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Effect of NaCl on the growth and the ionic balance K^+/Na^+ of two populations of *Lotus creticus* (L.) (Papilionaceae)

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Abstract

Lotus creticus (L.) is a major pastoral and forage legume in the arid climate of Tunisia where salinity is a serious production problem. A laboratory experiment was carried out to assess the physiological behaviour of two populations of *L. creticus* (Msarref (Msf) and Oued Dkouk (Odk)) in a solid substratum in the presence of salt. The tested concentrations vary from 0 to 400 mM NaCl. It has been shown that the two populations of *L. creticus* are fairly tolerant to salt at growth phase. The growth productions are recorded in absence of salt, mainly at the population of Oued Dkouk. The presence of salt in the medium affects growth of the whole plant for both populations. Compared to root biomass, the aerial one was more affected by salt. For all treatments, plants of both populations remain able to produce and to allocate dry matter to the different organs. However, the salinity generated a disruption at the level of water feeding of plants of the two populations. Compared to root organ, water contents in aerial organ proved to be the least affected by salt. The survey of the relation of water content of leaves according to its production in biomass showed that the expression of growth potentialities is associated with a better leaves hydration until 100 mM of salinity. It seems then that the decrease of growth under saline stress is not associated to a water (osmotic) effect. The survey of the Na^+/K^+ ratio showed for both populations an increase of Na^+ contents in aerial and root organs, with an excess of accumulation of these ions in the aerial organ particularly more marked at the population of Msarref. In spite of the predominance of the Na^+ ions, the two populations, mainly Oued Dkouk, remain able to assure K^+ selectivity. This selectivity is ensured mainly at the level of roots where high potassium content is recorded compared to the aerial organ. The tolerance of the two populations is probably acquired by their better faculty to assure K^+ selectivity and to compartmentalize Na^+ ions in leaves. Such a mechanism reflects probably an inclusive behaviour towards salt. This behaviour justifies the faculty of plants to maintain their growth even in very hard salinity conditions.

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Keywords: Growth; *Lotus creticus*; Osmotic adjustment; Ratio K^+/Na^+ ; Salinity; Tolerance

1. Introduction

Plant cover is needed to protect soil from natural and anthropogenic erosion, mainly where climatic conditions constrain plant growth (Vignolio et al., 2005). Soils with poor vegetation cover are susceptible to erosion by rainfall, the erosion increasing with slope (Rundel, 1995; Muzzi et al., 1997; Grace et al., 1998; Wali, 1999; Caroll et al., 2000). Desertification in the Mediterranean region is mainly due to

vegetation cover reduction and soil erosion (Kosmas et al., 2000). Mediterranean climate is characterized by hot, dry summers and cool, cold winters, which limits the use of different species for soil revegetation (Savé et al., 1999). Therefore, the use of native species for revegetation may be an interesting practice especially in those countries with dry climatic conditions, where salinity is often a serious problem because of the poor quality of irrigation water during the dry season (Sánchez-Blanco et al., 1998). Native species called Mediterranean plants are usually considered more tolerant and adapted to dry conditions and to soil salinity (Caballero and Cid, 1993). Plants exposed to high salt concentrations must withstand both water deficit and ion imbalance imposed by

