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Research Article

EFFECT OF SALINITY ON THE PHYSIOLOGICAL BEHAVIOR OF THE OLIVE TREE (VARIETY SIGOISE)

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ABSTRACT

Salinity is a major problem directly affecting the ecological balance and the development of agriculture in the Mediterranean basin, particularly North Africa. This phenomenon is considered as the most important abiotic factor limiting crops growth and productivity, degrading and polluting soils in arid and semi-arid. In order to study the influence of salinity, on the physiological parameters and to assess the potential of adaptation of the olive tree in a saline environment, three parcels containing the Sigoise variety and subject to different degrees of salinity were selected: Parcel 1 (non-saline); Parcel 2 (saline); Parcel 3 (very saline). Under a saline constraint, the results showed two contrasting tendencies, an intense increase in the content of proline, sodium (Na^+) and chlorophyll (b), while water content, potassium and chlorophyll (a) decreased strongly with increasing salinity.

Keywords: Salinity; olive tree; salt stress; proline; chlorophyll.

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1. INTRODUCTION

Every year, hundreds of thousands of hectares of fertile soils are degraded under the influence of salinity. Of all the cultivated soils in the world, 23% are affected by salinity problems [1]. In fact, saline soils cover 397 million hectares and sodium soils 434 million hectares [2]. Some authors consider it one of the most devastating environmental stresses, resulting in a significant reduction in area, productivity and crop quality [3].

In this context, the soils salinity and irrigation waters are among the main abiotic factors limiting plant productivity [4,5] and agricultural yield [6] in arid and semi-arid areas.

In these areas, the low and irregular rainfall amounts [7] and the high temperatures leading to excessive evaporation, in addition to poorly controlled irrigation [8] favor the soluble salts accumulation in soils [9]. The later causes significant physiology changes, growth and agricultural productivity of plants [10,11].

In light of this, the thorough knowledge of the plants behavior and reaction to salinity is crucial, to rationalize the interventions that aim to improve their water content and optimize their productivity. Indeed, the plants response to salts depends on the species, the variety, the soluble salts concentration, the growing conditions and the stage of development. The identification of salts tolerant varieties would certainly improve the agricultural production of the saline areas, or those irrigated with brackish waters, and may be of considerable interest for the purposes of plant-variety improvement [12,13].

In this context, the main purposes of the present work were to monitor the physiological (leaves chlorophyll and relative water content) and biochemical (proline and cations (Na^+, K^+)) behavior of the olive tree, “Sigoise” variety, conducted in three parcels with different degrees of salinity in an arid area.

2. MATERIALS AND METHODS

2.1. Study area

The study was carried out in the state of Relizane, an arid zone located in northwest Algeria and characterized by vast areas of saline soils. This area is known for its total dependency on agricultural activity and especially vegetables such as artichokes and arboriculture, particularly olive trees and citrus fruits. Despite its proximity to the Mediterranean (35 km), Relizane is a very hot arid area with an average annual rainfall of 300 mm/year. In this area, located between 0°29'22" and 0°29'59" of East longitude and between 35°43'34" and 35°44'10" of North latitude, three olive trees parcels with varying salt concentrations and conducted under drip irrigation were subject to this physiological study (Figure 1).

