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Morpho-physiological Responses of Olive Saplings (Olea europaea L. cv Chétoui) to Partial Root Drying Irrigation Technique with Salt Water

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***Abstract* – The effect of partial root drying (PRD) irrigation with salt water on split root olive (Olea europaea L. cv Chétoui) saplings was investigated. Four irrigation treatments were applied such as: FI- and FI+ (irrigation on both sides of root system with nutritive solution and NaCl was added respectively at 0 and 130mM), PRD- and PRD+ (irrigation on one side of the root system switched to the other every 4 weeks with nutritive solution and NaCl was added respectively at 0 and 130mM). Results showed that olive plant growth and the total biomass were unaffected by irrigation treatments. Also the leaf water statute especially the relative water content was similar for all treatments. The biochemical statute of leaves presented none variation in proline and soluble sugars content. The SPAD index decreased in FI+. As regards the soil quality it was found that PRD reduced the quantity of salt incorporated in the root zone.**

***Keywords* – Olive, Salinity, Partial Root Drying.**

I. Introduction

Nowadays, the scenarios of climate change predict an increase of aridity [1]. Mediterranean basin is threatened by changes and consequently water scarcity showed one of the main factors limiting agricultural development. The olive tree is typical specie of this zone and it traditionally cultivated under rain-fed conditions. The need for supplementary irrigation becomes necessary. While the extension of irrigated lands the great challenge for the coming years will be to increase or maintain production with less irrigation water. This could be achieved through the implementation of different irrigation strategies able for increasing irrigation water efficiency. The deficit irrigation strategy was for a long time adopted. It consists on the imposing of water stress during, drought tolerant phenological stages. It slightly reduced yield while it could also lead in an improvement in the quality of products [2]. The application of this method seems difficult to practices by growers because it need a good knowledge of phonological stages of species and cultivars. The partial root drying strategy was developed. It consists on the irrigation of the half root system and switching for the other part. It was based on the hypothesis of the synthesis and the transport of chemical signals from dry part of the root system to shoot inducing stomatal closure without important change in leaf turgor [3, 4, 5]. The adoption of PRD showed good agronomical results on olive trees [6, 7]. In another hand various studies affirmed that olive is moderately tolerant specie to salinity due to its ability to exclude toxic ions [8, 9]. So the use of low quality resources becomes an alternative for confronting the great water demand for irrigation. The present work is an application of partial root drying irrigation with salt water leading to alleviate the negative effect of salinity in root zone in olive saplings.

II. Material and Methods

A. Plant Material and Treatments

Uniform 3-year-old plants of 'Chétoui' olive cultivar were transplanted in 10 l black plastic bags containing sand–peat mixture (1:1 v/v). Olive plants were irrigated every 3 days with 500 mL of Hoagland's nutrient solution [10], containing 0 and 130 mM NaCl among treatments. The experiment lasted 6 months. The experimental design was a completely randomized with 4 treatments and 3 replicates per treatment.

Four treatments were applied:

FI- and FI+ were irrigations of the entire root system respectively with 0 and 130 mM of NaCl.

PRD- and PRD+ were irrigations of the half of root system respectively with 0 and 130 mM of NaCl switched to the other side every 4 weeks.

B. Measurements

Plant growth parameter:

For each plant, the length, the diameter and the leaf number of five marked shoots were determinate. In order to assess the effects of treatments on the dry matter distribution into canopy and roots, at the end of the experiment, plants were destructively harvested, divided into canopy and root system and dried till constant weight.

Leaf characteristics:

The leaf characteristics were also measured as indexes of leaf sclerophylly, according to the equations described by Bacelar et al. (2004) [11] and on at least fifteen leaves per treatment:

Relative water content (%): $RWC = ((FW – DW) / (TW – DW)) *100$

Specific leaf area (mm2/mg): $SLA = LA / DW$

Leaf tissue density (g/Kg): $LTD = DW / FW$

Water content at saturation (g H2O / g DW): $WCS = (TW - DW) / DW$

Water saturation deficit (%): $WSD = ((TW - DW) / (TW - DW)) * 10$

Actual water content (%): $WC = ((FW- DW) / FW)*100$

Succulence: $SUC = (FW – DW) / LA$

With:
FW: Fresh weight, DW: Dry weight, TW: Turgid weight, LA: Leaf area

Also a number of five fully expanded leaves of current year shoots per plant were used for SPAD measurements with the portable chlorophyll meter SPAD (Konica Minolta)

At the end of the experiment, fully expanded leaves from the mid-section of current year shoots were sampled for analysis:

Total soluble sugars were quantified following the phenol-sulfuric acid method Robyt and White (1987) [12], where 100 mg of leaf tissue were extracted in 80% (v/v) methanol heated to 70°C in a water bath. The extract was centrifuged for 10 min and the supernatant used for the estimation of the concentration of soluble sugars. The reaction mixture consisted of 1 ml 5% phenol and 5 ml 98% sulphuric acid. After the extract had cooled, its absorbance was determined using a spectrophotometer (Biochrom Libra S32) at 490 nm using D-glucose as standard.