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salt excess. Although water deficit always has a negative effect, many crop plants are primarily sensitive to Na^+ excess (Greenway and Munns, 1980) due to its adverse effects on K^+ nutrition, cytosolic enzyme activities, photosynthesis and metabolism (Niu et al., 1995; Ben Khaled et al., 2003). The depressive effect of salt on the growth is, according to Hajji et al. (1999), the results of (i) a reduction in the osmotic potential of the soil solution around the roots, (ii) an increase in the accumulation of some ions in harmful concentrations in tissues and (iii) a modification of the nutritional statute of the essential ions to the growth and the development. It is known that the capacity of plants to counteract salinity stress strongly depends on the status of their K^+ nutrition. Increasing K^+ supply in the root environment may mitigate the reduction of plant biomass due to an increase in salinity (Chow and Tsang, 1990; Delgado and Sánchez-Raya, 1999). It is possible that a high K^+/Na^+ ratio is more important for many species than simply maintaining a low concentration of Na^+ (Gorham et al., 1990; Rubio et al., 1999; Cuin et al., 2003). Potassium starvation regularly accompanies sodium toxicity (Flowers and Läuchli, 1983). Peng et al. (2004) have shown that the decline of salt tolerance under low K^+ conditions might have resulted from increased Na^+ entrance through the high affinity K^+ system. However, salt sensitive plants (glycophytes) try to restrict ion movement from roots to shoots whereas salt resistant plants (halophytes) tend to take up Na^+ ions (Slama, 1987; Hasegawa et al., 2000). In 1999, Amzallag showed that the toxicity of salt is frequently deduced from the negative correlations between the biomass of the aerial organs and its Na^+ content. Compared to the shoots, several studies have shown that roots are less affected (Greenway and Munns, 1980; Munns and Termaat, 1986; Mohamed et al., 1989). In other studies, it was shown that the growth of aerial organ was inhibited under salt stress by the decrease of root growth (Cramer et al., 1989; Yeo et al., 1991; Rengel, 1992). According to Levigneron et al. (1995), the increase of soil salinity is translated by an immediate reduction of shoot growth. The latter is associated to the reduction in the water potential gradient between the plant tissues and the medium. The halophytes and some tolerant glycophytes carry out the osmotic adjustment by concentrating salt in their tissues (Munns, 2002). But the quantities necessary to accumulate become quickly toxic for the sensitive glycophytes which are unable to adjust their internal osmotic potential (Mott and Steward, 1972; Munns, 1993). Consequently, the most studied criteria used to evaluate the tolerance of plants to saline stress appear (i) ionic transport and regulation such as the Na^+ foliar exclusion, high K^+/Na^+ selectivity of shoots (Shachtman et al., 1991; Wolf et al., 1991); (ii) the phloem Na^+ and Cl^- ions retranslocation (Zid and Grignon, 1991); (iii) synthesis of the nitrogenized molecules such as glycine betain (Gerard et al., 1991; Levigneron et al., 1995), polyamines (Le Dily et al., 1991) and proline accumulation (Ullah et al., 1994; EL Haddad and O'Leary, 1994) and (iv) Chlorophyllian fluorescence (Belkhodja et al., 1994).

Lotus creticus, a member of Papilionaceae family, grown on the beaches and cliffs of the Mediterranean coast, could be used for revegetation in saline conditions. Although, its introduction

requires knowledge about its eco-physiological characteristics in its natural habitat (Sánchez-Blanco et al., 1998). In earlier report, we have shown that this species is able to support a level of salinity around 300 mM in germinative phase (Rejili et al., 2006). *L. creticus* is cultivated in many countries; it is widely grown in arid and semi-arid region where soils contain high levels of salts. However, salt affected soils can be utilized by growing salt tolerant crops because such crops would allow expansion of crop production to areas where conventional reclamation procedures are economically or technically limited. Since *L. creticus* is a major pastoral legume crop (Neffati, 1994), it could be grown on salt-affected lands if it possesses high degree of salt tolerance. Keeping in mind the present study was conducted to assess the response of this crop to salt stress since the mechanism by which plant tolerates salt is complex and it differs from species to another (Greenway and Munns, 1980; Ashraf, 1994; Ashraf and Harris, 2004).

2. Materials and methods

2.1. Plant material and growth conditions

L. creticus seeds were collected from two sites in Southern Tunisia. Located in Jeffara, the first site (area of Msarref (Msf): $10^\circ 59' . 677^\circ\text{E}$ and $33^\circ 10' . 269^\circ\text{N}$) formed part of the lower arid bioclimatic stage. The second one which forms part of the Oued dkouk national park (Odk), is localised in the higher Saharan bioclimatic stage ($10^\circ 32' . 280^\circ\text{E}$ and $32^\circ 08' . 760^\circ\text{N}$). Seeds were sowed in plastic containers filled with a mixture of marketed peat and sterile sand (equal parts by vol.) during eight weeks. The pots were placed under natural conditions at a temperature ranging between $25/17^\circ\text{C}$ (day/night). Plants were daily irrigated. Seven weeks after sowing, the pots were left in five treatments corresponding to the different NaCl concentrations: 0, 50 mM, 100 mM, 200 mM and 400 mM. Two harvest periods, before (t_1) and after (t_2) application of salt, were realized. At the end of the salinization period, leaves and roots of plants were harvested and washed with distilled water, dried at 80°C and stored at room temperature for mineral analyses.

2.2. Mineral content analysis

Sodium and Potassium contents were determined in a digestion extract with HNO_3 (0.5 N) by atomic absorption spectrometry (Shimadzu, Japan).

2.3. Growth and nutrition analysis methods

2.3.1. Water content (WC)

The organs water contents were defined as follows:

$$\text{WC} = (\text{FW} - \text{DW})/\text{DW}$$

where:

DW Dry weight
FW Fresh weight

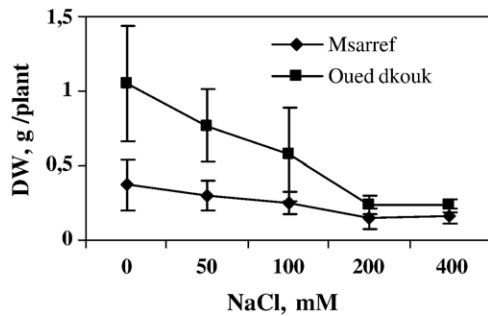


Fig. 1. Effect of different NaCl concentrations on the whole plant dry weight production of the two populations of *Lotus creticus*. Each point represents the average of 9 individual measurements. The confidence interval was calculated at the threshold of 95% (Initial dry matter of Msf=0.0735 g/plant and that of Odk=0.0919 g/plant).

