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Morphological responses of *Rhus tripartitum* (Ucria) Grande under water stress

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Abstract – Water availability is one of the main problems of future climate change. The expected increase in dry days per year for many parts of the world will further aggravate the problem, particularly in the arid and semi-arid zones of the Mediterranean basin. This climate situation can affect floristic biodiversity. For this reason, there has been interest especially *Rhus tripartitum* (Ucria) Grande, endangered species and belongs to the family Anacardiaceae. It has several interests: medicinal, pharmaceutical, pastoral.The aim of this study is to show the effect of different water regimes on the morphology and growth of seedlings. The plants were grown in a nursery, inside plastic recipients containing sandy soil and were irrigated with water (control T = 100% CC), S1 = 50% CC, S2 = 25% CC and S3 = stop irrigation) under water stress. The statestiques analyzes showed a significant variation ($p<0.05$) in the effect of the applied stress. Indeed, the results showed that the water deficit resulted in a decrease in the height of the main stem, diameter at the collar, number of leaves and number of branches. In parallel with the previous modifications, an increase in spine number was reported with the increase in stress severity in S3 (stop irrigation). This proves the tolerance of this species to the lack of water.

Keywords: morphology, *Rhus tripartitum* (Ucria) Grande, tolerance, water stress.

1. Introduction

Water availability is one of the main problems of future climate change (Ciais et al. 2005; Loreto and Centritto 2008). The expected increase in dry days per year for many parts of the world will further aggravate the problem, particularly in the arid and semi-arid zones of the Mediterranean basin (Luterbacher et al. 2006). Note that the arid and semi arid areas account for a third of the Earth (Noumi 2010). Sustainable development of a natural environment is based on sound management of natural resources (soil, vegetation and water). Plant species are among the natural resources that must be protected and better use. Since water resources are limited, the search for plants more adapted to drought is a fundamental issue for agricultural production and the protection of our environment (Hireche 2006). But, water stress is one of the environmental factors affecting plant growth and development (Beniken et al. 2013). During their long history of evolution, plant species have developed different mechanisms to deal with dry conditions. The latter respond to stress by morphological, physiological and metabolic changes (Temagoult 2009). Many species stimulate significant morphological and metabolic changes by osmotic adjustment that can be achieved from the accumulation of compatible solutes (amino acids, glycine betaine, sugars) into protoplasm (Bartels and Sunkar 2005). We are interested, in particular, in the *Rhus tripartitum* (Ucria) Grande. It is a thorny shrub with different uses (leaves, fruits, bark, ...). It represents a source of income and food for the user (Zouaoui et al. 2013). In addition to its economic role, Rhus tripartitum plays an irreplaceable role in the ecological balance, this species makes it possible to fight soil erosion. It is for this reason that it has been considered in the Bou Hedma National Park for the protection and conservation of biodiversity. In this context, this work aims to study the level of resistance of *Rhus tripartitum* to the water stress by applying different treatments.

2. Materials and methods

2.1. Plant material

Experiments were conducted in a naturally illuminated nursery at the National Institute of Research on Rural Engineering, Water and Forests (Tunis, Tunisia), in a semi-arid to mild winter bioclimatic zone at N36°50', E10°14', 3 m of altitude, 475 mm annual average rainfall, 2952 hours/year sunlight and 7.2 - 34.8°C of monthly average temperature. The mature seeds of this species were harvested from spontaneous adult shrubs located in the Bou Hedma National Park. The seeding was carried out in polyethylene bags filled with a growing substrate by mixing 2/3 sand and 1/3 forest soil. The plants obtained were irrigated regularly for 4 years.

Four water regimes were applied during the experiment. A control group (T) was kept permanently at the field capacity (irrigated daily) with a base potential between -0.18 and -0.25 MPa and 3 group of plants were subjected to a water stress at different level : 50% CC (S1) ; 25% CC (S2) and severe (S3) (stop irrigation) with a base potential between -1.2 and -1.5MPa. The water stress experiment was carried out during 45 days. The experimental design was a split-plot with six replications by treatment.

