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Decomposition and nutrient release of *Eichhornia crassipes* (Mart.) Solms. under different trophic conditions in wetlands of eastern Himalayan foothills

D. Balasubramanian[a], K. Arunachalam[a,*], A.K. Das[b], A. Arunachalam[a,1]

[a] *Restoration Ecology Lab, Department of Forestry, North Eastern Regional Institute of Science and Technology, Nirjuli 791109, Arunachal Pradesh, India*
[b] *Department of Botany, Rajiv Gandhi University, Rono-Hills, Itanagar 791112, Arunachal Pradesh, India*

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ABSTRACT

Response of decomposition rate (k) and nutrient release pattern of leaves, petioles and roots of *Eichhornia crassipes* (water hyacinth) to different trophic conditions were studied in three wetlands (Eutrophic-Dulikoto, Mesotrophic-Pichola Nishi and Oligotrophic-Nirjuli) located in the foothills of Arunachal Pradesh in the eastern Himalayan region. Significant differences in the C, N, P, K, lignin, cellulose and hemicellulose contents and C/N and C/P ratios were recorded in different plant parts of water hyacinth and also between wetlands. The decomposition rates (k) were also significantly ($P < 0.05$) different between trophic conditions ($F = 702.16$) and plant parts ($F = 1558.09$). The decay constants revealed that the decomposition rates were faster in petioles ($0.0252–0.0455k$ day^{-1}), followed by the leaves ($0.0176–0.0396k$ day^{-1}) and the roots ($0.0083–0.0130k$ day^{-1}). Potassium mineralisation and turnover rates were higher than that of C, N and P. In general, the turnover rate was faster in the leaves and petioles of *Eichhornia crassipes*, which varied from 22 to about 57 days under different trophic conditions studied. Roots, however, decomposed slowly (77–121 days). The k values were strongly correlated with C, N, P, C/N and C/P. Overall, the higher turnover rate indicates that water hyacinth can accelerate the nutrient recycling potential in wetlands whereby the total ecosystem services could be judiciously regulated temporally. Further, the present study could serve as a template model to assess and predict the effect of nutrient loading in the wetlands upon decay of floating aquatic macrophytes.

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1. Introduction

Aquatic macrophytes are the most productive plants in the biosphere (Moss, 1993) and acts as an important source of detritus in wetlands. Nahlik and Mitsch (2006) explained that harvested macrophytes are usually deposited adjacent to the wetlands, thereby allowing nutrients to return to the wetland upon decomposition. Further, this leads to continuous accumulation organic matter content of the sediment (Wetzel, 1981) and accelerates subsequent successional processes (Payne, 1986). Reportedly, nutrient revival resulting from decomposition of organic matter is a critical link for internal nutrient cycling in wetlands; decomposition returns nutrients to the system, provides an energy base for the detrital food web, contributes to the formation of soils and the accumulation of organic matter, and greatly influences productivity (Brinson et al., 1981; Elliott et al., 1993; Reddy and D'Angelo, 1994; Mitsch and Gosselink, 2000). And, the microbes (both bacteria and fungi) become involved in the decomposition vis-à-vis mineralisation processes (Mitsch and Gosselink, 2000). Thus, organic matter turnover is a link between macrophytic production, and nutrient cycling (Bianchini et al., 2006).

In fresh water ecosystems, aquatic macrophytes are responsible for much of the organic matter production. This is true to wetlands as well (Wetzel, 1990). A substantial part of both above- and below-ground plant productions can be buried in the sediments, contributing to nutrient immobilisation within wetlands and mediating energy flow at the ecosystem level (Richardson and Marshall, 1986; Granéli and Solander, 1988; Davis, 1991). Thorén et al. (2004) found that significant proportion of temporal wetland export of nitrate and dissolved organic nitrogen originated from the release of organic and inorganic nitrogen during decomposition. Therefore, the rate of decomposition is important as it affects the release rate of nutrients, the accumulation rate of litter in sediments and the state or quality of detritus.

Decomposition is an intricate process that is regulated by chemical characteristics of detritus (Sariyildiz, 2003) and by external factors (Corstanje et al., 2006). The decomposition rates in the

* Corresponding author at: School of Environment and Natural Resources, Doon University, Dehradun 248001, Uttarakhand, India.
E-mail address: arun70@gmail.com (K. Arunachalam).
[1] Present address: Division of Natural Resource Management, Indian Council of Agricultural Research, Pusa, New Delhi-110012, India.

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aquatic environment depend on abiotic factors including nutrients (López et al., 1998), supply of electron acceptors (Cunha-Santino and Bianchini, 2002), hydroperiod (Coughlan and Mayer, 1992), temperature (Mendelssohn et al., 1999) and pH (López-Archilla et al., 2001). Other factors such as plant detritus availability, chemical composition and morphological structure (Gessner, 2000), C:N:P ratio of plant (Enríquez et al., 1993), molecular mass (Boonchan et al., 2000), origin (Jonsson et al., 2001), as well microbiota metabolic activity, biomass and diversity (Sala et al., 2001) also affect the decomposition rates.

Earlier studies on water hyacinth decomposition showed that rates vary with tissue N and fibre content, while roots decay more slowly than leaves. For instance, DeBusk and Dierberg (1984) reported fibre content in the plant material as a dominant factor in regulating the decomposition and found that the roots with high fibre content decomposed slower than the aerial tissues and Singhal et al. (1992) reported that decomposition takes place initially by physical leaching and later by microbial processes. Recently, Geurts et al. (2010) revealed that the detritus with low C/P and C/N ratios showed high net nutrient mineralisation rates, and Song et al. (2011) concluded that N addition accelerated litter decomposition through increased litter quality (high total N and low C/N ratio) and enhanced microbial activity in a *Calamagrostis angustifolia* dominated freshwater marsh of northeast China.

