CIHEAM
Options Méditerranéennes

Effect of salinity on water stress, growth, and yield of maize and sunflower

Katerji N., van Hoorn I.W., Hamdy A., Karam F., Mastrorilli M.

in

Katerji N. (ed.), Hamdy A. (ed.), van Hoorn I.W. (ed.), Mastrorilli M. (ed.).
Mediterranean crop responses to water and soil salinity: Eco-physiological and agronomic analyses

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 36

2002
pages 55-71

Article available on line / Article disponible en ligne à l'adresse :

http://om.ciheam.org/article.php?IDPDF=5002170

To cite this article / Pour citer cet article

Katerji N., van Hoorn I.W., Hamdy A., Karam F., Mastrorilli M. **Effect of salinity on water stress, growth, and yield of maize and sunflower.** In : Katerji N. (ed.), Hamdy A. (ed.), van Hoorn I.W. (ed.), Mastrorilli M. (ed.). *Mediterranean crop responses to water and soil salinity: Eco-physiological and agronomic analyses.* Bari : CIHEAM, 2002. p. 55-71 (Options Méditerranéennes : Série B. Etudes et Recherches; n. 36)

CIHEAM
Centre International de Hautes Etudes Agronomiques Méditerranéennes

http://www.ciheam.org/
http://om.ciheam.org/

Effect of salinity on water stress, growth, and yield of maize and sunflower

N. Katerji[1], J.W. van Hoorn[2 *], A. Hamdy[3], F. Karam[3], A Mastrorilli[4]

Agricultural Water Management, 30 (1996) 237-249

Abstract

Maize and sunflower were grown in tanks filled with loam and clay, and were irrigated with water of three different levels of salinity. Predawn leaf-water potential and stomatal conductance were used as parameters for water stress. The predawn leaf-water potential of maize was higher than that of sunflower, but the effect of salinity and soil texture on the predawn leaf-water potential was the same for both crops. The stomatal conductance of sunflower was much higher and more severely affected by salinity and soil texture than the stomatal conductance of maize.

Although salinity had a more serious effect on the development of leaf area and canopy dry matter of sunflower, its effect on evapotranspiration and grain yield was the same for both crops. Soil texture had a stronger effect on the development of leaf area and canopy dry matter of sunflower, which also appeared in the evapotranspiration and grain yield, indicating that sunflower is more sensitive to drought than maize.

Keywords: Crop water stress; Crop water use efficiency; Leaf water potential; Stomatal conductance; Salt tolerance; Maize; Sunflower

[1] *INRA, Station de Bioclimatologie, 78850 Thiveral-Grignon, France*
[2] *Department of Water Resources, Agricultural University, Wageningen, Netherlands*
[3] *Instituto Agronomico Mediterraneo, 70010 Valenzano (Bari), Italy*
[4] *Instituto Sperimentale Agronomico, 70125 Bari, Italy*
* Corresponding author, retired.

1. Introduction

A previous publication (Katerji et al., 1994) presented the results of using saline water during emergence and early seedling growth of maize and sunflower. During their early growth stage, both crops showed a similar reaction to salinity, corresponding to the classification of Ayers and Westcot (1985). This publication completes the previous one, and presents the effects of salinity on maize and sunflower grown on two soils of different texture, from the stage of early seedling growth until harvesting.

The methodology is the same as in the previous experiments on beans (Katerji et al., 1992), and on wheat and potatoes (Van Hoorn et al., 1993), in which the observations of the effects of salinity on water stress of the plants were combined with observations on the development of leaf area, dry matter, and evapotranspiration, and finally on yield. In this publication the reactions of maize and sunflower to salinity, in combination with two soil textures, are compared.

2. Experimental procedures

2.1. Set-up

The set-up consisted of 30 tanks of reinforced fibre glass with a diameter of 1.20 m and a depth of 1.20 m. A layer of coarse sand and gravel, 0.10 m thick, was overlain by a re-packed soil profile of 1 m. At the bottom of the tank, a pipe serving as a drainage outlet connected the tank to a drainage reservoir. The set-up was covered at a height of 4 m by a sheet of transparent plastic to protect the assembly against precipitation.

One series of 15 tanks was filled with loam and a second series of 15 tanks with clay.

The tanks were irrigated with water of three different qualities: the control treatment with fresh water containing 3.7 mEq l^{-1} and an EC of 0.9 dS m^{-1}, and two saline treatments containing 15 and 30 mEq l^{-1} and with EC of 2.3 and 3.6 Ds m^{-1}, obtained by adding equivalent amounts of NaCl and $CaCl_2$ to fresh water. For each water quality, five tanks were available.

At each irrigation, surplus water was added to provide a leaching fraction of about 0.2. The evapotranspiration of the irrigation interval was calculated as the difference between the amounts of irrigation and drainage water.