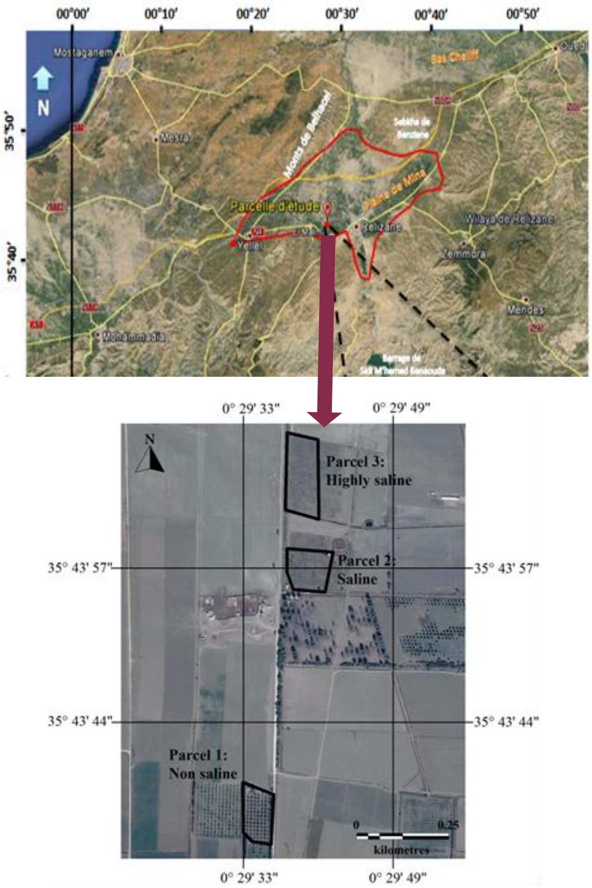

Fig.1. Location of the study area (source: Google earth, 2017).

2.2. Soil sampling and analysis

A total of 27 random soil samples were collected from each parcel, at vertical depth of 0-25, 25-50 and 50-75 cm respectively (9 samples at each depth). Measured soil parameters were granulometry, electrical conductivity on saturated soil paste extract (ECe), salinity through electromagnetic induction (EM38), limestone ($CaCO_3$) and organic matter (O.M).

2.3. Plant material collection and analysis

The plant material (especially leaves) was randomly collected at the four cardinal points of the olive tree, during the period from December to January, from the preceding spring shoots. The collected leaves were subject to: (1) the relative water content (RWC %) analysis, measured from fresh weight (FW), dry weight (DW) and turgescent weight (TW), calculated according to Barrs and Weatheley [14] (Equation 1).

$$RWC\ (\%) = [(FW - DW)\ /\ (TW - DW)] \times 100 \qquad (1)$$

(2) The determination of concentrations of chlorophylls a and b, using the optical density (O.D) of the wavelengths 645 and 663 nm and calculated according to Arnon [15] formulas (Equation 2 and 3).

$$Chl.a = 12.7\ (O.D_{663}) - 2.69\ (O.D_{645}) \qquad (2)$$

$$Chl.b = 22.9\ (O.D_{645}) - 4.86\ (O.D_{663}) \qquad (3)$$

(3) The determination of proline concentration according to Troll and Lindsley [16] method, modified by Monneveux and Nemmar [17], using the calibration curve, after determining the optical density at a wavelength of 528 nm. Finally, (4) the flame spectrophotometry was applied to the analysis of vegetable ashes, to determine the cations, Na^+ and K^+, according to the methodology described by Lafon et al., [18].

The obtained data were subject to a descriptive statistical analysis using Excel software. The comparison between the results of the 3 levels of salinity (3 parcels) was achieved through the analysis of variance (ANOVA) using a trial version of XLSTAT 2017.

3. RESULTS

3.1. Soil analysis

Through the 3 parcels, the granulometric analysis showed soils of clayey nature, the clay proportion ranges from 45% to 55% with a coefficient of variations ranging between 4 to 24%, whereas the percentage of sand was less than 8%. According to the USDA textural triangle, parcel 1 was of clay type, while parcels 2 and 3 were of silty-clay type. The chemical analysis (Table 1) showed slightly basic soils, moderately calcareous and an averagely rich in organic matter (OM), throughout the 3 parcels the OM showed a decreasing trend with increasing depth. In terms of electrical conductivity (ECe), the results showed that parcel 1 was non-saline with an average of 1.39 ds/m along the 3 horizons, the second parcel was saline (10 ds/m) and the third parcel highly saline with an average of 15 ds/m. the saline parcels 2 and 3, showed increasing levels of salinity with increasing depth.

The electromagnetic ratio between the horizontal and vertical mode [CEMH/CEMV] for the 3 parcels, was between 0.71 and 0.76, indicating leached profiles according to Corwin and Rhoades [19] classification (CEMH/CEMV < 1.05).

