11]; in contrast, the most salt tolerant crops like cotton [12;13] and sugar beet [14] are salt sensitive during germination. Similarly, some halophytes whose vegetative growth is often stimulated by salinity do not appear to be salt tolerant during germination [15]. Sorghum, barley, wheat and corn are more sensitive to salinity at early seedling stage than at later stages of growth [16;17;18]. Rice proved to be most sensitive at the seedling stage and to gain tolerance at the tillage and vegetative growth stages [19]. In maize salt sensitivity is particularly high at tasseling and low at grain filling [9]. Studies also on corn [20], cowpea [21], and triticale [22] indicate that sensitivity to salinity changes during growing season.

Maize (Zea mays L.) is the third most important cereal crop in the world after wheat and rice, and is grown all over the world under a wide range of climatic conditions. It is moderately sensitive to salinity and considered as the most salt-sensitive of the cereals with no yield reduction at ECe of 2 dS/m, 50 percent at ECe 9 dS/m and complete loss of yield at 15.3 dS/m [11]. Further studies showed that in water cultures, or on mineral soils with surface irrigation and continuous leaching, the maximum salt concentration in the soil saturation extract that does not reduce maize yields is about 1 100 mg/l total dissolved salts (ECe - 1.7 dS/m). The maximum permissible salt concentration of irrigation water to sustain maize production is considered to be about 300 mg/l, an ECW of 0.45 dS/m [23].

Bischoff et al [24] reported that maize is moderately sensitive to salinity, being more sensitive than field crops and about equal to many vegetable crops. With proper management however, it can be grown over a fairly wide range of irrigation water qualities, particularly where rainfall is sufficient to dilute or leach saline soil water caused by irrigation application. According to their data irrigation water salinity has its greatest influence on maize response during the seedling stage, which would therefore be the crop’s most critical growth period. At three weeks of age, the corn plant has a salt tolerance threshold of only 1 dS/m; whereas by tasseling and grain-filling stage it can tolerate an ECSW up to 9 dS/m without yield loss.

Zalba and Peinemann [25] found that fresh and dry matter production of maize plants were both significantly reduced by increasing salt concentration (NaCl) in irrigation water, and greater availability of nutrients such as N, P and K could not counteract the ionic absorption effect A competitive interaction processes between NO^{-3} and Cl^{-} was recorded in shoots but not in roots, leading to the hypothesis that competition between the two anions must be regulated at specific sites in leaves cells. They also demonstrated that maize is quite tolerant to salinity during germination and this behaviour is considered to be crop specific. This observation is in agreement with results obtained by [26;9;27;20]. Pasternak et al [27] found that the most sensitive period of maize to salinity is during the first three weeks after sowing. Rhoades et al [28] reported relative salt tolerance of various crops and indicate a value of 21-24 dS/m for 50% reduction of emergence, whereas only 5-9 dS/m for 50% reduction of yield. Katerji et al [29] reported a lower leaf area and dry matter production in leaf, stem, and roots of maize seedlings due to salinity. Bischoff et al [24] confirmed that corn is moderately sensitive to salinity, being more sensitive than field crops and about equal to many vegetable crops. The seedling stage was identified as the most sensitive to salinity with a tolerance threshold of only 1 dS/m vs 9 dS/m ECSW at tasseling and grain-filling stages without yield loss.

Being highly crosspollinated, maize has become highly polymorphic through the course of natural and domesticated evolution and thus contains enormous variability [30] in which salinity tolerance may exist, as found in trials by [31].

This study has been carried out for the purpose of studying the combined effect of irrigation with saline water and soil type on germination percentage of maize var SEL. CONETA.

Materials and Methods

The experiments were carried out under greenhouse conditions at the International Agronomic Mediterranean Institute, Valenzano, Bari – Italy. Temperature was constantly kept around 20° C.

The set-up consists of 70 pots with a volume of 0.005938 m^3 (diameter 20.5cm and depth 18 cm). 2 cm thick layer of coarse gravel was placed at the bottom of the pots to maintain proper drainage each pot was placed inside a plastic container to collect the drainage water. Seven water salinity levels and two soils were used in factorial combination. Salinity levels were: FW = fresh water corresponding to 0.9505 dS/m, 2, 4, 6, 8,10 and 12 dS/m), The two soils were clay soil (treatment A) and sandy loam soil (treatment B) (ISSS classification). Five pots with 10 seeds each were attributed to each treatment. The seeds were sown soil directly, and then all of the pots were irrigated with the different saline water levels from the first irrigation.

