Ecological Engineering 37 (2011) 1460–1466

Contents lists available at ScienceDirect

Ecological Engineering

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

Biomass accumulations and nutrient uptake of plants cultivated on artificial floating beds in China's rural area

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ARTICLE INFO

Article history:
Received 23 December 2010
Received in revised form 21 March 2011
Accepted 27 March 2011
Available online 22 April 2011

Keywords:
Biomass accumulation
Nutrient uptake
Artificial floating bed
Nitrogen
Phosphorus

ABSTRACT

Focused on water pollution in China's rural area, taking *Oenanthe javanica* (Oj), *Gypsophila* sp. (Gy), *Rohdea japonica* (Rj), *Dracaena sanderiana* (Ds), *Gardenia jasminoides* Var. *grandiflora* (Gg), *Gardenia jasminoides* Var. *prostrata* (Gp), and *Salix babylonica* (Sb) as research objects, this paper investigated the growth characteristics and nutrient uptake of these seven species cultivated on artificial floating beds. The results indicated that after about 130 days' acclimation, these seven species had different growth characteristics. The survival rates of each species were close to 100%. Dry matter biomass ranged from 33.7 to 307.1 $g\,m^{-2}$ in the following order: Sb > Gy > Oj > Ds > Gg > Gp > Rj. There were significant linear relationships between above-water and under-water biomass ($R > 0.875$); thus, the above-water biomass could best reflect the under-water biomass. N and P concentrations and distribution in the root, stem and leaf were quite different both within and between the species. N and P concentrations in plant body ranged from 15.31 to 23.15 $g\,kg^{-1}$ in the relationship Oj > Ds > Gy > Gp > Sb > Rj > Gg, and from 1.07 to 1.89 $g\,kg^{-1}$ in the relationship Rj > Gp > Oj > Gg > Gy > Sb > Ds, respectively. N and P accumulations ranged from 0.51 to 4.48 $g\,m^{-2}$ and from 0.062 to 0.331 $g\,m^{-2}$, respectively, in which plant nutrient uptake ability could be placed as follows: Sb > Gy > Oj > Ds > Gp/Gg > Rj. The outcomes also indicated that there were positive and significant linear relationships between N and P accumulations and plant biomass ($R > 0.964$), respectively; thus, plant harvest could be a means of taking N and P out of wastewater. Seven species, especially Sb, Gy, and Oj, had an ideal effect on TN and TP removal and could be widely utilized for the treatment of wastewater in rural areas.

1. Introduction

China has been renowned as a large agricultural country ever since ancient times and most of the people live in rural areas (Zhang, 2005). Along with economic and social development, the environmental situation is becoming more and more severe in Chinese villages. In most Chinese rural regions, pollution by domestic wastewater, which is hardly treated effectively, not only has substantially negative impacts on agricultural development, but also has detrimental effects on the improvement of environment quality and raising the quality of people's life (Reddy and Behera, 2006; Wang et al., 2008). However, at present the city wastewater treatment processes, which have been widely studied, cannot be effectively applied in tackleing rural environmental pollution problems to a great extent. Firstly, these advanced treatment technologies and methods require a variety of facilities, resulting in an extremely high cost of input and operation (Liu et al., 2009; Devi et al., 2007). Secondly, these processes involve strict engineering requirements and complex labor management (Zhang and Tan, 2010; Massoud et al., 2009). Considering the low level of economic development, shortage of energy, and lack of environmental technical staff in rural areas, it is undoubtedly very important to study how to explore the rural domestic wastewater treatment technologies of high efficiency, low investment, low running costs, low maintenance of technology, and low power consumption, which are essential and sensible to tackle decentralized wastewater.

Artificial Floating Island (AFI) technology (Watling, 1975; Mallison et al., 2001; Sun et al., 2009; Hu, G. et al., 2010; Hu, M. et al., 2010; Li et al., 2010), which has been proved to be cost-effective and feasible, is a surface soilless planting technology of modern agronomic and ecological engineering measures integrated comprehensively. Recently, AFI has been widely recognized as eco-technology all over the world and often installed at many weirs, rivers, ponds and lakes (Ahn et al., 2004). In general, AFI has mainly four functions, as follows: habitat for fish and birds, water purifi-

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doi:10.1016/j.ecoleng.2011.03.010

Table 1
Inflow water quality indexes of the river (t, pH, DO, SS, COD, TN, TP, and chl-a).

Index	t (°C)	pH	DO (mg L^{-1})	SS (mg L^{-1})	COD (mg L^{-1})	TN (mg L^{-1})	TP (mg L^{-1})	chl-a (μg L^{-1})
Range	−1–36.1	6.09–7.24	6.0–6.8	10.9–17.9	24–35	1.1–2.9	0.039–0.481	4.121–14.657
Mean	29.1	6.87	6.3	14.7	28	2.1	0.154	10.243

cation, break-water to protect the littoral zone and improvement of landscape, among which the utilization of water purification is intended to remove excess nutrients (mainly N and P) effectively and permanently out of the water volume. The amount of time required to do this varies according to the volume and condition of the water, the maturity of the island plants, the extent of active biofilm, and other environmental factors (John et al., 2009; Somodia and Dukát, 2004). Until now, although numerous studies on floating plantation have been made, most of these studies have focused on herbaceous species, especially aquatic plants (McKinstry and Anderson, 2003; Iamchaturapatr et al., 2007; Zimmels et al., 2008; Hu, M. et al., 2010; Lennard and Leonard, 2006; Li et al., 2010). In contrast, terrestrial plants, including shrubs and trees, have been studied merely as objective plants that can be grown on artificial floating beds. Moreover, there is also limited information about biomass accumulation and nutrient uptake by different nutritive tissues, such as root, stem and leaf. Hence, more studies need to be carried out, where emphasis can be put on biomass accumulation and nutrient absorption by root, stem and leaf components from different floating herb, shrub and tree species.

