ECOLOGICAL ENGINEERING 32 (2008) 156–165

available at www.sciencedirect.com

journal homepage: www.elsevier.com/locate/ecoleng

Dynamics of growth, carbon and nutrient translocation in *Zizania latifolia*

*Takashi Asaeda**, *Kian Siong*

Department of Environmental Science, Saitama University, 255 Shimo-okubo, Sakura, Saitama 338-8570, Japan

ARTICLE INFO

Article history:
Received 17 July 2007
Received in revised form
5 October 2007
Accepted 14 October 2007

Keywords:
Zizania latifolia
Carbon cycle
Emergent macrophytes
Nutrient cycle
Self-thinning

ABSTRACT

We studied the seasonal resource dynamics between organs of wild rice (*Zizania latifolia* (Griseb.) Turcz. ex Stapf.) to obtain a better understanding of its growth dynamics, carbon and nutrient translocation. The results of observation from January 2002 to February 2004 showed the shoot density markedly increased after emergence of shoots at the end of March until May (up to 800 ind/m^2). However the shoot mortality due to self-thinning reduced the total new shoots by more than 70% by the end of July. Thereafter, the shoot density was nearly constant with the aboveground biomass peaking at the end of August. In the late winter, the rhizome biomass declined by respiration loss to about 25% of its peak value. Meanwhile the decline in rhizome reserves from January to the end of April was about 20%. This small reduction compared with other perennial emergent species implies that there is a lower contribution of rhizome reserves to support new shoot formation. The initial heterotrophic growth of new shoots based on the rhizome resources lasted for a short period, then switched to autotrophic growth at the end of April or the beginning of May. Thus, in most periods of foliage development, nutrients were obtained mostly from soil through uptake by roots, not through resource allocation of the rhizome. In autumn, the standing dead shoots retained most of the nutrients and carbohydrates without translocating downwards. This suggests that in practice, the plant can remove nutrients from sediment more efficiently than other emergent plants.

1. Introduction

A wild rice species, *Zizania latifolia* (Griseb.) Turcz. ex Stapf., is one of the most common emergent species in East Asia, occurring along the littorals of freshwater marshes and streams (Okuda, 1978). With its high nutrient absorption capacity, *Z. latifolia* has great potential as a species for wastewater treatment wetlands (Miyata, 1993) or as a species to restore stream or littoral ecosystems (Okuda, 1978), where the common reed (*Phragmites australis*) has usually been used. Although its leafy and dense shoots are sometimes viewed as a potential threat to river management, its flexible structure makes it possible to create a vegetation area even under intense mechanical disturbances (Asaeda et al., 2005a). Moreover, *Z. latifolia* is one of the flood-tolerant crops and Bruins et al. (1998) has proposed a solution by converting rice to flood-tolerant crops such as *Z. latifolia* for lowland areas where flooding has often caused the crop loss.

Compared with *P. australis*, studies on the seasonal pattern of *Zizania* spp. have been limited (Lee and Stewart, 1981; Yamasaki and Tange, 1981; Weiner and Whigham, 1988; Power, 1996). Tsuchiya et al. (1993) reported the annual dynamics of *Z. latifolia* including the formation of secondary shoots, life span of leaves and annual biomass variation. Relatively low net production was also reported (Tsuchiya et al., 1997). In addition, the spring mortality of *Zizania* spp. shoots was intensively

---

* *Corresponding author*. Tel.: +81 48 858 3563; fax: +81 48 858 3563.
E-mail address: asaeda@mail.saitama-u.ac.jp (T. Asaeda).

0925-8574/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecoleng.2007.10.005

studied by Weiner and Whigham (1988), yet the discussion on the nutrient cycles and their survival strategies was very limited when compared with *P. australis* (Kuhl et al., 1997; Lippert et al., 1999; Asaeda et al., 2005b).

Like *P. australis*, *Z. latifolia* is a rhizomatous perennial plant that depends on its rhizome system for survival and expansion of colonies (Chapin et al., 1990). However, its relatively low root/shoot biomass ratio compared with *P. australis* (Tsuchiya et al., 1993) suggests that the plant has more efficient resource translocation and less dependence on rhizome resource, although further studies are necessary on carbohydrate budgets between the above- and below-ground organs. With *P. australis*, standing stocks of nonstructural carbohydrates and mineral nutrients in rhizomes decrease to one-third during the heterotrophic growing stage of foliage, then increase towards the end of the growing season by downward translocation (Dykyjova and Hradecka, 1976; Schierup, 1978; Graneli et al., 1992; Asaeda et al., 2006b).

