Climatical changes effects on the potential capacity of salt removing species

G. Bekmirzaev, J. Beltrao, M. A. Neves and C. Costa

Abstract **-** The effects of the climate changes on the environment and have become the one of the most complicated issue facing world leaders. Moreover, warnings from the scientific community are becoming louder, as an increasing body of science points to rising dangers from the ongoing buildup of human-related greenhouse gases - produced mainly by the burning of fossil fuels and forests. What is climate changes, how do we know they are happening, and what can we expect from them? Certainly, the answer to these questions we must be known and understood. Another problem related to these climate changes and global warming is the increase of soil salinity. Beside this increase, current problems arising the agricultural development are appearing, as natural disasters, drinking water scarcity, less food production, infectious diseases and lower soil productivity. Conventional techniques used to control soil salination process - soil leaching or fertilization enhancing - contribute highly to soil and aquifers contamination; on the other hand, the use of salt tolerant plant species will be very useful to the plants, but it does not solve the problem of soil or groundwater contamination. Hence, the only way to control the salination process and to maintain the sustainability of landscape and agricultural fields is to combat the salination problems by environmentally safe and clean techniques. One of these techniques is the use of salt removing species. In order to study the climatical changes effects on the potential capacity to remove soil salts, two horticultural leaf species *Tetragonia tetragonioides* and *Portulaca oleracea* were planted. The total growth and the leaf mineral composition of these species were studied. According to the results of plant growth and leaf analysis, it was seen that *Tetragonia tetragonioides* are the best salt removing species; on the other hand *Portulaca oleracea* was the most tolerant species to soil and water salinity. It was shown that this technique to control salinity is a powerful and environmental clean tool to maintain the sustainability of the landscape and of the agricultural areas. As final remarks, it is concluded that in arid climates and global warming, the clean and environmental safe procedures to control salinity could be associated to the conventional techniques, combining environmental, economical and social aspects, contributing, therefore, to increase the sustainability of the environment and plant growth.

Key words **-** soil removal; soil salinity; agronomic species; irrigation solution; soil quality; water quality; arid climate; global warming;

I. Introduction

Conventional techniques to combat the salination process can be characterized by four generations, as follows [1]: 1) problem of root zone salination by soil leaching, where contamination can be observed [2]; 2) use of trickle irrigation, namely subsurface trickle irrigation - economy of water, and therefore less additional salts; however the problem of groundwater contamination due to natural rain or artificial leaching can occur [3]; 3) enhanced fertilization increases the tolerance to salinity, but the sensitivity to salinity increases also [4], and the contamination will be increased by other hazards, like chemicals, such as nitrate [5]; 4) use of salt tolerant species - this technique will be very useful to the plants, but it does not solve the problem of soil or groundwater contamination [6]. The only way to control the salination process and to maintain the sustainability of landscape and agricultural fields is to combat the salination problems by environmentally safe and clean techniques, as follows: 1) Use of salt (ions) removing species [7] [8], [9]; 2) Use of drought tolerant crops species, because less water is applied and, therefore, less salts are infiltrated [10]; 3) reduction of salt application by deficit irrigation [11]; 4) application of minimal levels of water enough to obtain a good visual appearance GVA of the landscape [12]. In order to evaluate the plant ability to remove salts from soil, several horticultural leaf species living in saline environments were studied – *Tetragonia tetragonioides* and *Portulaca oleracea* [13], [14], [15], [16]. *Tetragonia tetragonioides* species are exotic leaf vegetable crops, living at a wild status in the Mediterranean Basin sand dunes; they have fast rate growth, higher biomass production (if properly managed), easy cropping (as winter or summer crop), and absence of diseases and pests of major importance, as well as good acceptance by local consumers as a leafy vegetable [17]. Moreover, it was demonstrated its capability as beside other interests, as a high biomass horticultural leaf crop, producing plant dry weight 40,000 – 50,000 kg ha^{-1}, if the plant population density is around 75,000 plants ha^{-1} [18], [19]. On the other hand, it was shown in Uzbekistan that *Portulaca oleracea* species are more tolerant to salinity and drought conditions, and can be used as vegetables, ornamentals or fodder [20].