The soil was crushed and sieved through a 5 mm sieve. The main physical and chemical characteristics of the soil under investigation are given in Table 1.

Tab. 1 - Physical and chemical characteristics of Clay and Sandy Loam soils under investigation

Soil physical characteristics		CLAY	SANDY LOAM
Clay (%)		44	16.5
Silt (%)		16	5.5
Sand (%)	Coarse	16.8	14.3
	Fine	23.2	63.7
Bulk density (g/cm3)		1.08	1.3
Moisture content by volume (%)	F.C	38.9	15.1
	W.P	26.9	9.3
	A.W	12	5.8
Organic Matter (%)		1.02	0.2
Soil chemical characteristics			
Ec (ds/m)		0.68	0.4
pH		7.8	8.2
Soluble anions (meq/l)	$CO3^-$	–	–
	HCO_3^-	2.0	2.2
	Cl^-	3.6	1.7
	SO_4^{--}	1.3	0.1
Soluble cations (meq/l)	Ca^{++}	3.6	1.5
	Mg^{++}	2.4	1.8
	Na^+	0.8	0.6
	K^+	0.1	0.1

The crop was Sweet Maize (*Zea mays L.*), Variety (SEL. CONETA) Euroselect Company. The saline water was prepared by mixing fresh water (0.9505 dS/m) with sea water (45.05 dS/m) at such ratios that the desired levels of EC were reached.

The germination experiment started on Jan 20, 2006. Seed germination measured as emergence of the seedlings at the soil surface. started on Jan 30, 2006, and Germination percentage was recorded daily for 44 days. At the end of the experiment, germination percentage, and the EC and the chloride in the soil were recorded, as well as plant growth parameters: seedling height, leaves and roots length, leaf area, top, leaves and roots fresh and dry weight.

Results and discussion

Soil Salinity

Measured EC values in different soil depth after maize seedlings are illustrated by Figure 1 EC values were higher in the surface depth 0-10 cm than the 10-20 cm layer. This holds true in both clay and sandy loam soil, but it was higher in sandy than the clay soil (not significantly, according to the analysis of variance). Increasing water salinity levels resulted in gradual increase in electrical conductivity values in both soil layers, and more so in the 0-10 cm depth. EC values were higher in the clay soil than in the sandy loam for the 0-10 cm layer whereas at the depth of 10-20 cm they were higher under sandy loam soil than under clay.

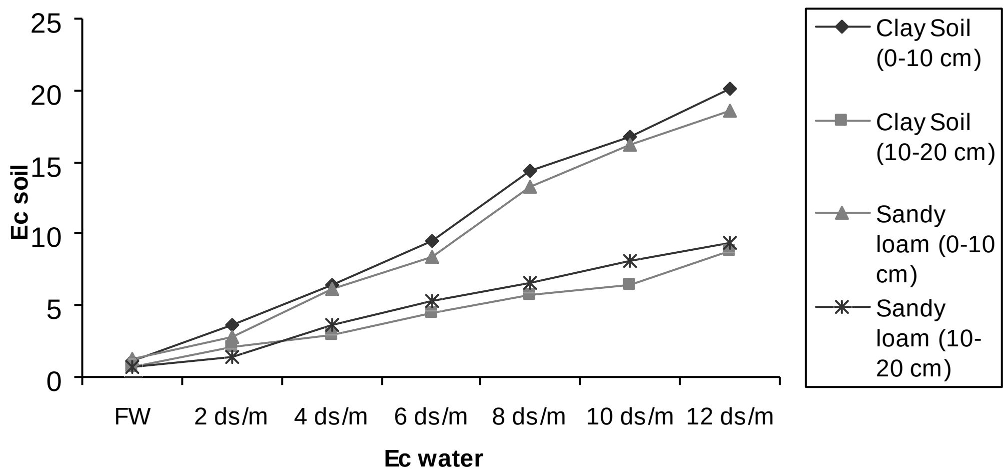

Figure 1. Effect of water salinity and soil type on changes of electrical conductivity in different soil depths at the end of the experiment

The chloride concentration left in the soil after maize seedling treated with saline water under two different soil types is graphically illustrated by Figure 2. A gradual increase in chloride concentration was observed with increasing water salinity levels in both soils, with differences between soils and layers as described for EC.

