The Effects Of Phosphorus Addition On Growth Of Tropical Coastal Plantations

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Abstract: The tropical forest productivity is limited by P. Casuarina equisetifolia has been widely established along nutrient-impoverished coasts and plays a role in resisting wind and erosion. To assess how phosphorus may affect the growth of coastal shelter plantations, we conducted a P gradient experiment in a young C. equisetifolia plantation with three treatments: 100 kg P ha-1 addition (P100), 50 kg P ha-1 addition (P50), and controls (CK). We measured soil properties and plant growth. Plant growth were not affected by the P gradient. Our results indicate C. equisetifolia plantation can sequestrate a large amount of C in biomass on poor soils compared with other ecosystems. Based on the widespread of C. equisetifolia on tropical and subtropical coasts, we suggest that C. equisetifolia shelter plantation could be a nature-based solution for climate change mitigation for its high C sequestration rate.

Keywords: P Limitation; Casuarina Equisetifolia; Biomass

Introduction

Carbon balance is essential for mitigating climate change. However, global deforestation and fossil fuel combustion aggravate carbon loss[1]. Globally, the plantation has been important carbon sinks and climate change solution[2]. Coastal shelterbelt forest is one kind of plantation intensively managed for windbreak and erosion control[3].

Since last century, global N inputs had eliminated N limitation and enhanced P limitation in some terrestrial ecosystems[4]. Studies showed that addition of P in P-limited ecosystems can promote plant growth, and thus increase carbon sequestrated in plant biomass[5].

C. equisetifolia is a N-fixing species and introduced worldwide for planted forest in degraded ecosystems[6]. C. equisetifolia plantation have covered Over 300 000 ha of China's costs and introduced in 150 countries[7]. However, studies showed that plant growth were severely limited N and P deficiency[8]. The symbiosis with frankia bacteria can contribute 38-67% of the uptake of N[9]. Therefore, growth of C. equisetifolia plantation may be limited by P rather than N. However, there were only limited studies on how fertilization may affect on C. equisetifolia growth[10].

Given the importance of P availability for C. equisetifolia growth, a better understanding how P addition affects on the growth processes is needed. In this study, we conducted a P fertilization experiment in a three-year old C. equisetifolia plantation to explore the effects of P addition on soil respiration, plant growth rate. We hypothesized that P addition could significantly increase soil P availability and accelerate plant growth.

1. Materials and method

1.1 Site description

The study plantation (111.01E, 21.41) is located in the coastline of Dianbai District, Maoming City, Guangdong Province, China. The landform is a typical sandy coast in South China. The climate in this area is a tropical monsoon climate, with the rainy season from April to September and the dry season from October to March of the following year. During the study period, the precipitation from October 2012 to September 2013 is 1700 mm. The average annual temperature is 23 °C. The soil is coastal aeolian sand, with a pH of 7.6. Typhoons destroyed the shelter plantations in 2008, and artificial reforestation occurred immediately in March 2009.

1.2 Experiment design

Fifteen plots measuring 10 m × 10 m were established in a completely randomized design, with five replicates. Three treatments were set: high P addition (P100), mediate P addition (P50), and a control treatment (CK) without P addition. Total fertilization rates were 100 and 50 kg P ha-1 yr-1 respectively in P100 and P50 plots. Soil samples were collected in October 2011 and October 2013, and total P and available P concentration were measured using the acid-soluble molybdenum-antimony colorimetric method. The soils characteristics in 2011 were listed in Table 1.

Table 1. The basic physical and chemical properties of soil samples from the 3 years old tropical C. equisetifolia plantation in 2011 before fertilization (mean±S.E.).

Soil layer (cm)	TN ($g\ kg^{-1}$)	NH_4-N ($mg\ kg^{-1}$)	NO_3-N ($mg\ kg^{-1}$)	TP ($g\ kg^{-1}$)	AP ($mg\ kg^{-1}$)	SOC ($g\ kg^{-1}$)
0-10	0.39±0.02	1.70±0.01	1.37±0.34	0.52±0.14	3.89±0.39	2.67±0.59
10-20	0.32±0.04	1.72±0.02	1.36±0.29	0.41±0.09	2.26±0.36	2.35±0.55

Note: TN refers to total nitrogen concentration; NH4-N refers to ammonium nitrogen concentration; NO3-N refers to nitrate nitrogen concentration; TP refers to total phosphorus concentration; AP refers to available phosphorus concentration; SOC refers to soil organic carbon concentration.

1.3 Biomass measurements

We recorded the height (H) and diameter at breast height (DBH) of all trees in the plots in October from 2011-2013. A growth model (Table 2) explicitly developed for C. equisetifolia in Southern China was used to calculate the standing biomass of roots, stems, branches and branchlets[11].

