Effects of container volume and pruning on morpho-functional characters of *Salix elaeagnos* Scop. under water stress for Mediterranean riparian ecosystems restoration

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Restoration success using nursery grown plants in riparian environments of Mediterranean areas is limited by summer high mortality rate due to severe drought stress. The aim of this work is to develop a morphological / physiological modified plant which could establish itself in low water availability areas. Four morphologic formats of *Salix elaeagnos* Scop. were tested depending on two factors: Container volume (3 and 6 L) and pruning (pruned and not pruned). Twenty four individuals of four different formats were grown in a nursery for at least three months and outplanted in a per liter filled assay pool simulating a riverbed restoration for 12 weeks. Morphi-physiological destructive measurements of 32 plants (8 per format) were done in the beginning (T0), half, 6 weeks, (T1) and ending (T2) of the assay. It was found that in T0, there were important biomass differences, being the 6 L volume and not pruned format (6NP) the highest. During T1, water availability was high and it was advantageous for 6NP which showed absolute and relative highest growth rates. However at T2, water availability declined and relative rates of growth and new roots production were higher for the 6 L volume and pruned format (6P). Three liters formats suffered harder water stress than 6 L ones. 6 L containers better performance is explained for its high volume and depth, which leads to reaching underground water level easily. Results shown as pruning, high root /canopy ratio can be beneficial when water conditions are or will be unfavorable in river restorations now and under potential new climate change conditions.

Key words: Agronomical practices, climate change, drought stress, leaf water content, relative growth rate, relative soil.

INTRODUCTION

Under Mediterranean weather and climatic conditions (Mitrakos, 1980) and due to socioeconomic development, geomorphological characteristics of water streams, from middle to last years of XX century rivers and creeks and consequently their associated vegetation where destroyed or degraded (http://www.restorerivers.eu/; http://www.ecrr.org/). River restoration refers to a large variety of ecological, physical, spatial and management measures and practices. These are aimed at restoring the natural state and functioning of the river system in support of biodiversity, control of flows, recreation, flood safety and landscape development. By restoring natural conditions, river restoration improves the resilience of streams systems and provides the framework for the sustainable multifunctional use of estuaries, rivers and streams. River restoration is an integral part of sustainable water management and is in direct support of the aims of the EU Water Framework Directive (2000), and national and
Planting riparian trees and shrubs is one of the most effective methods to recover river's ecological quality. It provides important benefits: Soil fixation, erosion reduction, high regeneration power after floods, slope stabilization, sediment retention and habitat formation enhancing biodiversity. One of the point that must be taken in consideration in river restoration is plant material, which must offer some important characteristics in order to promote a good ecological restoration, as to be autochthonous, available at nurseries and resistant to transplant (Cortina et al., 2006). *Salix* L. species are among the most common plant groups living in areas directly disturbed by floods. They are exceptionally adapted to this environment, since their mechanical properties make it possible to bear moderate freshets, and in case to be uprooted, swept or fragmented by more heavy freshets, they have full guarantee of sprouting new shoots (Karrenberg et al., 2002). The economic importance of *Salix* is currently increasing and emerging in a wide array of practical applications to restore damaged ecosystems (Kuzovkina and Quigley, 2005). Rosemary willow (*Salix elaeagnos* Scop.) is a common shrub, which is adaptable to perturbations and it shows high survivability and growth rates. Hence, it is good generalist for riparian restoration specially indicated for disturbed areas along the river banks (Francis et al., 2005). However, restoration success is not always optimal, due to low survivorship rates (Cortina et al., 2006). Plant establishment to field conditions is the most critic period, were higher mortality appears. In Mediterranean environments, the water stress associated to the first summer season is the main reason for plant dieback (Cortina et al., 2006; Chirino et al., 2008). Rivers and especially little Mediterranean streams can undergo high flow oscillations, becoming completely dry during long periods of time and hard droughts (Medici et al., 2008), which promotes the fact that water source for plants is the underground water table (Horton and Clark, 2001). Moreover, soil characteristics in medium and low stretches of certain rivers and streams show high gravelliness resulting in low water retention. Hence, phreatic level is a limiting factor in water resource availability (ACA, 2009). The potential climate change attributable to global change can increase local and general temperature (IPCC, 2007). These yearly small changes in temperature may have great influence in the atmospheric carbon balance (Valentini et al., 2000). This increase will not be the same around the world (IPCC 2007). Global change is the combination of many stresses in the same space and at the same time, which can cause synergic effects on vegetation (Liebot, 2010). Some models are generating scenarios of climate change that are showing us that some regions in the world will be affected by average duration of dry periods (4 to 6 months) and the length between periods (more 12 months), being these episodes from 3 to 8 times more frequent than at present (Sheffield and Wood, 2008). According to these models applied to aquifer recharge, basic river flow will suffer a hard reduction, and therefore also groundwater level (Medici et al., 2008; IPCC, 2007; ACA, 2009; ACCUA, 2011). With increasing aridity, the riparian vegetation of Mediterranean-type streams becomes shorter, more scattered, more restricted to the side of the active channel, and markedly different from the upland regions (Gasith and Resh, 1999). There is a restoration need in drier conditions of rivers and streams. Therefore, it is very necessary to develop new strategies to produce plants which can establish themselves in arid conditions.

