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SEEDLING ESTABLISHMENT OF MAIZE AND THE USE OF SALINE WATER IN DIFFERENT SOIL TYPES

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ABSTRACT – In a greenhouse of the Mediterranean Agronomic Institute of Bari, an experiment was conducted and consisted on the study of the response of 2 varieties of maize under 2 soil types (sandy-loam and sandy-clay), 8 salinity levels (FW, 2, 4, 6, 8, 10, 12 and 15 dS/m) and 3 treatments during the seedling establishment (A = control treatment, B = giving a first irrigation with freshwater and C = soaking seeds). Results showed no difference between the two varieties except stem dry matter and root depth; the increase of salinity in irrigation water affected negatively all the parameters, except the germination percentage; all this was more pronounced under the sandy-loam soil. Soaking seeds did not improve the germination rate; it accelerated the seedling emergence and, above the water salinity level corresponding to 10 dS/m, it reduced the germination percentage. Treatment B improved the germination percentage and the seedling tolerance to salinity.

Key words: maize, soil type, saline water, seedling establishment

INTRODUCTION

Maize (*Zea mays* L.) is a monoic annual plant which belongs to maideas tribe and the grass family of gramineae. The productivity of maize is due to its large leaf area and its C4 photosynthetic pathway.

Some tropical varieties of maize grow as tall as 7.5 m and may have more than 4 to 5 ears per stalk. Others are as short as only 0.9 m. Maize is cultivated at latitudes of 50 degrees north and south, and from sea level to 3600 meters elevation, in cool and hot weathers, and with growing cycles oscillating from 3 up to 13 months. It is a versatile crop, and it has tremendous genetic variability, which enables it to thrive well under tropical, subtropical, and temperate climates. It is grown in more countries than any other cereal (Mejía, 2003).

Of relevance for nutritionists, food technologists, and other scientists is the structural part which forms the mature kernel of maize. The kernel parts include: the pericarp or hull (thin covering which encloses the kernel); the endosperm (starch section of the kernel with both soft and hard starch); the germ (embryo), portion which contains a high proportion of oil (4.5 percent w/w).

The endosperm composition is the variable feature of maize that relates most closely with its food uses; its characteristics are also used as a base for maize classification (Mejía, 2003).

One of the major reasons prompting this study is the forecast increase in maize demand. In fact, by 2020, demand for maize in developing countries will probably surpass the demand for both wheat and rice. This shift will be reflected in a 50% increase in global maize demand from its 1995 level of 558 million tons to 837 million tons by 2020. Maize requirements in the developing world alone will increase from 282 million tons in 1995 to 504 million tons in 2020 (IFPRI, 2000). The challenge of meeting this unprecedented demand for maize is daunting.

The dominant constraint to bridging the gap between potential and actual yields is drought/moisture stress; Edmeades *et al.* (1992) estimated that annual drought losses in the early 1990's across tropical maize growing environments represented a 15% in production. Individual episodes of losses, however, can be far more extreme: a devastating drought in southern Africa in

1991–92 reduced maize production by about 60% (Rosen and Scott 1992, as reported in Heisey and Edmeades 1999).

Consequently, drought stress is one of the major physical factors responsible for limiting maize production. There are no technological means, other than the introduction of reliable irrigation, for restoring all maize lost to drought stress.

Drought stress particularly affects the ability of the maize plant to produce grain at three critical stages of plant growth: early in the growing season (when plant stands are established), at flowering, and during mid – to late grain filling:

i. By damaging plant stands at the beginning of a season, drought can strongly curtail yield. This is relatively common because the probability of drought is high at this time. A farmer confronted with this situation has several management options, all requiring replanting later in the season. They include replanting the field(s) with the same cultivar, planting a shorter maturity cultivar, or planting a different species that matures more rapidly.
ii. Mid-season drought is less likely to occur than drought at the beginning or end of the season, but it can be devastating because maize is particularly susceptible to drought stress during this period when the plant flowers. Short of irrigation, the farmer has no management alternatives since it is too late in the season to replant.
iii. Grain yield reductions from mid – to late grain filling are not nearly as severe as those produced by a similar stress during flowering. Again though, farmers are left with no management options for responding to the stress.

According to Bischoff *et al*. (2000), irrigation water salinity has its greatest influence on corn growth and yield response during the seedling stage, which is the crop's most critical growth period. The aim of the present experiment is to get further information about the reaction of 2 maize varieties to salinity in combination with two soil textures. In addition to the control treatment, two other treatments were introduced in order to study the effect of a first irrigation with freshwater and the effect of seed pre-conditioning.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse of the Mediterranean Agronomic Institute of Bari (Valenzano), located at an altitude of 72 m, at 41°C 03' 16'' E latitude. It is important to note that the greenhouse is equipped with aeration and heating systems (Fig. 1).


(a)

(b)

Figure 1. Greenhouse's equipments: (a) aeration and (b) heating systems

Set-up

The set-up consists on 384 perforated aluminium containers with the following dimensions (Fig. 2).

Figure 2. Aluminium container dimensions used in the experiment

One series of 192 containers was filled with a sandy-loam soil (Soil 1) and a second series with a sandy-clay soil (Soil 2). The following table gives the physical and chemical characteristics of both.

Table 1. Physical and chemical characteristics of the soils

	Physical characteristics				
	Clay (%)	Silt (%)	Sand (%)		Texture
			coarse	fine	
Soil 1	16	4	76	4	sandy loam
Soil 2	41,5	12,5	16,1	29,9	sandy clay

	Chemical characteristics							
	Soluble anions (meq/l)				Soluble cations (meq/l)			
	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
Soil 1	-	1,5	1,8	0,88	2,3	0,5	0,8	0,44
Soil 2	-	2	3,3	1,34	4,6	0,7	1,0	0,44

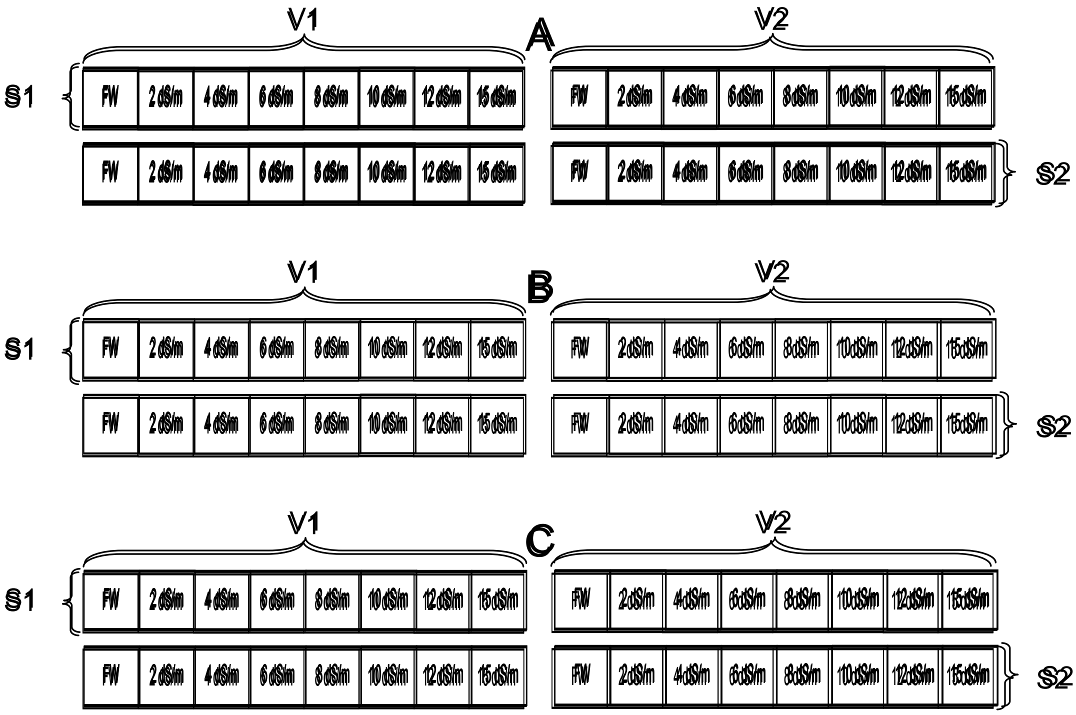
Every soil type was submitted to 3 different treatments: a control treatment (treatment A), a first irrigation with freshwater followed by the saline water treatment (treatment B) and a soaking treatment (to put the seeds in the irrigation water 12 hours before sowing, treatment C).

The containers were irrigated with water of 8 different salinity levels: the control treatment with freshwater; the others are the result of mixing freshwater (1.1 dS/m) with seawater (43.5 dS/m) in different ratios in order to obtain the following salinity levels: 2, 4, 6, 8, 10, 12 and 15 dS/m.

Since we tested 2 maize varieties in 4 repetitions, we had:

$$\begin{aligned} number\ of\ containers &= 4\ repetitions \times 8\ salinity\ levels \times \\ &\times 2\ soil\ types \times 2\ varieties \times 3\ treatments \\ &= 384\ containers \end{aligned}$$

The general lay-out of the experiment is reported below.



Where:

V1: variety 1 (PR33J24),
V2: variety 2 (LOLITA),
S1: soil 1 (sandy-loam soil),
S2: soil 2 (sandy-clay soil),
A: treatment A (control treatment),
B: treatment B (first irrigation with freshwater), and
C: treatment C (seed pretreating 12 hours before sowing).

The crop

Maize (*Zea mays*) was the chosen crop in our experiment. Ee tried to study the behaviour of two varieties: PR33J24 (variety 1) and LOLITA (variety 2), both of them belonging to the class FAO 600.