Table 1. Results of soil analysis

	Horizon	*ECe*	*CV %*	*pH*	*CV %*	*OM%*	*CV %*	*$CaCO_3$*	*CV %*
Parcel 1	H1	1.47	58.31	7.8	2.27	2.41	14.91	20.37	3.61
	H2	1.55	35.21	7.7	1.3	1.81	26.5	20.7	7.45
	H3	1.16	42.96	7.7	2.37	1.41	43.71	21.03	3.05
Parcel 2	H1	4.39	48.61	8.1	2.6	3.67	28.36	18.44	8.61
	H2	12.5	36.91	7.8	1.03	2.77	38.88	19.19	11.59
	H3	14.4	29.46	7.8	0.87	2.06	21.43	18.97	7.35
Parcel 3	H1	6.88	26.3	7.8	1.02	2.67	27.11	19.85	7.47
	H2	14.7	36.81	7.9	1.39	2.41	29.83	20.33	6.39
	H3	23.5	20.09	8.1	0.8	1.78	52.69	21.24	7.98

3.2. Olive tree physiological parameters

3.2.1. Relative water content (RWC %)

According to the salinity levels (Non saline, saline, highly saline) recorded throughout the 3 parcels, the results showed a very high regression in terms of leaves RWC ranging from 86.18% in the non-saline parcel (parcel 1) to 59.2% in the highly saline parcel (parcel 3), with respective regressions of 24.05% (saline parcel) and 26.98% (highly saline parcel) compared to the non-saline parcel (Figure 2).

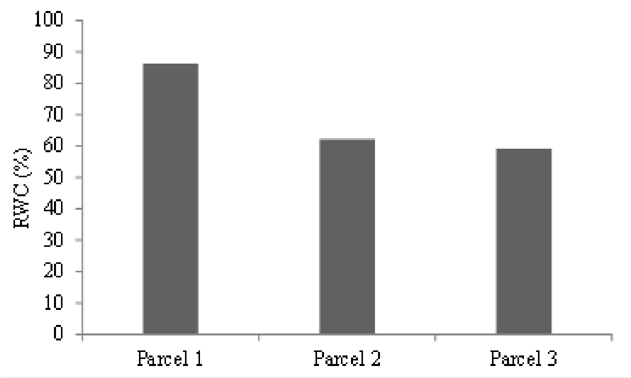

Fig.2. Variations of the RWC of the olive tree (Sigoise variety) according to salinity

According to the analysis of variance (ANOVA), the difference in RWC between the 3 olive tree parcels was highly significant ($P < 0.001$) between parcel 1 and the remaining parcels (parcel 2 and 3), whereas no difference was observed between the parcels 2 and 3 (Table 2).

3.2.2. Chlorophyll and proline content

The chlorophyll (a) and (b) concentrations showed a contrasting behavior according to salinity. In this context, the chlorophyll concentration (a) was highly negatively affected ($R = - 0.97$) by high salinity levels, whereas chlorophyll (b) concentration showed a strong increase ($R = 0.99$) with salinity degree (Figure 3). This pigments behavior indicates clearly a strong saline stress. The differences in chlorophyll (a) and (b) concentrations between the 3 salinity levels were highly significant ($P < 0.001$) according to ANOVA (Table 2).

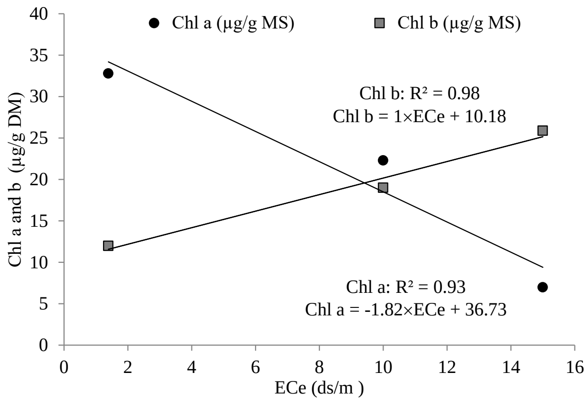

Fig.3. Evolution of chlorophyll (a) and (b) concentrations according to the salinity conditions

In saline conditions, the olive tree leaves showed increasing proline concentrations, positively related (R = 0.99) with increasing soil salinity, indeed, the lowest proline concentration (0.22 µg/g) was observed in the non-saline conditions, whereas the highest concentration (0.89 µg/g) was registered at the highest salinity level (15 ds/m) (Figure 4). The proline concentrations recorded in the Sigoise variety leaves under the 3 salinity conditions were all highly significantly different according to ANOVA (Table 2).