2.3.2. Relative average growth (RAG)

The RAG was calculated according to the formula of Hunt (1990) cited by Lachaâl (1998).

$$RAG = (DW_{t1} - DW_{t2}) / [DW * (t_2 - t_1)]$$

where:

$$DW = (DW_{t2} - DW_{t1}) / \ln(DW_{t2}) - \ln(DW_{t1})$$

DW_{t1} Dry matter mass (mg) before the application of salt

DW_{t2} Dry matter mass (mg) at the end of salinization period

2.3.3. Sensitivity rate index (IS)

The effect of salt on growth can be appreciated by a sensitivity rate index (IS) calculated according to the following formula:

$$I_s = [(DW_{NaCl} - DW_{control}) / DW_{control}] \times 100$$

2.3.4. Ionic contents

The ionic contents (IC) accumulated in the different organs during the culture were expressed in meq/gDW. It was calculated according to the following formula.

$$IC = \text{Ionic quantities} / DW(g)$$

2.3.5. K⁺/Na⁺ selectivity

The equivalent ionic fraction K⁺/(K⁺ + Na⁺) is given on the ionic contents of the shoots, stems and roots. Reported to the equivalent ionic fraction in the medium, this ratio defines the K⁺/Na⁺ selectivity in the plant. This estimate validity was given by Glenn et al. (1994).

2.3.6. Vacuolar compartmentation

To appreciate the Na⁺ compartmentalization degree in foliar tissues, we carried out an indirect evaluation by correlating

shoot water content with its Na⁺ content. When Na⁺ is compartmentalized in the vacuole, it was used for the osmotic adjustment and its vacuolar accumulation induced a supplement tissue hydration. However, if Na⁺ accumulation was extracellular, it involved tissue dehydration.

2.4. Statistic analysis

The follow-up of the various parameters under salt stress was given on the basis of nine replications for each treatment. The measured parameters were subjected to an analysis of the variance (Anova test). The confidence interval was calculated at the threshold of 95%.

3. Results

3.1. Plant growth

3.1.1. Whole plant growth

The dry matter of whole plants cultivated under salt stress is given in Fig. 1. In the absence of salt, plant growth was maximum and the Msf population plants were less productive than those of the Odk population. Such a result was confirmed by the Anova analysis which revealed a highly significant population effect ($P < 0.01$; Table 1). The presence of salt to 100 mM reduced significantly the dry matter production of both populations ($P < 0.01$). Compared to the control, the degree of reduction reached 50% for the Odk population was only 33% for the Msf population. At high levels of salinity (200 to 400 mM), plant biomass of both populations was statistically identical.

Table 1

Results of Anova test showing the effect of salinity on the dry matter production of whole plants, the organs (shoot, stems, roots) and on the relative average growth RAG at the two populations of *Lotus creticus*

Sources	Parameters	d.d.l	F	Sig.	
Population	DW whole plant	1	25.323	0.000	
	DW	Shoots	1	20.938	0.000
		Stems	1	31.500	0.000
		Roots	1	1.182	0.280
	RAG	Shoots	1	20.414	0.000
		Stems	1	9.594	0.003
Roots		1	2.307	0.133	
Treatment	DW whole plant	4	9.324	0.000	
	DW	Shoots	4	31.316	0.000
		Stems	4	9.314	0.000
		Roots	4	2.025	0.099
	RAG	Shoots	4	13.727	0.000
		Stems	4	6.190	0.000
		Roots	4	2.888	0.027
	Interaction	DW whole plant	4	3.090	0.020
		DW	Shoots	4	25.922
Stems			4	2.851	0.029
Roots			4	1.036	0.394
RAG		Shoots	4	1.830	0.131
		Stems	4	0.437	0.781
		Roots	4	0.728	0.575

3.1.2. Organ growths

The effect of salt stress on the dry matter of the different organs is illustrated in Fig. 2a and 2b. In the absence of salt, the shoots dry matter of Msf population was significantly lower than those of Odk population ($P < 0.01$; Table 1). The presence of salt affected significantly the shoots biomass ($P < 0.01$). Compared to the control, dry matter decreased by 50% for both populations at 100 mM of NaCl. At high salinity (200 and 400 mM), the shoots remained able to produce dry matter. The allocated dry matter represented, compared to control, approximately 40% and 20% for the two populations Msf and Odk respectively. The analysis of salt effect on stem biomass of both populations showed that, up to 100 mM, NaCl contribution did not modify the biomass of these organs. It was only with very high levels of salt (200 and 400 mM) that stem dry matter presented a highly significant reduction ($P < 0.01$; Table 1). The reduction reached 33% for Msf population and 50% for Odk population. Compared to

the aerial organs, the roots dry matter was not affected by salt stress.