Maize was sown at a density of 10 kernels per container the 12 December 2003. It was irrigated constantly to the field capacity without receiving any fertilizer, till the 1st of February 2004. Every 2days, the germination percentage was determined, and when we reached the end of the seedling establishment stage (the 1st of February 2004) as the number of leaves per plant reached 4; for every set, every soil, every variety and every irrigation water salinity level, the following measurements were done:

- maximum root system development (cm/plant),
- maximum dense rooting development (cm/plant),
- plant height (cm),
- leaf area (cm^2/plant)
- leaf dry matter (mg/plant),
- stem dry matter (mg/plant), and
- root dry matter (mg/plant).

In addition, the soil was subjected to chemical analysis in order to determine the EC_e of the extract of soil saturated paste (dS/m) and the chloride content (meq/l).

Finally, all data were subjected to ANOVA and the differences among the mean values were detected according to DUNCAN test.

RESULTS AND DISCUSSIONS

The Germination and Its Evolution

Regarding treatment A, the germination started 9 days after sowing. It was slow in the beginning, but it increased rapidly and reached a constant value. This was the general trend but, differences exist not only between the different water salinity levels, but also between the two soil types. In fact, the following figure shows the germination increase in percentage terms in both soil types and for the two varieties (Fig. 3).

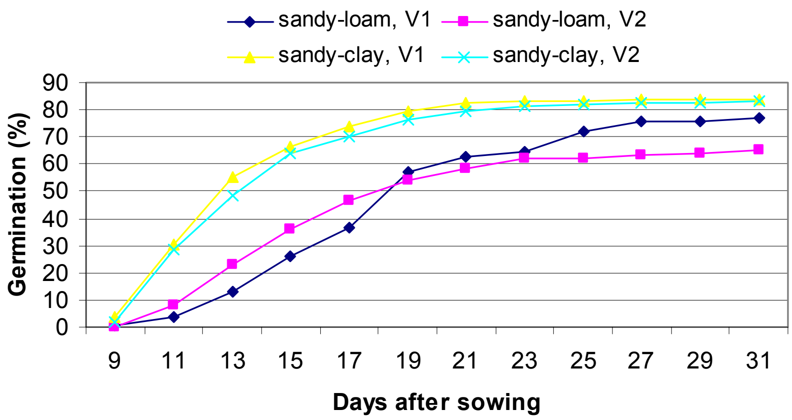


Figure 3. Germination percentage evolution in treatment A

Regarding the A treatment, it is evident that seeds germinated more rapidly in the sandy-clay soil than in the sandy-loam one. Seed germination rate in the sandy-clay soil was high in the beginning, and then it started decreasing. 3 weeks after sowing, the germination percentage attained its maximum; both varieties showed the same trend and no significant difference can be seen between them.

In contrast to the sandy-clay soil, in the sandy-loam one, seed germination rate remained constant during almost all the period of our experiment but it decreased more quickly with the second variety than with the first one. Although in day 9 after sowing less than 5% of the total seeds germinated (average regarding the A treatment, independently of the irrigation water salinity level), if we examine the evolution of the germination percentage for every water salinity level, the following figure results (Fig. 4).

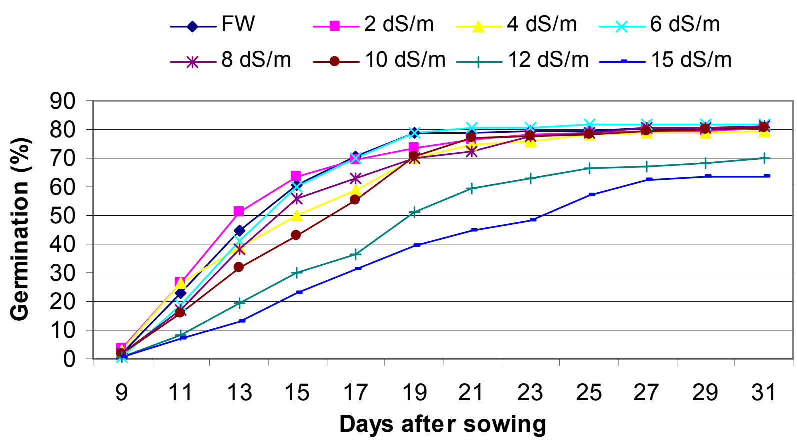


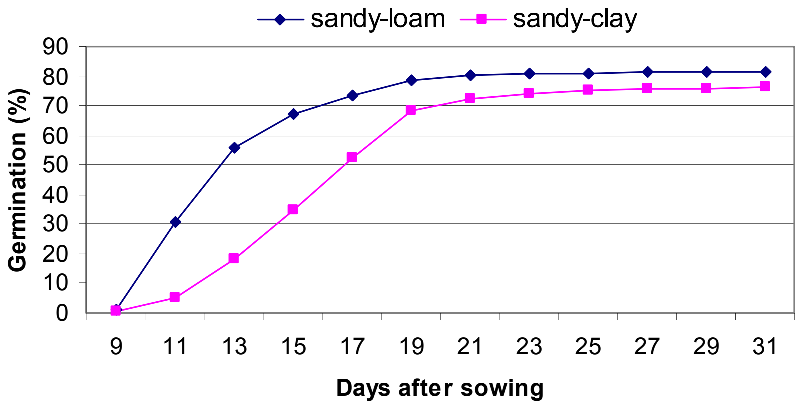
Figure 4. Water salinity effect on the germination evolution

It is evident that the germination evolution is strongly affected by the water salinity level, especially in the highest salinity levels: 12 and 15 dS/m.

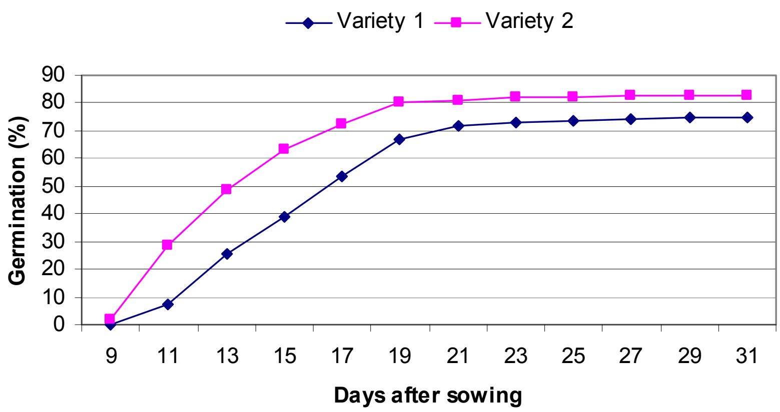
From the above mentioned figure, we can identify 3 groups:

1) The first one, which received freshwater or water with an EC of 2 or 4 dS/m: it is characterized by a high germination percentage not only at the end of the seedling establishment, but also at the beginning of this stage;
2) The second, which received water with EC of 6, 8 or 10 dS/m: it is characterized by a high final germination percentage which was initially low (about 2/3 of the first group);
3) The third, receiving an irrigation water of 12 and 15 dS/m: it reached lower values of germination percentage with a lower rate of evolution.

The figure 5 (a and b) shows the germination evolution under the treatment B.



(a) Differences between soil types



(b) Differences between varieties

Figure 5. Differences in germination evolution under treatment B

- If we compare the results in treatment B to those in the control (A), the main differences result in: a higher and faster germination under the sandy-loam soil. In fact, the light soils, such as the sandy-loam one, are characterized by the presence of a high porosity (macro-pores) and a lower resistance to the coleoptile, as compared to the other soils. By giving initially good quality water, we offered to the seedling a good environment for its establishment, resulting from the combination of sufficient moisture with a good aeration.
- Better results were obtained with the second variety.

If we isolate the variable variety from the soil type one, we will get the following figure.

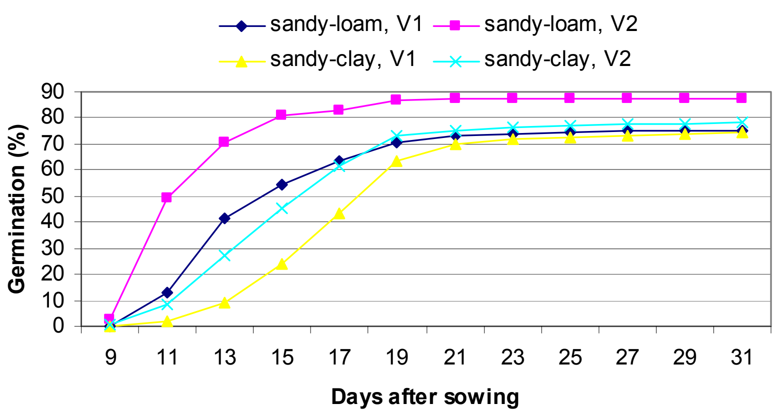


Figure 6. Germination percentage evolution under the treatment B

It is evident that the response of the two varieties under the sandy-clay soil remains almost the same. However, under the sandy-loam soil, the V2 germination was better not only for its faster rate, but also in terms of final germination percentage; it resulted the highest although it was the lowest one in treatment A.

The same comparison was done between the treatments A and C (Fig. 7 and 3). The soaking effect can be summarized as follows:
1) a higher germination percentage of V2 under the two soil types;
2) a higher initial germination and a higher rate of germination.

