Journal of Environmental Sciences Vol. 8, No. 4, pp. 499—503, 1996 ISSN 1001-0742

Laws of annual nutrient uptake in a Paulownia plantation

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Abstract——Characteristics of annual nutrient uptake of a 8-yr.-old Paulownia (Paulownia tomenlosa Steed × Paulownia fortunei Hemsl) plantation (spacing 6m × 10m) at Fengqiu Paulownia Experimental Station in the Yellow River, Huaihe River and Haihe River plains were studied within 2 years. Annual total uptakes of 5 macronutrients (N, P, K, Ca and Mg) in 1989 and 1990 were 287.3238 and 242.4234 kg/(hm^2.a), respectively. The study came to the following laws: (1) the nutrient uptakes of the Paulownia organs followed the order: leaves>branches>flowers>stems>roots; (2) the uptakes for different nutrient elements followed the sequence: N>Ca>K>P>Mg; (3) different organs of the Paulownia showed selective uptake and retention for the essential nutrients; (4) Paulownia's uptake of nutrient elements was mainly conducted during the period between the beginning of growth and the end of July.

Keywords: Paulownia; plantation; nutrient; uptake.

1 Introduction

Paulownia is not only one of the most important fast-growing timber trees in China, but also one of the lightest, and most highly adaptable trees. Its wood has little deformation and is easy to dry, moisture-proof, decay-resistant, and widely used in civil buildings, furniture, industry and so on. The branches are good firewood, and the leaves and flowers are good fodder for sheep and pigs. All the branches, leaves, flowers and fruits have their value in medical use. Having the excellent properties such as fast growth, sparse crown, deep foot system, multiple purpose uses, high value and others, Paulownia is a very good agroforestry tree species. It is ideal for interpolating and intercropping with other shade-tolerant trees, shrubs and crops. Being upper canopy, Paulownia trees with the lower story components form a multiple story system, which efficiently utilizes the limited land and ameliorate soil physical conditions. Therefore it is more productive, sustainable and protective. It yields multiple income and high economic value. So far, various agroforestry models have been developed in China. The main intercropped crops are wheat, corn, cotton, bean, peanuts, vegetables, melons, medicine herb, edible mushrooms and so on. Paulownia crop intercropping is one form of the most popular and distinguished system among Paulownia agroforestry in the north central plains of China. Paulownia trees effectively protect the understorey crops, favorably modify microclimate and therefore, increase the yield of the intercrop. Paulownia plantation in fact is one kind of the combinations in which trees are considered to be the main harvest object. It has wide representation in the Yellow River, Huaihe River and Haihe River plains. Study on laws of annual nutrient uptake is one part of the whole research project for Paulownia plantation ecosystem. It is of great importance to draw up a suitable management plan, fully tap latent production potentialities, and ensure the stability and balance of the plantation ecosystem.

2 General description of the area

Experimental plot selected for the study is located at 114°32′E longitude and 32°03′N latitude in Fengqiu, Henan Province. It belongs to warm temperate zone with a monsoon climate and four clear seasons. The average annual sunshine time reaches 2504. 8 hours, the average annual solar radiation 58. 33 kcal/cm^2, the average annual temperature 14. 4 ℃, the average annual rainfall 640 mm. >0℃ cumulative temperature 5272. 8℃, >10℃ cumulative temperature 4649. 7 ℃, and the annual foretells period 215 days. The area belongs to the Yellow River alluvial plain, sandy loam soil with pH 7. 5, even terrain, and deep and rich soil. There is a 30 cm clay layer being 1 m deep below soil surface, which holds nutrients and water, and is extremely beneficial to the growth of Paulownia trees which have a deep root system. Paulownia plantation is 8-yr.-old (1989). Spacing in row is 6 m, row spacing 10 m, density 167 trees/hm^2, stand average height 14. 9 m, and average diameter at breast height 30. 1 cm. One meter wide protective belt was kept along row.

3 Materials and methods

3. 1 Materials and investigation contents

Different Paulowina organs' (including stem, over 2-yr.-old branch, new branch, leaf, root, flower) increments, amount of different litterfalls, nuetient contents of different Paulownia organs and other parts studied in different months during growth phase.