2.2. Morphology measurements

The measurements were applied from February to June during 45 days vegetative growth of species. The morphological parameters are: the height of the main stem, diameter of stem to collar, number of leaves, number of spines, number of main branches and total number of branches per plant. Diameter was measured with a digital caliper rule (0-150mm, with a technical error of 0.01mm).

Growth in length (the height of the main stem) (a); total number of branches (b); Number of branches on main axis (c); number of spines (d); number of leaves (e) and diameter of stem to collar (f) of *R.tripartitum* seedlings subjected to different water treatments.

2.3. Determination of Moisture

The moisture content of the plants was determined by the oven drying process at 105 ° C(Twidwell et *al.,* 2002 ; Simpson, 1999) by calculating the moisture content: H%=(Weight α- Weight β) / Weight α*100 with α (Weight of sample "fresh plant" and et β (Weight of sample "dry plant").

2.4. Statistical analysis

The statistical analysis was done with SPSS 16.0 for Windows statistical software package (SPSS Institute Inc., Chicago, Illinois). Analysis of variance was performed for morphological measurements. Differences were accepted as statistically significant when $p < 0.05$. Post hoc comparison was performed by Student – Newman – Keuls (SNK) test.

3. Results and discussion

3.1. Morphological aspect

The observation of the *Rhus tripartitum* plants after 45 days of water treatment at different levels (T, S1, S2 and S3) revealed significant variations in the morphological appearance, particularly at the leaf level. They change from greenish color at the beginning of treatment to yellowish to reddish color with the prolongation and intensity of stress.

After 45 days of treatment, the leaves of the control plants remain green and in good hydration state. However, the stressed leaves gradually dry up and curl to finish falling (increase of the foliar abscission).

3.2. Effect of water stress on vertical growth

The histogram of figure. 1 shows the variation of the morphological parameters of the *Rhus tripartitum* seedlings under water stress.

Water stress results in reduced plant growth and production relative to genotype potential. Early water stress affects in parallel the growth of roots and aerial parts, the development of leaves and reproductive organs (Amoumen and Benhebireche 2013).

On the morphological level, our results show a depressive effect of water stress on certain growth parameters. In particular, the height of the main stem decreased with the extension and intensity of the water stress. The highest height is recorded in control T (58.25 cm) and the stressed plants S1 (64 cm) while the lowest is obtained in the stressed plants S2 (35 cm) with a reduction rate of 40% (Fig.1a). Reduced growth of the aerial parts affects both the main stem and the secondary axes. Similar results of

reduction in height growth are obtained in *Pinus caribaea* (63%) and *Pinus occarpa* (65%), in *Quercus robur* (35%) and *Fagus sylvatica* (26%) (Bezzala 2005).
Indeed, the total number of branches decreases significantly according to the water treatments applied. The highest value was obtained in control T (22 branches / plant), whereas the depressive effect was very marked in the S2 (7,16) and S3 (6,66 branches / plant) plants.
Whose, the reduction rate increases from 70% in non-irrigated plants (S3) (Fig.1b). For branching on the main axis, the most affected treatment is S2 (3 branches / plant) (Fig.1c).
Analysis of variance shows a highly significant effect of water stress on the number of spines / plants. The young plants S1 (6,66) (are the least thorny compared to the others). In parallel, an increase in the number of spines / plants is reported mainly in S3 (13,33 spines / plant). It is a form of adaptation of the species to the high degree of applied stress (Fig.1.d). On the other hand, water stress gradually reduced leaf / plant numbers. Of which, the reduction rate increases from 25% in S1 to 53% in S2 (Fig.1e). It should also be noted that the number of leaves of *R.tripartitum* seedlings decreased sharply from 190.5 to 89.16 leaves / plant respectively for the control and S2. These results are in line with those of Harouni et al. (1995), who worked on the production of leaves of argan plantlets, transplanted under different water regimes. They deduced that vegetative growth and especially leaf expansion are severely inhibited by water stress (new leaves develop slowly and senescence of the former accelerates). In addition, a significant decrease in the number of leaves is reported in durum wheat (*Triticum durum* Desf) of the carioca variety under severe stress (Amoumen and Benhebireche 2013).
The effect of drought is expressed by a gradual and rapid slowing down of growth, since the water stress reduces the turgidity, and consequently the expansive power of the leaves (Harouni et al. 1995).