3.1.3. Relative average growth (RAG)

Fig. 2c and 2d shows that the growth activity of aerial organs was significantly higher for Odk population than for Msf one ($P < 0.05$; Table 1). The roots RAG was, however, identical for both populations ($P > 0.05$). The presence of NaCl at levels exceeding the 100 mM resulted in a significant reduction of the aerial organs RAG for both populations ($P < 0.01$). The roots RAG was, however, significantly insensitive ($P > 0.05$).

3.1.4. Sensitivity rate index (IS)

As shown in Fig. 2e and 2f roots proved to be the least sensitive organs to salt for both populations (treatment effect: $P < 0.05$; Table 2). On the contrast, aerial organs did not express its maximum growth potentialities. It tolerated at 100 mM levels concentrations.

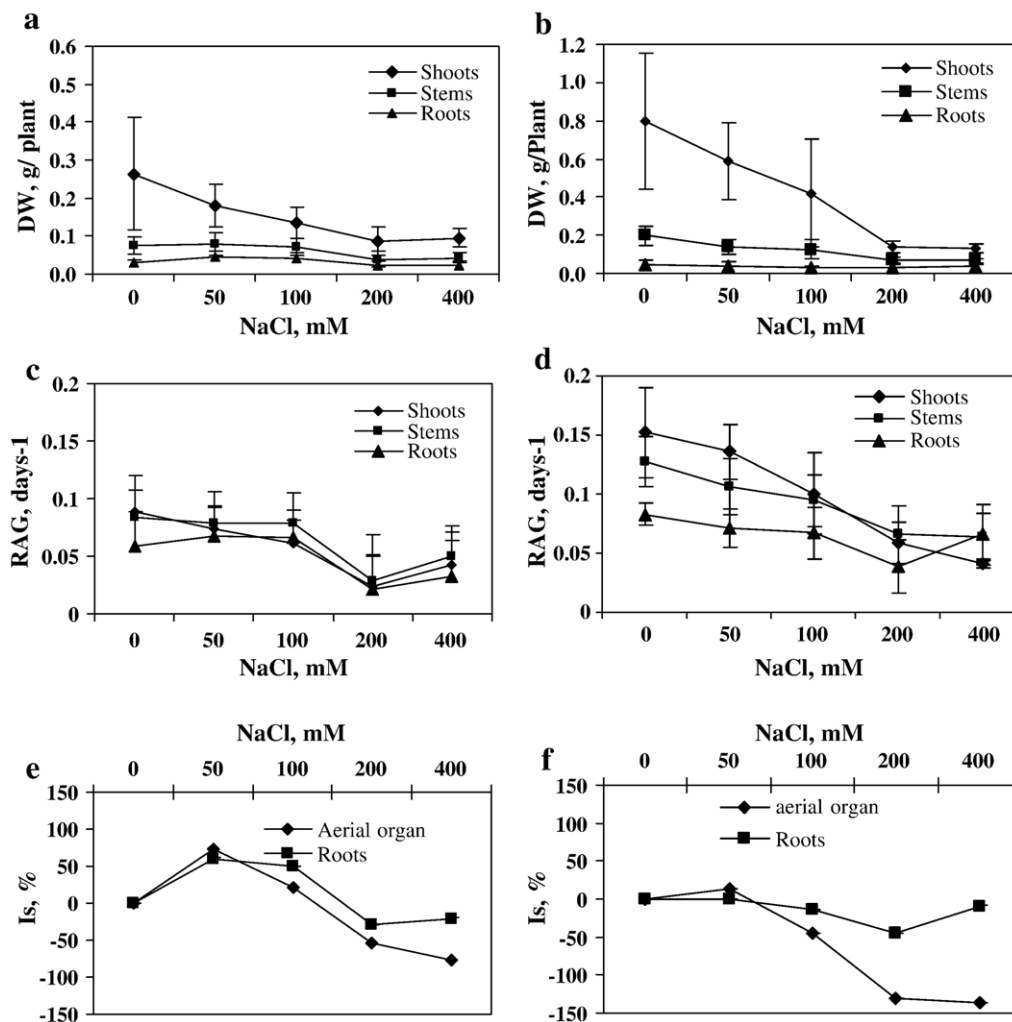


Fig. 2. Effect of different NaCl concentrations on dries weights productions (a,b), Relative average growth (RAG) (c,d) and Sensibility rate index (e,f) of the aerial and root organs of the two populations of *Lotus creticus* (Left Panels: Msarref and Right Panels: Oued dkouk). Each point represents the average of 9 individual measurements. The confidante interval was calculated at the threshold of 95%.