II. MATERIAL AND METHODS

II.1 Experimental procedure

The experimental work was conducted in the University of Algarve, Campus de Gambelas, in 2009, during May and June, with randomized potted plants. Irrigation water amounts were the minimal amounts enough to the plant survival (0.2 L d^{-1} pot^{-1}). The species were *Tetragonia tetragonioides* and *Portulaca oleracea*, submitted to 3 salinity treatments (T) salinity levels of irrigation water – 1 dS m^{-1} (T0), 10 dS m^{-1} (T1) and 20 dS m^{-1} (T2). In order to obtain these electrical conductivity values of the irrigation water ECw. In order to obtain these values, NaCl was added to the tap water, as follows: 0 (T0), 5.78 (T1) and 11.7 (T2) g L^{-1} NaCl (Fig. 1).

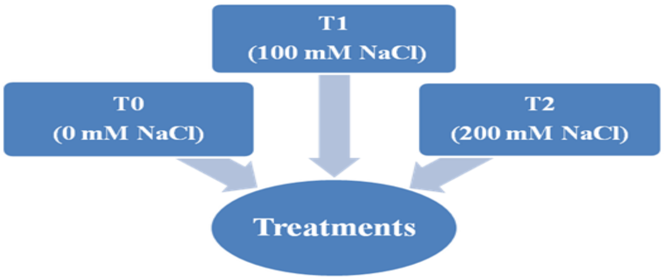

Fig. 1 experimental scheme

The number of plants per treatment was 4. The number of replications was 4. Four leaves plants were transplanted to 7 litter soil randomized pots in a greenhouse during the beginning of May (Figs. 2 and 3).

Fig. 2 *Tetragonia tetragonioides* (4 leaves)

Fig. 3 *Portulaca oleracea* (4 leaves)

A nitrogen daily continuous fertigation was applied daily with concentrations of 2 mM $NO_3^-$and 2 mM NH_4. The harvest occurred on the 23rd June (Figs. 4 and 5).

Fig. 4 *Tetragonia tetragonioides* in the greenhouse, at the end of the experiment

Fig. 5 *Portulaca oleracea* in the greenhouse, at the end of the experiment

II.2 Soil

Table 1 shows soil physical and chemical parameters was taken before the experiment. The soil characteristics were similar to those observed in some saline areas, in Mirzachuli steppe (Syrdarya province) Uzbekistan [21] and in Algarve (Portugal).

Table 1. Soil physical and chemical parameters before the experiment

Soil Parameters	Values
Texture	Silt loam
Sand (%)	57.8
Lime (%)	17.7
Clay (%)	24.5
Volumetric field capacity (%)	24
Volumetric wilting point (%)	12
pH (H_2O)	8.5
Electrical conductivity of soil, saturated with distilled water ECs (dS m^{-1})	0.3
N (%)	0.11
P_2O_5 (ppm)	31
K_2O (ppm)	189
Fe (ppm)	118
Mn (ppm)	40
Zn (ppm)	4.5
Total calcareous (%)	41.2
Ca (cmol[+]kg^{-1})	6.77
Mg (cmol[+]kg^{-1})	2.7
Na (cmol[+]kg^{-1})	0.5
K (cmol[+]kg^{-1})	0.3

II.3 Climate

The climatic data of the greenhouse during the experimental period (Figs. 6 and 7):

- Minimal relative humidity -16.2 %
- Maximal relative humidity - 93 %
- Average relative humidity – 58.63
- Minimal temperature – 12.1 ºC
- Maximal temperature – 45.1 ºC
- Average temperature – 25.59 °C

During the experimental period, the relative humidity of the greenhouse was increased, and the temperature was decreased.