In general, classical plant production in nurseries has focused in aerial development as the main commercial attribute (Cortina et al., 2006). The commonly used container volume in Mediterranean ecosystem restoration has been relatively small and shallow (max 3 L – 18 cm) (Pastor et al., 1999). Container characteristics are important determining outplanting performance (Tsakaldimi et al., 2005). It has been proved that larger and deeper container sizes increase root mass in certain riparian species including *Salix* spp. (Houle and Babeux, 1998; Dreesen et al., 2002) and other typical Mediterranean species of *Pinus* and *Quercus* genus (Chirino et al., 2008; Domínguez-Lerena et al., 2006; Lambamedi et al., 1998; Permán et al., 2006). However, there are not similar studies for riparian species under Mediterranean climate. Since it is considered that water availability is a limiting factor and water absorption potential is determined by root system size and depth (Carlson, 1986; Lloret et al., 1999), an optimum container is needed to develop such a root system.

Some agronomical treatments at nursery and / or field conditions as pruning plant aerial parts may stimulate photosynthesis because it helps keeping water balance in some species, reducing leaf total area (Erfadl and Luukkanen, 2003). In *Salix* species, individuals are perfectly able to compensate aerial biomass loss and survivorship is not affected (Hjaelten, 1999; Guillet and Bergström, 2006). High resprouting capacity of Salicaceae potentially points to pruning as a good practice to reduce transpiration (Hjaelten and Price, 1996; Karrenberg et al., 2002; Sennerby-Forsse and Christersson, 1994) and it might be an advantage under water stress conditions.

Quality description of forestry plant is based in two attribute types: Material attributes, which are directly measurable; and behavior attributes, which reflect plant response under certain environment conditions (Oliet et al., 2003; Ritchie and Landis, 2010). Behavior attributes can be considered synthetically because they can summarize in one or few parameters several morphophysiological quality characters (Burdett, 1990). For example: Root growth potential, relative growth rate, photosynthesis, water use efficiency etc. (Folk and Grossnickle, 1997).
The hypothesis held in this paper is that a bigger and deeper container will improve outplanted individuals capacity to reach underground water, and aerial part reduction will diminish transpiration and thus will improve drought resistance. To prove these hypotheses a restoration will be simulated where different treated Rosemary willow (S. elaeagnos) will be outplanted. Morphological characters which are good predictors for survivorship and growth, and are important for nursery production will be controlled, especially those related to water balance. The aims of the work were:

1. To develop a morphologic S. elaeagnos format with high water stress resistance and improved performance in restoration projects than standard formats.
2. To determinate the effect of container size and pruning on survivorship and growth under water stress conditions.

