

Short note

INFLUENCE OF WATER DEPTH ON GROWTH AND
REPRODUCTION OF *RANUNCULUS LINGUA*

Vlastik RYBKA^{1,*} and Martin DUCHOSLAV²

¹ Prague Botanical Garden, Nádvorní 134, Praha 7, CZ-171 00, Czech Republic

² Department of Botany, Faculty of Science, Palacký University, Šlechtitelů 11,
Olomouc, CZ-783 71, Czech Republic

(* Author for correspondence; e-mail: vlastik.rybka@botanicka.cz)

Received 12 January 2006; accepted 22 September 2006.

ABSTRACT. — The ability of *Ranunculus lingua* to grow at different water depths (from 0 to 80 cm) was tested. The plants from the tested depths did not differ significantly in their height and the number of shoots but differed in the number of leaves and generative organs. The lowest values were recorded at a depth of 30 cm and at a depth of 50 cm and deeper; the maximum was reached at a depth of 40 cm. The production of generative organs decreased significantly with increasing depth except for the peak at a depth of 40 cm. Significant changes in all the measured traits were recorded during the growing season. A wide plasticity of the species in depth tolerance was proved by experimental flooding. Differences in experimental and observed optimal water depth for *R. lingua* in Central Europe can be ascribed to the competition with littoral dominants. *R. lingua* usually occupies transition zones among dominants and its position in the hydrosere therefore varies with respect to the dominant competitor. Optimal water depth varied along a geographic gradient from Northern Europe (deeper water) to Central Europe (shallower water).

KEY WORDS. — Aquatic plant, competition, experimental flooding, hydrosere.

INTRODUCTION

Water depth is considered to be one of the key factors influencing the occurrence of helophytes in wetland communities (SCULTHORPE 1967, VAN DER VALK 1981). However a species performance and its position in the water gradient are highly influenced by the competition among species. Thus the position of a species along the hydrosere does not necessarily express clearly the species potential. It can be a performance of a realized niche (WISHEU & KEDDY 1992) in competition with other species.

Ranunculus lingua L. inhabits a wide range of wetland habitats in Europe from rarely encountered reed beds of fast-flowing waters through various types of reed beds of still waters and tall sedge beds to alder carrs (RYBKA 2003). It is recorded even from a water depth up to 1 m in Sweden (JOHANSSON 1993). During vegetation sampling in the Czech Republic a range of depths for *R. lingua* stands from – 80 cm to + 35 cm was recorded (RYBKA 2003). Different positions along the hydrosere in the Czech Republic in contrast to Sweden can be viewed as a result of changing environmental conditions and/or competition. Species

with a wider niche are usually relatively common, but this is not true for *R. lingua*. It declined in the Czech Republic during the 20th century (HOLUB & PROCHÁZKA 2000, RYBKA 2003). Knowledge of the species performance under competition-free conditions at various depths can help with the understanding of the species' potential and its limits.

Experiments on species performance and survival under different flooding conditions are relatively seldom. Studies are mostly focused on the influence of different water regimes on germination and establishment of various wetland species (e.g., HROUDOVÁ & ZÁKRAVSKÝ 1998, MORAVCOVÁ *et al.* 2001, CROSLÉ & BROCK 2002). The influence of a stable water level on the growth of *Butomus umbellatus* L. was studied by HROUDOVÁ (1989).

The main aims of the study were to find out (i) the pattern of growth performance and reproduction of *R. lingua* at different depths without competition, and (ii) the pattern of growth performance throughout the season in relation to different depths.

MATERIAL AND METHODS

LIFE HISTORY OF *RANUNCULUS LINGUA* AND THE ORIGIN OF PLANT MATERIALS

R. lingua is a clonal emerged helophyte with almost exclusive vegetative reproduction (JOHANSSON 1993, JOHANSSON & NILSSON 1993). In the Czech Republic, achenes are absent, or when produced, without the establishment of seedlings (RYBKA 2003). The new growth of leaves starts in the autumn and the plants are wintergreen. In the spring, shoots begin to elongate and the plants bloom from June to August. Simultaneously with the first flowers, the plants start to produce numerous lateral shoots from almost each node at the base of stalks. The first shoots produced are capable of developing a flowering branch, whereas the later ones remain at a stage with only a few leaves. At the end of August the flowering stalks die and the subsequent growth of new basal leaves from underground rhizomes begins (RYBKA 2003).