Chloride being the only element that does not under go any chemical reactions or precipitation under saline irrigation practices its concentration can be taken as a good indication to the soil accumulated salt.

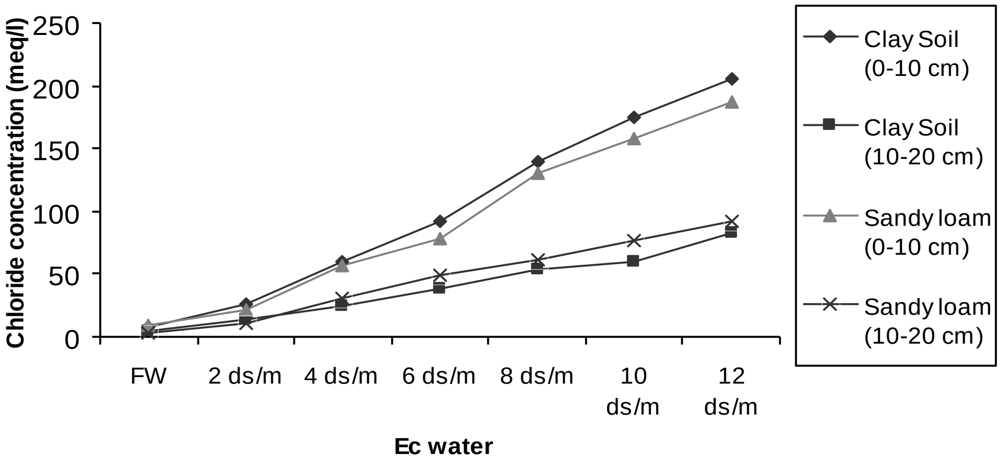

Figure 2. Effect of water salinity and soil type on chloride concentration in different

Sodium concentration left in the soil after maize seedling treated with saline water under two different soil types is illustrated by Figure 3. In the upper layer, the Na concentration was higher than those recorded in the next layer 10-20 cm depth for both soil types, but the absolute values were higher in sandy soil. Generally, the sodium concentration was gradually increased with increasing water salinity levels and it was higher in clay soil than sandy soil after application of saline water treatments.

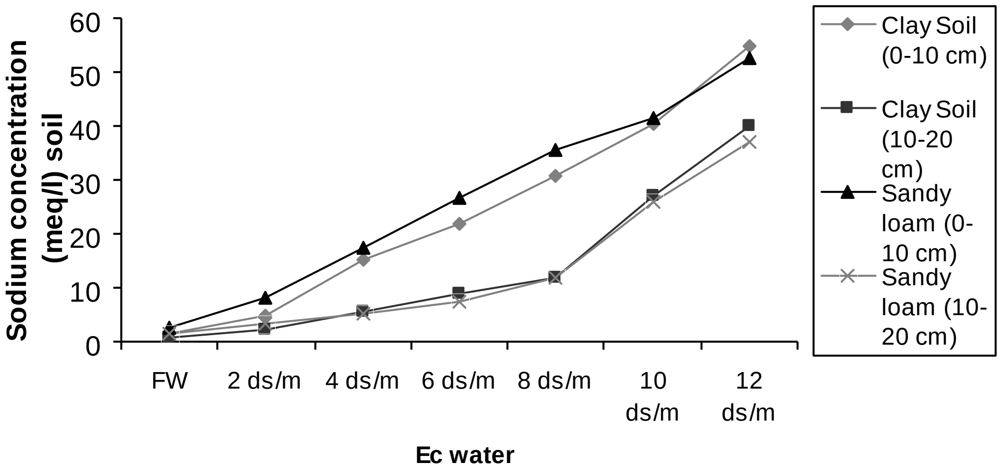

Figure 3. Effect of water salinity and soil type on sodium concentration in different

Germination Percentage (%)

The effect of irrigation with saline water on germination of maize seedlings is illustrated in fig. 4 and 5. Germination was affected by salinity and soil type both in timing and percentage. A delay in emergence was recorded starting at 8 dS/m in the C soil and 6 dS/m in the SL soil. Germination percentage was initially higher in sandy loam soil treatments for all salinity levels and the FW control, but reached higher final values in the clay soil (fig. 5).The final germination percentage was significantly affected by irrigation water salinity beyond 8 dS/m.