**MATERIAL AND METHODS**

**Experimental design**

**Nursery phase**

Cuttings 10 cm long of S. elaeagnos Scop. (common name: rosemary willow) were collected from several adult individuals found in Ripoll river in a St. Llorenç Savall, Catalunya (41°N, 2°E, 466 masl). They were planted in 300 cm³ plastic container or pots in February 2009. They were grown outdoor in the nursery Tres Turons SCP, in Castellar del Vallés, Catalunya, Spain (41°N, 2°E, 350 msnm). Growth substrate was standard peat moss (Vermhurg CC20, Gramoflor, Germany) and slow-release fertilizer of 3 to 4 month was added (1.5 g/dm³, Osmocote Plus® 15-8-11 N:P:K). Irrigation by sprinkler using Ripoll river water (electrical conductivity: 0.67 dS/m) was about 90 L/m² for one and a half hour, every other day. From rooted cuttings four treatments were prepared in summer 2010, counting 24 individuals each treatment with a density of 25 containers per m². The treatments were:

3NP: Container SMH 3 (Soparco-Odena, France; volume 3 L, diameter 18 cm, depth 15 cm). No pruning (standard commercial format).
6NP: Container C1600 (IEM Plastics, USA; volume 6.5 L, square cross-section 18 cm, depth 34 cm) and no pruning.

In January 2011, plants of 3P and 6P treatments were pruned to 20 cm height. Slow-release fertilizer of 8 to 9 month was added when outplanting (1.5 g/dm², Osmocote Plus® 15-8-11 N:P:K).

**Outplanting phase**

In January 2011, 96 plants were placed in a round plastic pool (diameter 3.5 m, depth 0.7 m). The growth medium was perlite (Europerl® A13, World Minerals Europe), to achieve maximum homogeneity and to facilitate root processing. Distance among plants was approximately 0.5 m giving a density of 10.39 plants per m². Treatments were mixed, simulating a real riparian restoration. However all non-pruned plants (NP) were placed in the north face to avoid shading to the pruned ones (P). Plants grew during a 12 weeks period. In the beginning of the field assay, pool was filled up to 40 cm with river water (conductivity: 0.67 dS/m), no fertilizer was added. Rainfall was registered through the essay.

**Non-destructive measurements**

**Morphologic development**

Height was measured as the vertical distance between the substrate and the highest shoot. Diameter at root collar was measured. When plants had more than one stem, equivalent diameter was calculated. Relative growth rate (RGR) of height and diameter was calculated as:

\[
RGR = \frac{[\ln(H_{t2}) - \ln(H_{t1})]}{(t_{2} - t_{1})}
\]

Where H was the height or diameter and t is the day of measure.

**Chlorophyll content**

Relative chlorophyll content was measured with a SPAD-502, (Konica Minolta®, Japan) in 5 leaves per plant (only for the third plant block).

**Soil water content**

Two capacitive probes EC-5 (Decagon Devices®, USA) were permanently installed at different depths: 30 and 0 cm (bottom). Water saturation values were weekly registered with a Procheck data logger (Decagon Devices®, USA). Water level from the bottom was also registered.

**Destructive measurements**

The 96 initial individuals were divided in three blocks of 32, each one formed by 8 individuals of each format. Block 0 was processed in the laboratory in the 0 week, so it was not planted in the assay pool and was considered as the control block at nursery outlet. Blocs 1 and 2 were planted in the pool were they grow for 6 and 12 weeks, respectively. Therefore the parameters measured in the laboratory were performed for each block in the beginning (T0), middle (T1) and end (T2) of the assay. All the dry weight measures were taken to drying the vegetal material in a air forced oven for 48 h at 65°C and using an analytic scale MS204S (Mettler Toledo®, Spain).

**Biomass**

Stems, leaves and roots were dried and weighted separately. Relation between underground and aboveground biomass was calculated (Root: Shoot ratio). Biomass growth was analyzed in terms of relative growth (biomass at T1 or T2 per biomass unit at T0). Biomass enhancement rate (BER) was calculated as the increase of the new formats respect the control format 3NP (Poorer and Naves, 2003).

**Leaf morphology**

Five leaves per plant were individually scanned and weighted, and were processed with WinFolia® software (Regents Instruments, Canada) software to obtain leaf area. Specific weight (g/m²), specific leaf area (m²/g) and total leaf area (TLA=specific leaf area × total leaves dry weight) were calculated.

