Soil pH values at sites of terrestrial carnivorous plants in south-west Europe

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Abstract: Although the majority of terrestrial carnivorous plants grow in acidic soils at a pH of 3.5-5.5, there are many dozens of carnivorous species, mostly mountainous or rocky *Pinguicula* species, which grow preferentially or strictly in neutral or slightly alkaline soils at pHs between 7-8. Knowledge of an optimum soil pH value and an amplitude of this factor may be important not only for understanding the ecology of various species and their conservation, but also for successfully growing them. I report soil pH values at microsites of 15 terrestrial carnivorous plant species or subspecies in SW Europe.

Introduction

The majority of terrestrial carnivorous plants grow in wetlands such as peat bogs, fens, wet meadows, or wet clayish sands. The soils have usually low available mineral nutrient content (N, P, K, Ca, Mg), are hypoxic or anoxic and usually acidic (Juniper *et al.* 1989; Adamec 1997; Rice 2006). Unlike mineral nutritional characteristics of these soils, which have commonly been studied and related to carnivorous plant growth in the field or greenhouse experiments and which have also been published (for the review see Adamec 1997), relatively very little is known about the relationship between soil pH and growth of terrestrial carnivorous plants. Although some limited knowledge of soil pH at habitats of carnivorous plants or in typical substrates exist among botanists and growers (e.g., Roberts & Oosting 1958; Aldenius *et al.* 1983; Studnička 1989; Correia & Freitas 2002; Garrido *et al.* 2003; Adlassnig *et al.* 2006; Rice 2006; Adamec 2009), these items of knowledge are not comprehensive and available for each species and are rather scattered. Even when new carnivorous plant species are described, the pH value of the soil in which they grow is usually not reported (e.g., Casper 2004).

pH value in the soil rooting medium is one of the most important soil factors, comparable with the available contents of macronutrients (Marschner 1995). On the one hand, soil pH tells about the availability of cation exchange of soil particles for H^+ and, on the other hand, it characterizes the ability of uptake of metallic cations from the soil by antiport uptake mechanisms (e.g., K^+/H^+). Moreover, the low soil pH known for the majority of terrestrial carnivorous plant habitats in combination with wet soils (or waterlogging) – i.e., hypoxia or anoxia and low redox potential – can cause both deficiency of some microelements (Mo) and toxicity of others (Fe^{2+}, Al^{3+}; Aldenius *et al.* 1983; Adamec 1997). In contrast, unusually high soil pH associated with high Ca^{2+} and Mg^{2+} soil contents can lead to soil phosphate precipitation and P deficiency of plants (Marschner 1995). In *Drosera rotundifolia* grown in a diluted mineral nutrient solution differing in pH, Rychnovská-Soudková (1954) showed a principal growth effect of different pH according to the mineral N forms available. Thus, though pH value of wet soils appears to be important for growth of carnivorous plants, only a few manipulative soil pH experiments have been conducted on carnivorous plants so far (Adamec *et al.* 1992; Adamec 1996). Results of these layman greenhouse growth studies, in which a natural peaty substrate was alkalized or acidified by ca. one pH unit using $NaHCO_3$ or HCl, are rather ambiguous but show that certain species may react – positively or negatively – on changes of soil pH.

The majority of terrestrial carnivorous plants grow in acidic soils, but the exact natural soil pH values or the pH amplitudes are known only for several species (e.g., Roberts & Oosting 1958; Aldenius *et al.* 1983; Studnička 1989; Adamec 1996, 2009; Correia & Freitas 2002; Garrido *et al.* 2003; Adlassnig *et al.* 2006). However, within the *Pinguicula* genus, there are several dozens of species growing in neutral or slightly alkaline limestone or dolomitic soils mostly in mountains with their habitats in wet, dripping or sprayed rocks (Rice 2006). They mainly occur in SW and S Europe and Mexico. It is known that some eurytopic, widely spread carnivorous species tolerate rather wide amplitude of soil pH values. E.g., *Drosera rotundifolia* in the Czech Republic was found to grow at pH between 2.9-6.5 (Adamec 1996) and *Pinguicula vulgaris* in N Sweden was reported to grow at pH values of 4.1-6.7 (Aldenius *et al.* 1983); the true pH amplitude can be much wider. On the other hand, an immensely rare Czech endemic lowland species *Pinguicula bohemica*, which is very similar to the former species with which it can co-occur, is stenotopic and only grows within a very narrow range of pH between 6.2-6.9 in base-rich fens (Studnička 1989). It is anticipated that European mountainous *Pinguicula* species occurring on wet limestone or dolomitic rocks (e.g., *P. grandiflora*, *P. vallisneriifolia*, *P. poldinii*) shall grow in alkaline or at least neutral soils. In line, the only pH soil measurement available for *P. crystallina* from SE Turkey shows soil pH of 7.5 (Adamec & Pásek 2000). In this study, I show soil pH values at microsites of 15 terrestrial carnivorous plant species or subspecies in SW Europe.