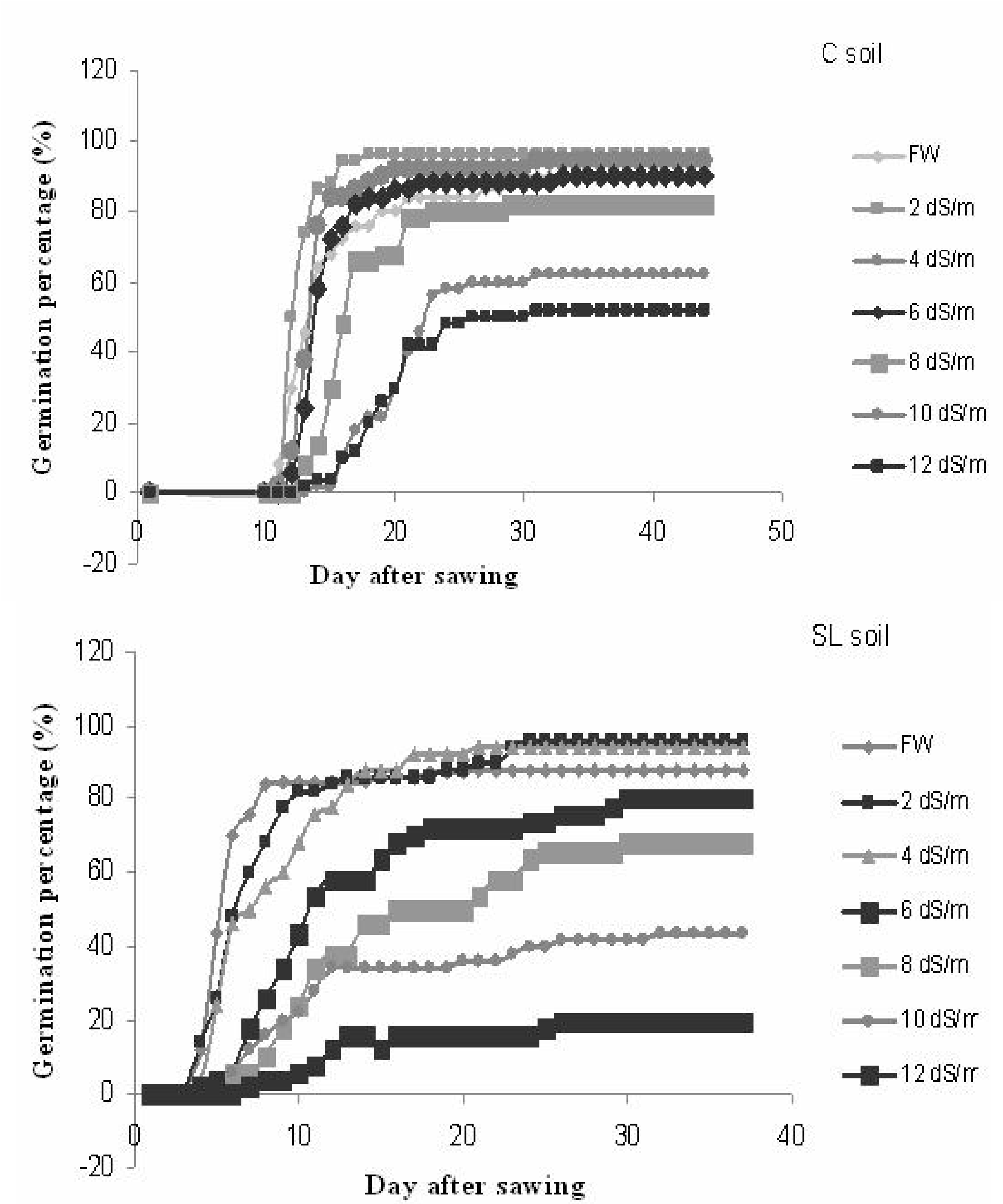

Figure 4. Percentage of emergence as a function of irrigation water salinity level and time from sowing in clay (C) and sandy-loam (SL) soil.