**Root growth potential (RGP)**

This parameter was only measured in blocks 1 and 2, which had
been planted in the assay pool. All the roots exploring new medium (perlite) were considered new roots. These were cut and weighted. A subsample was taken from new roots, which was scanned and weighted, to be processed with WinRhizo® software (Regent Instruments, Canada). From root length values of the subsample, specific length (m/g) and RGP was calculated, considering t as the total length of new roots (RGP = specific length × new roots dry weight) (Folk and Grossnickle, 1997).

Relative water content (RWC)

Five leaves randomly collected from each plant were weighted before and after placing them in a water solution for one day at dark and 5°C (saturation weight or maximum swelling). Finally, dry weight was obtained and relative water content was calculated as:

\[
\text{RWC} = \left( \frac{\text{[fresh weight} - \text{dry weight]}}{\text{(saturation weight} - \text{dry weight})} \right) \times 100
\]

Data analysis

Statistical analyses to find differences in data between time and plant and container format, were carried out using R free software (version 2.11.1, 2010). A type II factorial ANOVA test followed of a multiple means Tukey comparison test was performed considering three factors: container size (3 and 6 L), pruning (NP and P) and time (T0, T1 and T2).

RESULTS AND DISCUSSION

Water evolution during the pool assay

On T0 pool was water filled up to 40 cm from the bottom. Thus, both sensors bottom (0 cm) and sensor 30 cm from bottom were under water, displaying water saturation values of 59.9%. During the first 6 weeks, water level went down steadily, rising 16 cm on week 6 (T1). At this time, point sensor Bottom displayed 58.2% while sensor 30 cm did 1.1%. Since week 2, when water level dropped to 23 cm, sensor 30 cm displayed 2%. However, accumulated rainfall during first 6 weeks was considerable: 117 mm, but not sufficient to compensate evapotranspiration and consequently increase water storage. Between week 7 and 12, water level keep on dropping regularly. From week 10 onwards water level was under 1 cm and sensors detected no humidity (Figure 1a). Rainfall was 34 mm between T1 and T2 period.

Water conditions have been unfavorable even though accumulated rainfall (151 mm in 12 weeks). Perlite showed low capillarity because when water level dropped under the sensors, medium displayed water saturation values near to zero (Figure 1b). Therefore, fast elongation of new roots to reach phreatic permanent flood level has been decisive on water availability for plants (Francis et al., 2005). It might be considered that original substrate (peat coming from nursery), has retained rainfall water, mitigating the effects of water stress. However, calculations considering effective rainfall collection surface, water retention capacity of peat, and transpiration measurements in Salix species on field conditions, that this effect would be negligible. Thus results obtained in this work will be analyzed considering only pool water level, which has been much higher during T1 period than T2.

Plant material at T0

The plant formats showed big differences when the assay began (T0). Average height of NP willows was 131.6 cm while P was 46.5 cm. It means that NP plants were 193% higher than P (p<0.001), but no differences in diameter were found. About total dry weight, NP plants showed 124% more biomass than P (p=0.004), while 6 L volume plants where 50% heavier than 3 L ones (p=0.002). Stem dry weight is the big part of the total biomass. Plants NP have 220% more stems (p<0.001) than P ones. About root dry weight, formats NP were 66% heavier than P. Format 6NP was the heaviest (27.1 g) significantly higher than 3P, the lowest one (10.2 g, Figure 2). Therefore it was not container volume that determined root weight at T0, but pruning (p=0.003). About Root:Shoot ratio, P plants showed higher values than NP ones and significant interaction (p=0.006, results not shown) was found between volume and pruning factors.

About leaf biomass, 6 L treatments had 133% more leaves than 3 L (p<0.001) and NP plants were 81% higher than P plants (p=0.004). Formats P presented lower leaf specific weight to NP (p=0.02). Total leaf area was 75% higher in 6 L plants (p<0.001). Finally, leaf relative water content (RWC) was very similar between treatments. The only significant difference was between 3P format, the highest (87.35%) and 3NP format, the lowest (78.19%). As had been shown previously, the four treatments have shaped different formats during nursery phase. Therefore, evolution of these formats during the assay will be analyzed considering its nature at planting time.