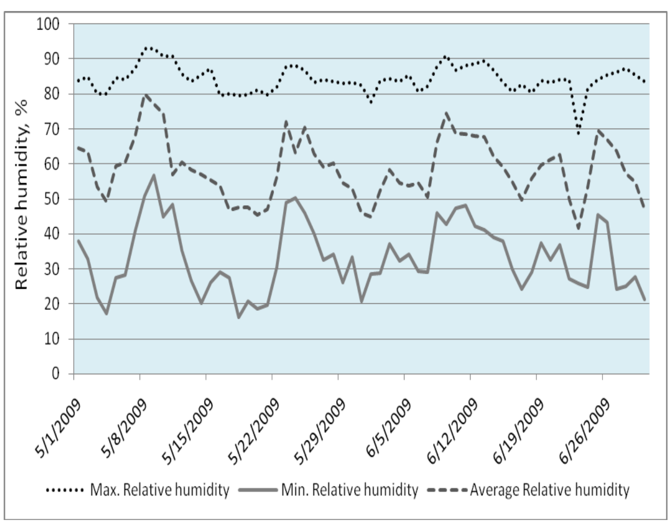

Fig. 6 relative humidity (%) of the greenhouse during the experiment period, from the 1st May until the 30th June, 2009

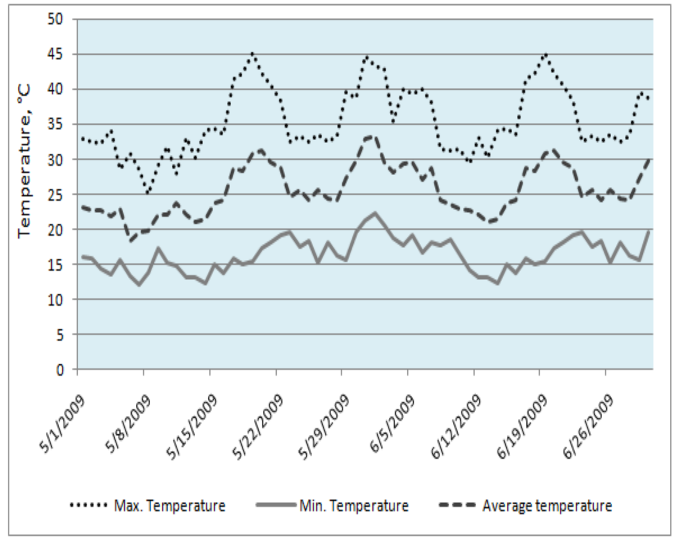

Fig. 7 maximal temperature (°C) of the greenhouse during the experiment period from the 1st May until the 30th June, 2009

II.4 Chemical analyses

Dried leaves, stems and roots were finely grounded and analised (Na, K, Ca, Mg, and Fe) by using the dry-ash method. The levels of Na and K were determined by flame photometer and the remaining cations were assessed by atomic absorption spectrometry. Chloride ions were determined in the aqueous extract by titration with silver nitrate according to Piper [22]. Plant nitrogen was determined by the Kjeldhal method. Phosphorus was determined by colorimetry method according to the vanadate – molybdate method [23]. All mineral analyses were only performed in the leaves.

II.5 Statistical analyses

Statistical analyses were made with an SPSS 11.0 [24] computer program. Two - way analyses of variance (ANOVA), least significant difference and Duncan's multiple - range tests ($P<0.05$) for comparisons between treatments over time were conducted.

III. RESULTS

The salinity had a significant effect on the stem length (Figs. 8 and 9) and on the number of nodes (Figs. 10 and 11) of both species. The stem length and the number of nodes of both crops showed low variations between T1 and T2 treatments. On the other hand, there was a great increase of the stem length and of the number of nodes on the T0 treatment.

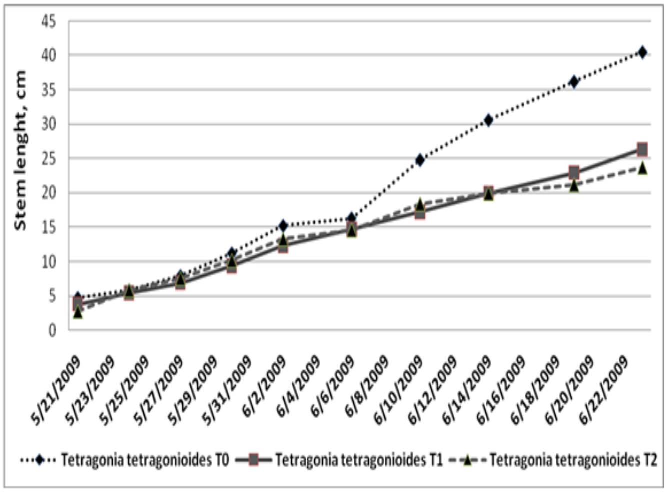

Fig. 8 mean stem length (cm) of Tetragonia tetragonioides, according to the treatments (T0, T1 and T2)