3. 2 Methods

Diameter at breast height, and crown diameter of all trees in a 3 hm^2 plot were measured. Trees were divided into different classes according to their range of diameter at breast height. Ten diameter class representative trees were chosen to form a fixed sample.

3. 2. 1 Increment measurement

Diameter at breast height, diameters at branch base, numbers of new branches and leaves of the sample trees were investigated at monthly intervals. Stems and branches' increments were calculated according to the allometric regression equations between diameter at breast height and stem biomass, and between diameter at branch base and over 2-yr.-old branch biomass respectively. The increments of new branches and foliage were estimated according to their number and practical sample investigation. As root increments are difficult to obtain, ratio of root to stem was used for root increment calculation. Five 1 m×1 m square litterfall collectors were set up properly according to trees' spacing in row and row spacing in the sample plot. Litterfall was collected at regular intervals, classified and then weighed.

3.2.2 Sample drying

Samples were continuously dried in a blast constant temperature drying oven under 105℃ condition and weighed every 2 hours until each weight was constant after being weighed 3 times continuously, which was regarded as the absolute dry weight of the sample.

3.2.3 Measurement of nutrient element content

Semimicro Kjeldahl method was used to determine N content; Ultraviolet spectrophotometer to determine P; and atomic absorption spectrophotometer to determine K, Ca, and Mg.

4 Results

Nutrient uptake of Paulownia depends on its growth speed and nutrient content during annual growth course. Previous research showed (Wu, 1993): the soil of this plantation contained 35 elements. Paulownia stem 28, leaf bud 31, new branch and flower bud 34, and root and flower 35 elements. In this research, only 5 macronutrients (N, P, K, Ca and Mg) which have a close relationship with matter production were studied. In order to get the data of Paulownia nutrient uptake, net production of Paulownia stand was accurately determined first. Nutrient uptake was calculated according to net production and its nutrient content. The Paulownia nutrient uptakes in 1989 and 1990 are shown in Table 1 and Table 2.

Table 1 Uptakes of nutrient elements in Paulownia plantation in 1989 Unit: kg/hm^2

		Stem	Branch	Leave	Root	Flower	Other	Total	Monthly total
Beginning growth May 30	N	0.2744	5.4402	42.9846	0.7019	6.9862		56.3946	
	P	1.7675	3.8328	15.6070	0.3863	5.0931		26.6867	
	K	1.4485	6.4293	21.1154	1.0293	4.7476		34.7701	
	Ca	0.4148	2.8437	13.7709	0.2176	1.7390		18.9860	
	Mg	0.3254	1.1128	2.9072	0.1687	0.8226		5.3367	142.1740
October	N	0.0071	0.3043	−5.9500	0.0183		0.1842	−5.4361	
	P	0.0454	0.4736	−1.2705	0.0100		0.0580	−0.6835	
	K	0.0373	0.1613	−1.0890	0.0265		0.0484	−0.8155	
	Ca	0.0107	1.9771	0.1815	0.0056		0.0476	2.2225	
	Mg	0.0084	0.6935	0.5445	0.0044		0.0179	1.2687	−3.4439
Total	N	0.9674	12.8245	63.1000	2.4999	6.9862	0.5051	86.8831	
	P	6.2313	9.8073	26.1103	1.3620	5.0931	0.1519	48.7631	
	K	5.1025	11.3162	28.1657	3.6290	4.7476	0.1328	53.0938	

Table 1 (continued)

	Ca	1.4623	20.8712	54.5701	0.7672	1.7390	0.1305	79.5409	
	Mg	1.1472	2.5146	13.9152	0.5949	0.8226	0.0492	19.0437	287.3238
	$\sum$	14.9107	57.3338	185.8613	8.8530	19.3885	0.9767	287.3238	

Table 2 Uptakes of nutrient elements in Paulownia plantation in 1990 **Unit: kg/hm²**