3.2. Organ hydration

The water content of the aerial and root organs under salt stress is given in Fig. 3a and 3b. In the absence of salt, the aerial organs of the two populations presented different water contents. The variance analysis confirmed that population factor acted significantly on water content of these organs ($P < 0.01$; Table 2). For Msf population, the root water content represented half of the aerial organs. Salinity has significantly improved water content of the aerial organs for both populations ($P < 0.01$; Table 2). This improvement was reached at 100 mM for both populations. Beyond these concentrations, the water contents of the aerial organs decreased considerably with the increase of salt. This was confirmed by the variance analysis which showed that the “population” and “treatment” factors acted significantly on this parameter ($P < 0.01$). The interaction between these factors was also significant at the threshold of 1% ($P < 0.01$). The roots water state was not affected by salinity. At 400 mM, the organ hydrations (aerial and root) of both populations were identical.

It was showed previously that the growth of both populations was affected by salt stress. However, a significant improvement of the water status of the aerial organs was showed. It seems that the growth decreasing under salt stress wasn't associated to a water (osmotic) effect but it was probably the consequence of a massive accumulation of toxic ions and/or of limited nutrient absorptions (ionic effect).

3.3. Ionic contents

3.3.1. Sodium

Fig. 3c and 3d shows that in the absence of salt, the both organs populations presented very low Na^+ contents. These contents didn't exceed the 0.5 meq/g DW. The presence of salt involved a Na^+ aerial tissues improvement with an excess of accumulation for Msf population. At 400 mM, the values reached 5 meq/g DWAP for Msf population, were only 2.5 meq/g DWAP for Odk population. The both population's roots were definitely less rich in Na^+ ; the sodic contents exceeded hardly the 2.5 meq/g DWR. Significant differences in Na^+ accumulation between the two populations were revealed by the Anova analysis at two factors ($P < 0.05$) (Table 2).

3.3.2. Potassium

The potassium content of the aerial and root organs is presented in Fig. 3e and 3f. In the absence of salt, the organs K^+ contents were significantly more important for Msf population than for Odk. This was confirmed by the variance analysis where a highly significant population effect was revealed ($P < 0.01$; Table 2). The presence of salt induced a potassium content reduction, particularly in the aerial organs. This was confirmed by the Anova test which detected a highly significant treatment effect at the threshold of 1% ($P < 0.01$). The rooted potassium nutrition was statistically identical at the both populations ($P < 0.05$). The roots K^+ content proved to be insensitive under salt stress.

3.4. Vacuolar compartmentation

The data of Fig. 4a and 4b, correlating shoots water content with its Na^+ content, showed that the presence of salt in the medium provoked a sodium accumulation in the photosynthetic organs for both populations. This foliar accumulation was associated with an increase of water content until a 100 mM level of salinity, for both populations. These observations suggest that the Na^+ ion underwent a certain compartmentation mechanism. However, this sodic accumulation made probably the plants to osmotically adjust themselves and to maintain its water potential gradient, essential for the water circulation from the medium to the plant organs.

4. Discussion

Results relating to plant cultivated stages in presence of different salt concentrations showed that Odk population was more productive than Msf population in absence of salt (population effect: $P < 0.05$). The presence of salt in the medium affected both biomass production and plant development of both populations (treatment effect: $P < 0.01$). Concerning biomass production, our results confirmed that dry matter of the aerial organs (Fig. 2) was significantly affected by NaCl levels exceeding the 100 mM. This reduction appeared relevant for Odk population. The same result was shown by Sánchez-Blanco et al. (1998) on plants of *L. creticus* spp *creticus* cultivated on hydroponic medium. Le Houérou (1986) showed that *L. creticus* was able to support 100 mM of NaCl

Table 2

Results of Anova test showing the effect of salinity on the sensibility rate index, sodium, potassium and water contents of aerial and root organs at the two populations of *Lotus creticus*