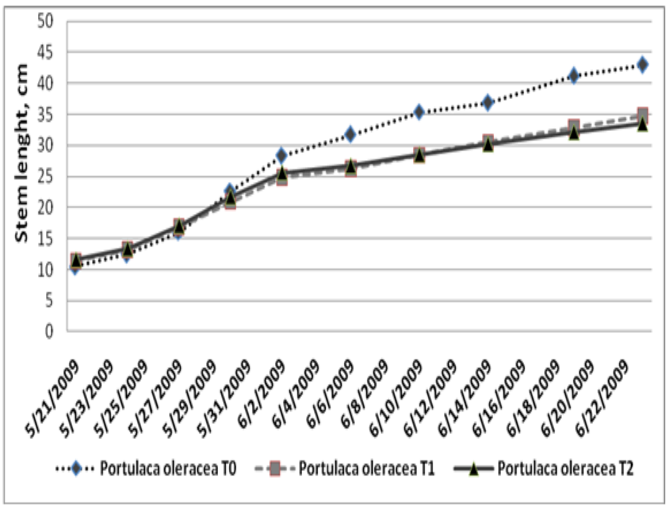

Fig. 9 mean stem length (cm) of *Portulaca oleracea* according to the treatments (T0, T1 and T2)

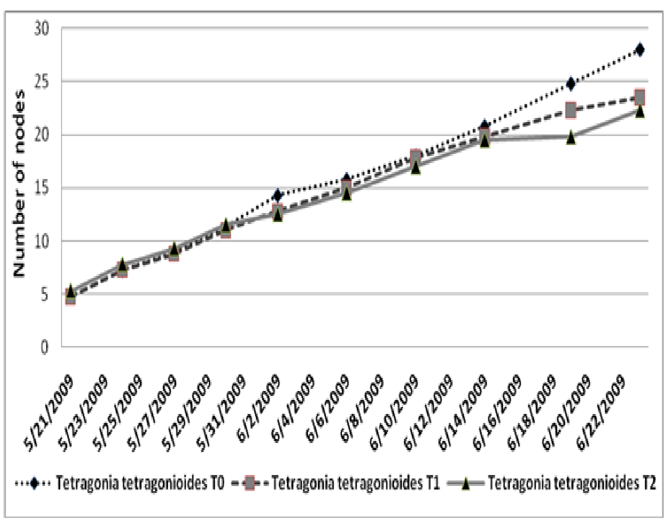

Fig. 10 mean number of nodes per plant on *Tetragonia tetragonioides*

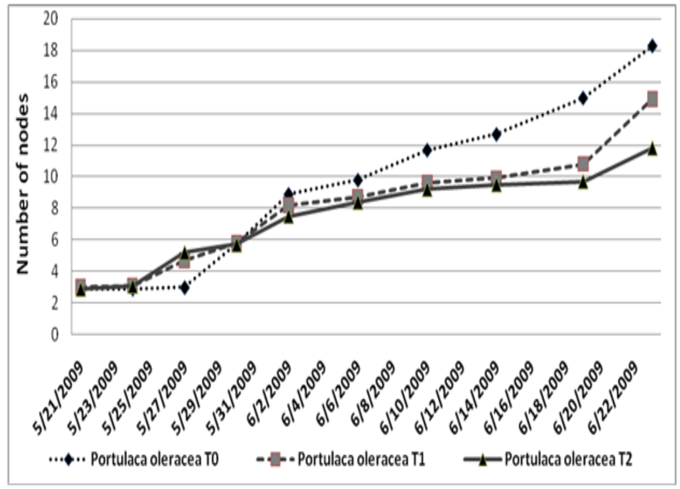

Fig. 11 mean number of nodes per plant on *Portulaca oleracea*

During the experimental period, there was a significant decrease of the number of leaves on salt treatments T1 and T2 (Figs. 12 and 13), and therefore, a great decrease of plant yield for both species.