To determine soil salinity, the chloride concentration of soil water was calculated from the salt balance of irrigation and drainage water and converted into EC of soil water by the equation $\ln EC = 0.824 \ln Cl - 1.42$, the value of which was divided by 2 for the conversion to EC_e Owing to differences in water application, evapotranspiration and drainage, differences in soil salinity may appear between both soils.

2.2. Crop

Maize (*Zea mays*, variety hybrid Asgrow 88) was sown at a density of 21 grains per tank. This was reduced to 12 plants at the six-leaf stage, and finally to five plants per tank at harvest time because of the successive samplings to determine the growth parameters. Fertilizing was done three times: at the start of vegetative growth, 3 weeks later, and at the start of flowering, a total equivalent to 120 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1}. When 50% of the plants had attained a phenological stage, this date was noted: sowing 27 July 1993 (day *t*), emergence (*t* + 4), six-leaf stage (*t* + 15), start of flowering (*t* + 37), start of ear formation (*t* + 48), harvest (*t* + 98).

Sunflower (*Helianthus annus*, variety hybrid ISA) was sown at a density of 21 grains per tank. This was reduced to 16 plants at the four-leaf stage, and finally to five plants per tank at harvest time. Fertilization was done at the start of flowering, equivalent to 75 kg N ha^{-1} and 35 kg P_2O_5 ha^{-1}. The crop development was as follows: sowing 22 April 1994 (day *t*, emergence (*t* + 4), ten-leaf stage (*t* + 30), stage of complete vegetative development (*t* + 51), start of flowering (*t* + 74), start of grain formation (*t* + 85), grain formation completed (*t* + 116), harvest (*t* + 134).

2.3. Water stress of the plant

Two parameters were used to characterize the water stress of the plant: the predawn leaf-water potential and the stormatal conductance.

Both parameters were determined on leaves of the upper part of the canopy, the predawn leaf-water potential on one leaf per tank (so on five leaves per treatment), and the stomatal conductance at midday on the upper leaf surface, well-exposed to sunlight, of two leaves per tank (so on ten leaves per treatment).

2.4. Growth and yield

The leaf area and dry matter of leaf and stem were determined at successive phenological stages, on five plants for maize and ten plants for sunflower, equally distributed over the five lysimeters per treatment, first the leaf area and afterwards the dry matter.

At harvest, the dry matter of leaf and stem and the grain yield of the remaining five plants were determined for each lysimeter. The following yield components were determined: for maize, the number of ears per plant, the number of grains per ear, the weight of 1000 grains; and for sunflower, the number of grains per plant and the weight of 1000 grains.

3. Experimental results and discussion

3.1. Water stress of the plant

The predawn leaf-water potential of maize and sunflower on loam (Fig. 1), which increased at each irrigation and decreased afterwards, differed with the three water qualities, systematically showing the greatest difference between the treatments before irrigation.

The average level for maize was clearly higher then for sunflower, and the predawn leaf-water potential of the control treatment attained a value of less than -0.1 MPa after irrigation for maize, as against a value of about -0.3 Mpa for sunflower. Similar differences have been observed under field conditions (Bethenod and Katerji, 1995).

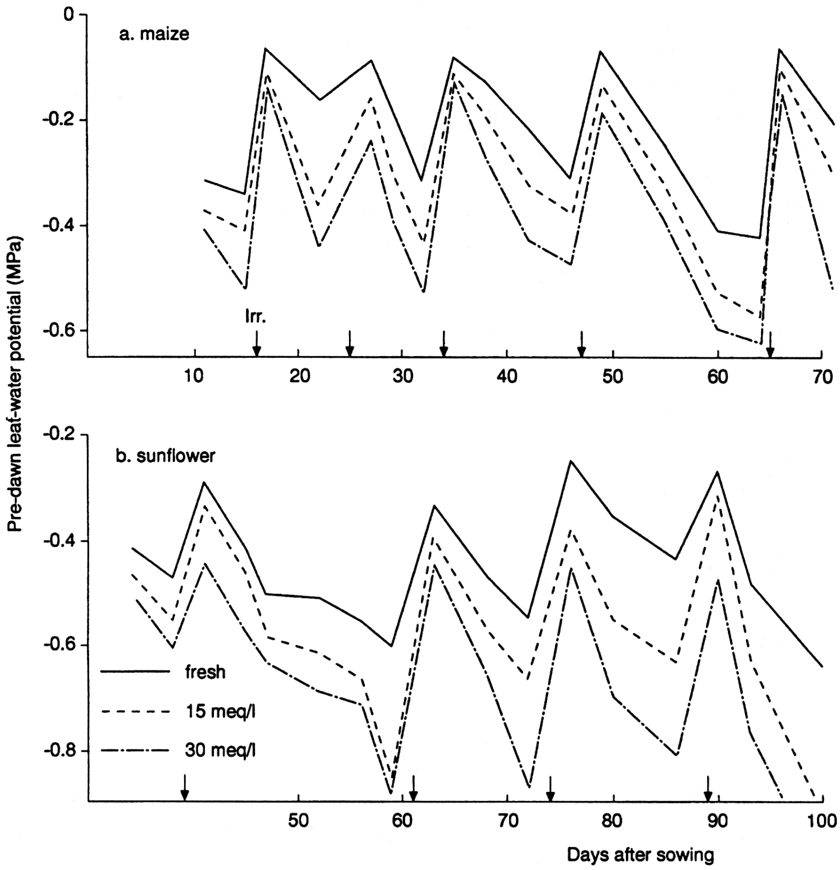

Fig. 1. *Predawn leaf-water potential of maize and sunflower vs. days after sowing on loam.*

The decrease of the predawn leaf-water potential of sunflower was rather slow between 47 and 56 days after sowing, when the average daily temperature was about 18°C, 3°C lower than du ring the earlier and later days.