Methods

Dozens of sites of terrestrial carnivorous plants of the *Pinguicula* genus, *Drosera intermedia*, and *Drosophyllum lusitanicum* were visited during a trip of Czech carnivorous plant growers to SW France, Spain, Portugal, and NW Italy during 26 April – 6 May 2005. As some plant populations did not flower, exact species determination was not possible. Otherwise, the determination was also partly based on pieces of exact information on the distribution of some species (or hybrids) provided by local experts. Exact site names are omitted here for the reason of plant protection. Mixed soil samples were collected using a pair of forceps very close to the root system at each microsite and placed into plastic vials. Usually from 3-5 subsamples from different adjacent plant colonies, ca. 6-12 g of wet mass of a mixed sample was collected at each site. Water pH of the collected soil samples was measured in a laboratory by a pH electrode in soil suspensions (soil:water ca. 1:2 v/v; 5 h). Median and range of values are shown (Table 1). When needed, median was calculated through H^+ concentrations. For comparison, published soil pH data on *Drosophyllum lusitanicum* from Spain and Portugal (Adamec 2009) are also presented.

Results and Discussion

The species studied can be subdivided by their soil pH values into two distinct categories (Table 1). One category, represented by *P. lusitanica*, *Drosera intermedia*, and *Drosophyllum lusitanicum*, can be called as “acidophilous”. These species clearly prefer acidic soils (medians 4.2-5.8), their soil pH amplitudes are rather wide (usually >2 pH units; see also Adamec 1996, 2009), and the upper pH ranges reach medium values of ca. 6.5-7.0. *D. lusitanicum* is a typical example as its total pH range known from the literature is 3.6-7.0 (see Adamec 2009). At several visited sites, *D. lusitanicum* grew at dry, rocky, or stony microsites very close (commonly only 20-30 m) to wet *P. lusitanica* microsites (especially along roads) and, thus, the pH values based on the same substrate were similar. Other typical members of this category are *Drosera rotundifolia* growing at pH between 2.9-6.5 (Adamec 1996) and *P. vulgaris* between at least 4.1-6.7 (Aldenius *et al.* 1983). As these “acidophilous” species usually do not extend to pH of 7.0, they probably cannot grow in slightly alkaline soils. Soil pH values usually correlate with the content of available Ca^{2+} plus Mg^{2+} and, thus, it is accepted that the growth of these “calcifuge” species at medium or

Table 1. pH values of mixed soil samples from microsites in SW and S Europe. ?, uncertain determination of the plants. n, number of microsites. *, data taken from Adamec (2009).

Species	n	Median	Range
P. grandiflora	2	7.27	7.04-7.78
P. grandiflora subsp. *rosea*	1	8.04	--
P. grandiflora × *P. vulgaris* ?	1	5.69	--
P. grandiflora × *P. longifolia* ?	2	7.23	7.11-7.40
P. dertosensis ?	2	7.20	6.91-8.74
P. mundii	2	7.66	7.54-7.83
P. vallisneriifolia	3	7.74	7.49-7.78
P. longifolia subsp. *causensis*	2	7.35	7.08-8.27
P. longifolia subsp. *longifolia*	2	7.17	7.04-7.36
P. longifolia subsp. *reichenbachiana*	5	7.55	6.90-7.89
P. crystallina subsp. *hirtiflora*	1	6.90	--
P. poldinii	1	7.51	--
P. lusitanica	7	5.84	4.21-6.57
Drosera intermedia	3	4.21	3.79-5.05
*Drosophyllum lusitanicum**	10	4.40	3.67-5.30

higher pH values is rather inhibited by these divalent cations than by pH in itself (Rychnovská-Soudková 1953; Juniper *et al.* 1989).

On the other hand, all the other *Pinguicula* species or their hybrids (but *P. grandiflora* × *P. vulgaris* ?) investigated can be considered "neutrophilous" and/or "alkalophilous" (Table 1). The typical soil pH values are within 7.0-8.0. Theoretically, as a water suspension of milled pure limestone or dolomite should have pH >8.5, the commonly measured lower values prove that the alkaline soil bedrock in the rooting medium was neutralized and acidified by soil organic matter and root exudates. Similarly as in the case of the "acidophilous" species, the pH amplitude was wide 1-2 pH units and could be caused by different proportion of organic matter in the soils which usually occurred on vertical limestone rocks. Moreover, these soils on vertical rocks were mostly only 10-15 mm deep. The results show that "neutrophilous" *Pinguicula* species grow in soils the pH of which never decreases below 6.9. The putative hybrid *P. grandiflora* × *P. vulgaris* indicates that the exceptionally low soil pH (5.7) for "neutrophilous" *Pinguicula* species was influenced by the "acidophilous" parental species *P. vulgaris*.

The results shown in Table 1 should be taken into account when preparing suitable peaty substrates for different plant groups. While "acidophilous" species grow well in acidic, base-poor peaty substrates at pH of 4.0±0.5, the "neutrophilous" species need an addition of ca. 5-10 % (v/v) milled or ground limestone for alkalization of the acidic peat to the pH of >7.0 (Rice 2006).

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