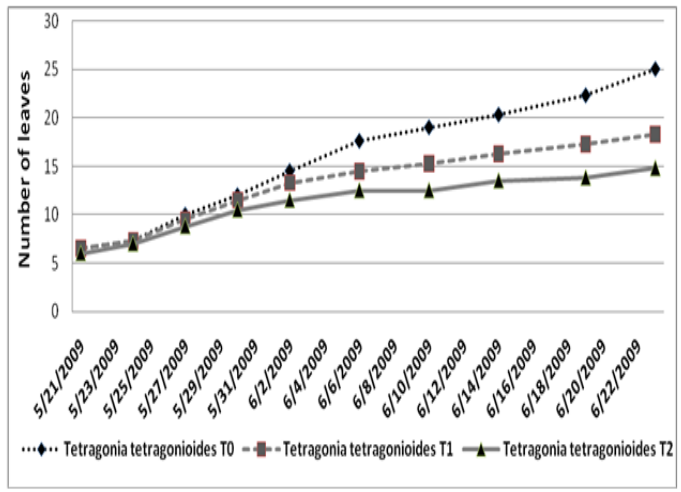

Fig. 12 mean number of leaves per plant on *Tetragonia tetragonioides*

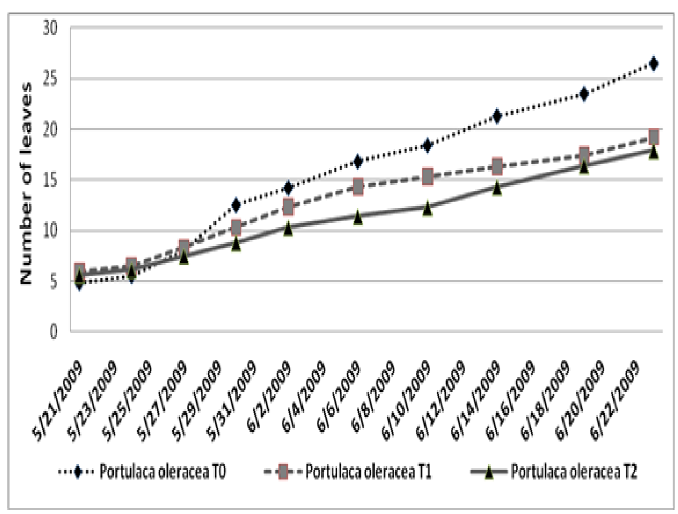

Fig. 13 mean number of leaves per plant on *Portulaca oleracea*

The pH of drainage water and soil are shown in Tables 2 and 3, respectively. It may be seen that differences of pH between the studied species and salt treatments were low.

Table 2. pH of drainage water for all treatments

Treatments	*Tetragonia tetragonioides*	*Portulaca oleracea*
T0	7.97	8.18
T1	7.82	7.93
T2	7.81	7.53

Table 3. Soil analyses of pH was taken after the experiment

Soil Parameters	pH
Sample of soil (used for experiment)	7.95
Soil of *Tetragonia tetragonioides*	7.69
Soil of *Portulaca oleracea*	7.70

The electrical conductivity (ECw) of drainage water for the different species and treatments (T1, T2 and T3) is shown in the Table 4. For each treatment, it may be seen that the ECw of drainage water is higher than the ECw of irrigation water. It increased with the enhanced of the salinity of the irrigation water. It may be seen also that the electrical conductivity of drainage water was larger on the case of *Tetragonia tetragonioides*, which shows that these species are more efficient as salt removal species than the *Portulaca oleracea* species.

Table 4. Electrical conductivity (ECw) of drainage water on the end of the experiment

Treatments	*Tetragonia tetragonioides* dS m^{-1}	*Portulaca oleracea* dS m^{-1}
T0	1.19	1.41
T1	19.7	20.2
T2	30.3	31.8

The electrical conductivity of soil (ECs), saturated with distilled water (dS m^{-1}) for the different species and treatments (T1, T2 and T3) and species is shown in Table 5.

For each treatment, it may be seen that the soil ECs increased with the enhanced of the salinity of the irrigation water. It may be seen also that the soil electrical conductivity was larger on the case of *Tetragonia tetragonioides*, which shows that these species have higher potential capacity to remove salts from the soil than *Portulaca oleracea* species.