		Stem	Branch	Leave	Root	Flower	Other	Total	Monthly total
Beginning growth May 30	N	0.2315	4.5901	36.2675	0.5983	5.8944		47.5818	
	P	1.4913	3.2338	13.1681	0.3259	4.2972		22.5163	
	K	1.2221	5.4246	17.8157	0.8685	4.0056		29.3365	
	Ca	0.3500	2.3993	11.6189	0.1836	1.4672		16.0190	
	Mg	0.2746	0.9390	2.4529	0.1423	0.6939		4.5027	119.9563
October	N	0.0072	0.3041	−5.9700	0.0169		0.1891	−5.4527	
	P	0.0471	0.4624	−1.2805	0.0104		0.0582	−0.7024	
	K	0.0354	0.1615	−1.0900	0.0284		0.0491	−0.8156	
	Ca	0.0106	1.9651	0.1725	0.0069		0.0483	2.2034	
	Mg	0.0083	0.6933	0.5512	0.0051		0.0188	1.2767	−3.4906
Total	N	0.8273	11.7887	53.4794	2.2796	6.6574	0.6394	75.6881	
	P	5.3290	9.0152	18.9190	1.2420	4.8653	0.2014	39.6719	
	K	4.3636	10.4022	20.4083	3.3091	4.5352	0.1681	43.1865	
	Ca	1.2505	19.1855	46.2501	0.6996	1.6612	0.1652	69.2123	
	Mg	0.9811	2.2113	10.0826	0.5424	0.7858	0.0623	14.6655	242.4243
	$\sum$	12.7515	52.7030	149.1394	8.0727	18.5212	1.2364	242.4243	

Uptakes of the 5 macronutrients in Paulowina plantation in 1989 and 1990 reach 287.3238 and 242.4243 kg/(hm^2.a) respectively (Table 1 and Table 2). Among the uptakes of different organs, foliage took up the most, making up 65.03% and 61.52% (including insect eating 0.34% and 0.51%) of the total uptake each year respectively; branches were the next, comprising 19.95% and 21.74%; and then flowers making up 3.08% and 3.33%. The uptake rates of different elements decreased in the following order: N>Ca>K>P>Mg. According to the data analysis, different organs showed selective uptake and retention for the essential nutrients. Foliage absorbed more N and Ca, making up 63.31% and 66.87% of its total uptake, roots took up more K and N, stems retained more P and K, branches took up more Ca and less Mg, and flower contained more N, P and K.

The results from Table 1 and Table 2 also shown that Paulownia nutrient absorption mainly took place during the period between the early days of growth and the end of July, comprising 93.31% and 94.72% of the total absorption in 1989 and 1990, respectively. After August, some easy mobile elements like N, P, K were gradually released to the environment. This is because leaf function greatly decreased from August, nutrients were leached by rain and organic matter moved to other tissues, which resulted in the uptakes of elements like N, P, K with high re-absorptibility were minus values.

Nutrient uptakes were also affected by human activities. Besides nutrients were partly retained each year, the return process of organic matter were seriously disturbed by the local people. Most of the late debased were away from the plantation. Grass-cutting and cattle-grazing also took place in Autumn. In 1989 and 1990, 108.0633 and 79.2979 kg/hm^2 of nutrients in debased were taken out respectively. The moving out of nutrients led to reduction of stand productivity so that the nutrient uptake in 1990 (242.4243 kg/hm^2) was evidently lower than that in 1989 (287.3238 kg/hm^2). Therefore, in management, we should not only protect litterfall and vegetation, and avoid nutrients being moved away, but also fertilize reasonably according to nutrient loss to maintain a stable forest soil fertility.

5 Conclusions

The important findings of this study can be summarized as follows:

Paulownia plantation nutrient uptakes in 1989 and 1990 reached 287.3238 and 242.4243 kg/hm^2 respectively. Nutrient absorption of different Paulownia organs followed the sequence: foliage > branches > flowers > stems > roots.

Paulownia's absorption rates for different nutrient elements decreased in the following order: N > Ca > K > P > Mg.

Different Paulownia organs selectively took up (or retained) nutrient elements: foliage contained more N and Ca; root more K and N; stem more P and K; branch more Ca; and flower more N, P and K.

Paulownia plantation nutrient absorption mainly took place before the end of July. This provided a reliable basis for management to determine the amount and time of fertilization.

Large amount of nutrient loss greatly affected the forest productivity. So the ground vegetation must be protected. In the meantime, we must fertilize adequately, and make sure that the forest soil had enough nutrient to supply.

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(Received July 14, 1995)