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Seasonal dynamics of soluble carbohydrates in rhizomes of *Phragmites australis* and *Typha latifolia*

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ABSTRACT

Seasonal dynamics of concentrations of soluble carbohydrates (sucrose, glucose, fructose, and their sum denoted as total non-structural carbohydrates, TotCarb) in rhizomes of *Phragmites australis* (common reed) and *Typha latifolia* (cattail) were monitored in an irrigation channel and at Lake Kumaşır shores in Kahramanmaraş, Turkey, during the vegetation period 2004–2005. The soluble carbohydrate concentrations of the rhizomes of *Phragmites australis* and *Typha latifolia* were low at the beginning of the vegetation period; they reached their minima in February and March, respectively. Thereafter, soluble carbohydrate concentrations of both plants gradually increased until maximal values in August, thereafter decreasing gradually. Total soluble carbohydrate concentration in *Typha latifolia* rhizomes was higher than that of *Phragmites australis* during all months. Fructose prevailed in soluble carbohydrates throughout the season in *Phragmites*, followed by sucrose and glucose. In *Typha latifolia* the major sugar was glucose, followed by sucrose and fructose.

Introduction

Common reed, *Phragmites australis* (Cav.) Trin. ex Steud., and cattail, *Typha latifolia* L. are widespread rhizomatous wetland species in the temperate regions of the world (Clevering et al., 2001; Inoue and Tsuchia, 2009). They share many morphological traits, such as tall, unbranched shoots and a network of rhizomes, generally producing dense monospecific stands (Bellavance and Brisson, 2010). One of the functions of the rhizomes is to store carbohydrates, which support a quick shoot growth in the following spring (Koppitz, 2004; Kubin and Melzer, 1996). In addition, the stored carbohydrates in the rhizomes support the respiration and/or fermentation metabolism in the rhizomes themselves. They present the only source of carbohydrates for rhizomes during winter when shoots have died off (Brändle and Crawford, 1987). They also play important roles in the propagation and migration of the plant (Čižková-Končalova et al., 1992), provide structural support for the roots, provide anchorage for the plants during moderate disturbances (Granéli et al., 1992), and effect regeneration after heavy disturbance (Archibald, 1995). Carbohydrates in the form of sugars (sucrose, glucose and fructose), starch or fructosans (Ho, 1988) are stored in tissues of rhizomes.

Reed and cattail are important components of the littoral zone in many freshwater ecosystems and are the dominating species in various wetland habitats. Especially in Europe they are seen as serving many human and wildlife needs, improving biodiversity, stability of lake and river margins, and preservation of water quality, apart from their important ecological functions for wetlands (Brix, 1999; Steinbachová-Vojtíšková et al., 2006). On the other hand, overgrowth of emergent vegetation that dominates aquatic habitats is often viewed as a potential threat to shallow ecosystems, and therefore, control of dramatic expansion of these aquatic plants has attained attention also (Marks et al., 1994).

Production and growth dynamics studies concerning the aboveground parts of *P. australis* and *T. latifolia* stands are more common than those regarding the belowground parts, given the difficulty in sampling rhizomes of the plants, which spread deep into the soil (Engloner, 2009; Karunaratne et al., 2004). Hence, the roles carbohydrate storage and carbohydrate translocation play still rather neglected subjects characterizing the population ecology of clonal wetland plants (Chapin et al., 1990). Carbohydrate storage is particularly important in perennial plants in regions with cold winters, since the non-structural reserve carbohydrates are necessary for the tolerance of cold climatic conditions, which involves the danger

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of frost injury and prolonged winters followed by vegetation periods with low temperatures and limited carbon assimilation (Klimeš et al., 1999). Carbohydrate translocation between aboveground (AG) and belowground (BG) parts is one of the critical processes that determine the life cycle of clonal plants (Asaeda and Karunaratne, 2000; Asaeda et al., 2006). The pattern of successive upward and downward translocations is inherently common to perennial clonal plants like *Phragmites* or *Typha* (Asaeda et al., 2008). However, carbohydrates are not translocated between aboveground and belowground organs at a constant rate (Asaeda et al., 2008). Environmental conditions, in particular temperature and solar radiation, and some other factors affect translocation rates (Asaeda et al., 2006; McNaughton, 1974). Important are under such aspects winter temperatures (Dickerman and Wetzel, 1985), water depth (Grace, 1989; Pohl et al., 1999), flooding (Brändle, 1985), salinity (Rolletschek and Hartzendorf, 2000), nutritional status (Grace and Wetzel, 1981), cutting of the plants (Asaeda et al., 2006), mycorrhizal status (Dunham et al., 2003), age of the rhizomes (Asaeda et al., 2006), mechanical damages to aboveground tissues (Pohl et al., 1999), die-back of stands (Dinka and Szeglet, 1999), genotype of the plants and altitude (Asaeda et al., 2005; Clevering et al., 2001; Koppitz, 2004).

