Water-Use Efficiency and Growth Capacity of Two Amaryllidaceae Species under Three Different Water Regimes

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Abstract

***Habranthus tubispathus* and *Rhodophiala bifida* are two Amaryllidaceae species native to Argentina showing a potential interest for using as garden plants. Both species show a different distribution, since *H. tubispathus* is usually found in more xeric habitats than *R. bifida*. The objective of the present work was to study the growth capacity and the water use efficiency at leaf and plant level of *R. bifida* and *H. tubispathus* under different water regimes. Bulbs of both species were grown in pots under greenhouse conditions during spring and subjected to three different water regimes: field capacity, 60% of field capacity and 40% of field capacity. During the first ten days, all plants were grown under well watered conditions. Thereafter, water stress treatments were applied for a period of six weeks. Variations in plant water use efficiency (WUE_p), biomass production and gas exchange parameters, including water use efficiency at leaf level (both A/g, intrinsic water use efficiency, and A/E, instantaneous water use efficiency), were analyzed. Both species showed similar biomass production regardless the water regime. By contrast, *Rhodophiala* presented a higher WUE_p than *Habranthus* and both species showed a higher WUE_p under water stress (up to4 g dry matter l^{-1} in *Rhodophiala* and up to 2.7 g dry matter l^{-1} in *Habranthus*) than under field capacity (1.6 g dry matter l^{-1} in *Rhodophiala* and 1.0 g dry matter l^{-1} in *Habranthus*). Similar results were observed when WUE at leaf level was analyzed. The correlation between WUE_p and A/g was positive and significant when both species were considered. By contrast, this correlation was not significant for each single species, suggesting the difficulties to estimate WUE_p from gas exchange measurements.**

INTRODUCTION

Water availability is one of the most limiting factors in worldwide agriculture and ornamental plant production (Wallace, 2000), and particularly affects arid and semi-arid regions. Most of these areas are characterized by a strong seasonal variability of precipitation with severe drought periods. In these regions, the available water for ornamental purposes is scarce and private and public green areas irrigation is usually restricted during severe drought periods. Therefore, water use efficiency is one of the key parameters when selecting genotypes and/or species for arid and semi-arid areas (Condon et al., 2004).

Water use efficiency is not easy to determine properly at plant level and, in addition, it is highly time consuming. Because of it, several approaches to this parameter have been proposed. Leaf water use efficiency estimated from leaf gas exchange measurements (both instantaneous and intrinsic water use efficiency, i.e. net photosynthesis/leaf transpiration and net photosynthesis/stomatal conductance, respectively) are relatively easy and rapid to be determined. Regrettably, the relationship between leaf and plant water use efficiency is not always clear (Tomás et al., 2012).

Habranthus tubispathus (L'Hér.) Traub and *Rhodophiala bifida* (Herb.) Traub are two Amaryllidaceae species native to Argentina showing a potential interest for using as garden plants. Both species show a different distribution, since *H. tubispathus* is usually found in more xeric habitats than *R. bifida* (Zuloaga and Morrone, 1996).

The objectives of the present work were to study the growth capacity and the water use efficiency at leaf and plant level of *R. bifida* and *H. tubispathus* under three different water regimes

MATERIAL AND METHODS

The experiment was developed under greenhouse conditions at the University of the Balearic Islands (Spain). Forty bulbs of each species were planted in 1 L pots in March. A mixture of horticultural substrate and perlite (3:1) was used. In order to avoid soil evaporation, a 2 cm superficial layer of perlite was disposed in each pot. The soil water content was kept at field capacity for 8 weeks to allow root development to explore most of the soil volume in the pot, by irrigating with deionized water. Afterwards, 3 soil water treatments were applied: Field capacity, 60% of field capacity and 40% of field capacity during 6 weeks. Plants under water deficit were not irrigated until their soil water content reached the 60% and the 40% of field capacity, respectively. Soil water regime was managed by weighing each pot every two-three days (a total of 22 irrigation events were performed in all treatments) and restoring its soil water content according to the treatments imposition. Plant water consumption was then registered. Pot weight at field capacity was previously determined after irrigation and 24 h drainage. At field capacity, soil water content was 84% (w/w).