Sources	Parameters		d.d.1	F	Sig.
Population	Sensibility rate index (IS)	Aerial organs	1	3.579	0.062
		Roots	1	3.183	0.078
	Water Content	Aerial organs	1	12.074	0.001
		Roots	1	0.030	0.862
	Na^+ content	Aerial organs	1	55.593	0.000
		Roots	1	1.262	0.265
K^+ Content	Aerial organs	1	13.509	0.000	
	Roots	1	0.749	0.390	
Treatment	Sensibility rate index (IS)	Aerial organs	4	4.237	0.004
		Roots	4	2.668	0.038
	Water content	Aerial organs	4	27.337	0.000
		Roots	4	20.910	0.000
	Na^+ content	Aerial organs	4	24.255	0.000
		Roots	4	5.701	0.000
K^+ content	Aerial organs	4	20.411	0.000	
	Roots	4	1.592	0.184	
Interaction	Sensibility rate Index (IS)	Aerial organs	4	0.236	0.917
		roots	4	1.171	0.330
	Water content	Aerial organs	4	10.981	0.000
		roots	4	14.034	0.000
	Na^+ content	Aerial organs	4	4.207	0.004
		roots	4	4.183	0.004
K^+ content	Aerial organs	4	1.680	0.163	
	roots	4	0.265	0.900	

concentrations. Abdelly (1992) showed that salt delayed new shoots development and induced a reduction of its expansions in medic plant. Erdei and Kuiper (1979) showed that growth of *Plantago media* was reduced at as low concentration as 25 mM NaCl and the plants were killed at 75 mM, while the salt tolerant *Plantago maritima* still maintained growth at 300 mM NaCl.

The effect of salinity on biomass depends on plant size and its relative average growth (RAG). The depressive action of salt on growth appeared by a significant reduction of the aerial organ growth activity (Fig. 2c and 2d). For instance, shoots were more affected than stems for both populations. Compared to the aerial organs, the roots dry matter was not affected by salt stress. The same results were shown by Vinit-Dunand et al. (2002) in cucumber plants. Several authors suggested that, under saline stress, the osmotic effect is responsible for the aerial organ growth reduction (Muuns and Termaat, 1986; Yeo et al., 1991; Rengel, 1992). Indeed, the data of Fig. 4a and 4b, correlating the foliar biomass with its water content for both populations, showed that expression of growth potentialities was independent, at both populations, of its hydration until 100 mM of salt. This result pleaded in favour of the previous hypothesis.

Plants exposed to saline stress were prone to an osmotic stress and to specific toxicity effects of Na^+ and Cl^- ions (Bernstein and Hoyward, 1958; Shannon, 1984; Ayer and Westcot, 1985; Hajji et al., 1999). Flowers et al. (1977) summarized the depressive effect of salinity on the growth by a nutritional and/or hydrous imbalance. The significant correlation between the aerial biomass production and its Na^+ content suggest that, for both populations, the growth decrease was due to the ionic toxicity (Fig. 5a and 5b).

Generally, the most salt tolerant plants accumulate Na^+ in their shoots whereas sensitive plants do not. In the first type, called "Includers", salt was trapped and accumulated in the aerial organs cells, mainly in its vacuoles (Yeo and Flowers, 1986; Levigneron et al., 1995). In the second type, "Excluders", the salt conveyed to the shoots, fault to be trapped, was re-exported towards the roots by the phloemic tissue (Lessani and Marschner, 1978; Wieneke and L uchli, 1980; Slama, 1982; Fortmeir and Schubert, 1995). Our results (Fig. 4c and 4d) showed that the two studied populations accumulated Na^+ ions in its photosynthetic organs. This accumulation was associated with an improvement of water content for a level of salinity around 100 mM. Such a mechanism reflects probably an