3.3. Effect of water stress on radial growth

Water deficit had a negative influence on radial growth for all stress levels applied. A significant difference is observed between water treatments ($p < 0.05$). The lowest diameter was obtained in the S3 plants (0.46 cm) compared to the control (0.63 cm) (Fig. 1f). A similar result was observed in okra where the response of water stress manifested by an inhibitory effect on the vertical and radial growth of the plants provoking a reduction in height and diameter at the collar (Nana et al. 2010).

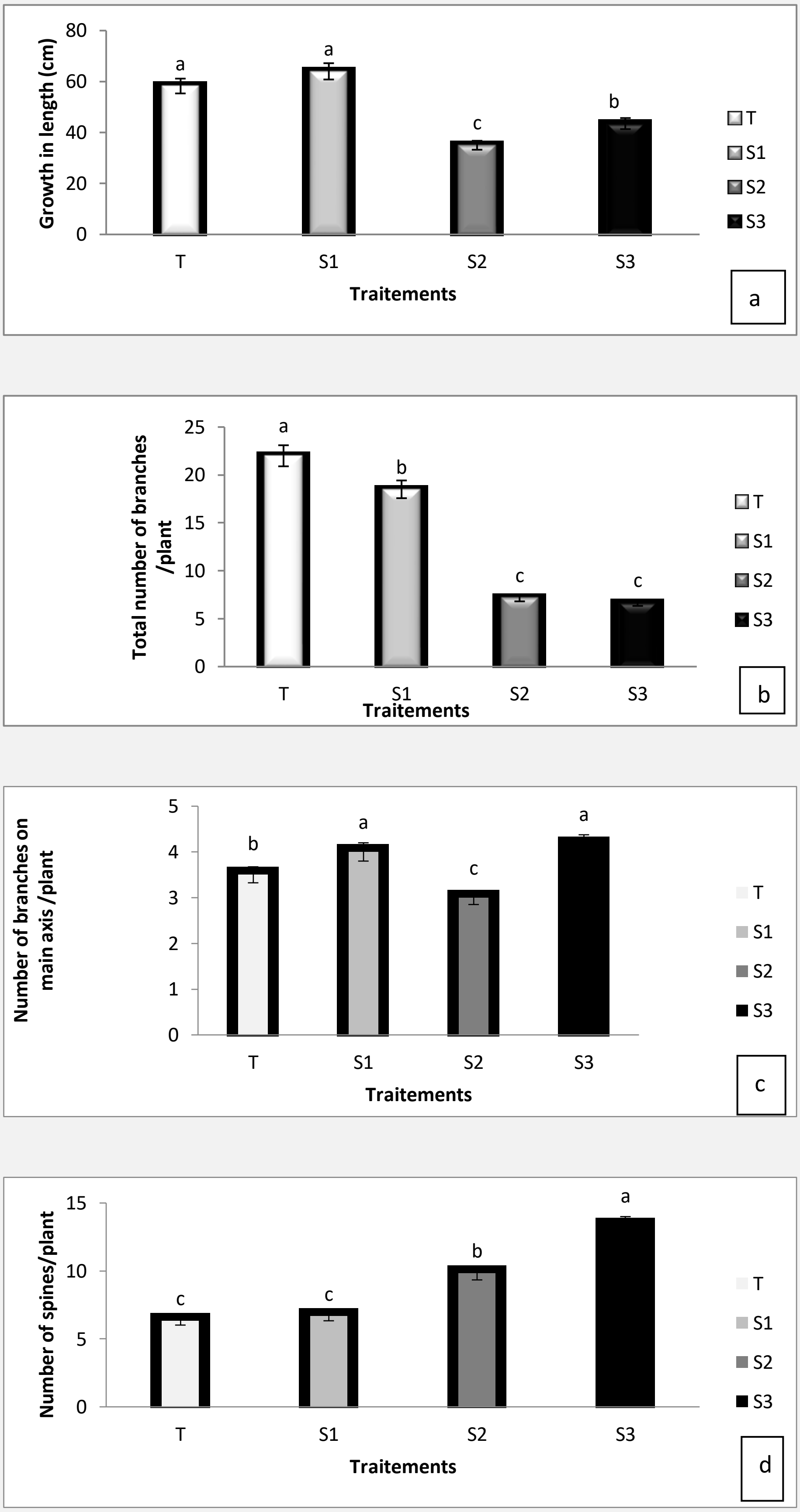
Table 1. Morphological responses of *R. tripartitum* for different water treatments