For each species, 24 uniform plants were selected to carry out the experiment. Total plant biomass (including leaves, roots and bulb) was determined on six plants per species at the initial of the experiment (B_0). Roots and bulbs were separated from the soil by using a hose pipe and a sieve in order to avoid biomass losses as much as possible. The remaining 18 plants of each species were kept under field capacity during 10 days before soil water treatments were applied. At the end of the experiment, total plant biomass was also determined (B_f) on six plants per species and treatment. Biomass production was then calculated as B_f-B_0. Water use efficiency at plant level was calculated as produced biomass/consumed water for the whole experimental period.

Net photosynthesis (A), stomatal conductance (g_s), and transpiration (E) at leaf level were measured at the end of the experiment in 6 replicates per species and treatment by using an infrared gas analyzer (Li-Cor 6400, Li-Cor Inc., Nebraska, USA). The cuvette conditions were fixed at 1500 µmoles photons $m^{-2}s^{-1}$toensure light-saturated photosynthesis and the CO_2 partial pressure was set to 400 ppm. The measurements were done at mid-morning of sunny days on healthy sunny exposed leaves. Water use efficiency at leaf level was calculated as A/E (instantaneous water use efficiency) and A/g_s (intrinsic water use efficiency).

Pearson Correlations were obtained by using SPSS statistical package (SPSS, 2006). Differences between means were assessed by Duncan Test analyses ($p<0.05$).

RESULTS AND DISCUSSION

Soil water content of field capacity treatment was kept between 80-100% during all the experiment. Water stress treatments reached 60% and 40% of soil field capacity after 1 and 2 weeks of withholding watering, respectively. Afterwards, soil water content of water stressed plants was kept between 50-60% and between 30-40%until the end of the experiment (data not shown).

Both *H. tubispathus* and *R. bifida* showed no differences on biomass production among treatments (Fig. 1). Dry biomass production of *H. tubispathus* was about 1.7 g in all treatments. In *R. bifida*, biomass production varied from 3.5 g in plants under soil field capacity and 60% of soil field capacity to 3.2 g in plants under 40% of soil field capacity, although this difference was not significant. On this regard, water supply at soil field capacity did not represent any advantage on plant growth when compared to both 60% and 40% of soil field capacity in both species, suggesting the high ability of these species to survive under water stress conditions and highlighting their potential interest as ornamental species in arid and semi-arid areas.

Both species showed a higher WUE_p under deficit irrigation than under soil field capacity (Fig. 2). In *H. tubispathus*, WUE_p was significant different among treatments, from 1.0 gL^{-1} in plants under soil field capacity to 2.0 g L^{-1} and 2.8 g L^{-1} in plants under 60% and 40% of soil field capacity, respectively. By contrast, *R. bifida* plants only showed significant differences in WUE_p between soil field capacity plants and those grown under 40% of soil field capacity (1.8 and 4.0 gL^{-1}, respectively). These values are within the normal range of water use efficiency reported for C_3 species. Similar differences in WUE_p between well watered and water stressed plants have also been reported in some species (Van den Boogaard et al., 1997) and are a consequence of the predominance of stomatal limitations over the biochemical ones under mild and moderate water stress (Lawlor and Cornic, 2002).

The correlation between WUE at plant and leaf level (intrinsic water use efficiency) was positive and significant (Pearson's correlation coefficient, r=0.53, $p<0.01$) when both species were considered (Fig. 3), although this significant correlation was not observed for each single species. Moreover, WUE_p was not correlated to instantaneous water use efficiency (A/E), suggesting the difficulties to generalize the estimation of WUE_p from gas exchange measurements. Indeed, such relationships has been reported to differ among species and environmental conditions in previous studies (Van den Boogaard et al., 1997; Flexas et al., 2010; Tomás, et al., 2012).These difficulties are probably related to the scarce variation of both instantaneous and intrinsic water use efficiency under mild and moderate water stress conditions (Flexas et al., 2004).

In conclusion, both *H. tubispathus* and *R. bifida* showed an increase of WUE_p under deficit irrigation, what highlights the interest of these species to be used for ornamental purposes in arid and semi-arid areas.

