

The influence of water level on the growth and photosynthesis of *Hydrocotyle ranunculoides* L.fil.

Andreas Hussner*, Christine Meyer

Abteilung Geobotanik, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, D-40225 Düsseldorf, Germany

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Abstract

Floating Pennywort (*Hydrocotyle ranunculoides* L.fil.), a native to North America and naturalized in Central and South America, is an invasive aquatic weed in western Europe and several other regions worldwide. *H. ranunculoides* settles primarily in stagnant to slow-flowing waters (e.g. ditches, canals, rivers, lakes and ponds). The species prefers sunny and nutrient-rich sites and forms dense interwoven mats, which can quickly cover the surface of infested waters. In this study, the effect of three different water levels on growth of Floating Pennywort was investigated. Plants were cultivated on high-nutrient soils under waterlogged, semi-drained and drained conditions. Highest relative growth rates (RGR) of $0.097 \pm 0.004 \text{ g g}^{-1} \text{ dw d}^{-1}$ were reached under waterlogged conditions. This was significantly higher than RGR of plants cultivated semi-drained and drained. Floating Pennywort showed some phenological adaptations to drained soil conditions, including significant differences in the relative amounts of leaf, petiole and shoot biomass, whilst the relative amount of root biomass was not significantly influenced by the water level. Furthermore, Floating Pennywort reached under drained conditions lower relative water contents (RWC) of leaves, petioles and shoots, a significant shorter length of internodes, a significant lower extent of shoot porosity (POR), a lower chlorophyll content and an increased $\text{Chl}_a:\text{Chl}_b$ ratio. In addition, maximum gas exchange of drained cultivated plants is significantly lower, due to strongly decreased leaf conductance under reduced water availability. Overall, *H. ranunculoides* showed ability to grow under different water levels, but performed best under waterlogged conditions.

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Introduction

Spreading alien plants are a well-known phenomenon in almost all parts of the world and an important aspect of global change (Chapin et al., 2000; Vitousek et al., 1997). Particularly wetlands seem to be vulnerable to

plant invasions, and 24% of the world's most invasive plants are wetland species, even though $\leq 6\%$ of the earth's land mass is freshwater wetland (Zedler and Kercher, 2004).

Floating Pennywort, *Hydrocotyle ranunculoides* L.fil., an aquatic plant native to North America, is naturalized in Central- and South America and widespread in several parts of the world as an invasive aquatic plant (EPPO, 2006; Preston and Croft, 1997). In Europe, *H. ranunculoides* is known from Belgium (Denys et al., 2004; Verloove and Heyneman, 1999), Germany

*Corresponding author. Tel.: +49 211 8113683; fax: +49 211 8113335.

E-mail address: Andreas.Hussner@uni-duesseldorf.de (A. Hussner).

(Hussner and Lösch, 2007; Hussner and van de Weyer, 2004), Denmark, France, Italy, Portugal, Spain (EFSA, 2007; EPPO, 2006), United Kingdom (Newman and Dawson, 1999; Shaw, 2003) and the Netherlands (Baas and Duistermaat, 1998; Baas and Holverda, 1996a, b). Floating Pennywort became a nuisance in some European countries, e.g. in the Netherlands (Pot, 2002) and in the UK (Newman and Dawson, 1999), and is therefore considered to be an important aquatic weed in Europe (Gassmann et al., 2006; Sheppard et al., 2006).

H. ranunculoides grows either in stagnant to slow-flowing water, often forming floating mats, or as a helophyte in riparian vegetation. The species grows best at sunny places and nutrient-rich sites, with a biomass doubling time shorter than one week under favourable climatic conditions (Hussner and Lösch, 2007). This fast growth can lead to several problems for human use of waters, e.g. blocking navigation by forming large rhizomatous mats (Pot, 2002; Ruiz-Avila and Klemm, 1996). As another consequence, such large floating mats can influence the hydrochemistry of the underlying water layers up to anoxic conditions in extreme.