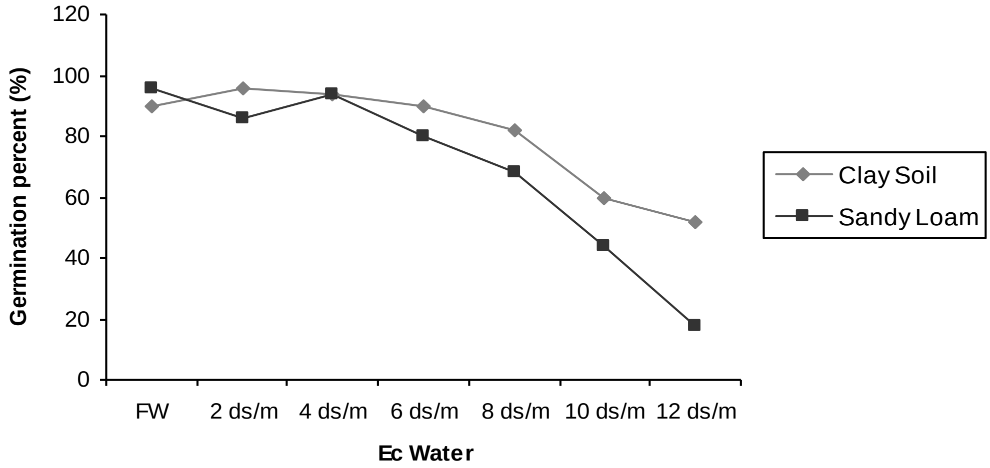

Figure 5. The effect of irrigation with saline water on germination of maize seedlings.

Effects of irrigation water salinity on germination and emergence have been reported in several plant species. A decrease of germination percentage with increased salinity has been reported in triticale (32), alfalfa (33;34), lettuce (35), wheatgrass (36) and barley (37). Similarly, Allen *et al* (38) indicated that alfalfa populations decreased with decreasing osmotic potentials from –1.0 to –1.6 MPa NaCl. However, Chartzoulakis (39) reported that salinity delayed germination of greenhouse cucumber, but did not reduce the final percentage of germination even at 10.7 and 16.2 dS/m EC (about –0.6 and –0.9 MPa).

Tajbakhsh et al (40) found significant differences among barley varieties for germination percentage, frequency of abnormal seedlings, and Na+, K+ uptake. Also, they reported that barley cultivars showed decreasing germination percentage with increased salinity. However, the tolerant cultivars showed significantly less decrease in germination and still germinated well at –1.2 MPa. Similar results were found in the pot (sand and peat) experiment, in which irrigation with saline water (–1.8 MPa) delayed seedling emergence and reduced the final emergence percentage of both tolerant and susceptible cultivars.

Considering the soil type effects, our results confirm reports of Hamdy (41) that in sandy soil, although salts accumulated relatively less than in clay soils, seed germination percentage was lower.

Seedling biometrics

Values of plant height as affected by water salinity and soil type are illustrated by Fig.6. This indicator of plant growth was negatively affected by irrigation water salinity beginning from the level of 4 dS/m, and tended to decrease with increasing water salinity level without significant differences between soils. The relative decrease amounted to 72% on average compared to the fresh water treatment.

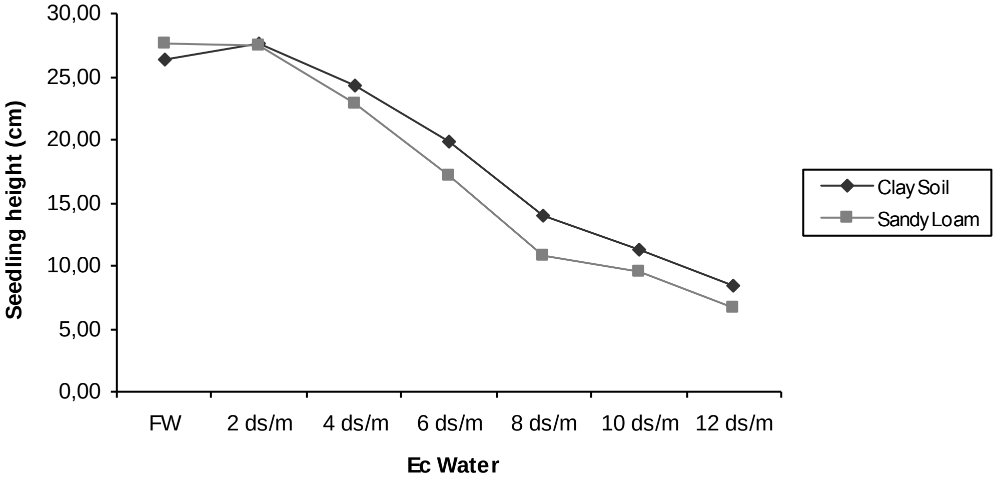

Figure 6. Effect of irrigation water salinity and soil type on maize seedling height.