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Figures

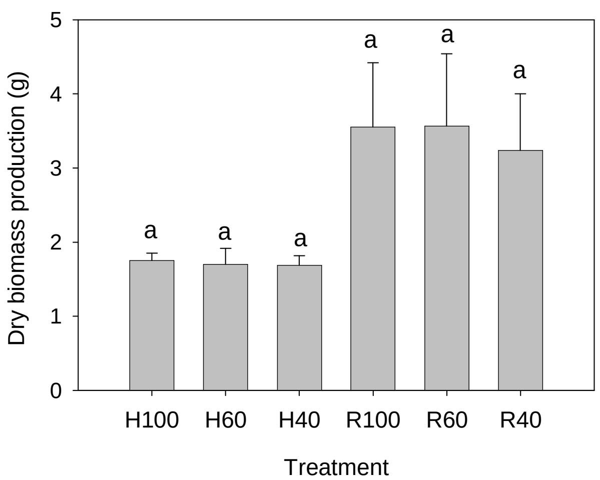

Figure 1. Total dry biomass production of *Habranthus tubispathus* (H) and *Rhodophyala bifida* (R) grown at field capacity (100), 60% of field capacity (60) and 40% of field capacity (40). The same letters between treatments of the same species represent not significant differences by Duncan's comparison test (p>0.05). Values are means of six replicates ± SE.

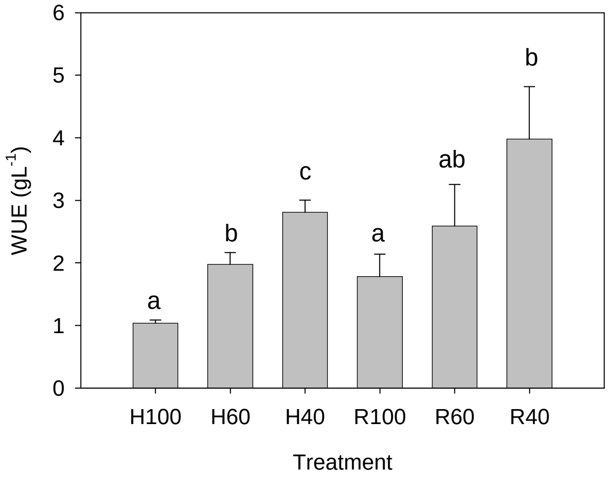

Figure 2. Water use efficiency at plant level (WUE_p) of *Habranthus tubispathus* (H) and *Rodophiala bifida* (R) grown at field capacity (100), 60% of field capacity (60) and 40% of field capacity (40). Different letters between treatments of the same species represent significant differences by Duncan's comparison test ($p<0.05$). Values are means of six replicates ± SE.

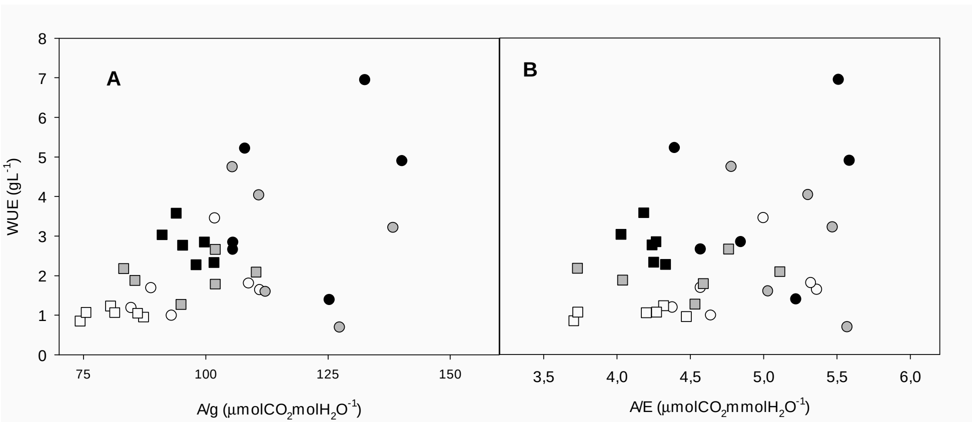

Figure 3. Relationship between water use efficiency at plant level (WUE_p) and A) intrinsic water use efficiency (A/g) and B) instantaneous water use efficiency (A/E) in *Habranthus tubispathus* (squares) and *Rhodophiala bifida* (circles) grown at three different water regimes: field capacity (white symbols), 60% of field capacity (grey symbols) and 40% of field capacity (black symbols).The correlation between WUE and A/g was moderately significant (r=0.53, $p<0.01$) (A); and between WUE and A/E was not significant (r=0.33, $p>0.05$) (B).

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