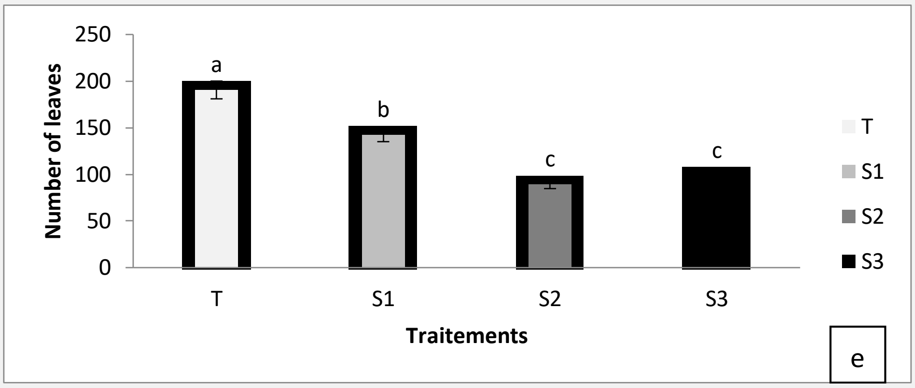
	Treatments			
Parameters	**T (100 %CC)**	**S1 (50% CC)**	**S2 (25 CC%)**	**S3 (stop irrigation)**
****Height of the main stem**	58.25 ^{a}	64^{a}	35^{c}	43.5^{b}
****Total number of branches**	22^{a}	18.5^{b}	7.16^{c}	6.6^{c}
****Number of branches on main axis**	3.5^{b}	4^{a}	3^{c}	4.16^{a}
****Number of spines**	6.33^{c}	6.66^{c}	9.83^{b}	13.33^{a}
****Number of leaves**	190.5^{a}	142.16^{b}	89.16^{c}	98.5^{c}
****Diameter of stem to collar**	0.63^{c}	0.35^{c}	0.61^{b}	0.46^{a}

The values are the average of six plants
** Values followed by different letters are significantly different according to the Student -Newman-Keuls test ($P \leq 0.0$

3.4. Effect of water stress on biomass and moisture production

Aerial biomass and root biomass are sensitive to water stress, especially in non-irrigated plants (S3). The aerial part, in particular, is highly affected. This situation is encountered at the level of fresh weight, dry weight and moisture content (H%).
The highest fresh weight of the aerial part was obtained in the control (37.96) and to a lesser extent in S1 (23.89) and S2 (21.28) g while the lowest value was obtained in S3 (10.88 g).
Similarly, for the fresh weight of the root part. A remarkable decrease in S3 (32.03 g) compared to control (68.24 g).
The dry weight results of the aerial part showed that the highest value was obtained in the control (19.43 g) compared to the stressed S3 (9.88 g). Similarly, for the dry weight of the root part. We recorded a remarkable decrease in S3 (22.99 g) compared to the control (33.02 g). The highest moisture percentage of the aerial part was obtained in the Control (49.37%) and S1 (48.04,%) compared to S3 (11.44%). Analysis of the variance shows a significant effect of stress under different water treatments. So, treatment S3 (absence of irrigation) has a depressive effect on the moisture content of the aerial part.