Table 5. Electrical conductivity (ECw) of soil on the end of the experiment

Soil Parameters	EC, dS m^{-1}		
	T0	T1	T2
Soil of *Tetragonia tetragonioides*	0,130	0.612	1.098
Soil of *Portulaca oleracea*	1,939	2.204	2.632

Despite the low dry matter production at the end of the experiment, *Portulaca oleracea* grew without drought, flooding or salts injury symptoms and the plant yield was not greatly affected by salt conditions; moreover, plant tissues accumulated large amounts of sodium and chloride in salt conditions. On the other hand, *Tetragonia tetragonioides* (Fig. 14) produced higher dry matter than *Portulaca oleracea* (Fig. 15) and showed, therefore, great capacity for ions accumulation.

It was shown for both species that the partition among plant organs was affected by the medium salt concentration for both species, as follows: there was an increase of the percentage of dry matter of the leaves in saline conditions and a decrease in seeds; the percentage of dry matter of stems was constant in all treatments.

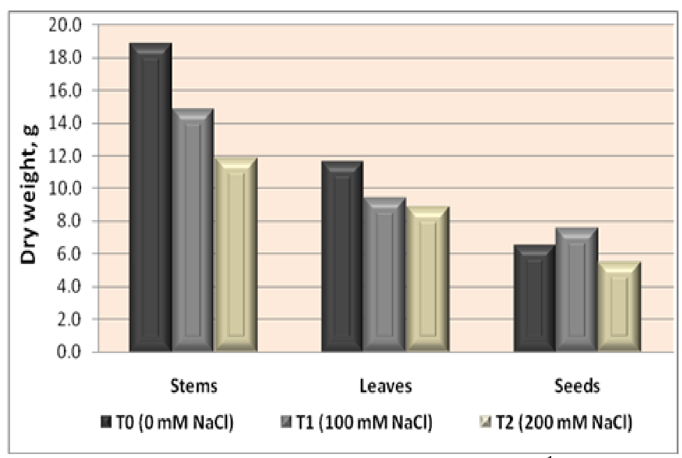

Fig. 14 dry matter of *Tetragonia tetragonioides* (g $plant^{-1}$)

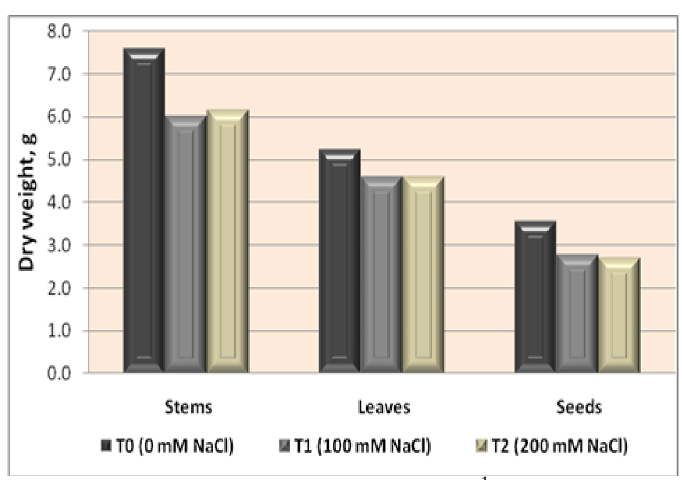

Fig. 15 dry matter of *Portulaca oleracea* (g $plant^{-1}$)

The salinity had a significant effect on the leaf mineral composition of *Tetragonia tetragonioides* for the majority of analyse mineral elements, as follows (Table 6): 1) the total nitrogen leaf content of both crop showed low variations among treatments, apparently not related with the salinity.; 2) there was a great increase of sodium and chloride concentrations when water salinity increased; 3) there was a general decrease of potassium, calcium, and magnesium leaf content of crop; 4) the salinity of irrigation water affected phosphorus and iron leaf content.