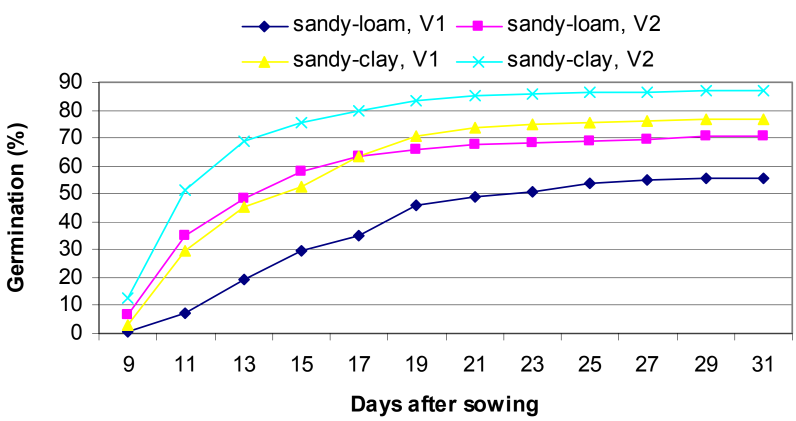


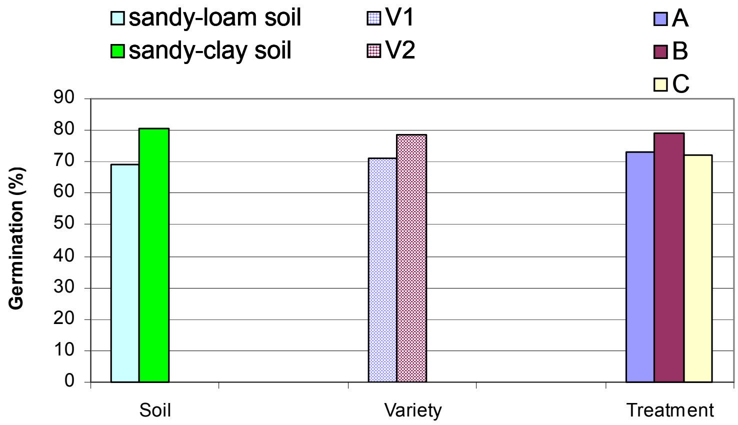
Figure 7. Germination percentage evolution under treatment C

From a practical viewpoint, for a farmer, the most important parameters are:
- a high germination rate; and
- a fast germination and seedling establishment.

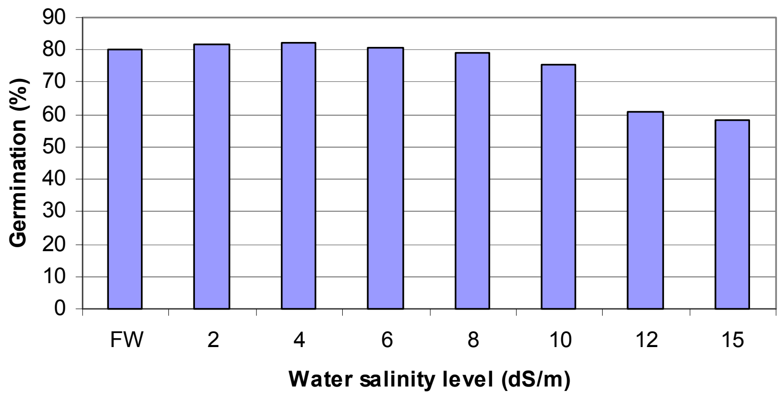
Consequently, we are going to give more weight to the germination percentage analysis at the end of the seedling establishment, and as we have 4 variables:
- water salinity levels: freshwater, 2, 4, 6, 8, 10, 12 and 15 dS/m;
- varieties: PR33J24 and Lolita;
- soil types: sandy-clay soil and sandy-loam soil; and
- seed treatments: A: directly irrigated with the different water of different salinity level,
  B: receiving a first irrigation with freshwater, then, water of different salinity levels;

C: seeds were soaked in the irrigation water, 12 hours before sowing.

we will try to compare the single variables between them, and then make the cross comparison. As a consequence, the following figure (8) shows the germination percentage as affected by the soil type, variety and seed treatment (a) and the water salinity level (b)



(a) Soil type, variety and seed treatment effects on the germination percentage



(b) Water salinity effects on germination

Figure 8. Soil type, variety, seed treatment and water salinity level effects on the germination percentage

As a general effect, all the above mentioned variables affected the germination percentage at the end of seedling establishment; this was significant at a probability of 5% for the seed treatments and at 10% for soil types, variety and water salinity levels. However, from the previous figure (8, b) we can see that the water salinity level effect becomes significant when it exceeds 10 dS/m.

Let's analyze the effect of the water salinity level on germination, as it is an important parameter, if we are going to use it in drought and/or scarcity conditions, and to make the linkage with the previous result (the germination is affected when the water salinity level exceeds 10 dS/m). In fact, this was the case for the two varieties, under the two soil types and the 3 treatments (Fig. 9 a, b, c, d, e and f).

We reported a significant difference between the two varieties at 10% probability (a higher germination percentage of the second variety). Both varieties showed a high and stable germination percentage, except in the highest water salinity, although generally, results of the first variety were lower than those of the second one, yet, not statistically significant. In fact, the above mentioned significance is due mainly to a lower germination of the first variety under the treatment C, when irrigated with a water of 10 and 12 dS/m in the sandy-loam soil (Fig. 9 a, b, c and d).

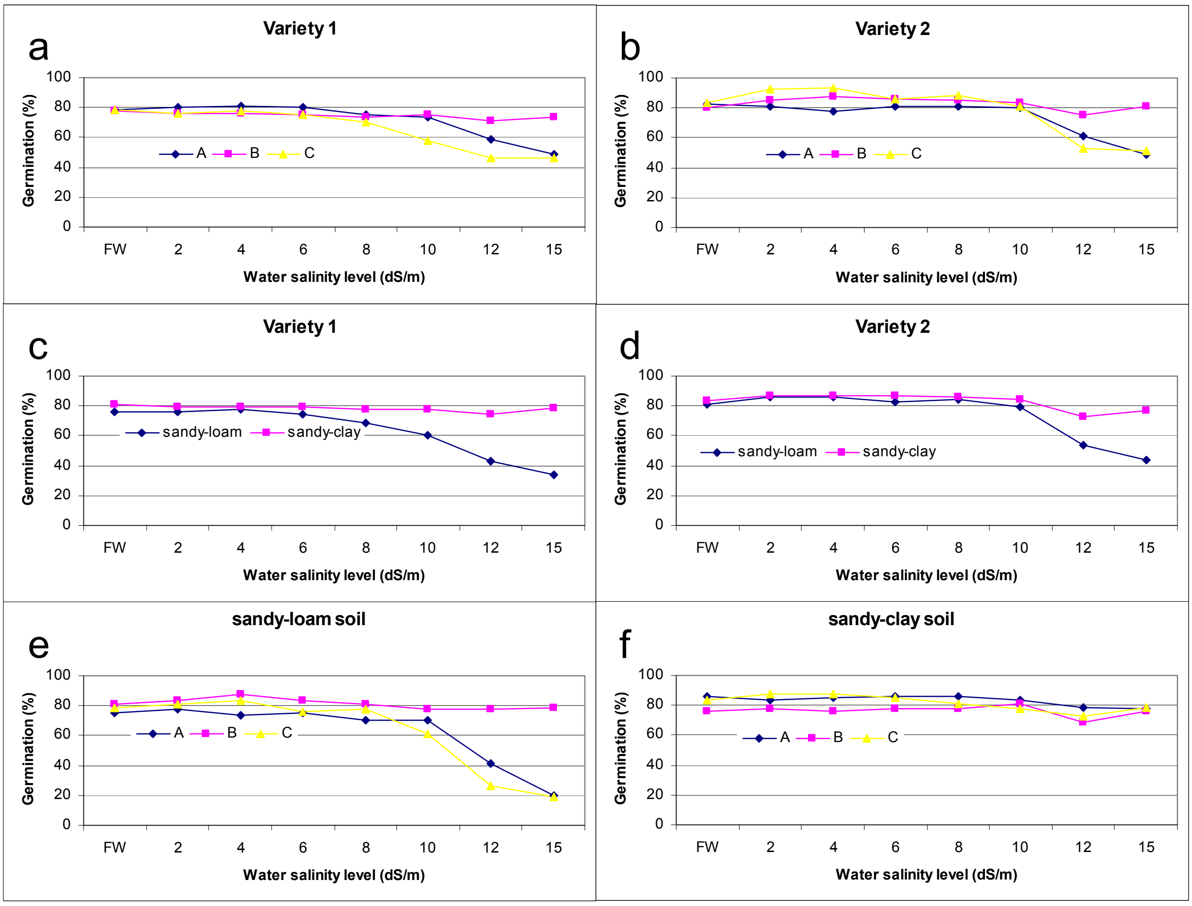


Figure 9. Water salinity level, seed treatment and soil type effects on the germination percentage of every variety

It is also evident that soil type influences the germination through its physical and chemical characteristics.

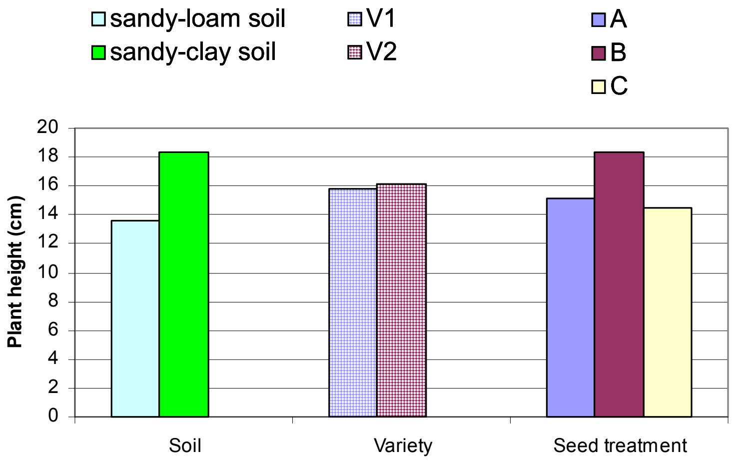
In fact, the previous figure (Fig. 9 c, d, e and f) shows clearly how the soil type had a great effect on the germination percentage, only when water of high EC was used (10, 12 and 15 dS/m). In fact, under the sandy-clay soil, the germination percentage remained the same, for the 3 treatment, probably due to soil-buffering ability. However, in the case of sandy-loam soil, the germination percentage persisted higher only under the B treatment; it decreased drastically for the other two treatments when an irrigation water of more than 10 dS/m was used. In fact, under the B treatment, giving a first irrigation with freshwater means creating a good germination-environment for the seeds, and which was reflecte by a good germination, which was completely the opposite to the case of the C treatment (Fig. 9 e).