The plant materials used for the experiment originated from a population occurring in the Plané loučky wetland near the town of Olomouc (N 49°37',

E 17°14'). They occurred in the *Caricetum elatae* Koch 1926 community (HANÁKOVÁ & DUCHOSLAV 2003). Water fluctuation at the site was measured at two week intervals (one month interval during winter) in the period 1994–2002 and were as follows: mean = –17 cm; median = –7 cm; max. = 12 cm, min. = –91 cm, interquartile range = 25 cm; n = 156.

EXPERIMENTAL FLOODING

The experiment was carried out at the Department of Botany, Palacký University, Olomouc. The experimental tank was designed with different depth levels, from 0 up to 80 cm (top of pots) in steps of 10 cm. There was automatic watering once a day and a constant discharge of excess water kept the level in the tank constant. Water was not maintained by any means, only filamentous algae were removed whenever they occurred.

R. lingua plants were cultivated from 1997 onwards in a tank of 80 × 60 × 30 cm filled with soil up to 5 cm from the top and with water kept around the surface of soil. On 11 May 1999, 27 shoots 30–35 cm long and rhizomes 10 cm in length were planted in 13 × 13 × 15 cm pots filled with commercially available substrate on a base of peat (Klasmann Inc.), covered with a thin layer of gravel on the top of the substrate and randomly placed at different depths. Three plants were used for each depth. The size of the shoots was not different among the different levels of depth at the beginning of the experiment (ANOVA, $P > 0.05$). We are aware of the possibility of pseudoreplication in our experimental design.

The following traits were recorded weekly for all plants, from the beginning of July: plant height, number of leaves, number of shoots, and number of reproductive organs (buds, flowers and carpel heads). The recording was stopped by the end of August when the growth of shoots ended (7 recording dates).

STATISTICS

To ensure homogeneity of variance, the measured variables were log-transformed except for plant height. The analysis of variance on repeated measures (within-subject) designs using the general linear models approach was performed to test for differences in the measured plant traits. The experimental design included one between-subject term (depth) and one within-subject term (time). The Geisser-Greenhouse corrected probability levels on the within-subject F tests were used. NCSS 2001 (HINTZE 2001) was used for all the statistical analyses.

RESULTS

The plants growing at different depths did not differ in plant height or in the number of shoots but showed significant differences in the number of leaves and generative organs. On the other hand, significant changes in all the measured traits were recorded during the growing season (Table 1).

Plants showed a non-significant unimodal distribution of height with a maximum at 40 cm of water depth whereas those at 0 cm were the smallest. There was a non-significant slight decline of the plants' height from the end of July. Plants at different depths behaved similarly throughout the growing season.

The number of leaves differed significantly with respect to depth. The lowest values were recorded at a depth of 30 and at a depth of 50 cm and more; the maximum was reached at a depth of 40 cm. At the end of the growing season, the number of leaves pattern among the different depths levels became markedly different compared to that from the beginning and the middle

of season, illustrated by a significant time \times depth interaction term.

Although the pattern of the number of shoots was very similar to the results for leaves, only the seasonal pattern was significant.

The production of generative organs decreased significantly with increasing depth except for the depth of 40 cm. Flowering reached its peak at the end of July for all depths. There was almost no generative reproduction at a depth of 70 cm or more.

DISCUSSION

The experimental set up allowed us to assess the effect of water depth on the growth performance of *Ranunculus lingua*, without considering effects of competition. Water depth did not significantly influence the height of tested plants because the plants in deeper water, despite their lower number of internodes (expressed by the number of leaves), elongated their internodes more in order to emerge. The slight reduction of the height of plants during the season was caused by two factors. After flowering, the plants often lost their flowering branches before fruiting. Some plants at a shallow depth were partially broken by wind when they emerged.

The values obtained for the number of leaves and shoots must be considered together, because the numbers of both organs are closely correlated. The non-significant difference in the production of shoots is caused by their lower variation among different depths. The significant difference in the number of leaves is caused partly by a slower growth of lateral shoots at a higher depth. The highest number of leaves and shoots at a depth of 40 cm is due to the easier emergence at this depth, compared to deeper sites and, regarding the contrast to lower depths, due to a longer protection of lateral shoots in a less turbulent aquatic environment in tanks in comparison with windy aerial environment. The reduction in the number of leaves and shoots occurs by the end of the flowering of the main axis at the end of July, when leaves from spring growth are dying and some lateral shoots are aborted. Afterwards a new

Table 1. Summary of analysis of variance on repeated measures (within-subject) designs using the general linear models approach showing the effect of different water depths (between-subject factor) during the time course (within-subject factor) on plant height, the number of leaves, the number of shoots and the number of generative organs of *Ranunculus lingua*.