Table I

Evapotranspiration of maize (mm day^{-1}) from 24 July 1993 until 4 November 1993

Soil	Water quality	Dates						Total	
		24.7-4.8	4.8-12.8	12.8-21.8	21.8-12.9	12.9-30.9	30.9-4.11	mm	(%)
Loam	Fresh	3.5	5.0	6.0	9.9	7.9	3.2	607	100
	15 mEq l^{-1}	3.1	4.9	6.0	9.3	7.5	3.0	578	95
	30 mEq l^{-1}	3.0	4.8	5.3	7.6	6.5	2.5	494	81
Clay	Fresh	3.6	5.9	7.1	11.3	8.0	2.8	644	100
	15 mEq l^{-1}	2.9	5.2	6.6	9.6	6.8	2.4	552	86
	30 mEq l^{-1}	2.8	4.9	6.1	8.2	6.4	2.3	505	78

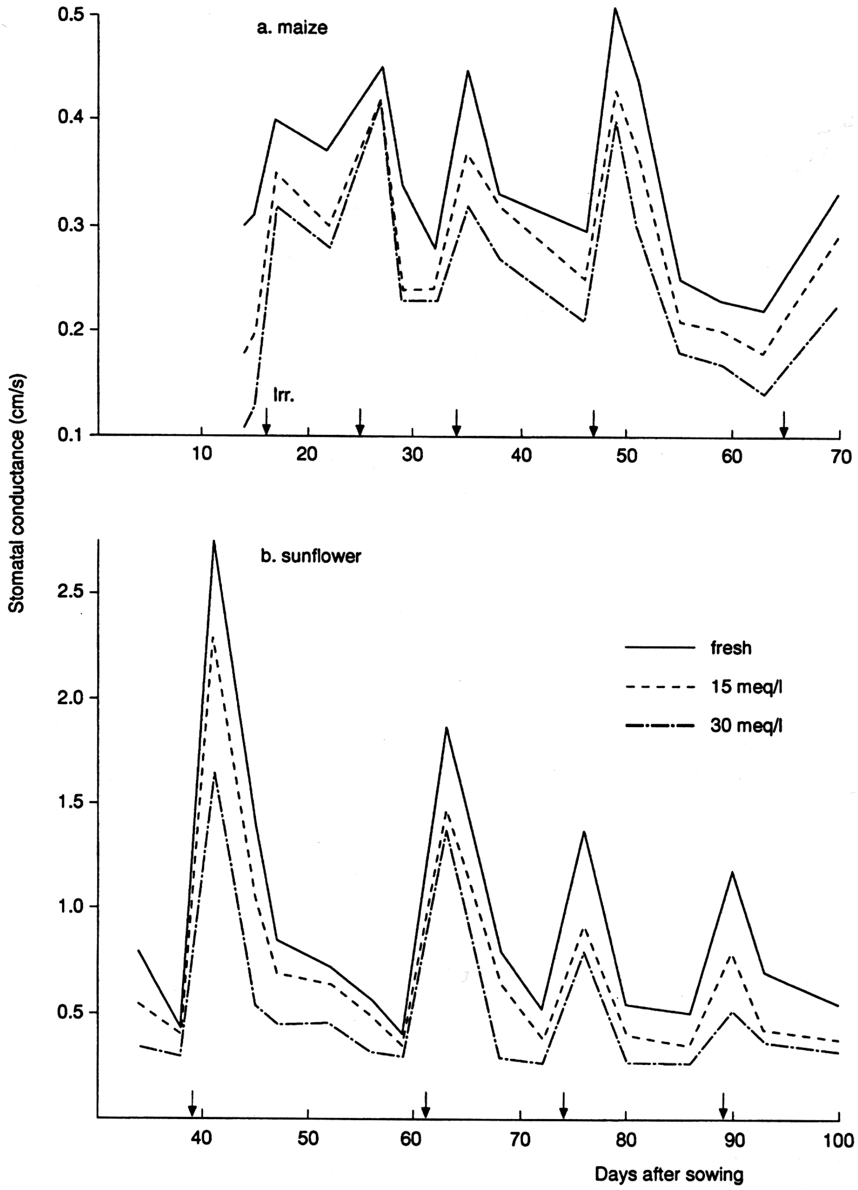

***Fig.* 2.** *Stomatal conductance of maize and sunflower vs. days after sowing on loam.*

The development on clay soil was similar to that on loam, but the average level was about 10% lower for both maize and sunflower.