The Vegetative Part

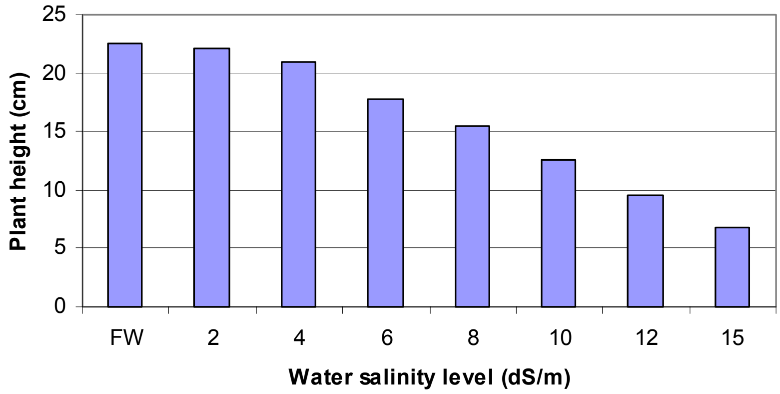
At the end of the seedling establishment, we measured the plant height (cm) and the leaf area (cm^2), analyzing all the interactions. In addition, we weighted the dry matter of every part (leaves and stem) in order to analyze them separately for possible differences.

Plant Height

Regarding the plant height, and as average values, no significant difference was reported between the varieties, yet, a significant one at a probability of 10% was noticed when analyzing the response to the soil types (sandy-loam and sandy-clay), seed treatments (A, B and C) and water salinity levels (Fig. 10).



(a) Soil type, variety and seed treatment effects on the plant height



(b) Water salinity effects on plant height

Figure 10. Soil types, varieties, seed treatments and water salinity levels effect on plant height

In fact, regarding the varieties, both varieties showed the same reaction to the irrigation water quality (plants higher when irrigated with water of better quality as well as the same height decrease as a result of the irrigation water salinity increase (Fig. 11).

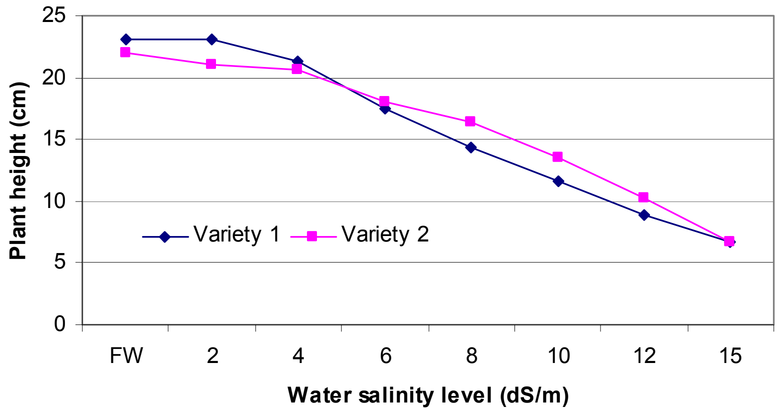


Figure 11. Interactions varieties x water salinity levels

As a result, we can mention that both varieties have the same sensitivity to salinity during the seedling establishment. Furthermore, under the B treatment, plants resisted more to high salinities and differences between treatments became evident when the salinity of irrigation water exceeded 8dS/m (Fig. 12) under both soil types (sandy-loam and sandy-clay soil).

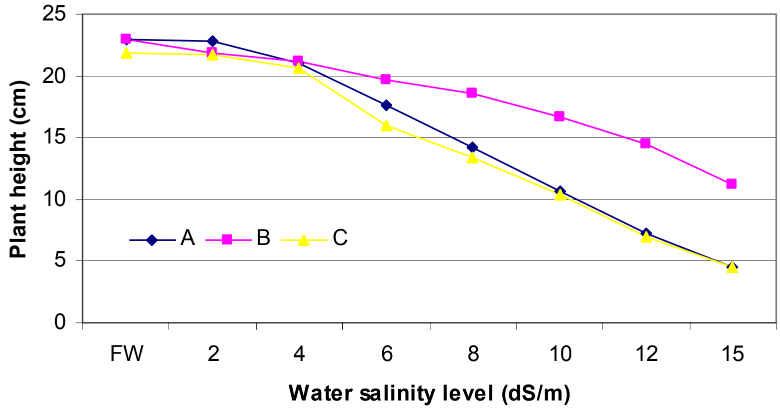


Figure 12. Interactions water salinity level x treatments

Leaf Area

One of the most important parameters is the leaf area; it influences the photosynthesis and growth of the plant. However, and as average values at the end of the seedling establishment, the leaf area of the first variety was 22.15 cm^2/plant whereas it was 23.60 cm^2/plant for the second one, which means a significant difference at a probability of 5%. This was also the case of the interactions varieties x soil types and varieties x seed treatments, except the B treatment, where the difference becomes significant at 10% probability (Fig. 13).

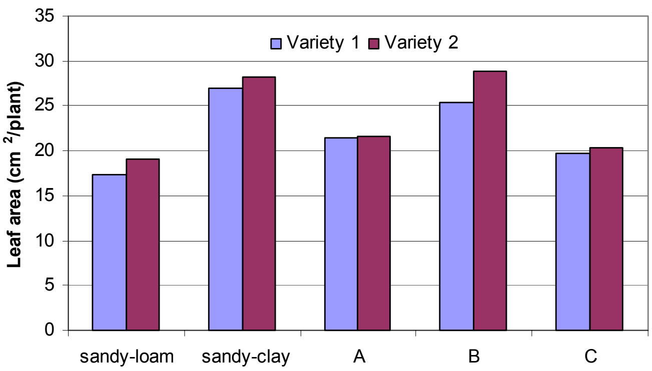
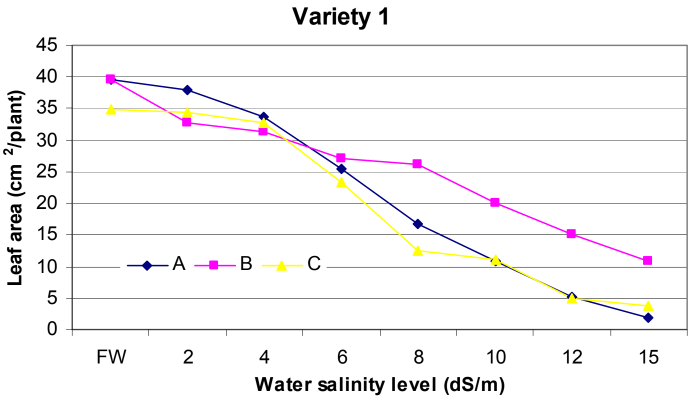
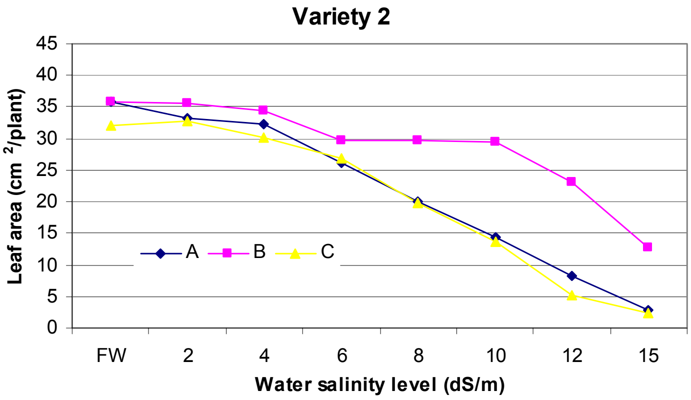


Figure 13. Effect of the Interactions soil type x variety and seed treatment x variety on the plant leaf area

In fact, under lower salinity levels, the leaf area developed by the first variety is higher than the one developed by the second variety. Then, and due to the salinity increase, leaf area of both varieties is negatively affected, yet, this reduction is higher with the first variety, especially under the B treatment. Consequently, as an average, the leaf area of the second variety is higher, and significantly, although at low salinities, the first variety developed larger leaves (Fig. 14).



(a) seed treatments and water salinity effects on the first variety leaf area development



(b) seed treatments and water salinity effects on the second variety leaf area development

Figure 14. Leaf area as affected by the seed treatments and water salinity levels

The soil type has a great effect on the leaf area development at almost all levels of the irrigation water salinity (Fig. 15).

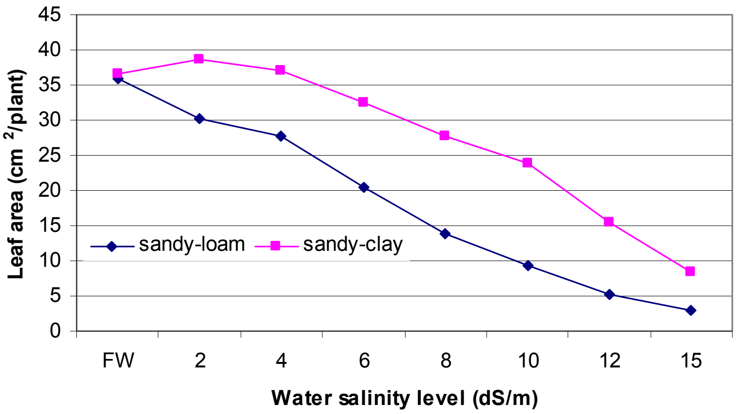


Figure 15. Interactions soil types x water salinity levels and their effect on leaf area development

In fact, sandy-clay soil is, from one hand, richer in macro and micro-elements, that's why it allowed a better development of the leaves when water of low salinity was used. From the other hand, and under high water salinity levels, clay particles intervene as buffer in reducing the harmful effects of some cations (such as Na^+) present in the soil solution, permitting a better development of the leaf area with respect to the sandy-loam soil.