Although *Z. latifolia* is one of the most important members in the littoral zone of streams and rivers, the seasonal resource dynamics between organs of the plant is still unclear due to limited available information. This study was aimed at elucidating the phenology by examining the dynamics of growth and carbon, nitrogen and phosphorus allocation in the above- and below-ground compartments of wild rice.

2. Study site

The study site was a uniform stand of *Z. latifolia* about 30 m by 30 m wide at the fringe of a freshwater marsh 40 km north of Tokyo (35°59′00″N, 139°40′53″E). In 2002, the marsh was muddy and inundated throughout the year, except in January–March and December. In 2003, the marsh was dry from January to May, inundated to about 10 cm depth in June and July but dry again from August to September. From October to November, the marsh was inundated again up to 30 cm depth, however, the water level started to decrease in December and dry during winter. A *P. australis* stand had been present adjacent to the *Z. latifolia* colony for more than 15 years, and during the inundation period, water depth and substrate conditions were essentially the same between the colonies. Observation was conducted once a month or once every 6 weeks from January 2002 to February 2004. Daily temperature, solar radiation and precipitation recorded at the nearby weather observatory (10 km south) indicated that meteorological conditions during the observation period were normal in this area. Located in the center of natural reserves, nutrient concentration in the water column was relatively stable during the observation period; 1.08–1.8 mg/l for total nitrogen, 0.04–0.3 mg/l for ammonium nitrogen and 0.013–0.27 mg/l for total phosphorus.

3. Methods

3.1. *Biomass sampling and chemical analysis*

At each sampling, three replicates of above- and below-ground biomass were sampled in three quadrats 50 cm by 25 cm wide, taken in a uniform part of the stands, more than 2 m away from the edge of the stands and from previously sampled spots. Belowground biomass was excavated as a 50 cm by 25 cm wide and about 40 cm thick undisturbed soil block, and all remaining roots and rhizomes at the bottom of the hole were also collected. The belowground samples were carefully washed in a 4-mm mesh sieve by pressurized tap water and all materials retained in the sieve were collected for further sorting. The aboveground parts were sorted into live and dead shoots. Brownish parts of shoots were also separated and were sorted into dead shoots. Then, the living shoots were sorted into stems, leaf sheaths and leaf blades. Shoot density, shoot height and the number of live and dead leaves were recorded for both living and dead shoots. Living belowground parts were sorted first into rhizomes, stem bases, roots and buds. Foul-smelling and non-turgid materials were considered as dead. Rhizomes were distinctively categorized into two groups, i.e. less than and more than 7 mm in diameter. The thinner rhizomes extended vertically from the stem base, spreading widely after turning horizontally, while the thicker rhizomes extended relatively horizontally. Rhizomes were classified into four categories, white fresh, yellow hard, yellow soft rhizomes and vertical rhizomes, based on their textures, colors, hardness, smells and morphologies. Mortality loss of rhizomes during the period of two consecutive observation times was estimated from the amount of dying rhizomes at the start of the period. Although this does not correspond exactly to the mortality during the period, the comparison with the increment length of dead rhizomes in the period indicated a favorable agreement ($R^2 = 0.66$). A small portion of each sorted fresh sample was freeze-dried, weighed and ground into powder with a Wiley Mill for chemical analyses. The remaining portion was dried at 85 °C for more than 72 h until constant weight was achieved.

Analyses of total nonstructural carbohydrates (TNC), water soluble carbohydrates (WSC), total carbon content (TC), total nitrogen (TN) and total phosphorus (TP) were performed in triplicate, separately for each rhizome category, roots, stem bases, leaf blades, sheaths and stems and dead rhizomes and shoots, respectively. Both TC and TN were determined with a CHN-analyzer (MT-5, Yanaco CHN Corder, Japan). The TP was determined by the Molybdenum Blue method (Murphy and Riley, 1962). The TNC, a measure of the total energy reserves, was determined using α-amylase (EC 3.2.1.1 Type VII-A, Sigma–Aldrich Co., USA), based on a procedure developed by Wong (1990). The WSC, immediately translocatable carbohydrates (Graneli et al., 1992), was extracted with hot water. In all cases, carbohydrates in the extracted solutions were measured by the phenol–sulfuric acid colorimetric procedure of Dubois et al. (1956). Standards of starch and sugars, as well as plant powder standards, were used as controls throughout the analysis. The total carbon concentration of the structural component (TSC) was estimated as the TC concentration minus the carbon concentration of the TNC, containing carbon at approximately 42%, based on analyses of pure starch spiked with 0–20% glucose using the CHN-analyzer. The standing stock of each component in individual organs was then estimated as the concentration per unit area. Then, the standing stock in each category was calculated as the product of concentration and biomass.