Proline was determined spectrophotometrically following the ninhydrin method of Trolls and Lindeslay (1955) [13]. 300 mg of leaf tissue were homogenized with 10 ml of 3% aqueous sulphosalicylic acid and then filtered. Two millilitres of glacial acetic acid was then added to 2 ml of the filtrate derived from the leaf tissue, and boiled for 1 hour. The mixture was extracted with toluene and proline was quantified spectrophotometrically at a wavelength of 520nm from the organic phase using toluene as a blank.

Substrate analysis:

In order to evaluate the salt accumulation in the substrate, at the end of the experiment, three samples from each treatment were taken to determine the electrical conductivity (EC) in the soil solution extracted from saturated paste. Also the pH was measured using a pH meter.

Statistical analysis:

Statistical analyses were performed using the SPSS statistics 20. The treatment means were compared using least significant difference (LSD) and Duncan test calculated at 5% level.

III. Results and Discussion

A. Plant Growth

According to shoot length, leaf number, shoot diameter and leaf area measurements, the plant growth was evaluated (Table 1). Results showed that all parameters were unaffected by treatments except the leaf area. The lowest values were observed in FI+ treatments however PRD treatments showed a slight decrease comparatively to control (FI-). Only for the leaf area results are in accordance with previous studies which affirmed that plant growth was inhibited by intermediate and high salinity treatments with significant variation according to olive cultivars [8, 14]. The application of PRD treatment with salt water reduced the effect of salinity comparatively to full irrigation. Also, PRD treatments even with 0 mM of NaCl slightly decreased the leaf area. This is in accordance with previous works on PRD which revealed that this irrigation technique leads to control the vegetative growth in olive tree [7, 15].

Table 1: Effects of treatments on plant growth parameter: Shoot length (cm), Leaf number/shoot, Shoot diameter (cm) and Leaf area (mm2)

Treatments	Shoot length (cm)	Leaf number/ shoot	Shoot diameter (cm)	Leaf area (mm^2)
FI-	25.18 ±5.36*a*	38.80 ±5.89*a*	2.65 ±0.52*a*	409.09 ±80.09*a*
FI+	25.40 ±3.59*a*	38.57 ±9.69*a*	2.76 ±0.46*a*	243.65 ±59.82*c*
PRD-	24.80 ±6.09*a*	33.00 ±8.33*a*	2.71 ±0.43*a*	339.25 ±48.95*b*
PRD+	21.05 ±4.82*a*	32.71 ±7.22*a*	2.49 ±0.30*a*	310.25 ±51.61*b*

Statistical analysis given that all treatments presented similar cumulative total biomass dry weight (Table 2). Canopy dry weight is also unaffected by treatments however the root dry weight showed differences between treatments. In fact, the PRD- treatment stimulated the root system growth and it had the highest value (53.84 g). This is in accordance with some results which affirmed that PRD technique increased the root system growth. Some authors [16] found that DI and PRD decreased potato plant biomass to a similar extent as compared to FI even through the pattern of biomass partitioning among different plant organs was different. Comparatively to control, deficit irrigation strategy decreased biomass allocation to leaves and stems while increasing it into roots and tubers; however PRD increased biomass allocation to roots. Whereas treatments with salt water had the same root dry weight values like control. Contrary to some researches where it mentioned that irrigation with saline water reduced plant growth even with intermediate salt concentration [14]. Also it was affirmed that plant growth, (i.e. shoot length, total leaf area and dry weight) is inhibited by moderate and high salinity for the majority of olive cultivars [17].

Table 2: Effects of treatments on root, canopy and total biomass dry weight.

Treatments	Root weight (g)	Canopy weight (g)	Total biomass (g)
FI-	45.42*ab*	112.68*a*	158.10*a*
FI+	47.00*ab*	94.42*a*	140.75*a*
PRD-	53.84*a*	112.55*a*	166.39*a*
PRD+	42.04*b*	105.50*a*	147.55*a*

Means within the same column followed by different letter differ significantly according to Duncan's test at 5%

B. Leaf Characteristics

The observation of different leaf characteristics illustrated in the table 3 given that RWC and WSD were unaffected by treatments. The two water regimes with two salt concentrations given important values. RWC was around 80% and WSD was between 16.7 and 20.5%. Statistically results are similar between treatments. Like in

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previous studies on PRD effects on olive plants no difference was recorded between water regimes [6]. Also, it was affirmed that RWC and WSD of olive leaves submitted to drought to test alleviation products were unaffected by treatments. For the effect of salinity, previous studies showed that six months of salinization were sufficient to decrease the RWC of some cultivars, and this decrease was more evident in plants submitted to severe salt stress (225 mM) than in plants irrigated with 150 mM NaCl treatment [14]. As reported previously [18, 19], olive is able to high osmotic adjustment leading to a high water potential gradient between leaves and substrate. Then mechanism would to help the plants to preserve appropriate leaf water status. SLA, WCS and WC showed the same response. The highest values were observed in the FI+ treatment that is plants received salt water for the whole root system. However the WC was increased in this treatment. Contrary to other results [20] which affirmed that these parameters didn't affected by drought or alleviating products in olive. The determination of SUC presented that is increased by full irrigation regimes as indicated previously [20].