The stomatal conductance of both crops (Fig. 2) also showed a difference between the three water qualities, but in contrast to the predawn leaf-water potential, the greatest differences between the treatments appeared after irrigation.

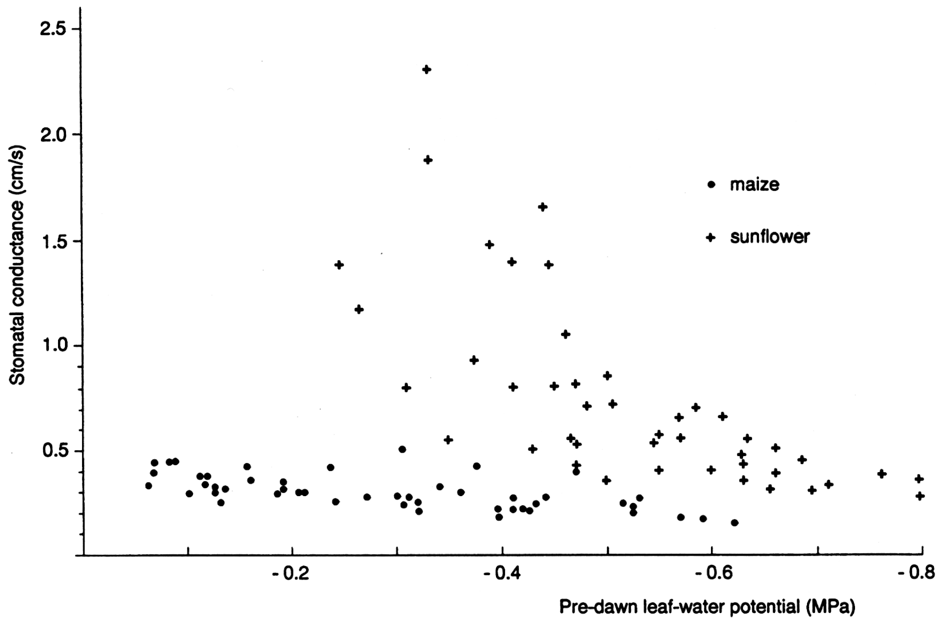

***Fig.* 3.** *Stomatal conductance of maize and sunflower vs. predawn leaf-water potential.*

Table 2

Evapotranspiration of sunflower (torn day- 1) from *14* April *1993* until *3* September *1994*

Soil	Water quality	Dates						Total	
		14.4-16.5	16.5-31.5	31.5-22.6	22.6-19.7	19.7-6.8	6.8-3.9	mm	(%)
Loam	Fresh	2.8	10.5	12.5	17.2	13.7	7.9	1450	100
	15 mEq l^{-1}	2.6	10.6	10.7	15.6	12.8	6.6	1310	90
	30 mEq l^{-1}	2.4	7.8	10.1	13.8	11.0	6.0	1157	80
Clay	Fresh	3.0	10.2	9.8	13.1	12.9	6.2	1215	100
	15 mEq l^{-1}	2.4	8.6	8.8	12.1	10.4	4.9	1040	86
	30 mEq l^{-1}	2.7	7.7	8.2	11.5	9.8	4.7	994	82

Table 3

Yield of maize and soil salinity

	Loam			Clay		
	Fresh	15 mEq l^{-1}	30 mEq l^{-1}	Fresh	15 mEq l^{-1}	30 mEq l^{-1}
Grain yield (kg m^{-2})	0.67	0.67	0.53	0.5	0.48	0.41
Total canopy dry matter (kg m^{-2})	1.46	1.38	1.26	1.3	1.19	1.13
Ears/plant	1.20	1.24	1.03	1.06	1.00	1.00
Grains/ear	522	487	505	526	486	441
Weight of 1000 grains (kg)	0.24	0.25	0.23	0.2	0.22	0.21
EC_e (dS m^{-1})	0.8	1.8	3.0	0.8	1.9	3.7

A clear difference between the crops appeared in their maximum values and their average level of stomatal conductance, being much higher for sunflower than for maize. The difference, also mentioned by other authors (Turner, 1974; Boyer, 1976), can be explained by the greater stomatal density and stomatal dimensions of sunflower. De Deparcevaux (1972) mentions a density of about 85 stomates mm^{-2} on the upper leaf surface for sunflower, whereas the density for maize is about half that value. For the same value of the predawn leaf-water potential, the stomatal conductance of sunflower was much higher, and showed a far greater variation than for maize (Fig. 3).

A difference between the crops was also apparent in the effects of soil texture and salinity. The average stomatal conductance of sunflower on clay was about 35% lower than on loam, as against an average difference of about 5% for maize; the average value of sunflower on the most saline treatment was about 40% lower than on the control, as against 25% for maize.