Height and diameter growth

All plants survived during the assay. However, to analyze growth beyond survivorship, information is given about plant quality. It is related with the new environment, genetic potential and morphological and physiological status of plants at transplant time (Mexal and Landis, 1990).

In general, plants had small weekly growth in height and diameter. About height relative growth rate (RGRh), P willows showed a significant higher RGRh than NP, especially during the first 6 weeks (n=68). In this period, highest RGRh recorded was on 3P, followed by 6P. Treatments NP showed significant lower RGRh (Table 1). The need to recover aerial biomass and to raise photosynthetic structure could explain the higher growth
rate on pruned plants together with the high water availability at substrate level respect canopy surface. There are morphologic differences between 6P and 3P which have been observed in the field that should be highlighted, although no measures have been taken. Format 3P had few shoots which tend to elongate. This observation agrees with the work by Hjaelten and Price (1996) on S. lasiolepis. However, format 6P had many shoots which tend to multiply. Therefore there is an intrinsic effect in the interaction pruning-volume that might determine resulting aerial plant morphology.

About diameter, although 6 L plants showed higher RGRd in the whole period, it was not statistically significant due to high variability. It might be explained by two factors. First, the shrub nature of rosemary willow and its high sprouting capacity causes it to produce between one and seven stems per individual. Thus, equivalent diameter measures are subjected to high dispersion rates and increase error. On the other hand, stems are not uniform and it makes hard to take accurate measures every week. Possibly bigger container determines a root morphology which allows higher diameter growth (Dominguez-Lerena et al., 2006), even though it is not statistically sustained.

Height and diameter are broadly used attributes in nurseries for quality control. However these attributes do not always have a predictive capacity on survivorship and growth in reforestation (Cortina et al., 2006). Study species characteristics, a multi-stem shrub, advise against using these parameters to define plant quality.

**Biomass growth**

NP plants showed a significant increase on every parameter in T1, but not in T2 (Figure 2, Table 4). Format 6NP presented the highest relative and absolute increases in T1. Format 3NP did not have any significant increase and it even lose 36% of leaves at T2 (Table 2). Format 3P grew significantly in weight in every parameter at T1 and it showed some important relative increases in T2 (aerial parts 123%, p<0.001). However, it was the format presenting less biomass in all sampling days and parameters (Figure 2). On the other hand format 6P showed low relative increases in T1 while in T2 increases significantly in every parameter, being the format which obtained the highest relative growth rates in total (176%, p<0.001) roots (269%, p<0.001) and stems (171%, p<0.001), even though leaves dry weight did not increase through the time (Table 2). All the formats tended to allocate biomass to underground fraction, increasing R:S ratio through the time.

Overall, in T2 willows 6L presented 69% more total biomass than 3L ones, being 6NP the highest, 3NP and 6P similar in the middle and 3P the lowest. Willows NP showed more biomass than P ones, but this difference was bigger in T1 (124%) than in T2 (62%). This tendency was very similar in every biomass parameter (Figure 2).
It means that P plants had a total relative growth rate 23% higher than NP, and 6 L plants 51% higher than 3 L ones. Thus, format 6NP was the one accumulating more biomass, but the highest relative biomass increase was in 6P.

Dry weight of different plant fractions displays information about response of every format to transplant, just like its capacity to assimilate carbon and allocate it to functional parts (Chapin, 1991). During first 6 weeks every format gains biomass in all fractions, but specially 6NP. In this period water soil availability was relatively high and therefore having higher biomass at point zero may be advantageous when initial conditions are favorable (Cortina et al., 2006). However, when checking relative growth rates through 12 weeks, tendency changes.

Format 6P reaches the most important biomass increases in most of the parameters. Thus, pruning may reduce water stress effect decreasing transpiring surface (Savé et al., 1993).

### Biomass enhancement rate (BER)

Biomass enhancement rate was used to compare the weight increase of the three format tested against standard, 3NP format.

A substantial increase in biomass was observed in format 6NP respect the control one, 3NP. Already at T0 it had produced significantly more leaves, and it showed highly positive BER values in all parameters at T1 and T2, reaching a 106% higher increase in total dry weight at T2 (Figure 4).