The SPAD measurements showed significant effect of treatments (Fig.1). In fact, FI+ treatment showed the lowest value comparatively to other treatments. As it was mentioned in previous study salt stress decreased the chlorophyll content of leaves. Also, deficit irrigation strategies exhibited lowered chlorophyll-a and chlorophyll-b content said previously [21].

Table 3: Effects of treatments on leaf sclerophylly indexes: RWC (%), SLA (mm^2/mg), LTD (g/Kg), WCS (gH2O/gDW), WSD (%), WC (%) and SUC (mg H_2O/mm^2)

Treatments	FI-	FI+	PRD-	PRD+
RWC	81.54±2.52*a*	82.12±5.99*a*	79.42±7.44*a*	82.78±4.83*a*
SLA	5.13±0.46*b*	6.25±1.84*a*	5.69±0.53*ab*	5.17±0.34*b*
LTD	496.4±1*a*	443.6±1*b*	532.6±3*a*	508.5±2*a*
WCS	1.24±0.09*b*	1.73±1.02*a*	1.11±0.09*b*	1.16±0.12*b*
WSD	18.4±2.5*a*	17.8±5.9*a*	20.5±7.4*a*	16.7±5.0*a*
WC	50.35±1.78*b*	55.63±10.6*a*	46.73±3.15*b*	49.14±2.53*b*
SUC	0.19±0.01*a*	0.22±0.09*a*	0.15±0.01*b*	0.19±0.02*ab*

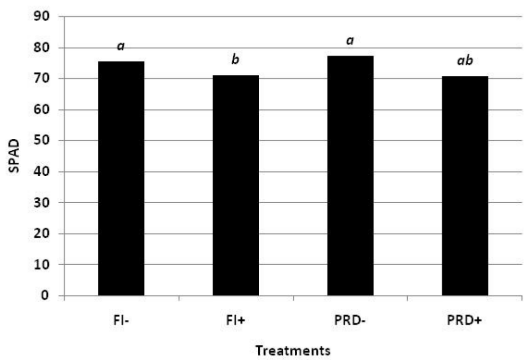

Fig.1. Effects of irrigation treatments on SPAD index.

The determination of soluble sugars and proline content of leaves presented no significant differences between treatments (Fig 2 and 3). Olive plants were unaffected neither by the salt stress nor by the water stress. Despite previous works revealed the accumulation of carbohydrates and proline in leaves for confronting stresses [22]. Also, in olive plants submitted to water stress a higher accumulation of proline and soluble sugars was noted from RWC approximately of 50% [19]. With these treatments values didn't decrease from 79% that is why there are not differences with control.

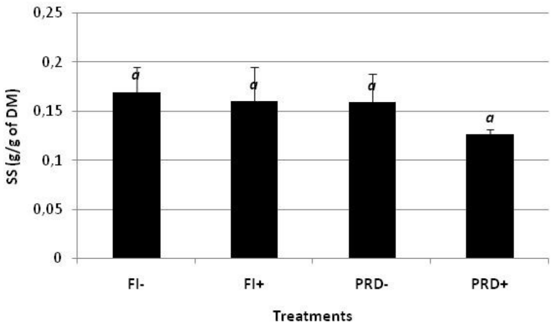

Fig.2. Effects of irrigation treatments on soluble sugars content of leaves.

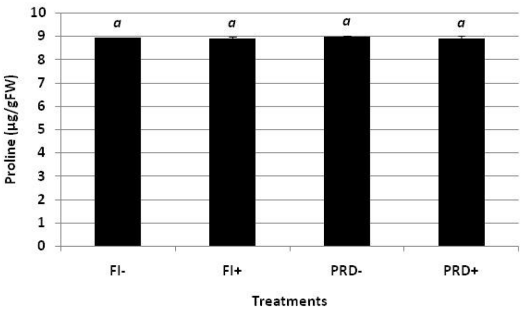

Fig.3. Effects of irrigation treatments on proline content of leaves.

C. Substrate Characteristics

At the end of the experiment, the substrate analysis given that PRD+ treatment had the same electric conductivity with control (FI-). However the FI+ treatment increased the salt concentration (Table 4). Therefore the partial root zone drying irrigation technique alleviated the salt accumulation in the soil. Results are in accordance with others [23] which affirmed that PRD treatments supplying half of irrigation amount added less salts to soil and kept moderate level of salinity in the soil. The soil pH was stable.

Table 4: Electric conductivity (ms) and pH of substrate solution for different treatments

Treatments	Electric conductivity (ms)	pH
FI-	2.54 *b*	6.78 ±0.01
FI+	4.81 *a*	7.38 ±0.02
PRD-	2.5 *b*	6.01 ±0.01
PRD+	3.17 *b*	7.07 ±0.01

IV. Conclusion

The results of this experiment showed that partial root zone drying irrigation technique could be used with low quality of water. The adoption of this technique didn't

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affect the plant growth and biochemical statute. The irrigation of half of root system switched every one month leads to preserve the soil quality and avoid salt accumulation. This technique can be an alternative to assure a sustainable agriculture using salt water.

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