Table 6. Mineral compositions of *Tetragonia tetragonioides*

Treatments	Na	Cl	K	Ca	N	P	Fe	Mg
T0	3.50^{b}	1.28^{b}	1.58	0.0018	0.33	0.060^{a}	0.0003	0.15^{a}
T1	6.41^{a}	3.00^{a}	0.62	0.0015	0.35	0.035^{b}	0.0003	0.10^{b}
T2	6.33^{a}	3.50^{a}	0.99	0.0010	0.43	0.018^{c}	0.0004	0.08^{b}

The salinity of irrigation water had a significant effect on the mineral composition of *Portulaca oleracea* leaf content for the majority of the analysed mineral elements (Table 7), as follows: 1) the total nitrogen leaf content showed low variations among treatments; 2) there was a great increase of sodium and chloride concentrations, with the increase of salinity concentration; 3). a low increase of potassium leaf content was shown, with the increase of the saline water; 4) a very low decrease of calcium and magnesium leaf content was verified when the salt concentration of irrigation water was greater; 5) the salinity did not affect iron leaf content.

Table 7. Mineral composition of *Portulaca oleracea*

Treatments	Na	Cl	K	Ca	N	P	Fe	Mg
T0	1.41	1.75^{c}	1.92	0.0028^{a}	0.39	0.12	0.0002	0.200^{a}
T1	2.87	2.60^{b}	2.44	0.0023^{ab}	0.37	0.07	0.0003	0.193^{ab}
T2	2.81	3.43^{a}	2.66	0.0018^{b}	0.38	0.09	0.0002	0.190^{b}

Dry matter of the both species were compared to the fresh weight of them and measured yield with respect to it that the salinity treatments had a significant effect to harvest of the both species. The obtained results to compare over the yield of the both species that yield of *Tetragonia tetragonioides* was two times low than yield of *Portulaca oleracea* (Fig. 16).

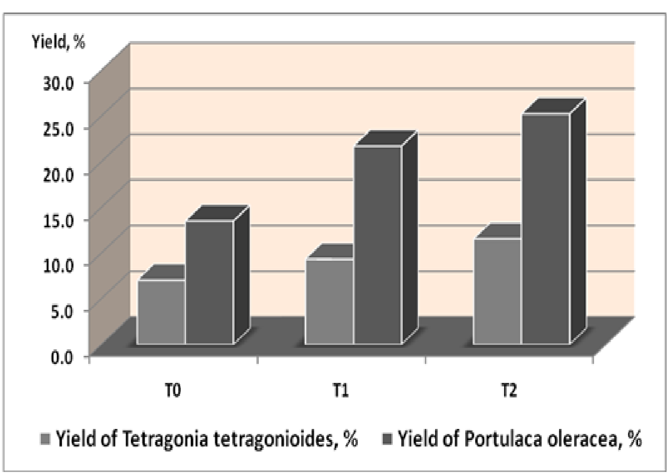

Fig. 16 yields of *Tetragonia tetragonioides* and *Portulaca oleracea* on the end of the experiment

IV. CONCLUSIONS

Tetragonia tetragonioides showed to be the most potential salt (ions) removal species. Moreover, at the end of the experiment, *Tetragonia tetragonioides* was the sole species that had produced significant amounts of dry matter. The reasons were: Fast rate growth, higher biomass production (if properly managed), easy cropping (as winter or summer crop). Moreover, it can be suggested that *Tetragonia tetragonioides* is very interesting species because:

1) The higher biomass production potential: apart the growth rate, this specie can produce several yields during the year (summer and winter).
2) Easy multiplication (seed propagation) and easy crop management.
3) Species tolerant to drought and hot conditions.
4) Protection from soil erosion due excellent soil covering.

The potential of *Portulaca oleracea* as salt removal plant was also high, but lower that *Tetragonia tetragonioides*. This was explained by the larger biomass production of *Tetragonia tetragonioides.*

On the other hand, for very arid climates, *P. oleracea* may substitute successfully *Tetragonia tetragonioides*, once that *Portulaca oleracea* is much more tolerant to drought and salt conditions. Moreover, these both species can be planted, as ornamentals, in saline soils, even without irrigation.

These new clean techniques to control salinity showed that agricultural production can be maintained through the reduction of salts application due to the decrease of irrigation amounts, reducing the leaching. On the other hand, the applied salts through the irrigation can be eliminated by using the salt (ions) removing species. As final remarks, it is concluded that in arid climates, the clean and environmental safe procedures to control salinity could be associated to the conventional techniques, combining environmental, economical and social aspects. Hence, these two salt removing species may contribute to increase the soil sustainability of irrigated areas under climatic changes, and also may be used as food crops.

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