While much of data is available on decomposition of *Eichhornia crassipes* in laboratory and constructed wetlands, decomposition pattern of individual organs in natural wetlands experiencing different trophic conditions are relatively few. Hence, the present study aimed at understanding the decay pattern vis-a-vis nutrient mineralisation of different parts of *E. crassipes* growing under different field level trophic conditions in the wetlands located in the foothills of biodiversity-rich Indian eastern Himalaya.

2. Materials and methods

2.1. Study site

The present study was conducted in three wetlands experiencing different trophic conditions *viz*., Dulikoto (eutrophic), Pichola Nishi (mesotrophic) and Nirjuli (oligotrophic) located in Papum Pare district (27°60′N latitude, 93°31′E) of Arunachal Pradesh, north-eastern India. While, water level in the wetlands is locally affected by the urbanisation and intensive agricultural practices, intensive rainfall during monsoon results in higher water table in all the three wetlands.

2.2. Decomposition dynamics

Fresh samples of *E. crassipes* were harvested separately from the three wetland sites (Dulikoto, Pichola Nishi and Nirjuli) several days before decomposition experiment and separated into leaves, petioles and roots. Subsequently, the samples from three different wetlands were kept separated and air-dried for two weeks. Decomposition rate was studied using litter bag technique. The macrophytes were incubated in their respective wetland from which they were collected. For determination of decay rate, 10 g of each plant parts (leaves, petioles and roots) were placed into the 15 cm × 15 cm nylon bags of 1 mm mesh size. To compensate the loss of litter bags while handling, processing and transporting, extra litter packs were prepared. In total, about 400 litter bags were prepared for each site, which includes 130 extra litter bags for each of the plant parts. Each litter bags was marked with plant parts type and sites on a plastic label. The litter bags were returned to the three wetlands for incubation in the month of September 2009. Litter bags of different plant parts were submerged under water by fixing them together on a bamboo pole with the help of nails.

The litter bags were retrieved on seven sampling days *viz*., 0, 3, 7, 14, 34, 66, 91 and 115. On each sampling, six replicates of each plant parts from all three wetlands were collected. Upon retrieval, litter bags were kept in de-ionised water for 15 min and then rinsed of adhering macroinvertebrates and sediment particles. Then each plant parts were removed carefully from litter bags and oven-dried separately at 85 °C for 48 h to a constant weight and analysed.

2.3. Plant litter chemistry

Before incubation in the wetland for decomposition, the plant samples were analysed for initial carbon (C), nitrogen (N), phosphorus (P), potassium (K), cellulose, hemicellulose and lignin content. For all the chemical analyses, the oven-dried plant samples were ground in a laboratory Wiley mill and sieved through 0.5 mm mesh screen. The ground plant material was again dried at 65 °C to a constant weight and then analysed. Carbon (C) was measured by combustion method in a Muffle furnace where plant materials were incinerated at 550 °C for 4 h (Wetzel and Likens, 1991). A total of 50% of the ash-free mass was calculated as the C content (Drake et al., 2003). Nitrogen was determined by Kjeldhal auto-analyser procedure (Allen et al., 1974), after a tri-acid wet oxidation in $HNO_3 + H_2SO_4 + HClO_4$ (with selenium catalyst). Phosphorus was determined according to molybdenum blue method (Jackson, 1973) and K was determined using a flame photometer (Allen et al., 1974). Cellulose, lignin and hemicellulose were extracted through SOC Fibra Plus version 0.1 (PELICAN Equipments, Chennai, India). The powdered plant samples were first boiled in an acid-detergent (20 g of cetyl trimethylammonium bromide dissolved in 1 L of 1.0 N H_2SO_4) and filtered to remove acid-soluble proteins and other labile cell wall constituents (Goering and Van Soest, 1975; AOAC, 1990; Sadasivam and Manickam, 1996).

2.4. Calculation and statistical analysis

All the data were analysed statistically using Microsoft Excel, STATISTICA 6.0, and ORIGIN 7.0. The differences between initial chemical characteristics such as C, N, P, K, cellulose, hemicellulose and lignin concentrations of the leaves, petioles and roots were analysed through Post Hoc least significant mean deviation (LSMEANS) at the 0.05 significance level. Three-way analysis of variance (ANOVA) was used to compare the variations in dry mass, litter chemistry and nutrient release pattern along sampling time (days), among three plant parts and three wetland stations.

The litter detritus decomposition rates were analysed and modelled exponentially by first order models (Jenny et al., 1949; Olson, 1963; Petersen and Cummins, 1974; Wieder and Lang, 1982). First-order models assume that litter decomposes at a constant rate over time.

$$W_t = W_0 \ e^{-kt}$$

where 't' is the time (days), 'W_t' the litter DM remaining at time 't' relative to the start of the experiment (%), W_0 the initial litter DM at time 0 (defined as 100%), 'e' the base of natural logarithm and 'k' is the decomposition rate coefficient (per day). In first order model 'k' values were derived from linear fit to $\log_e$ transformed data with time (Olson, 1963; Benfield, 1996). Polynomial equations were used to characterize the observed decay pattern (Arunachalam et al., 2003). Time for 50% turn over ($t_{50} = 0.693/k$), 99% turn over ($t_{99} = 5/k$) and turn over rates ($1/k$) were calculated according to Singh and Shekhar (1989).