Climate change scenarios predict for Europe a further increase in temperature and length of growing season, combined with lower rainfalls in summer but higher rainfalls in winter. This will implicate a shift in water regimes to more fluctuating water levels in Central European waters, with an increase of low water level periods in dry summer seasons (IPCC, 2007; Spekat et al., 2007). In this study, the effect of such low water level periods on growth and photosynthesis of *H. ranunculoides* was investigated in comparison with waterlogged and half-drained conditions, to characterize the probable further performance of the species in Central Europe.

Material and methods

Growth conditions

To investigate the growth of *H. ranunculoides* under different water levels, single nodes with one leaf and roots (total dry weight 0.07 ± 0.02 g) were potted in 30 l pots, with 5 replicates for each water level. The pots were filled with soil containing $\text{NH}_4\text{-N}$: 3.9 ± 0.06 mg/kg soil, $\text{NO}_3\text{-N}$: 103.9 ± 1.7 mg/kg soil, P_2O_5 : 31.1 ± 0.5 mg/100 g soil and $\text{P}_2\text{O}_5\text{-P}_{\text{tot}}$: 61.2 ± 0.3 mg/100 g soil. Two weeks after planting, water levels in the different containers were adjusted to three different ones (a: water level 5 cm above soil surface = waterlogged; b: water level 17 cm below soil surface = semi-drained; and c: soil wet, but aerated = drained). Pots were placed outdoors, and, to avoid position effects, their positions were randomised four times during the experiment that lasted for 72 days.

Gas exchange measurements

Maximum net assimilation rates of CO_2 (A_{Max}) reached by *H. ranunculoides* under different water regimes were measured with a leaf chamber analyzer LCA4 in connection with a portable leaf chamber PLC4/TC, with a leaf temperature controller and a portable light unit (ADC, Hoddesdon, UK). Conditions were a photosynthetic photon flux density (PPFD) of $1500 \mu\text{mol photons m}^{-2} \text{s}^{-1}$, a vapour pressure deficit (VPD) of 1.5 ± 0.1 kPa and a temperature of 25.0 ± 0.5 °C. In addition, diurnal courses of leaf gas exchange of waterlogged *H. ranunculoides* plants were measured with a second LCA4 porometer (ADC, Hoddesdon, UK). Following Jarvis (1976), the dependency of transpiration rates (E) and leaf conductance (g) upon leaf to air vapour pressure deficit was determined by plotting E and g data from diurnal courses against VPD data.

Relative growth rate

The pots were harvested 72 days after the initiation of the experiment. Biomass was separated into leaves, petioles, shoots and roots, and dried at 105 °C to a constant weight. Relative growth rate (RGR) was calculated using the term $\text{RGR} = (\ln W_f - \ln W_i) / d^{-1}$ [W_f : final dry weight and W_i : initial dry weight (Lorenzen et al., 2001)]. Initial dry weight was determined from plants of similar size and fresh weight, compared with those used in the growth experiments.

Tissue porosity

The porosity (POR) of fresh harvested shoots and roots was determined by pycnometry. For this, 0.1–0.3 g root resp. shoots (gently blotted dry on tissue paper) were exactly weighed and thereafter placed in 25 ml volume pycnometers, filled with deionized water, and reweighed. After that, roots or shoots were removed from the pycnometer, ground with mortar and pestle, and returned quantitatively to the pycnometer (using water to rinse the mortar) and reweighed. Porosity was computed using the formula $\text{POR} = (\text{PG} - \text{PR}) / (\text{P} + \text{R} - \text{PR})$, where PG = mass of pycnometer with grounded roots or shoots and water, PR = mass of pycnometer with intact roots or shoots and water, P = mass of water-filled pycnometer, and R = mass of roots or shoots (Burdick, 1989). Porosity is presented as a relative value between 0 and 1.

SLA, relative water content

Specific leaf area (SLA) of *H. ranunculoides* plants was determined following the standardized protocol of

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