Most of the previous studies were performed on carbohydrate storage of *P. australis* and *T. latifolia* rhizomes. Few studies present original data on the seasonal dynamics of reserve carbohydrates in natural reed (Asaeda et al., 2006; Čižková et al., 1996; Granéli et al., 1992; Koppitz, 2004; Kubin and Melzer, 1996; Pohl et al., 1999; Woitke et al., 1997) and cattail stands (Linde et al., 1976; Asaeda et al., 2008). However, the information is not yet adequate to understand fully the carbohydrate metabolism and storage of these species (Asaeda and Karunaratne, 2000; Asaeda et al., 2006). Studies on seasonal dynamics are of major importance in understanding the stability and survival of *P. australis* and *T. latifolia* stands under different habitats and conditions of environmental stress (Karunaratne et al., 2004). Concerns related to the die-back of reeds and the resulting loss of biodiversity in Europe, and invasion of reeds and cattails threatening biodiversity of wetlands in many areas of the world have demanded a broader understanding of the seasonal dynamics of these plants (Asaeda et al., 2006; Brix, 1999; Shih and Finkelstein, 2008).

Studies on the seasonal dynamics of reserve carbohydrates in *Phragmites* and *Typha* were mostly performed in Central and Northern European countries such as Switzerland (Haldemann and Brändle, 1986), Sweden (Granéli et al., 1992), Germany (Pohl et al., 1999), Hungary (Dinka and Szeglet, 1999), Czech Republic (Čižková et al., 2001) and some non-European countries such as USA (Linde et al., 1976), Canada (Thompson and Shay, 1985), and Japan (Asaeda et al., 2006). There is not adequate data to evaluate seasonal changes of soluble carbohydrates in rhizomes of *Phragmites* and *Typha* in Mediterranean countries including Turkey. The place selected for this work extended the geographical range of such studies and includes new data into the relevant body of knowledge.

Materials and methods

Study area

Rhizome material of *P. australis* and *T. latifolia* was collected in an irrigation channel and in Kumaşır lake wetland, respectively, in Kahramanmaraş province, located in the East Mediterranean Region of Turkey. Average annual precipitation for this area is 561.5 mm, 99.6% of which occurs between November and May. The average annual temperature and humidity are 17.4 °C and 57.8%, respectively. The lowest average monthly temperature is given in December (5.4 °C), and the highest in August (28 °C) – see Table 1.

Table 1
Some monthly climatic data of Kahramanmaraş province for the studied period.

Months	Temperature (°C)	Rainfall (mm)	Humidity (%)
March, 2004	12.9	7.1	48.3
April, 2004	15.9	39.9	49.9
May, 2004	20.0	28.7	62.0
June, 2004	25.8	0.0	56.8
July, 2004	29.3	0.4	53.1
August, 2004	28.0	0.2	58.3
September, 2004	26.3	0.0	45.4
October, 2004	21.0	1.4	58.2
November, 2004	11.1	263.2	68.0
December, 2004	5.4	61.6	64.8
January, 2005	6.2	93.7	65.6
February, 2005	6.5	65.3	63.7
Average	17.4	46.8	57.8

The freshwater lake Kumaşır is situated in the southwest of Kahramanmaraş province (37° 34.8′ 00″ N, 36° 55.8′ 00″ E, 440 m a.s.l., 9 ha surface area). Temperature of the lake water ranges between 7.0 and 20.5 °C, and pH between 6.6 and 7.7 (Table 2). Total chloride concentration of the lake is 3.8–10.6 mg l^{-1} and total sulphate level 23.6–19.2 mg l^{-1} (Table 3; Kara and Bahadiroglu, 2001). The irrigation channel has a total area of more than 1000 m^2. Lake Kumaşır and the irrigation channel are naturally colonized by *T. latifolia* and *P. australis*, respectively. During the investigation, water depth at sampling varied 0.3 m below the soil surface in the irrigation channel and 0.4 m above ground in the lake. Depth of standing water was measured using a steel measuring tape. The topography of the channel is uniform; the substrate is sandy clay (0.5 m). More than 95% of the rhizome systems of the two plants are located within the top 0.5 m.

Method

Growing sites of *Phragmites* and *Typha* at the lake shores and channel banks were investigated monthly and plants were harvested from both sites. Rhizome material was collected 12 times from March 2004 to March 2005. Four replicate samples of rhizomes were taken each time by excavating soil monoliths of a total surface area of 15 m^2 from the rhizome zones. Rhizomes were cleaned of soil with a pressurized water spray. Thereafter washed rhizomes were dried in the oven at 85 °C to a constant weight (Karunaratne et al., 2004). Samples were stored until analysis at −20 °C (Kohl et al., 1998).

The concentration of soluble carbohydrates (sucrose, glucose, and fructose) and total soluble carbohydrates of the rhizomes (TotCarb) were determined according to Anthrone method as described by Morris (1948). 0.1 g of rhizome sample was mixed into 10 ml of distilled water and the solution was blended in a blender for 1 min after which it was filtered using a filter paper. 1 ml of this solution was mixed with 9 ml of 0.2% anthrone solution in a test tube and

Table 2
Seasonal variation of some physical parameters in Lake Kumaşır.

Date	pH	Salinity (%)	Temperature (°C)
January	6.95	0.32	7
February	7.13	0.14	7
March	7.49	0.23	12
April	7.17	0.35	19
May	7.42	0.37	24
June	7.34	0.5	17.5
July	7.26	0.41	16.5
August	7.26	0.43	20.5
September	7.53	0.15	19
October	6.79	0.38	13
November	7.69	0.32	14
December	6.58	0.32	15