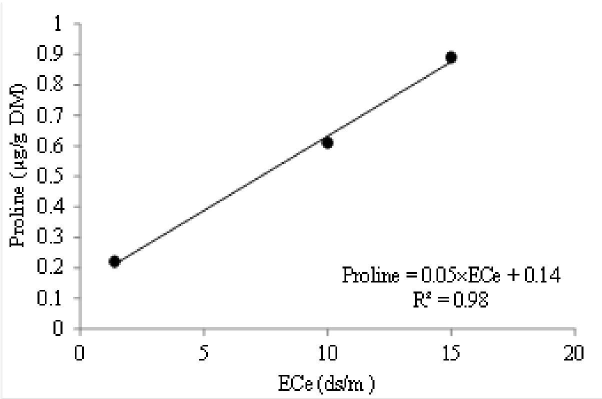

Fig.4. Variation of proline concentration according to the salinity levels

3.2.3. Sodium and potassium content

Under saline conditions, the accumulation of Na^+ and K^+ was inversely proportional in the olive tree leaves and strongly affected by salinity. Indeed, the results showed increasing levels of Na^+ and decreasing levels of K^+ with increasing salinity (Figure 5). Indeed, the correlation analysis showed a strong positive relationship between the soil exchangeable sodium and olive tree foliar sodium regardless of the salinity level (Figure 6). According to ANOVA (Table 2), the differences in the accumulation of these 2 cations under the influence of the first and second salinity level (respectively 1.39 and 10 ds/m) were not significant, while being significant ($P < 0.05$ for Na+) to highly significant ($P < 0.01$ for K+) compared to the third level (15 ds/m).

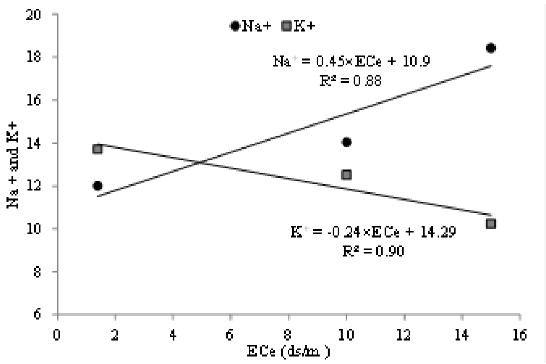

Fig.5. Evolution of Na+ and K+ concentrations under saline conditions

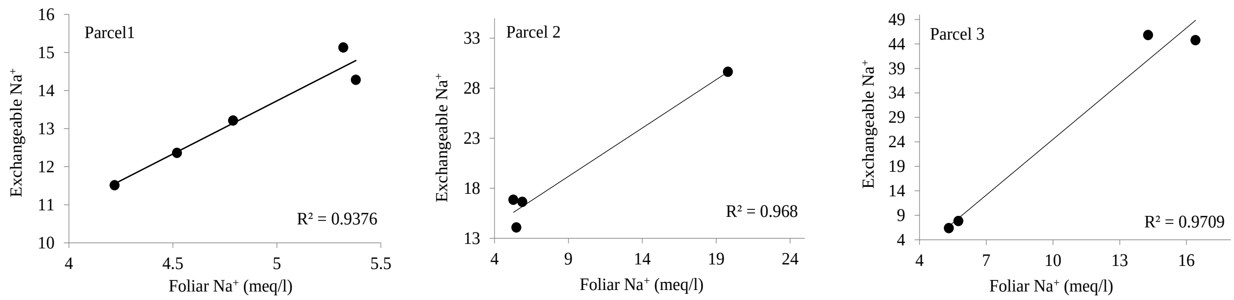

Fig.6. Correlation between soil exchangeable Na+ and olive tree foliar Na+ in 3 levels of salinity

Table 2. ANOVA test, showing the groups and the significance of the differences recorded between the physiological parameters under the influence to the 3 levels of salinity.