Growth in length (cm)
Traitements
T
S1
S2
S3
a
Total number of branches /plant
Traitements
b
Number of branches on main axis /plant
Traitements
c
Number of spines/plant
Traitements
d



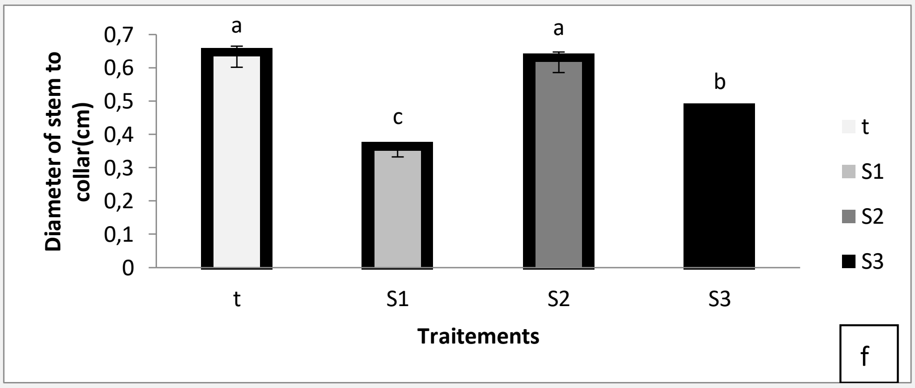


Figure 1. Growth in length (the height of the main stem) (a); total number of branches (b); Number of branches on main axis (c); number of spines (d); number of leaves (e) and diameter of stem to collar (f) of *R. tripartitum* seedlings subjected to different water treatments (T1: 100 % CC; S1: 50 % CC; S2: 25 %CC et S3: Non-irrigated) After 45 days. Values represent averages of 6 individual measurements. Safety intervals are calculated at the 5%

Concerning the percentage of the moisture of the root part, the results obtained are of the order of 42.27%; 37.82%; 35.70% and 27.45% respectively in the control, S1, S2 and S3.
Moreover, the lack of water is a decisive factor for the growth of plants, particularly in arid and semi-arid regions. It induces in the stressed plants a decrease in the relative content of water, and a significant reduction in the production of total biomass (Albouchi et al. 2000). Similarly, lack of water affects the distribution of biomass in stressed plants, linked to the complementarity of root and aerial growth functions (Bezzala 2005).
Our results showed that the greatest reduction in dry aerial biomass was observed in plants subjected to severe stress S3 (9.88 g) compared to control (19,43 g). A Similar result are obtained from *Casuarina glauca*. Water stress seems to induce a preferential allocation of biomass in the roots.
This can be explained by the improvement in the efficiency of water use, which is favorably mediated by osmotic adjustment to maintain a very important photosynthetic activity, in order to ensure a satisfactory level of yield (Albouchi et al. 2003). Similarly, comparable variations are noted on dry root biomass. The most important weight is obtained in the control, while the lowest weight is obtained in the plants subjected to the most severe stress S3. This biomass reduction can be explained by the lowering of relative water content, which would be largely due to cellular dehydration phenomenon. It could be attributed to an inhibition of the synthesis of starch, and therefore to a low gain of the aerial and root biomass. Similar results have been reported in *Pinus radiata* (Bezzala 2005), *Cedrus atlantica* and *Pinus nigra* (Aussenac and El Nour 1985), *Pinus ponderosa* (Mc Millin and Wagner 1995), *Quercus robur* and *Fagus sylvatica* (Bezzala 2005). Moreover, the development of the root part at the apex of the aerial part is considered by several authors as a criterion of resistance to drought (Harouni et al. 1995). It would make better use of available water, which becomes more accessible (Bezzala 2005). The fresh and dry biomasses of the different parts of the plant were clearly affected by the water stress. The

effects of water regime on the fresh and dry weight of leaves, stems and roots were very highly significant (Beniken et al. 2011).