The decrease in the maximum stomatal conductance of sunflower with time may be attributed to the increasing air saturation deficit during the growing period, whereas the latter decreased in the case of maize.

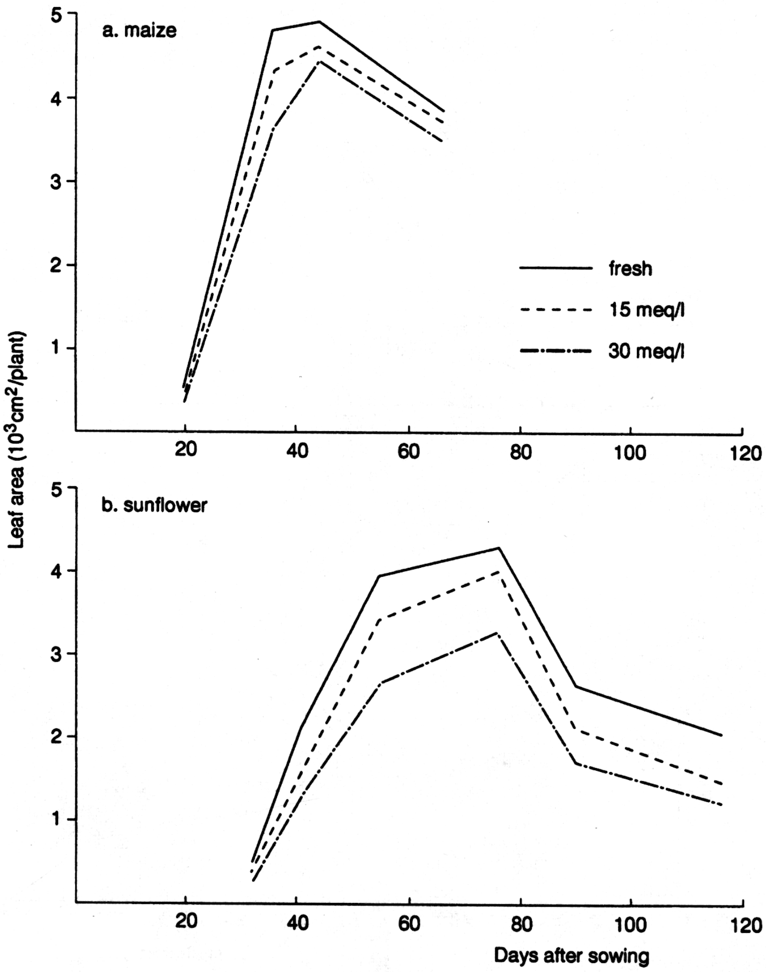

***Fig.* 4**. *Leaf area of maize and sunflower vs. days after sowing on loam.*

3.2. Evapotranspiration

The evapotranspiration, presented in Tables 1 and 2, showed the same effect of salinity for both maize and sunflower, a reduction of about 20% between the control and the most saline treatment of both soils.

The effect of soil texture only appeared for sunflower, with an average reduction of between 15 and 20%.

The evapotranspiration of sunflower is much higher than that of maize, a phenomenon also mentioned in a literature review by Robinson (1978). According to Mihalyfalvy (1962), sunflower consumes twice as much water in the greenhouse as in the field. Although the growing period for sunflower is longer than for maize (i.e. about 140 against 100 days), which thus increases the total evapotranspiration, the difference can chiefly be explained by:

1. better extraction of soil water owing to the higher extraction potential of sunflower roots (Bames, 1938; Hattendorf et al., 1988);
2. low internal resistance of sunflower to water flow (Black, 1979);
3. higher stomatal conductance, as was already shown in Fig. 2.