Except the B treatment, generally, the leaf area decreased linearly with the increase of the water salinity level. In addition, if we try to relate the leaf area to the water salinity level, using a simple linear relation, we get a high coefficient of correlation (0.979); this can be easily seen by the next figure.

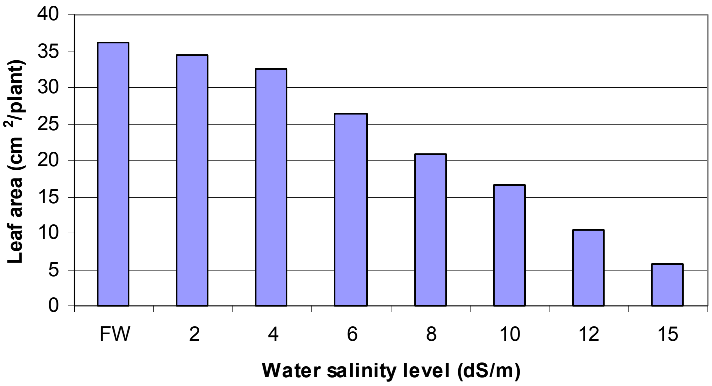
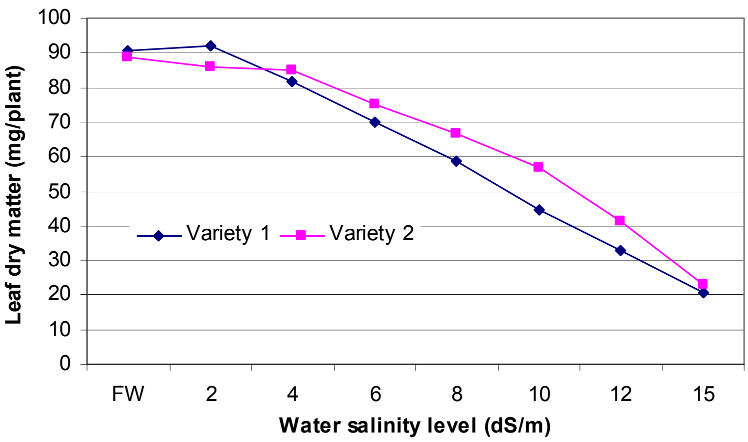


Figure 16. The leaf area as affected by the water salinity level

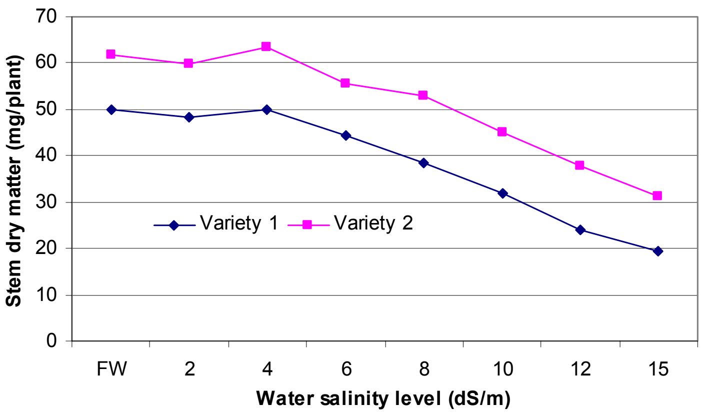
Vegetative Dry Matter

The vegetative dry matter is the result of the sum of leaf dry matter and stem dry matter. In order to make the discussion lighter, we are going just to mention the differences between the different variables effect on the leaf dry matter and the stem dry matter, in order to take them into consideration once we will analyze the vegetative dry matter.

Analyzing the leaf dry matter and the stem dry matter of every variety separately, we identified a significant difference at 10% of probability regarding the stem dry matter, whereas a significant one at 5% of probability in the case of leaf dry matter. This can be explained by the fact that the second variety was able to develop a thicker stem as they had the same height; this remained true as the water salinity level increased (Fig. 17).



(a) leaf dry matter: interaction varieties x water salinity levels



(b) stem dry matter: interaction varieties x water salinity levels

Figure 17. Leaf (a) and stem (b) dry matter as affected by the water salinity level for the two varieties

Regarding the other variables (soil type, seed treatment and water salinity level), and as average values, leaf dry matter and stem dry matter showed the same results (a significant difference between the soil types at 10% probability; no significant difference between A and C treatments, yet a significant one at 10% probability with respect to the B one and a decrease in both leaf and stem dry matter as a result of water salinity increase).

As regards the vegetative dry matter and as average values, it followed the same trend of the stem dry matter, as influenced by it, which means:

- a significant difference between the soil types, at 10% probability: a high vegetative dry matter production under the sandy-clay soil (127 g/plant in the sandy-clay soil versus 89 g/ plant in the sandy-loam one);
- a high and significant vegetative dry matter production of the second variety (116 g/plant);
- a high dry matter production under the B treatment (127 g/plant) compared to 101 g/plant under the A treatment and 100 g/plant under the C treatment; and
- a significant decrease in the dry matter production when the salinity of the irrigation water exceeds 6 dS/m (Fig. 18).

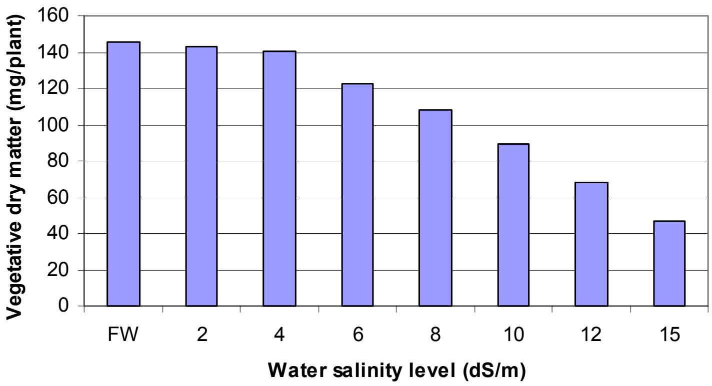


Figure 18. Water salinity level effect on vegetative dry matter production at the end of the seedling establishment

Furthermore, compared the plant height and leaf area reactions to the soil type and seed treatment, the vegetative dry matter showed a similar trend. In fact, the dry matter production, under the sandy-clay soil, was higher thanthe one under the sandy-loam soil (Fig. 19).

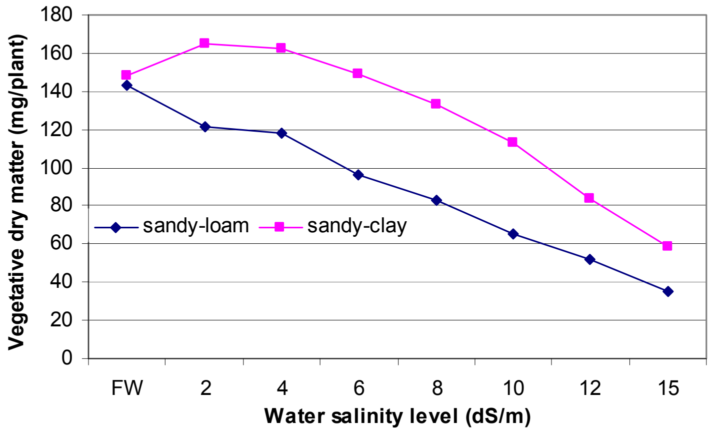


Figure 19. Vegetative dry matter reaction to the soil type

Indeed, under the sandy-clay soil, and compared to the sandy-loam one, maize seedling was able to develop larger leaf area, as well as a superior height, reflected by a bigger dry matter.

Regarding the seed treatment effect, dry matter production under the treatments A and C was almost similar. Below a water salinity level of 6 dS/m, the B treatment was not different from the others, however, above this value, and as the plants resisted to higher salinity levels as a consequence of the first irrigation, the leaf area as well as the plant height remained high (Fig. 14 and 12) and so was the vegetative dry matter (Fig. 20).

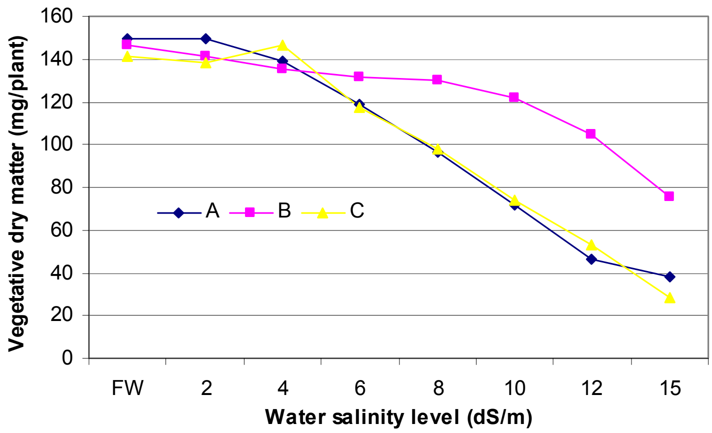
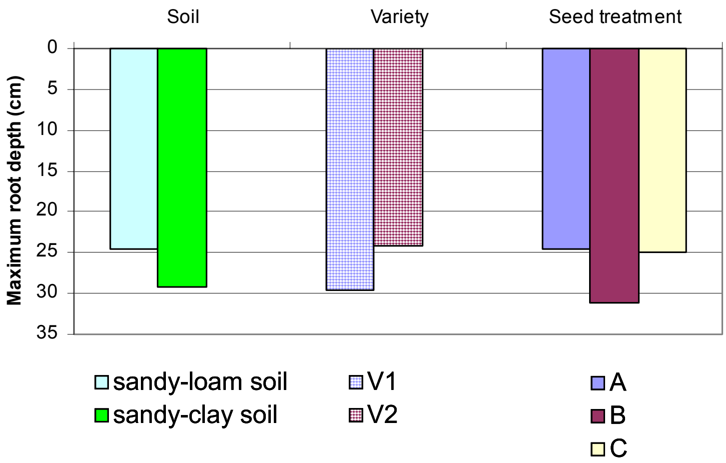


