Relations between K⁺ uptake and photosynthetic uptake of inorganic carbon by aquatic plants

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Abstract

The uptake of K⁺ by the leafy shoots of four submerged higher aquatic plants (Elodea canadensis, Ranunculus aquatilis, R. trichophyllus, and Callitriche hamulata) with different HCO₃⁻ affinity was measured in successive 2-h periods under the conditions of high or low photosynthetic rates (i.e. at pH 7.5 or 10). At pH 7.5 the uptake of K⁺ by species with the higher HCO₃⁻ affinity (E. canadensis, R. trichophyllus) was significantly faster than that by species with a lower HCO₃⁻ affinity (R. aquatilis, C. hamulata). In the former group of species, the K⁺ uptake rate at pH 7.5 was 1.7 - 3.5 times higher than at pH 10. At pH 10, the soft-water species, R. aquatilis, had the lowest net photosynthetic rate (Pₑ) of the three HCO₃⁻ users but, in contrast to the relative hard-water species, R. trichophyllus, showed a small K⁺ efflux (47 nmol kg⁻¹ s⁻¹). Thus, K⁺ uptake by shoots was not strictly correlated with Pₑ. A significant K⁺ efflux (73 - 86 nmol kg⁻¹ s⁻¹) occurred from all HCO₃⁻ users in darkness. The relatively low K⁺ uptake by the strict CO₂ user, C. hamulata, was quite independent of Pₑ and light or darkness. It may be suggested that uptake of K⁺ by shoots of submerged plants depends on their HCO₃⁻ affinity.

Additional key words: Callitriche hamulata, Elodea canadensis, HCO₃⁻ affinity, hard- and soft-water species, leafy shoots, R. aquatilis, R. trichophyllus.

Introduction

Submerged aquatic plants take up dissolved inorganic carbon and also substantial amounts of certain mineral nutrients by their leaves. Furthermore, many submerged

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Abbreviations: FM - fresh mass, PAR - photosynthetically active radiation, Pₑ - net photosynthetic rate; TA - total alkalinity.

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plants can use HCO$_3^-$ (besides free CO$_2$) as a carbon source for photosynthesis (Allen and Spence 1981, Maberly and Spence 1983). Of all chemical factors studied, the occurrence of higher submerged plants in standing waters usually correlates most positively with total alkalinity (TA), although the range is very wide in every species, and also with pH and Ca$^{2+}$ concentration (Hellquist 1980, Kadono 1982, Arts and Leuven 1988). In standing waters, HCO$_3^-$ users usually grow at medium to high levels of TA (1 - 5 meq dm$^{-3}$) whereas most species which use solely CO$_2$ are found in waters with low to medium TA (0.3 - 2.0 meq dm$^{-3}$; Hellquist 1980, Kadono 1982, Spence and Maberly 1985, Sand-Jensen 1987). However, naturally soft and hard waters differ not only in TA (i.e. HCO$_3^-$ concentration) but also in concentrations of Ca$^{2+}$, Mg$^{2+}$, Na$^+$, and K$^+$ (Hutchinson 1975).

In rooted submerged macrophytes, the uptake of K$^+$, Ca$^{2+}$, Mg$^{2+}$, and Cl$^-$ can be higher by leaves as compared to roots (Barko 1982, Waisel et al. 1982, Barko et al. 1991). It has been shown that the short-term uptake of K$^+$ by leaves was dependent on light and photosynthesis (for a review see Jeschke 1976). It has been found in some HCO$_3^-$ users that K$^+$ uptake occurs simultaneously with HCO$_3^-$ use (Prins et al. 1982). Thus, K$^+$ uptake might differ in HCO$_3^-$ users and non-users.

The aim of this paper was to investigate the relation between photosynthetic uptake of CO$_2$ and HCO$_3^-$ and uptake of K$^+$ by leafy shoots of four submerged species showing different HCO$_3^-$ affinity and partly different ecological requirements for TA. The main attention was paid to K$^+$ uptake at high pH which often occurs in dense stands of submerged macrophytes (Pokorny et al. 1984).

**Materials and methods**

The following species were used: *Elodea canadensis* Michx. (growing within a wide range of TA with its optimum at medium TA), *Ranunculus aquatilis* L. (growing in soft to medium-hard waters), *Ranunculus trichophyllus* Chaix (medium to hard waters), and *Callitrichche hamulata* Kütz. (soft to medium-hard waters). All species, except for *C. hamulata*, were cultivated outdoors in two plastic 1.5 m$^3$ containers in pots with mixed sand and peat. Irradiance was reduced to about one-third of full-sun. TA in the container with *E. canadensis* and *R. trichophyllus* was kept within 1.4 ± 0.1 meq dm$^{-3}$ by adding NaHCO$_3$. The pH values ranged from 8 to 9. *R. aquatilis* was grown in the other container, the TA of which was reduced to 0.30 meq dm$^{-3}$ by adding HCl, with the pH 7 - 8. Totally submerged plants of *C. hamulata* were collected from the Golden Canal at Třeboň (South Bohemia, Czech Republic; TA 1.4 meq dm$^{-3}$, pH 7.5 ± 0.2).

K$^+$ uptake was investigated in a pH-statuated glass chamber. The chamber was magnetically stirred and the temperature was kept at 22.0 ± 0.1 °C. Eighty cm$^3$ of an experimental solution was placed in the chamber and vigorously bubbled (5 cm$^3$ s$^{-1}$) with humidified CO$_2$-free air through a fine capillary to remove CO$_2$ continuously and keep dissolved O$_2$ concentration low ≤ 0.40 mM during photosynthesis. The pH of the solution was continuously monitored with a single pH electrode and a separate