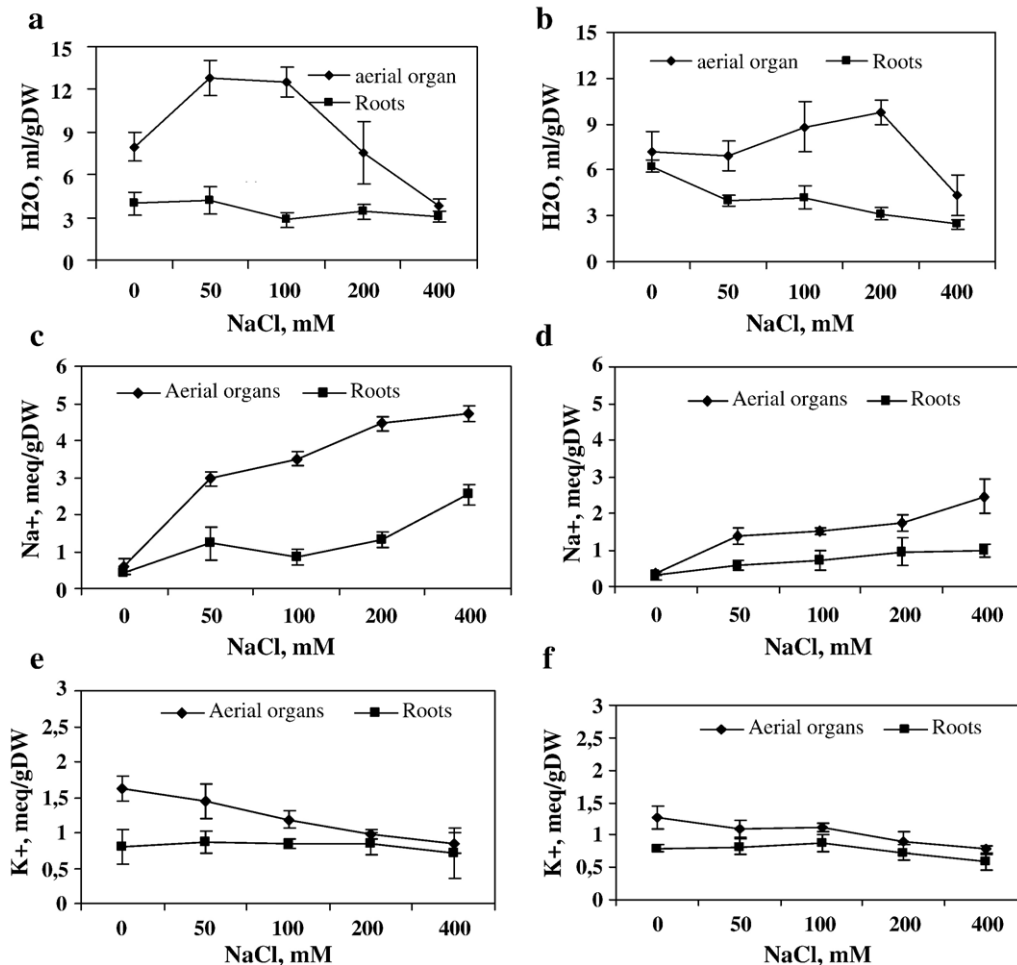


Fig. 3. Variation of the water (a,b), sodium (c,d) and Potassium (e,f) contents in the aerial and root organs of the two populations of *Lotus creticus* cultivated under salt stress (Left Panels Msarref and Right Panels: Oued dkouk). An average of 9 repetitions and confidence interval was calculated at the threshold of 95%.

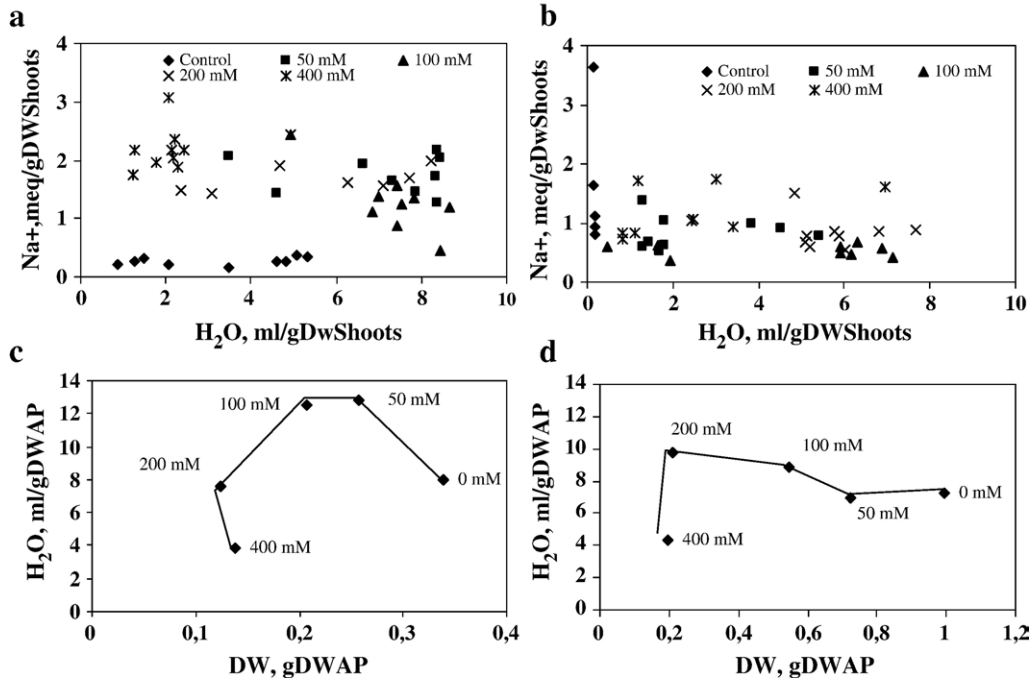


Fig. 4. Correlations between foliar water content and its sodium content (a,b) and between the aerial organs growth and its water content (c,d) at the two populations of *Lotus creticus* cultivated under salt stress (Left Panels: Msarref and Right Panels: Oued dkouk). An average of 9 repetitions and confidante interval was calculated at the threshold of 95%.

inclusive behaviour of the plants and a good aptitude to use the dominant ions (Na^+) for the osmotic adjustment. Consequently, plants have probably adapted to the osmotic stress by either closing their stomata or increasing the osmotic pressure of the

leaf cells. This osmotic behaviour on solid substratum was also shown by Sánchez-blanco et al. (1998) on hydroponic medium.