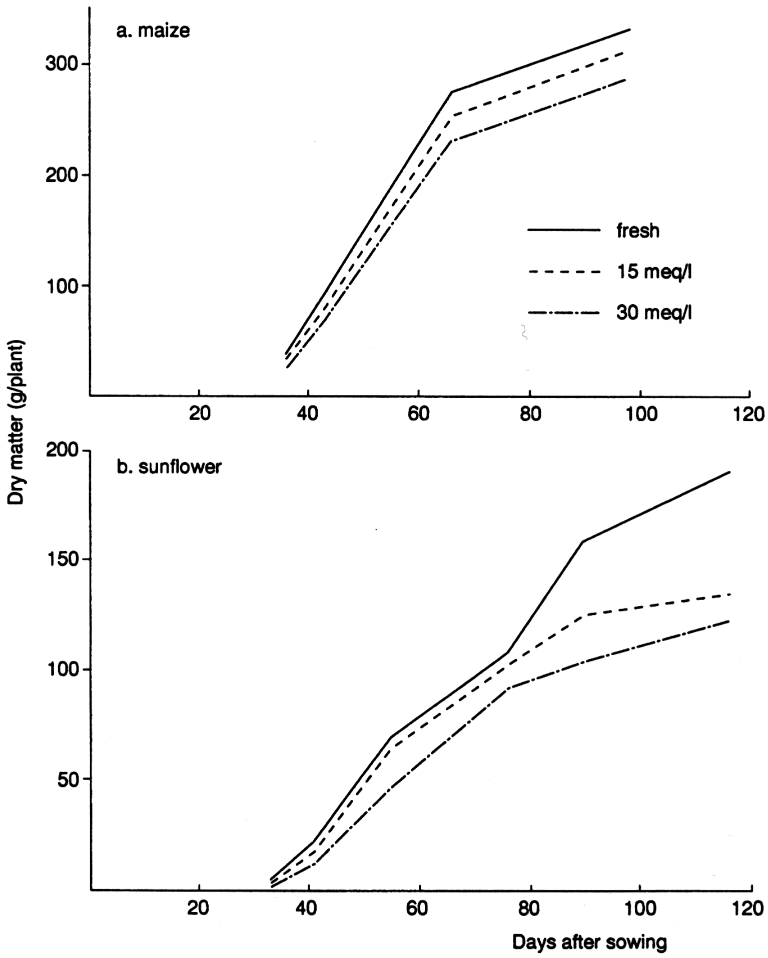

Fig. 5. *Canopy dry matter of maize and sunflower vs. days after sowing on loam.*

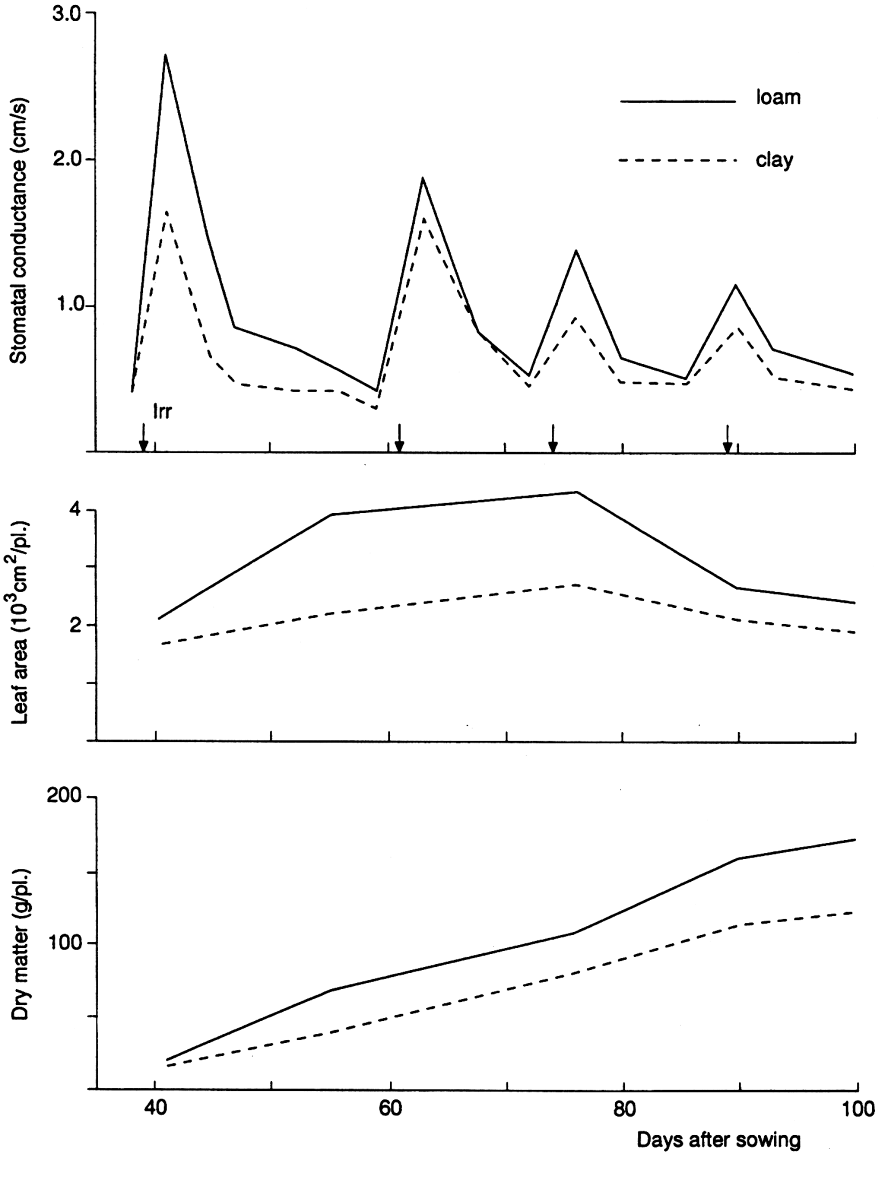

Fig. 6 *Stomatal conductance, leaf area, and canopy dry matter of sunflower vs. days after sowing for two soil textures and fresh water.*