Figure 20. Vegetative dry matter reaction to seed treatments

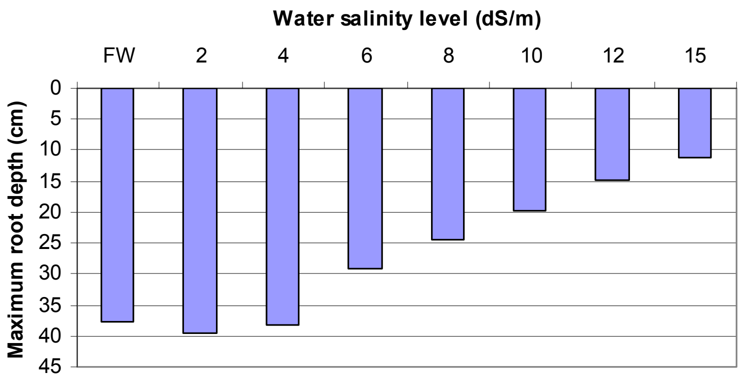
The Root System

Maximum Root System Development

Regarding the root system, its reaction, as an average one, showed a significant difference at 10% probability to the soil type, the seed treatment and the water salinity level; a significant difference was also noticed in the favour of the first variety (Fig. 21).



(a) maximum root system development as affected by the soil type, the variety and the seed treatment



(b) maximum root system development as affected by the water salinity level

Figure 21. Maximum root system development as affected by the soil type, the seed treatment, the water salinity level as well as variety

The previous figure (21, a), shows no significant differences between the A and C treatments. Consequently, kernel's soaking did not improve maize rooting aptitude. However, by giving a first irrigation with freshwater, maize seedling irrigated with water of mid to high salinity level, developed deeper roots as, during the beginning of the germination process, they didn't face any physiologic stress due to the high salt concentration (Fig. 22).

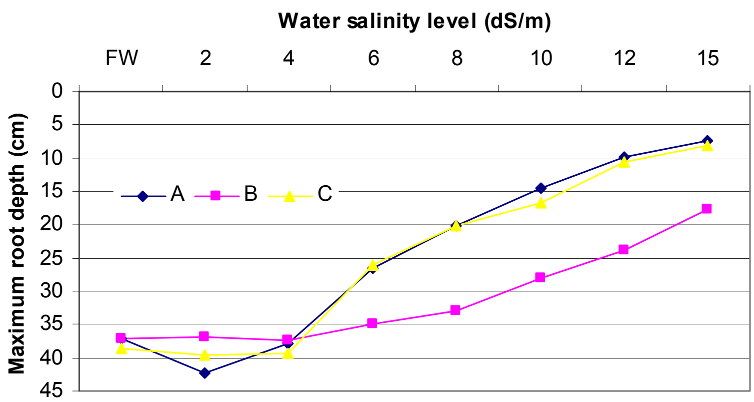


Figure 22. Interactions: seed treatments x water salinity level, on the root system development

In contrast, the reaction of both varieties when irrigated with water of high salinity was the opposite. In fact, under favourable conditions (when irrigated with water of less than 6 dS/m salinity), the first variety developed deeper root system than the second one (Fig. 23), not only under the sandy-clay soil, but also under the sandy-loam one and this, for all the seed treatments (Fig. 24).

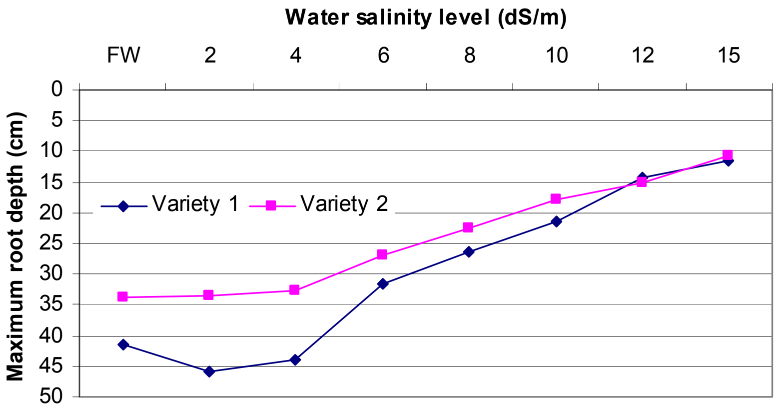


Figure 23. Varietals root system development as affected by the irrigation water level

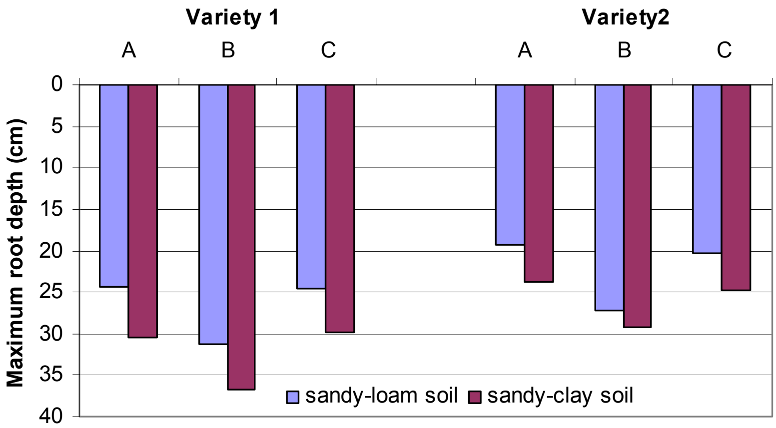


Figure 24. Varietals root system development as affected by the soil type and the seed treatment

Root Dry Matter

As average values, root dry matter, as influenced by the soil type and the seed treatment, showed the same trend (high root dry matter under the sandy-clay soil and the B treatment (Fig. 25)).

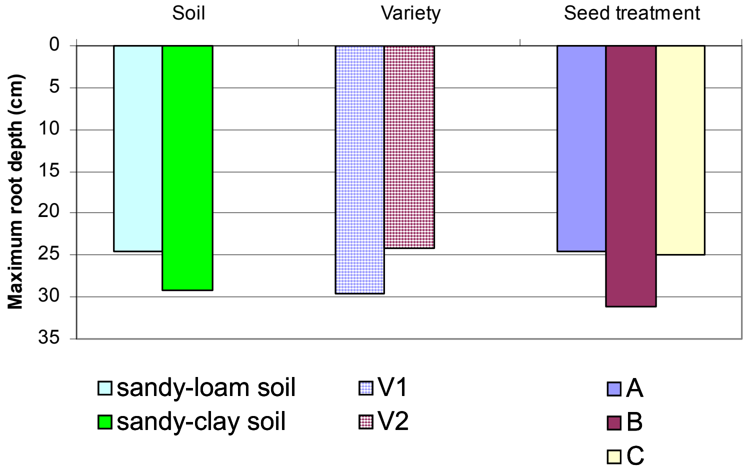


Figure 25. Root dry matter reaction to the soil type, seed treatment and varieties

Although a deeper root system was found in the first variety (Fig. 21a), the second variety shows a higher root dry matter production, as reported in the previous figure.

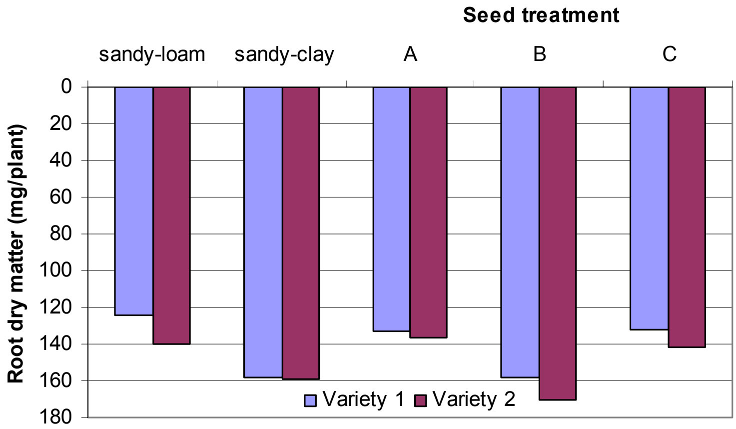
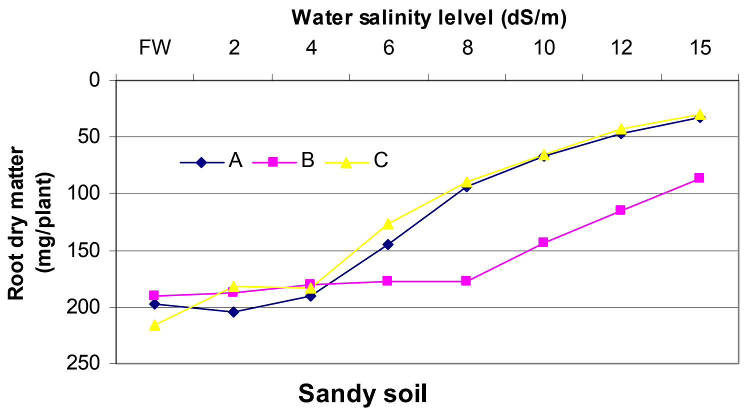


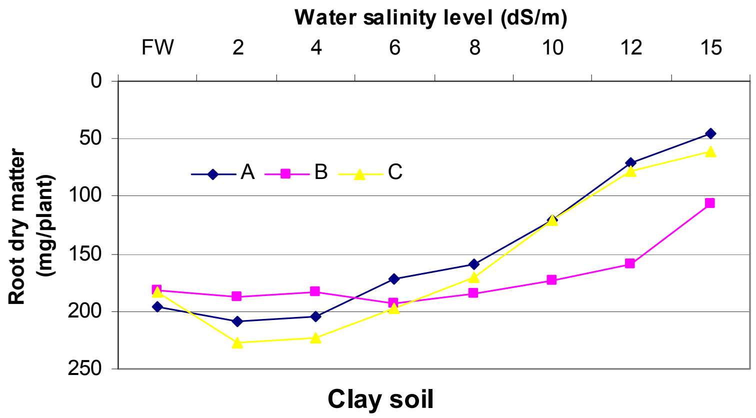
Figure 26. Root dry matter in response to the soil type and the seed treatment for both varieties

While the first variety developed a deeper rooting system and a significantly higher density at 5% probability under both soil types and for the 3 seed treatments the second variety developed a more intense root thickness.