The maintenance of suitable potassic nutrition to support growth of different organs requires a good selectivity, in the

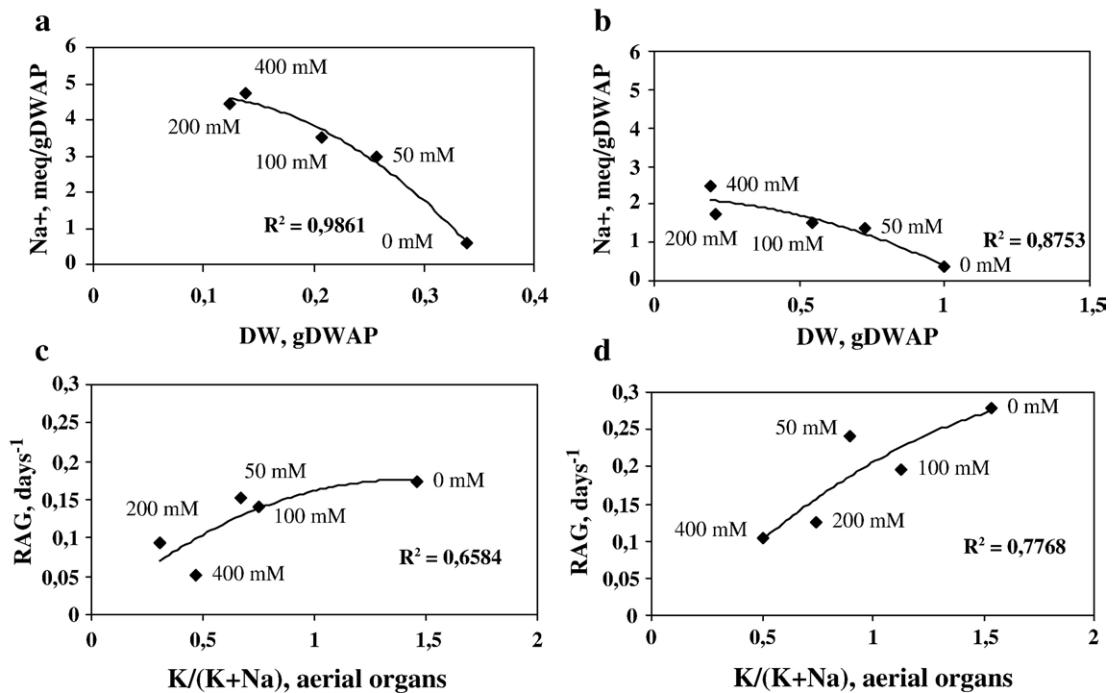


Fig. 5. Correlations between Correlation between the aerial organs biomass and its sodium contents (a,b) and between the aerial organs RAG and between RAG and ionic selectivity (c,d) at the two populations of *Lotus creticus* cultivated under salt stress (Left Panels: Msarref and Right Panels: Oued dkouk). An average of 9 repetitions and confidante interval was calculated at the threshold of 95%.

aerial organs, of K^+ absorption, accumulation and transport compared to Na^+ . Many studies on halophytes and some tolerant glycophytes plants showed that a high foliar K^+/Na^+ ratio is a salt tolerance criterion (Gorham et al., 1990; Shachtman et al., 1991; Wolf et al., 1991; Yeo, 1998). Our results (Fig. 5c and 5d) showed that organs of two populations, in particular Odk, remained strongly selective for K^+ ions. However, the rather weak correlation detected at the Msf population seems to be the consequence of the strong Na^+ and K^+ competition. The later limits the potassium absorption, an essential ion for plant growth and development.

5. Conclusion

The comparative study about the effect of salinity on growth of two populations of *L. creticus* showed that the Odk population has a significant higher production than Msf in absence of salt. The presence of salt (50 to 400 mM) affected negatively both populations growth. Such negative effect is more obvious on aerial organs than on roots. Both population leaf water contents were significantly augmented with the increase of salt concentrations (until 100 mM). In both populations, an increase in the contents of Na^+ in both parts, above and underground, was recorded even though, an excess of accumulation of these ions was more marked in the aerial organ of the Msf population. The presence of high quantities of Na^+ in the aerial biomass may be attributed to the export, towards the aerial organ of the roots absorbed Na^+ essence. To escape from the ionic effects of Na^+ , both populations probably express a certain mechanism of compartmentation. In addition, the high levels of Na^+ generated a kind of competition on the level of the sites of K^+ absorption, mainly at the Msf population, and thus limited the absorption of this essential element for plants growth and development.

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