Aimed at reducing water pollution in rural areas in the city of Honghu in China through, implementing AFI technology, seven aboriginal plant strains including aquatic and terrestrial species were selected as research objects, including herbal species: *Oenanthe javanica* (Oj), *Gypsophila* sp. (Gy), *Rohdea japonica* (Rj), *Dracaena sanderiana* (Ds); shrubs: *Gardenia jasminoides* Var. *grandiflora* (Gg), *Gardenia jasminoides* Var. *prostrata* (Gp), and trees: *Salix babylonica* (Sb). To summarize, the objectives of our study were (1) to evaluate and compare plant growth adaptability to reveal whether the terrestrial plants can acclimate and survive in aquatic condition, (2) to estimate biomass, to determine nutrient (TN and TP) distribution in the root, stem and leaf components, and to evaluate relevant nutrient uptake abilities, and (3) to evaluate water volumes purified by plant absorption.

2. Materials and methods

2.1. Study site

The study was carried out in a village called Chengfeng (29°45′N, 113°28′E) in the city of Honghu, approximately 180 km southwest of the capital of Hubei, Wuhan. The mean annual temperature is approximately 16.5 °C and the mean monthly temperature ranges from 3.5 °C in January to 33.5 °C in August. The mean annual rainy season over a 60-year period is 128 days, and relative annual precipitation is 1205 mm.

There is only one river, called Central River, located behind the village houses, which receives the wastewater of the villagers (about 150 farmers). This river was chosen as the research site. The mean width, depth and flow column of the river are 5 m, 1.5 m and 3150 m^3/h, respectively. Before the construction of artificial floating islands, river cleaning was conducted for the purpose of removing the aquatic weeds and building the field experiment conditions. The inflow water quality from the river was monitored once per month during the test (Table 1).

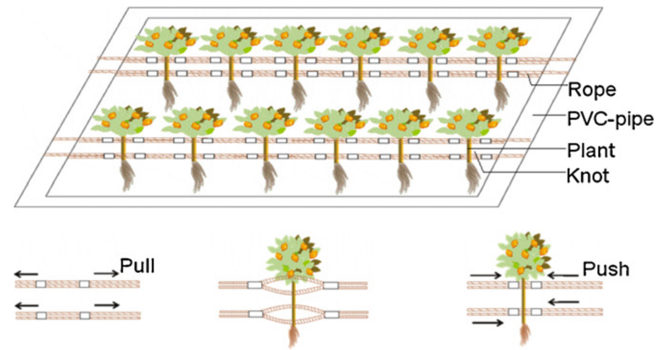

Fig. 1. Structure of artificial floating bed (2 m × 1 m) and transplanting method.

2.2. Experimental design and management

An artificial floating bed named a pipe-rope bed (Fig. 1), whose size was 2 m by 1 m, was designed uniformly. The bed backbone (or body) set around the periphery was 4 PVC-pipes (Φ40 mm). In total, 34 ropes were fixed tightly around the 4 pipes at some distance (approximately 18 × 17 cm), in order to make sure that each unit area had 33 rope knots which could be used to grow and fix plants during the experiment.

The experiment started on March 10, 2009, and ended on July 19, 2009 (130-day experiment). At the beginning of the experiment, young seedlings purchased from the local market were transplanted into the rope knots, except that species Sb was grown by the cuttings method (Li et al., 2006). Before the experiment the typical physiological conditions of each species were investigated (Table 2). Only one taxon could be cultivated into each knot on the bed, and considering the possible allelopathy effect among different species (Szczepanska, 1971; Uchida and Tazaki, 2005), only one variety of plant could be grown within each bed. All the artificial floating beds (140 rafts) were randomly connected in a line by a rope and fixed onto the water surface in the river, so that the total area of floating beds could go up to 280 m^2, and the mean coverage rate related to beds was approximately 40%. Afterwards, daily

Table 2
Initial physiological indexes (total length and fresh biomass) of the seven tested species (means ± sd, n = 6).

Species[a]	Total length (cm)	Single fresh biomass (g)		
		Root	Stem	Leaf
Oj	9.5 ± 0.2	0.67 ± 0.1	0.51 ± 0.1	
Gy	16.0 ± 0.4	7.87 ± 0.1	4.80 ± 0.2	
Ds	17.2 ± 0.1	4.48 ± 0.2	13.73 ± 0.3	
Rj	13.1 ± 0.3	2.32 ± 0.0	24.67 ± 0.7	
Gg	26.4 ± 0.8	3.27 ± 0.1	19.90 ± 0.1	4.57 ± 0.2
Gp	13.4 ± 0.4	2.20 ± 0.1	8.86 ± 0.1	2.31 ± 0.3
Sb	14.9 ± 0.0	–	10.50 ± 0.7	–

[a] As species Oj, Gy, Ds and Rj belong to cluster strain and it is difficult to distinguish stem and leaf separately, stem and leaf were incorporated together as one unit during statistics. Oj, *Oenanthe javanica*; Gy, *Gypsophila* sp.; Rj, *Rohdea japonica*; Ds, *Dracaena sanderiana*; Gg, *Gardenia jasminoides* Var. grandiflora; Gp, *Gardenia jasminoides* Var. prostrate; Sb, *Salix babylonica*. The following figures and tables have the same abbreviations for species names.