Regarding the root dry matter reaction to the seed treatments, concerning the B one, it remained constant (no significant difference at 5% probability) till receiving an irrigation water of 8 dS/m, while under the other treatments (A and C), root dry matter decreased drastically once we exceeded a salinity of the irrigation water of 4 dS/m; this was the same under both soil types (Fig. 27).



a



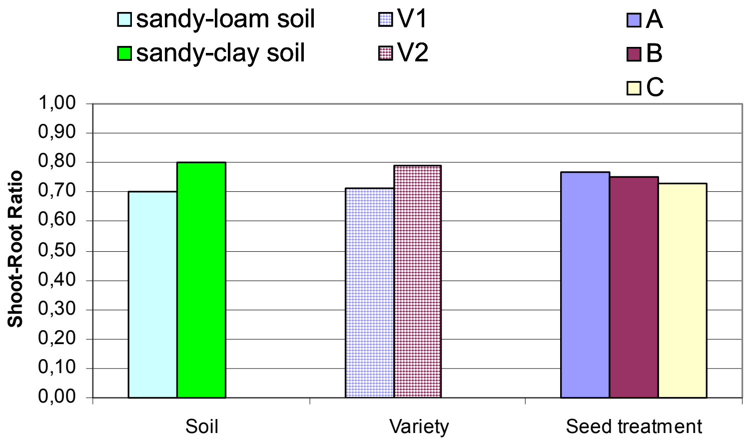
b

Figure 27. Root dry matter reaction to seed treatments and water salinity levels for both soil types

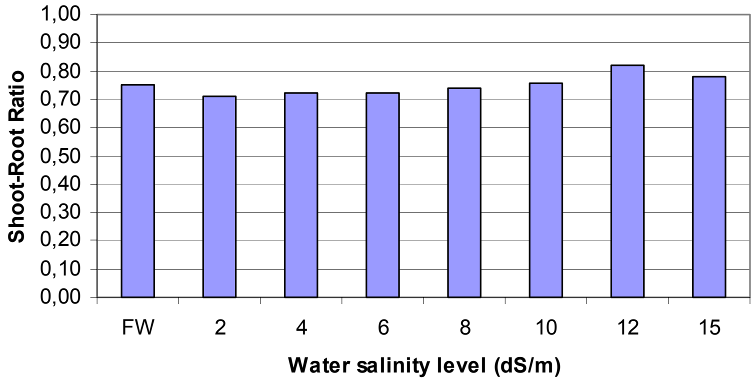
Shoot to Root Ratio

Under all conditions, the shoot to root ratio was lower than 1, which means a higher development of the root part; a logic result as we are studying maize seedling establishment. However, significant differences exist (Fig. 28):

- at 10% probability between the soil types (a);
- at 5% probability between the varieties (a); and
- at 5% probability between the different water salinity levels (b).



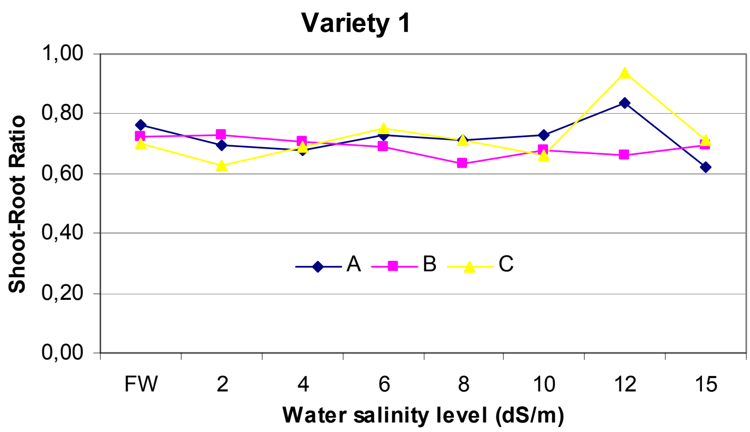
a



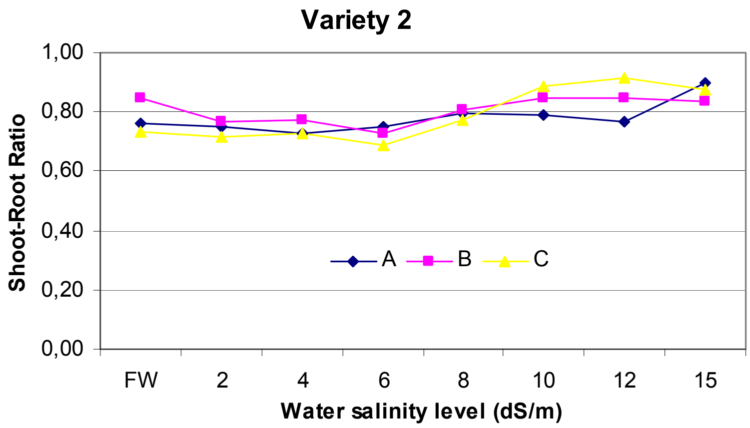
b

Figure 28. Shoot to root ratio as affected by the different variables

Previously, under the B treatment, maize was able to grow better, compared to the other seed treatments, as average values. However, from the figure number 28 a, it is evident that seed treatment affects both the vegetative and the root part, at the same rate, for both varieties (Fig. 29).



a



b

Figure 29. Shoot to root ratio as affected by the interactions: seed treatment, water salinity level and variety

Soil Salinity (ECe and Cl⁻)

Soil fertility can be characterized by several factors: organic matter content, density, macro and micro-elements present in the soil solution or adsorbed at clay particles, salinity, alkalinity, sodicity, … etc.

The trend in ECe (dS/m) and chloride content (meq/l) of the analyzed soils showed a similar tendency under all the interactions; an example is illustrated below (Fig. 30).

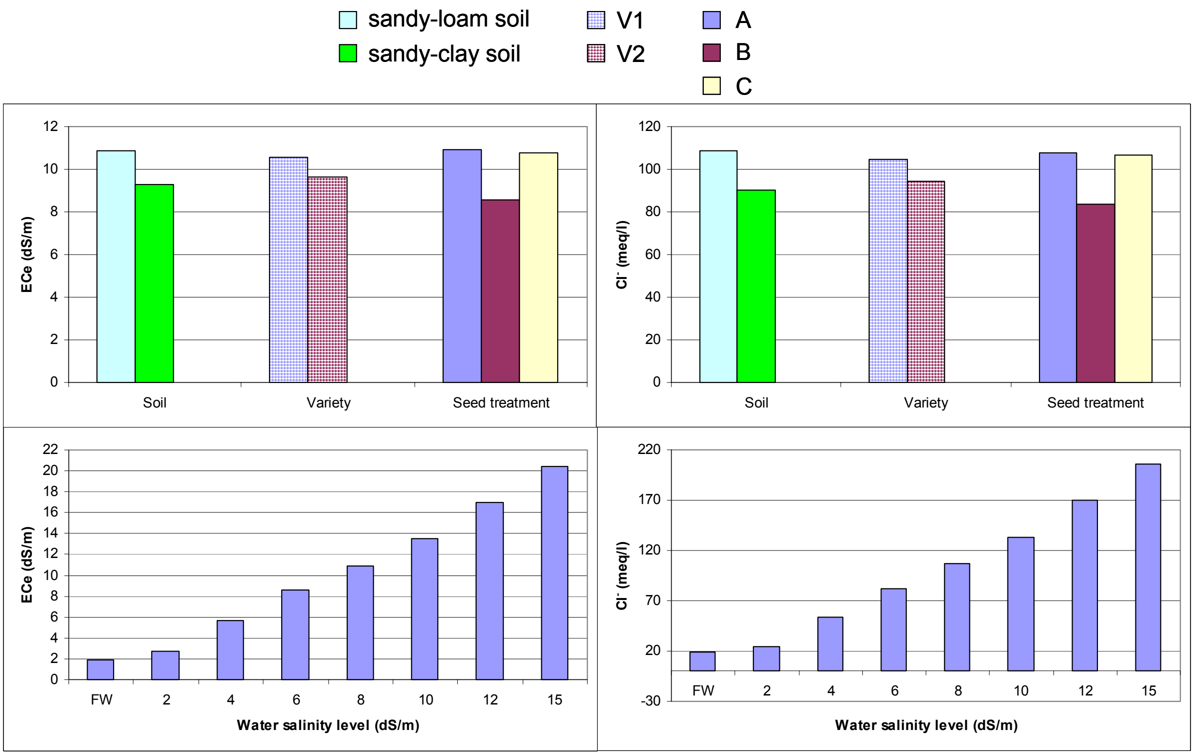


Figure 30. ECe (dS/m) and Cl^- (meq/l) reaction to the soil type, variety, seed treatments and water salinity level

Consequently, we are going to do the discussion for both of them at the same time.