Plant trait	Term	F	P
Height	Depth	1.7	0.156
	Time	3.1	0.045
	Depth \times Time	0.5	0.928
Nr. leaves	Depth	3.6	0.012
	Time	20.6	< 0.001
	Depth \times Time	2.4	0.014
Nr. shoots	Depth	1.5	0.243
	Time	13.3	< 0.001
	Depth \times Time	1.4	0.182
Nr. generative organs	Depth	5.7	0.001
	Time	7.5	0.002
	Depth \times Time	1.3	0.273

branching from the base of plants increases the number of leaves again. This result is in accordance with observations at natural stands (RYBKA 2003).

The peak of the generative reproduction at a depth of 40 cm is outstanding, because except for this depth, there is a trend of a decrease in the number of reproductive organs according to increasing depth. The plants grown at shallower depths were more exposed to wind and some of them broke. This is also common in natural stands (RYBKA 2003). Medium depth stimulates branching, which results in more flower buds. When growing deeper than 60 cm, plants possibly cannot produce more flower buds, because the cost of flowering becomes too high and new shoots need a longer time and more resources to emerge.

A constant water level was kept in the tank with experimental plants during the whole study. However, natural stands with *R. lingua* are subjected to water level fluctuation during the growth season. Its role and limits for survival and reproduction in natural populations remain only partially known. A necessity of shallow water for germination and early ontogenetic development for many hydrophytes was proven (e.g., VAN DER VALK 1981, HROUDOVÁ *et al.* 1988, HROUDOVÁ & ZÁKRAVSKÝ 1998, MORAVCOVÁ *et al.* 2001, CROSLÉ & BROCK 2002). Some species, e.g., *Botus umbellatus*, need water fluctuation to avoid competition, but in cultivation they are able to grow at a constant water level (HROUDOVÁ 1989). *R. lingua*, however, rarely reproduces generatively and can survive adverse conditions through vegetative growth for a longer time. The influence of winter conditions on the survival of *R. lingua* was not determined. Plants were wintered in frost-free conditions for technical reasons.

Both experimental data and the observations in nature (JOHANSSON 1993, RYBKA 2003) revealed a wide depth range tolerance of *R. lingua*. In northern Sweden, at the northernmost edge of the range, population size is limited mostly by abiotic factors, one of the most important being frost (JOHANSSON 1993, JOHANSSON & NILSSON 1993). There, the highest density of ramets was at a depth of 50 cm, but *R. lingua* was observed at depths up to 1 m. In southern Sweden, however, *R. lingua* density

showed a bimodal distribution with a maximum at depths of 30 and 70 cm respectively. Its distribution was negatively correlated with *Phragmites australis* (Cav.) Steud. Plants in southern Sweden are therefore limited mostly by competition (JOHANSSON 1993). The most preferred depths in our experiment (Fig. 1) are typical of a littoral zone, which is an area with strong competitors often forming monospecific or dominant stands (HEJNÝ 1960). Although *R. lingua*, like many other wetland plants such as *Phragmites australis*, *Typha latifolia* L., and *Carex elata* All., is considered as a CS-strategist (FRANK & KLOTZ 1990), it is in fact a weaker competitor when compared with the latter. According to WISHEU & KEDDY (1992) species with a wide inclusive niche, which has been proved for *R. lingua* by experimental flooding, use only part of it as a realized niche. Among 32 populations monitored in the Czech Republic and Poland, none occurred at a depth higher than 20 cm on average during the vegetation season, but usually with a water table near the surface (RYBKA 2003). In the population of *R. lingua* where plants were taken for the experiment, a visible gradient in plant height and number of flowering shoots was observed in a different pattern than obtained from the flooding test. The tallest and the most flowering plants were near the shoreline of a pool and only sterile shoots occurred in deeper water (RYBKA 2003). Frost periods in Central Europe are a less severe threat than in northern Sweden, so plants are able to grow more landwards along the hydrosere. The main limiting factor in Central Europe is probably similar to the situation in southern Sweden and can be ascribed to the competition with littoral dominants. *R. lingua* usually occupies transition zones among dominants and its position in the hydrosere therefore varies with respect to the dominant competitor (RYBKA 2003). In southern Sweden, however, *R. lingua* grows both land- and waterwards from reed beds (JOHANSSON 1993), while in the Czech Republic it is always found growing landwards (RYBKA 2003). We can only hypothesize about reasons for such a pattern, but absence of *R. lingua* waterwards from reed beds in the Czech Republic might be caused by its competitive exclusion from expanding reed under strong nitrogen pollution. *R. lingua* also