Table 2. Relationship between biomass of C. equisetifolia components and model parameters; equations are given for the relationship to total biomass represented by diameter (D) and height (H), as D2H, where y is the biomass of tissues; x is D2H; a and b are parameters of the model.

Tissues	Equation	a	b	R2
Root	y=a+bx	2.812	0.004	0.94
Stem	y=axb	0.498	0.024	0.94
Branch	y=axb	0.027	0.781	0.71
Branchlet	y=axb	0.122	0.494	0.60

1.4 Statistical analysis

We assessed the effects of P fertilization on soil properties, plant biomass using Turkey HSD post-hoc tests. Plant biomass was analyzed by repeated measures two-way ANOVAs. The statistical analyses were performed with SPSS 20.0 for Windows (SPSS Inc., Chicago, USA) and figures were created with Origin Pro 9.0 (OriginLab Corp., Northampton, USA). Results are reported as significant at P0.05.

2. Results

Phosphorus addition had not increased th TP and AP in soil collected in 2013 at both 0-10 cm and 10-20 cm layers(Table 3). From 2011 to 2013, C. equisetifolia increased from 14.98±1.74 Mg ha-1 in 2011 to 53.45±7.31 Mg ha-1 in 2013. but were respond to P addition (Fig. 1).

Table 3. The basic physical and chemical properties soil samples from the plots of the tropical C. equisetifolia plantation in 2013 (mean±S.E.), and superscript letters within a column reflect significant differences among the four treatments at $P<0.05$.

Soil Layer	0-10cm			10-20cm		
Treatment	CK	P100	P50	CK	P100	P50
TP (g kg-1)	0.10±0.01	0.18±0.02	0.14±0.03	0.07±0.004	0.10±0.02	0.11±0.04
AP (mg kg-1)	0.05±0.003	0.33±0.18	0.19±0.07	0.02±0.005	0.08±0.04	0.04±0.02

Note: TP refers to total phosphorus; AP refers to available phosphorus.

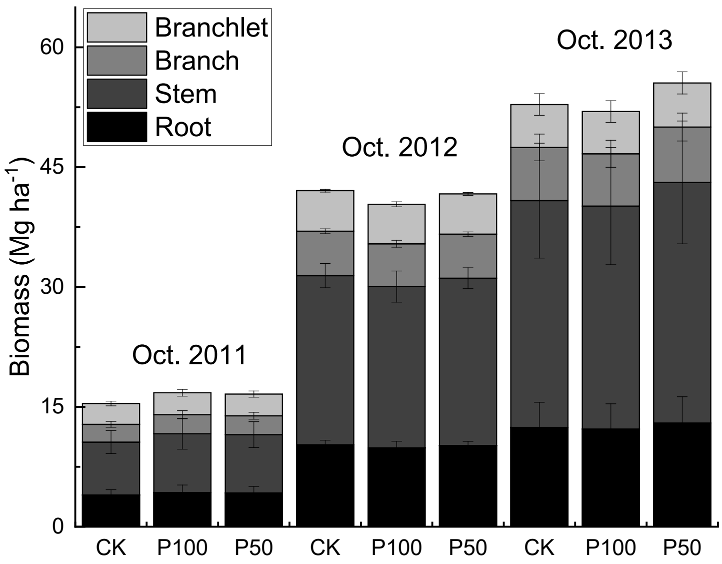

Fig. 1 The biomass of C. equisetifolia tissues from October 2011 to October 2013, where CK is unfertilized controls, P100 is 100kg P ha-1 yr-1 addition, and P50 is 50 kg P ha-1 yr-1 addition; mean values ±S.E. are given for n = 5 plots per treatment.

3. Discussion

The coastal sandy soils had only c. 25.5% of total P concentration of inland soils in the region, where the plant growth is mainly limited by P[12]. Therefore, it is very likely that the plants would face severe P limitation, we thus hypothesized that P addition should stimulate plant growth. Researches on P addition experiments in terrestrial ecosystems demonstrated that extra P input could significantly plant growth in P-limited forest[13-15]. However, we did not observe the effects of P fertilization on plant growth in our study.

During the three years, the biomass of the plantations had increased three-fold with high growth rate. The productivity of the C. equisetifolia plantation was much higher than that of tropical and subtropical afforestation (4.00 Mg C ha-1 yr-1) worldwide[16]. The construction of the shelter plantations on sandy coasts thus can contribute to Carbon sequestration and windbreak. Studies also found that Casuarina plantations had higher productivity than Acacia and Eucalyptus plantations[17].

We suggest that developing C. equisetifolia could be a good solution for greenhouse effect and sea lever rising for coastal regions.Future studies should focus on the sustainable development of C. equisetifolia plantation.

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