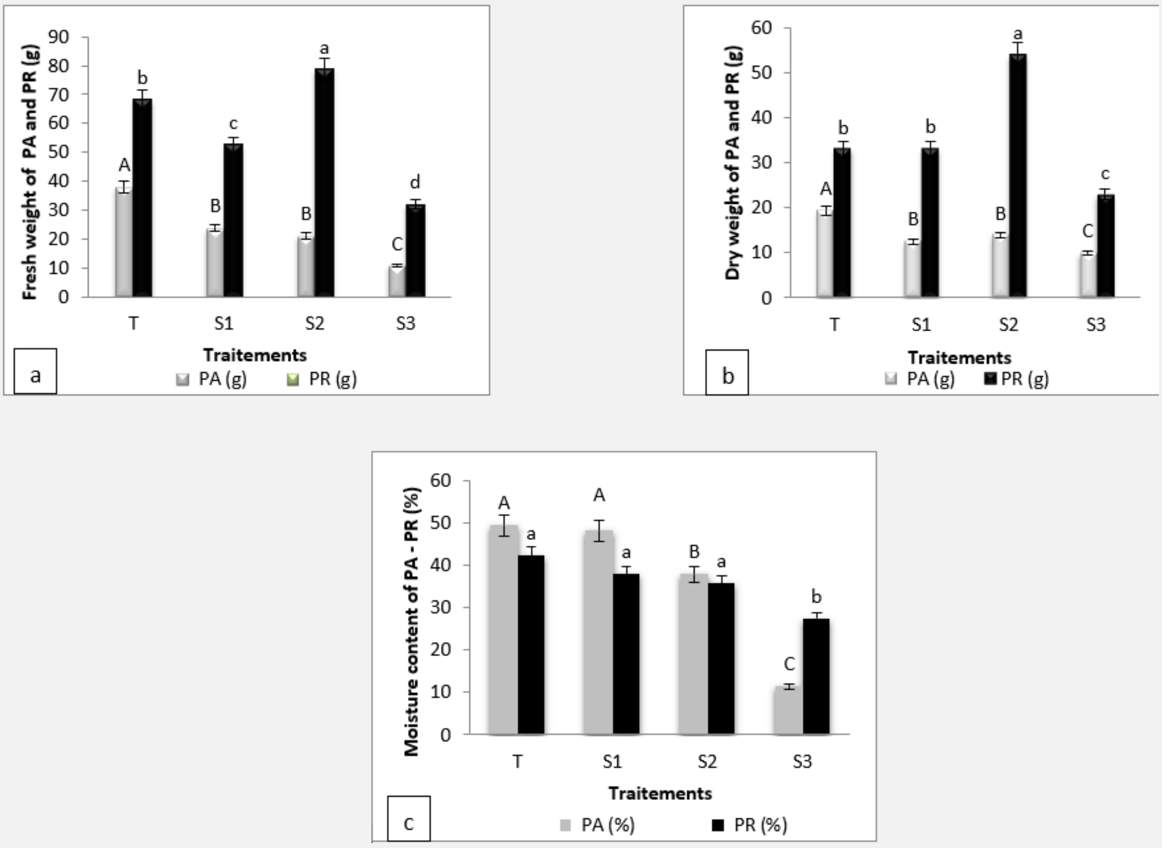


Figure.2. Variation of fresh weight (a); Dry weight (b) and Moisture content PA–PR % (c) of aerial and root part under the effect of the water stress

4. Conclusion

During a water stress, the overall resistance of the plants appears as the result of many morphological changes. The analysis of our results showed that the aerial part, in particular the stressed leaves, pass from the greenish to the reddish color according to the intensity of the stress.

They dry up gradually and wind up to finish falling which judges the reduction of fresh and dry biomass of the aerial part.

The impact of water stress was accompanied by a reduction in leaf number, total number of branching, number of branches on the main axis and diameter at the collar with a significant difference between the different treatments. When the intensity of the water stress increases, acclimatization develops by increasing the number of spines in order to adapt to the stress applied. All these morphological responses can maintain the physiological balance of *Rhus tripartitum* to drought.

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