Format 6P showed negative stem BER values in T0. However it tended increase in BER, reaching values around zero on roots and stems, or even significantly positive leaf BER values (53%, p=0.02). Therefore, format 6P does not overcome 3NP in biomass, but it gains more biomass during three months. If tendency would carry on, 6P but have positive BER values in few weeks after the end of the assay. Therefore 6NP clearly improves biomass growth from the standard format, but 6P shows the best tendency and it must be considered too.

### Leaf morphology and physiology

Chlorophyll leaf content (SPAD) weekly measured did not change in any treatment through time. It stood around 32 in all formats except 3P, which was significantly lower to the rest (p<0.001) with a value of 27.

About total leaf area, it has been observed that volume determines a higher leaf area for 6 L plants (p<0.001). Tendency through the time is to keep similar values in 6 L but 3 L plants even decreased significantly in T2 (Table 4). Leaf specific weight of all treatments tends to rise through the time, but in different ways. In T1 all specific weight values rise significantly except for 3NP format. Volume factor is significant (p<0.001) being 6 L treatments the highest leaf specific weights (141 g/m²). On the other hand at T2 a significant interaction among factors appears (p=0.041). Formats 3L rise, and finally become the ones with the highest specific weight (185 g/m², p<0.001, Table 4). Moreover, RWC decreases in every format reaching values around 66%, without group
Figure 3. Root growth potential (RGP) in root total length (m) for each format in Times 1 and 2. (mean ± standard deviation, n=8). Different letters show significant differences between times and formats.

Figure 4. Biomass enhancement rate (BER) from format 6NP and 6P respect 3NP. (n=8; p<0.001 *** p<0.01 ** p<0.05 *). Format 3P has been omitted because all BER values were negative.

Table 3. Dry weight of new roots related to root initial dry weight.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3NP</td>
<td>0.08</td>
<td>0.24</td>
</tr>
<tr>
<td>3P</td>
<td>0.04</td>
<td>0.21</td>
</tr>
<tr>
<td>6NP</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>6P</td>
<td>0.06</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Remarkable values for each time in bold.

There is another consideration about container differences, which has been observed but not measured. Format 3NP at T0 shows very compressed roots in the container, so new roots growth will be almost entirely in the new medium. Conversely, 6L formats (and especially 6P) can still produce new roots in the original medium after transplant, so that counted roots to calculate RGP are only those standing out of the original substrate. This phenomenon may have produced an underestimation. Exploring new medium guarantees to reach the phreatic level quickly, and it provides sufficient water availability (Francis et al., 2005) at least during the first weeks. It was observed that at T2 all treatments have produced long roots to the pool bottom, so even though it was no directly measured, most likely all plants reached the bottom with at least one root. This observation agrees with the work by Francis et al. (2005), where high root

Root growth potential (RGP)

Root growth potential gives information of the capacity to outcome transplant impact and to explore the new medium (Oliet et al., 2003). In the current study few differences are found among formats except in 3P. Format 3NP showed the highest total length of new roots in T1 (527 m) but only significantly different than 3P. In T2, the highest RGP is for 6NP format (1583 m), but again only significantly different than 3P, but not from 3NP and 6P (Figure 3). Since root specific length values were not significantly different between times and formats, new roots dry weight show a very similar tendency than RGP. However specific length decreases significantly between times for P formats (p=0.001 for 3P and p=0.015 for 6P, Table 4).

The intrinsic variability of the attribute should be considered (Sutton, 1990). RGP depends largely of plant reserves at transplant time, and most of these are found in the roots (Dickmann and Pregitzer, 1992; Kozlowski, 1992). Hence, normalizing RGP to root dry weight at T0 might be indicative of the capacity to produce new roots from the existing (Noland et al., 1996). Considering this index, in T2 format 6P is higher than all the others T2 which stay with similar values (Table 3). However these values only point a tendency and they are not sustained by any statistic test.