From the above figure, it is evident that, at the end of the seedling establishment, both ECe and Cl^- were significantly influenced by the soil type, the cultivated variety, the seed treatment (A, C versus B) and the water salinity level.

Concerning the different seed treatments, the difference between the B one and the A and C became significant when the irrigation water had a salinity higher than 6 dS/m; in the case of the sandy-clay soil for both ECe and chloride content (Fig. 31).

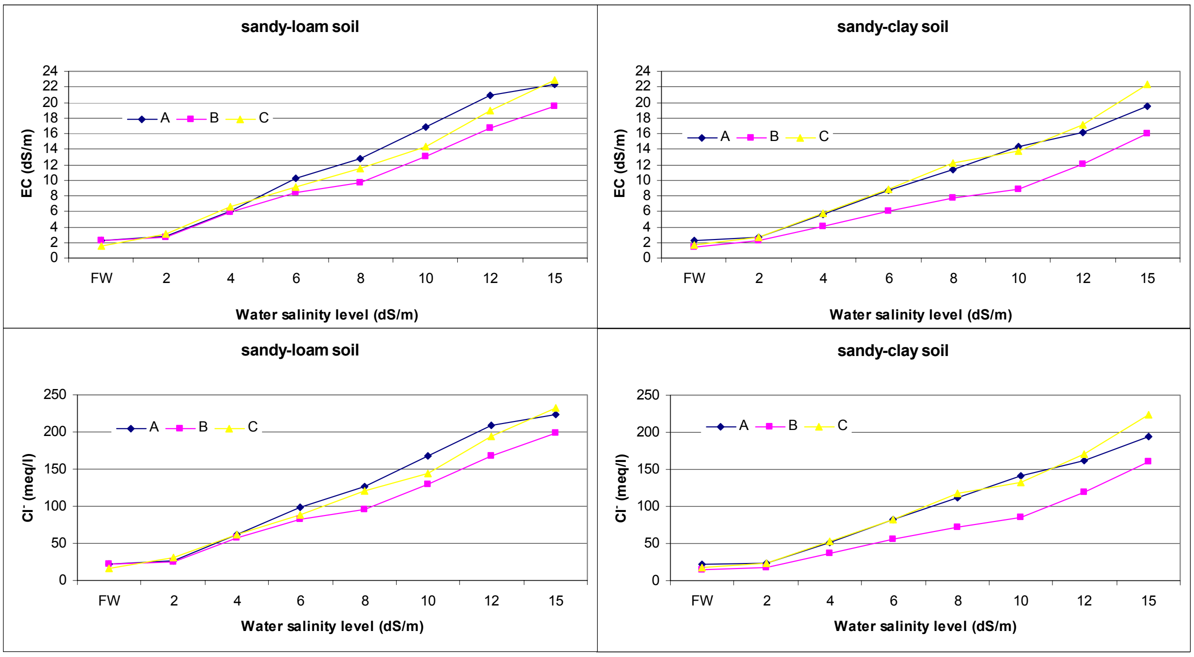
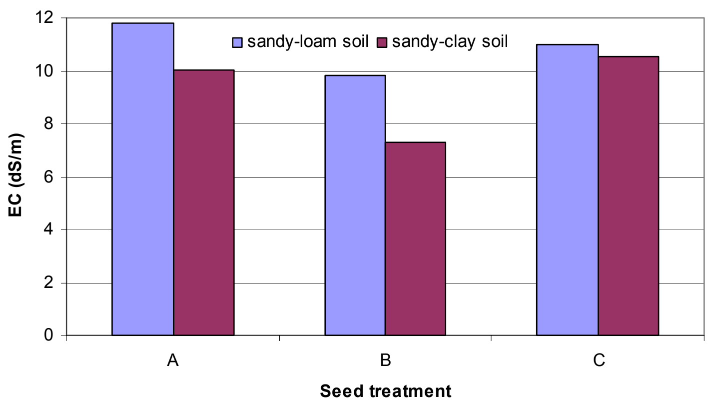


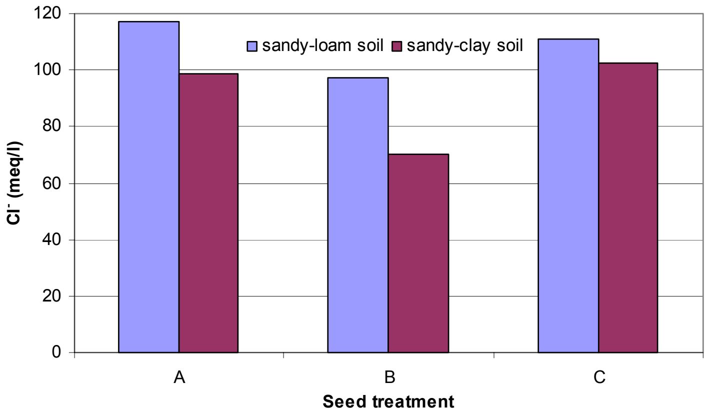
Figure 31. ECe (dS/m) and Cl^- (meq/l) reaction to the interaction: soil type x seed treatment x water salinity level

In addition, it is evident that above 4 dS/m, differences between the two soil types become bigger and bigger, especially, for the treatments A and C.

However, under the sandy-loam soil, it is clear that the different treatments didn't show a significant difference. In fact, the effect of a first irrigation with freshwater (B treatment) was more efficient under the sandy-clay soil than the sandy-loam one, being at the origin of a lower ECe and chloride content at the end of the seedling establishment, and as a consequence, the difference between the different treatments was not significant under the sandy-loam soil, while it was significant under the sandy-clay one. This can be also seen by the next figure.



ECe



Cl^-

Figure 32. ECe (dS/m) and Cl^- (meq/l) reaction to the interaction: soil type x seed treatment

CONCLUSION

Under the normal conditions (A treatment), maize germination percentage started to be affect by the water salinity level when this exceeded 10 dS/m, under the sandy-loam soil, whereas it remained more or less constant under the sandy-clay soil. However, this does not mean that the seedling will be able to grow as much as when receiving water of good quality. In fact, once the salinity of the irrigation water exceeded 4 dS/m, the plant height started decreasing significantly, for both varieties and under both soil types. The leaf area reaction was a little bit different than the height. In fact, under the sandy-loam soil, it decreased linearly as the salinity of the irrigation water increased whereas it remained constant till a salinity of 4 dS/m under the sandy-clay soil. In addition, although both varieties showed the same height reaction; concerning the leaf area, the first one developed bigger leaf area, but, more sensitive to the salinity increase, while the second one developed slightly smallest leaf area when irrigated with water of low salinity level, yet, more constant till a water salinity of 4 dS/m.

To combine the plant growth and the leaf area development, the shoot dry matter was measured. This decreased linearly with the increase of the water salinity level under both soil types, although the sandy-clay soil productivity was higher than the sandy-loam one. In addition, the second variety was able to convert more efficiently water into biomass. In fact, even though its leaf area was slightly smaller, it developed thicker stems, and as a consequence, more shoot dry matter.

Regarding the root part, the first variety developed a deeper root system compared to the second one. In fact, in the range 1 to 4 dS/m, the root system of both varieties was constant while between 4 and 10 dS/m, we registered a decrease in the root depth of both varieties, however, the rate of decrease was higher in the first variety than in the second one so that, receiving an irrigation water of 10 dS/m, the rooting system of both was the same; this remains true to both soil types. However, as the thickness of the second variety's root was higher than the first, root dry matter was the same for both till irrigating with water of 10 dS/m, after that, the second variety's dry matter became higher, under both soil types.

Regarding the ECe and Cl^- values at the end of the seedling establishment, no difference was reported when applying an irrigation water with 1.1 or 2 dS/m, which means that the plant, although still young, is able to absorb salts and store them without any harmful effects to neither the shoot part, nor the root one.

When an irrigation water of 4 dS/m was applied, the plant didn't show any symptoms of stress; however, salts started to accumulate in the soil (ECe increased from 2.7 to 5.9 dS/m and Cl^- from 27 to 61 meq/l).

Above that water salinity level, the seedlings started suffering seriously from salinity stress, while salts accumulated more and more, leading to high ECe and chloride content.

The soaking treatment didn't improve the germination; it accelerated the seedling emergence and, above the water salinity level 10 dS/m, it reduced the germination percentage. Regarding the other growing parameters (plant height, leaf area, maximum rooting system, shoot and root dry matter, as well as the ECe and chloride content), seed soaking did neither improve nor reduce any of the above parameters.

Finally, regarding the B treatment, which consisted on giving a first irrigation with freshwater instead of the respective saline one, it improved the germination percentage as well as the seedling resistance to salinity. In addition, as we gave less saline water, ECe and chloride content at the end of the seedling establishment were lower.

REFERENCES

Edmeades, G.O., J. Bolaños, and H. R. Lafitte. 1992. Progress in selecting for drought tolerance in maize. In D. Wilkinson (ed.), Proc. 47th Annual Corn and Sorghum Research Conference, Chicago, December 9–10, 1992. ASTA, Washington. Pp. 93–111.

Heisey, P.W., and G.O. Edmeades. 1999. Maize Production in Drought-Stressed Environments: Technical Options and Research Resource Allocation. Part 1 of CIMMYT 1997/98 World Maize Facts and Trends; Maize Production in Drought-Stressed Environments: Technical Options and Research Resource Allocation. Mexico, D.F.: CIMMYT.

International Food Policy Research Institute. 2000. 2020 Projections. Washington, D.C.:IFPRI.

Mejía D. 2003, Post Harvest Compendium, Maize. (Eds) Danilo Mejía & Emanuela Parrucci Information Network on Post-harvest Operations (2003). Food and Agriculture Organization of the United Nations (FAO).