	RWC (%)	*Chl a (µg/g)*	*Chl b (µg/g)*	*Proline (µg/g)*	*Na^+*	*K^+*
Parcel1	86.18^a	6.98^a	25.89^a	0.22^a	12.72^a	13.72^a
Parcel2	62.13^b	22.63^b	18.14^b	0.61^b	14.04^a	12.51^a
Parcel3	59.20^b	32.78^c	12.04^c	0.89^c	18.42^b	10.23^b
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.05	< 0.01

4. DISCUSSION

In the arid region of Relizane, salinization constitutes the major threat to agriculture and land degradation, this phenomenon is all the more serious under the effect of the acute drought that affects this area. Indeed, according to Duchaufour [20], saline soils can only be encountered in arid and semi-arid climates; because in a humid climate whatever the origin and form of the sodium ion, this ion is rapidly exported from the profile into the drainage water. In this region, the olive tree and more precisely the Sigoise variety is the main arboricultural crop. According to Walali et al [21], a favorable soil in growing olives must be deep, permeable, well balanced in its particle size distribution (50% clay + silt and 50% of coarse fraction) and a pH of from 8 to 8.5, unfortunately most of these favorable conditions are not met in the study area, indeed, this area showed very fine-textured soils (clayey and silty-clayey texture) with considerably varying salinity, ranging from non-saline (1.4 ds/m) to highly saline (15 ds/m). This soil salinity was highly influential on the physiological parameters of the olive tree, one of the most strategic crops in this area. Because salinity is a phenomenon that often leads to a reduction in plant water availability, the relative water content (RWC %), a very important parameter describing the water status and the osmoregulation ability [22], showed that the effect of salinity resulted in 27% decrease in olive tree RWC, from 86.2% in the non-saline conditions to 59.2% in the highly saline conditions. A very similar RWC decrease of 29.3% (from 75.9% to 46.6%) was reported by Hassani et al., [23] with the same crop in almost the same conditions. Thus, the increase in soil osmotic pressure is the most obvious action of salinity, leading to a reduction in water availability for olive trees in the saline area of Relizane, this osmotic stress affecting crops in saline conditions was also reported by Jagesh and al., [24] and Khalova et al., [25]. In addition to RWC, the soil salinity showed a major negative impact on olives chlorophyll pigments (a and b), indeed strong declines in chlorophyll (a) concentration accompanied by strong increases in chlorophyll (b) concentration were observed with increasing salinity, the same negative effects of salinity on plants chlorophyll pigments were also highlighted by Levingneron et al., [26]; [27]; [28], these authors reported that this behavior was partially due to the reduction of carbohydrates synthesis in saline conditions. In a parallel manner to chlorophyll (b), the increase in soil salinity led to high Proline accumulation in olive leaves (Sigoise variety). The high proline concentration in saline conditions was also observed by Bel Fakih et al., [29] in banana and Chartzoulakis and Klapaki, [30] in tomato, tea and olive. This proline accumulation could play a significant osmoticum role, intervene in the regulation of cytoplasmic pH or create a nitrogen stock used later during the plant stress period. As for the mineral elements, cations analysis (Na^+ and K^+) is among the key analyses in saline areas, according to Hadji and Grignon [31], Hamrouni et al., [32] it shows the degree of plant sensitivity or tolerance to salts and ion dynamics, expressed either by their absorption, transport or accumulation. In light of this, Na^+ and K^+ showed a contrasting behavior in the saline area of Relizane, while Na^+ showed a strong positive increase with increasing salinity, K^+ remarkably decreased in the olive leaves. The same findings were emphasized by several authors, [33], [34] and [35] showed that N^+ contents were higher in the aerial parts and especially in leaves. This phenomenon was explained by a competitive interaction between Na^+ and K^+, leading to potassium retention inhibition in the presence of high concentrations of Na^+ [36]; [37] .

5. CONCLUSION

Crops development, growth and yield depend primarily on the availability of certain environmental conditions such as water, light, climate and soil characteristics, but also on plant genetic abilities. In this study, the physiological behavior of olive tree, Sigoise variety was assessed under salinity as limiting factor. Thus, it was revealed that the salt excess in soil solution was accompanied by an accumulation of proline, chlorophyll (b) and sodium in olive leaves, whereas water content, potassium and chlorophyll (a) were negatively affected by salt.
Nevertheless, the Sigoise variety showed a very good adaptability to saline stress, making it among the recommended species for the development of agricultural lands affected by salinity, an ever-increasing phenomenon in arid and semi-arid regions.

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