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shock and water shortage conditions going worse force plants to restrict transpiration and finally stop growth. However response is different depending on the format, and the intrinsic properties that arise from the combination volume-pruning, as it is shown on the significant interactions detected in T2 in each water status parameter (leaves dry weight, p=0.009; RWC, p=0.022; specific leaf weight, p=0.041). Hence, plants which have more substrate (6 L) were less affected by drought stress as suggested by lower specific weights and higher relative growth rates. Conversely, in 3L formats, shock is longer and no recuperation signs appear.

differences, which indicates an important stress level (Bradford and Hsiao, 1982). These data point out that all formats are under water stress. There is a double response to this stress: In one hand reduction of leaf area due to leaf loss, and on the other hand hardening of remaining ones. Therefore it is possible that transplanting
elaboration rates are described in S. elaeagnos in response to a decreasing water level in similar experimental condition to the current study. Parameter RGP correlates with survivorship and growth (McKay, 1999). However, sufficient water availability could have mitigated this possible relation (Simpson and Ritchie, 1997) during first weeks. Overall, from RGP data it is shown that 3P has a poor response and 6P is capable to produce more roots in relation to the initial root volume than any other treatment. Plants tend to allocate biomass to roots, or at least root growth is higher than aerial in all formats but 3P. This tendency is more pronounced during last 6 weeks, when more water deficit is given. This observation agrees with other studies which demonstrate that R:S ratio increases in drought situations (Timmer and Miller, 1991; Villar-Salvador et al., 2004; Ovaska et al., 1993). However this response can be explained by carbohydrate accumulation to roots as a reservoir tissue (Von Fircks and Senerby-Forsse, 1998) as a water stress consequence. Hence, water availability is probably neither dependant of root volume or R:S ratio, but deep rooting capacity (Padilla and Pugnaire, 2007). Results demonstrate that a bigger container is beneficial, because it allows higher growth and better drought resistance at nursery and in the first steps after transplant. The main attribute to explain better performance of 6 L containers is probably depth. Several studies in forestry confirm this hypothesis (Padilla and Pugnaire, 2007; Permán et al., 2006; Chirino et al., 2008). However, other factors may be also important, such as a less dense and deformed root system in 6 L, which could help overcoming transplant shock (Dominguez-Lerena et al., 2006). Pruning is a practice that forces to mobilize root reservoirs to sprout (Von Fircks and Senerby-Forsse 1998; Carpenter et al., 2008). Therefore it is very important to have enough root volume as it is demonstrated in the current study by 6P better performance in front of 3P. Pruning advantage appears when water availability decreases. It seems that plants with reduced aerial biomass have better resistance and is capable to keep on growing (South and Blake, 1994; Carpenter et al., 2008; Savé et al., 1993). Therefore, it is possible that in more extreme conditions, pruned plants would show better survivorship rates. Formats 6 L perform better in the experiment. Much more considerations about these formats suitability should be done, such as weed competency, herbivory, flood resistance or economic feasibility. Results do not demonstrate physiological advantage of 6P on 6NP, but, pruning can permit high plant density at nursery, which improves sources use efficiency (Cortina et al., 2006). Different pruning levels could be tested in a further study. Moreover, it would be need to run a longer assay completing a summer period, testing plant material in drier conditions. Observed tendencies could not be indicative of the long term restoration success, but they are objective indications for the early stages of landscape restoration (Cortina et al., 2006). Larger samples would be needed to offset certain attributes variability, such as RGP. These morphologic treatments should be tested in other species to contrast it as a general hypothesis for nursery plants for restoration. However, results point 6P format as the optimum one for restoration in potentially dry riparian environments, with a 3 month guarantee from nursery exit and with good survivorship expectations.

### Conclusion

According to climatic change models applied to Mediterranean region, rivers will suffer a reduction on water input and therefore groundwater level will be harder
to reach by plants. Riparian restoration of degraded river systems usually involves the planting of native pioneer species such as *S. elaegnos* in order to restore modified floodplain communities. Plant capacity to reach underlying water is determinant on survivorship and growth. Nursery practices are determinant on restoration exit, in this way, big container volume and specially depth, promote positive attributes for plants at root level used in plant restoration in wide environmental conditions. The size of aerial parts of plants can provide avoidance mechanism against environmental stresses, in spite of growth reduction.

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