Similar effects of salinity were found by Essa (42) on different soybean cultivars. He found that salinity-induced stress significantly reduced seed germination, plant height and shoot dry weight.
The leaf area of maize seedlings (fig 7.) was slightly increased with the water salinity level of 2 dS/m as compared to the fresh water treatment, although the increment was not significant in the sandy loam soil. At these levels of water salinity, the absolute values of leaf area were higher under sandy loam soil than those recorded with clay soil.

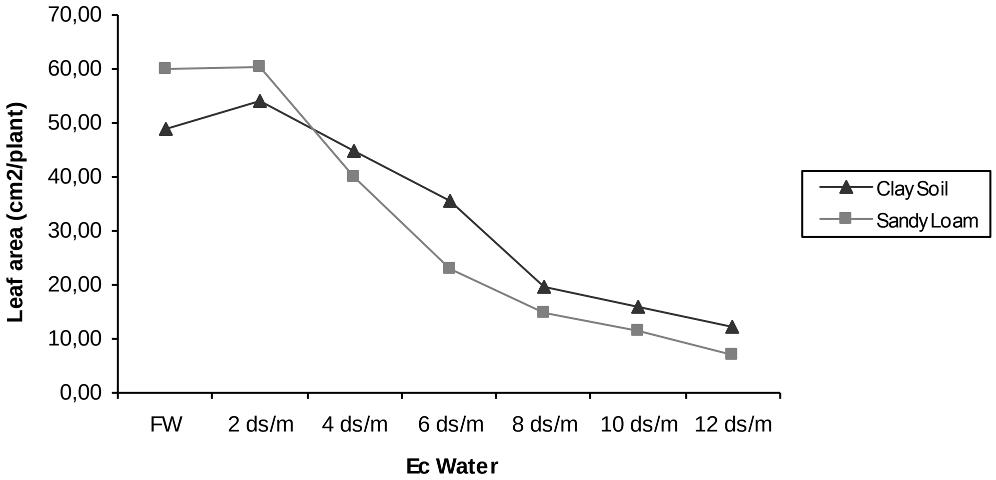

Figure 7. Effect of saline irrigation water and soil type on leaf area of maize seedlings cm2/plant at the end of experiment duration (44 day).

Reduction in leaf area was induced with application of 4 dS/m water salinity and gradually continued up to 12 dS/m salinity level. From this point, the values of leaf area were higher – although not always significantly - under clay soil than sandy loam soil. Water salinity induced relative decreases of about 67%, 81% for 10 dS/m level and 75%, 88% for 12 dS/m, for clay and sandy loam soil, respectively. Rashid et al (43) found that leaf area parameters were adversely affected by the addition of salts. On the other hand, Munns et al (44) found no differences in leaf expansion between wheat cultivars and no relationship between leaf expansion rate and salt-tolerance over a10-days period.

Leaf dry weight is presented in Figure (8). It was significantly affected by water salinity, increasing at 2 dS/m in clay, and decreasing when water salinity level was increased beyond 4 dS/m in both soils.

Strong decrease in leaves dry weight was recorded with highly saline water (12 dS/m) as compared to the other salinity levels or fresh water control. Such high salinity level induced relative decrease in dry weight approximately by 94% and 98% on the base of fresh water treatment, for clay soil and sandy loam soil, respectively.

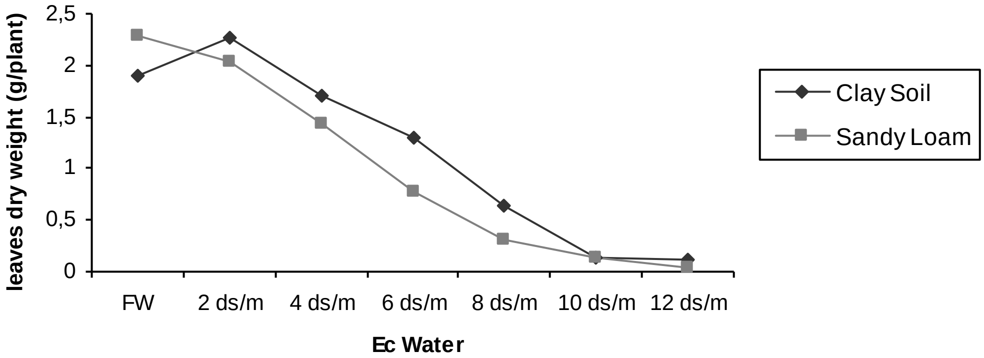

Figure 8. Effect of water salinity levels and soil type on leaves dry weight of maize seedlings at the end of experimental duration.