Table 4

Yield of sunflower and soil salinity

	Loam			Clay		
	Fresh	15 mEq l^{-1}	30 mEq l^{-1}	Fresh	15 mEq l^{-1}	30 mEq l^{-1}
Grain yield (kg m^{-2})	0.351	0.291	0.263	0.216	0.193	0.154
Total canopy dry matter (kg m^{-2})	1.039	0.818	0.744	0.597	0.514	0.385
Grains/plant	1280	1183	1159	950	926	831
Weight of 1000 grains (kg)	0.062	0.056	0.051	0.051	0.047	0.042
EC_e (dS m^{-1})	0.8	2.7	3.8	0.8	2.0	3.9

3.3. Growth and yield

The leaf area (Fig. 4) and the canopy dry matter (Fig. 5) of both crops showed a clear effect of salinity, more pronounced for sunflower than for maize, which corresponds with observations by Connor and Jones (1985).

The leaf area of maize was not affected by soil texture, and the dry matter showed only a slight difference: about 5% and 10%, respectively, at t + 63 and t + 99. In contrast to maize. the leaf area and dry matter of sunflower were clearly affected by soil texture, showing, for all three water qualities, an average reduction of about 30% on clay, a difference corresponding to the strong effect of soil texture on the stomatal conductance of sunflower (Fig. *6).*

Tables 3 and 4 present the yields of maize and sunflower, expressed by the grain yield and by the total dry matter of grain, leaves, and stem, the grain yield components, and the average soil salinity during the growing season in the layer 0-100 cm. Salinity and soil texture both have a more severe effect on the grain yield of maize than on its total dry matter: the grain yield of the 30 mEq l^{-1} treatment on loam and clay showed an average decrease of about 25%, as against a decrease of about 15% for the total dry matter. The average grain yield on clay, compared with loam, also showed a decrease of about 25%, as against 10% for the total dry matter. The filling of the grains, expressed as the weight of 1000 grains, was more affected by soil texture than was the number of grains.

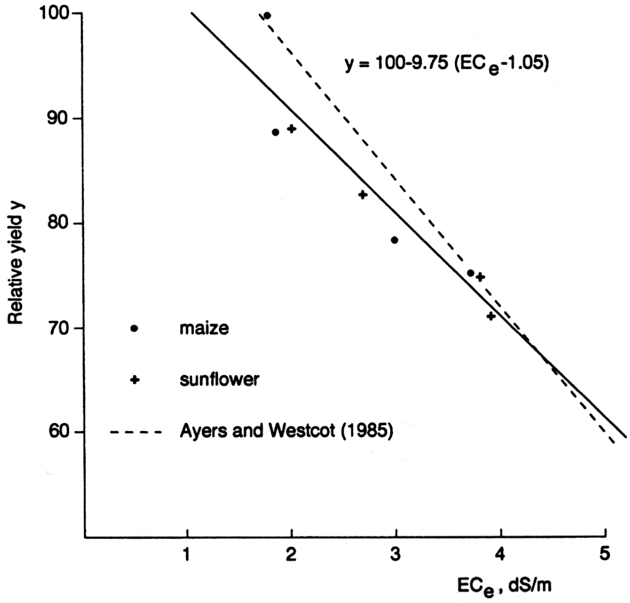

Fig. 7. *Relationship between relative yield of maize and sunflower and soil salinity.*

Table 5

Water use efficiency for grain yield and total dry matter of maize and sunflower (kg m^{-1})

	Loam			Clay		
	Fresh	15 mEq l^{-1}	30 mEq l^{-1}	Fresh	15 mEq l^{-1}	30 mEq l^{-1}
Grain yield						
Maize	1.12	1.17	1.08	0.85	0.88	0.82
Sunflower	0.24	0.22	0.22	0.18	0.18	0.15
Total dry matter						
Maize	2.42	2.40	2.57	2.06	2.16	2.24
Sunflower	0.72	0.62	0.64	0.49	0.49	0.39

In the case of sunflower, salinity and soil texture had about the same effect on the grain yield and on the total dry matter: the most saline treatment showed a reduction of about 30% for both the grain yield and the dry matter; the decrease in grain yield and dry matter owing to soil texture was about 40%. The reduction was much more severe than for maize, as could be expected from the development of leaf area and dry matter during the growing season.

In the case of sunflower, salinity and soil texture both affected the number of grains per plant and the weight of 1000 grains, and more clearly than in the case of maize. Salinity had a stronger effect on the filling of the grains, expressed as the weight of 1000 grains, than on the number of grains, whereas soil texture had a stronger affect on the number of grains.

The relative yields of maize and sunflower (Fig. 7) showed the same reaction to soil salinity, which corresponds well to the relationship according to Ayers and Westcot (1985).

Table 5 presents the water-use efficiency for the grain yield and total dry matter of maize and sunflower, which clearly appeared to be affected by soil texture, but not by salinity. The water-use efficiency of maize is much higher than that of sunflower, which corresponds to observations already mentioned in the literature (Blanchet et al., 1982).