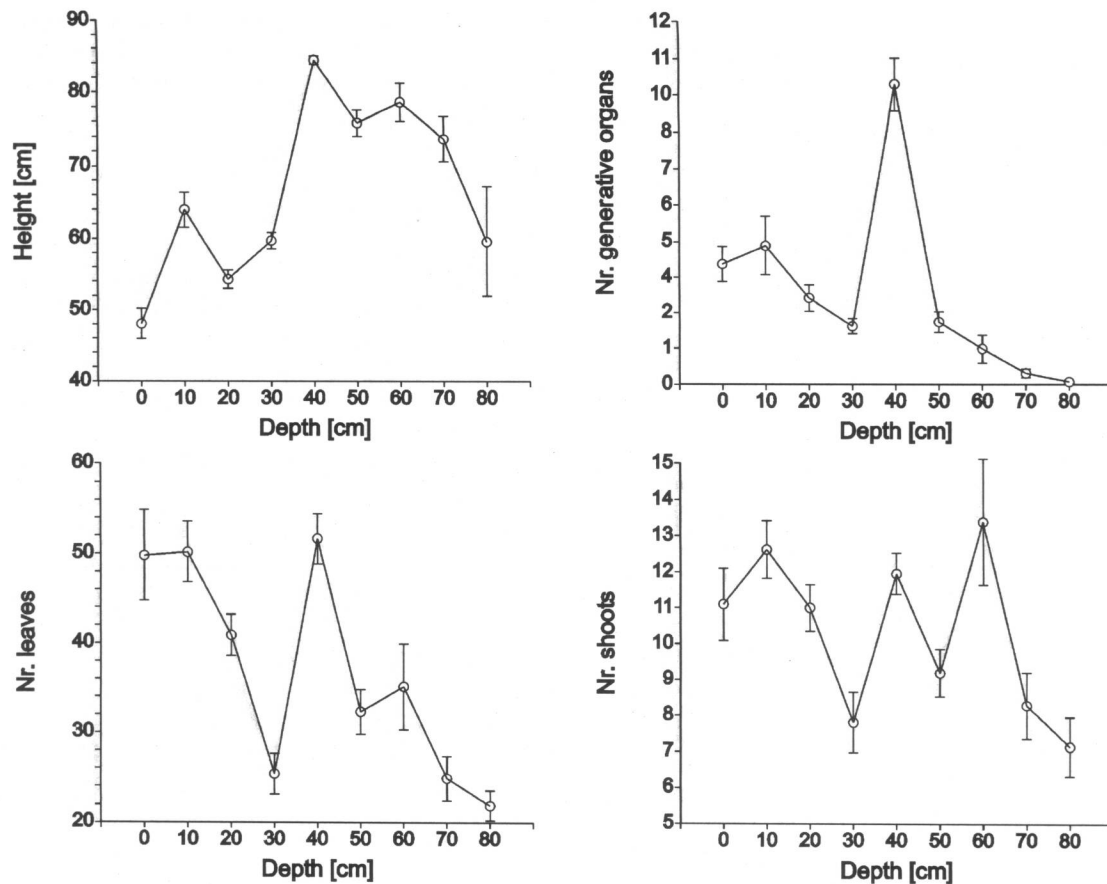


Fig. 1. Changes in selected traits (mean \pm SE) of *Ranunculus lingua* at different water depth levels.

produces wintergreen basal leaves in Central Europe, which are absent in populations from Sweden (JOHANSSON 1993). Those wintergreen leaves likely provide a selective advantage.

Taking into consideration all mentioned differences, we can conclude that the performance of *R. lingua* is a result of a trade-off among optimal depth for growth, winter survival and competition with dominants. Optimal water depth varies along a geographic gradient from Northern Europe (deeper water) to Central Europe (shallower water).

ACKNOWLEDGEMENTS

This study was partly supported by the grant no. 153100014 from the Ministry of Education of the

Czech Republic. We thank the anonymous reviewer for the valuable comments on a previous version of the manuscript.

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