In this regard, our results are in agreement with those reported by Tajbakhsh et al [(40)] Kayani et al [(45)]; Rashid et al [(43)], where they found an adverse effect of salinity on leaf expansion as well as on growth in general. Mer et al [(46)] elucidated that the reduction of the growth of young plants of the test crop species in saline soil can be attributed largely to reduced water absorption caused by reduced water potential in the root environment.

The changes in root dry weight is illustrated by Figure (9). An increase was recorded between the fresh water and 2 dS/m water salinity levels in the clay soil. Root dry weight decreased with increasing water salinity levels beginning with addition of 4 dS/m for the clay soil and from 2 dS/m fro the sandy loam. The total decrease was about 90% and 94% for clay and sandy loam soil, respectively.

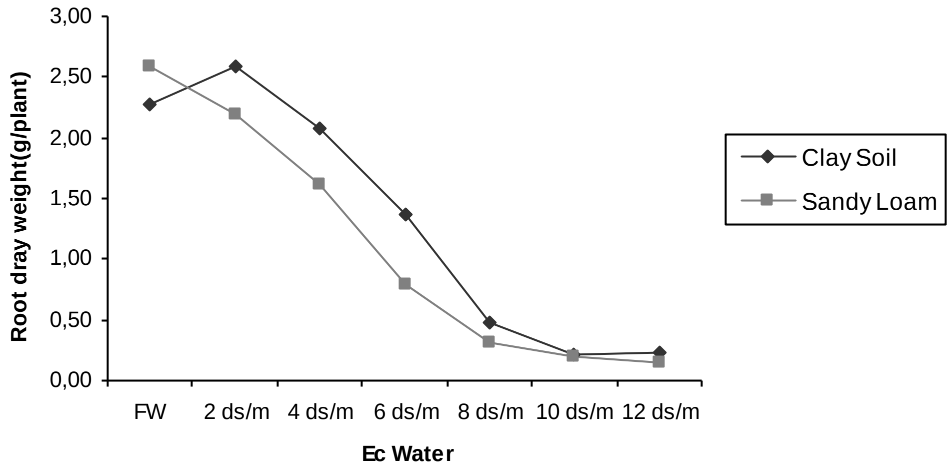

Figure 9. Effect of water salinity and soil type on root dry weight of maize seedling at the end of experimental duration.

Our data show that biometric characters of maize seedlings were affected by lower values of salinity in the irrigation water than the germination timing and percentage. This may be interpreted as a lower sensitivity to salinity of the germination stage per se, although it must be considered that earlier stages of plant growth are usually exposed to a lower accumulation of salts in the soil due to use of saline irrigation water. However, Lynch *et al* [(47)] found that a cultivar that was most sensitive at the seedling stage proved more resistant at maturity, whereas the one with greatest initial resistance to salinity was more sensitive at maturity, this indicating a significant effect of the growth stage.

Considering the soil type effects, our results confirm reports of Hamdy [41] that in heavy clay soil, although salts accumulated relatively more than in sandy soil, seeds had a higher germination rate and the seedling was better developed than sandy texture.

CONCLUSIONS

The maize var. SEL. CONETA proved moderately sensitive to salinity in irrigation water but the germination stage was more resistant since germination percentage was not inhibited significantly using water of salinity level up to 8 dS/m, whereas the growth of seedlings was inhibited at a lower salinity levels starting at 4 dS/m. Increments in the irrigation salinity level did not stop germination but they delayed and reduced it gradually. Seed germination and seedling growth were less affected by salinity of irrigation water in fine textured soil (the clay soil) rather the coarse textured soil.

Nevertheless, under saline irrigation practices in clay soils the Ec, Cl- and Na+ accumulation was higher than that in sandy loam soil.

Therefore, soil properties and climatic conditions, not only salt tolerance degree of the crop, should be taken into consideration when decided to reuse the saline water in irrigation practices.

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