4. Conclusions

A comparison of the reactions of maize and sunflower to salinity and texture showed a much higher stomatal conductance for sunflower and a correspondingly high evapotranspiration. This does not lead to a correspondingly higher production. Therefore, the water-use efficiency of sunflower for both grain yield and dry matter is much lower, attaining 1/4 to 1/5 of the value for maize. Maize is a more economic water utilizer owing to its better stomatal control (Burrows and Milthorpe, 1976).

As observed in earlier experiments on wheat and potatoes, soil texture, through its effect on pore size distribution, root development, and capillary water flow, affects stomatal conductance, evapotranspiration, growth, and yield. Its effect on sunflower was much more severe than on maize, leading to a grain yield reduction of about 40% for sunflower, as against 25% for maize. According to our observations, sunflower is more sensitive to drought than maize is, in contrast to the classification of Doorenbos and Kassam (1979).

Salinity affects stomatal conductance, leaf area, and dry matter development, more in the case of sunflower than of maize, but finally its effect on evapotranspiration and grain yield was the same for both crops. This result corresponds to the classification by Ayers and Westcot (1985).

Acknowledgements

The authors wish to thank the students Elias Abou Rejaili and Abdelkhalek Abidli for the work they contributed during their MSc study at the Instituto Agronomico Mediterraneo.

References

Ayers, R.S. and Westcot, D.W., *1985.* Water Quality for Agriculture. FAO Irrig. Drain. Paper No. *29,* Rev. 1, Food and Agriculture Organization of the United Nations, Rome.

Barnes, S., *1938. Soil* moisture and crop production under dryland conditions in Western Canada. Can. Dep. Agric. Publ., *595: 1-43.*

Bethenod, 0. and Katerii, N., *1995.* Etude de l'efficience instantanée de l'eau: Comparaison entre des plantes isohydrique (Mais) et anisohydrique (Tournesol). In: Utilisation d'Indicateurs d'état Hydrique des Plantes pour la Conduite de l'Irrigation. Rapp. final du Contrat No. *8001* de la D.G. VI, Bruxelles.

Black, C.R., *1979.* The relationship between transpiration, water potential, and resistances to water movement in sunflower *(Helianthus annus).* J. Exp. Bot., *30: 235-243.*

Blanchet, R., Merrien, A., Gelfi, N., Conahe, G., Courtiade, B. and Puech, J., *1982.* Estimation et évolution comparée de Fassimilation nette de couverts de mais *(Zea mays),* tournesol *(Helianthus annuus)* et soja *(Glycine max)* an cours de leurs cycles de développement. Agronomic, *2: 149-154.*

Boyer, J.S., *1976.* Water deficit and photosynthesis. In: T.T. Kozlowski (Editor), Water Deficits and Plant Growth. Academic, New York, pp. *153-190.*

Burrows, F.J. and Milthorpe, F.L., *1976.* Stomatal conductance in the control of gas exchange. In: T.T. Kozlowski (Editor), Water Deficits and Plant Growth. Academic, pp. *103-146.*

Connor, D.J. and Jones, T.R., *1985.* Response of sunflower to strategies of irrigation. II Morphological and physiological responses to water stress. Field Crop Res., *12: 281-293.*

De Deparcevaux, S., *1972.* Aspects biophysiques des 6changes entre les feuilles et le milieu envirormant. Oecol. Plant., *7: 371-401.*

Dooreabos, J. and Kassam, A.H., *1979.* Yield response to water. FAO Irrig. Drain. Paper No. *33,* Food and Agriculture Organization of the United Nations, Rome.

Hattendorf, MT, Redefs, M.S., Amos, B., Stone, L.R. and Gwin, R.E., *1988.* Comparative water use characteristics of six row crops. Agron. J., *80: 80-85.*

Katerji, N., van Hoom, J.W., Hatudy, A., Bouzid, N., El-Sayed Mahrous, S. and Mastrorilli, M., *1992.* Effect of salinity on water stress, growth, and yield of broad beans. Agric. Water Manage., *21: 107-117.*

Katerji, N., van Hoom, J.W., Hamdy, A., Karam, F. and Mastrordli, M., *1994.* Effect of salinity on emergence and on water stress and early seedling growth of sunflower and maize. Agric. Water Manage., *26: 81-91.*

Mibalyfalvy, 1., *1962.* Water requirement of sunflower grown as a second crop for green manuring. *Novenytermeles, 11: 101-108.*

Robinson, R.G., *1978.* Reduction and culture. In: Sunflower Science and Technology, Agronomy Monogr. No. *19, pp. 89-143.*

Turner, N.C., *1974.* Stomatal behavior and water status of maize, sorghum, and tobacco under field conditions 11. A low soil water potential. Plant Physiol., *53: 360-365.*

Van Hoom, J.W., Katerji, N., Hamdy, A. and Mastrorilli, M., *1993.* Effect of saline water on soil salinity and on water stress, growth, and yield of wheat and potatoes. Agric. Water Manage., *23: 247-265.*