GROWTH RHYTHMS OF THREE *Ormosia* SPECIES SEEDLINGS OF DIFFERENT PROVENANCES

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[1] Received on 29.08.2019 accepted for publication on 23.10.2019.
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ABSTRACT – The superior provenance is a prerequisite for ecological restoration, and a better mastery on the growth rhythms of *Ormosia* species is fundamental to reforest effectively. For the selection of better provenance and the formulation of artificial cultivation methods, the height and the ground diameter of *Ormosia hosiei* Hemsl. et Wils., *O. xylocarpa* Chun ex L. Chen and *O. henryi* Prain seedlings of different provenances were monitored in the first year. The results showed that their dynamic growths presented a slow-fast-slow trend that fit a "S" growth curve by the logistic mathematical model, and the growth of *Ormosia* species seedlings of different provenances significantly differed. The accumulated growth increment of *O. xylocarpa* was the largest (averagely 45.50 cm) and the accumulated growth increment of *O. henryi* was the least (averagely 20.33 cm). Thus, *O. hosiei* of Jiujiang provenance, *O. xylocarpa* of Liping provenance and *O. henryi* of Longquan provenance have a stronger adaptability for future artificial cultivation in Jiangxi China.

Keywords: Height growth; Logistic equation; Ormosia henryi.

RITMOS DE CRESCIMENTO DE TRÊS ESPÉCIES DE MUDAS Ormosia DE DIFERENTES ORIGENS

RESUMO – A origem melhor é um pré-requisito para a restauração ecológica, e um melhor domínio dos ritmos de crescimento das espécies ***Ormosia*** *é fundamental para reflorescimento com eficácia. Para a seleção de melhor origem e a formulação de métodos artificiais de cultivo, a altura e o diâmetro do solo de mudas* ***Ormosia hosiei*** *Hemsl. et Wils.,* ***O. xylocarpa*** *Chun ex L. Chen e* ***O. henryi*** *Prain de diferentes origens foram monitoradas no primeiro ano. Os resultados mostraram que seus crescimentos dinâmicos tiveram uma tendência lenta-rápida-lenta que se correspondia a uma curva de crescimento "S" no modelo matemático logístico, e o crescimento de espécies de mudas* ***Ormosia*** *de diferentes origens diferiram significativamente. O incremento de crescimento acumulado de* ***O. xylocarpa*** *foi o maior (em média de 45,50 cm) e o incremento de crescimento acumulado de* ***O. henryi*** *foi o menor (em média de 20,33 cm). Assim,* ***O. hosiei*** *da origem de Jiujiang,* ***O. xylocarpa*** *da origem de Liping e* ***O. henryi*** *da origem de Longquan têm uma adaptabilidade mais forte para o futuro cultivo artificial em Jiangxi, China.*

Palavras-Chave: Crescimento Elevado; logístico equação de; Ormosia hosiei.

1. INTRODUCTION

Ormosia hosiei Hemsl. et Wils., *O. xylocarpa* Chun ex L. Chen and *O. henryi* Prain can provide precious timbers for top grade furniture, craft carvings and special decorations, among which *O. hosiei* and *O. henryi* are State protection (category II) and endangered plants in China (Wang and Chen, 1999). With the development of economy and society, the three *Ormosia* species are endangered in some regions in China due to the excessive cutting and utilization without reforestation, which is extremely affecting our national ecological safety and wood safety (Deng et al., 2011; Liu et al., 2017; Wang et al., 2015).

Most of the *Ormosia* species possesses a long dormancy period prior to seed germination and their ability of natural regeneration is poor because of their seeds enwrapped hard and dense seed coat with the waxy layer and poor permeability. According to the literatures, *O. hosiei*, *O. xylocarpa* and *O. henryi* mainly distribute in Anhui, Jiangxi, Hubei, Guangdong, Guizhou, Zhejiang, Guangxi, Hunan, Sichuan, Yunnan, Fujian, Hainan, China (Chinese ethnographic editorial board, 1994). However, the wild resources have been cut down in large quantities, and the native habitats have been destroyed seriously. Now the natural forests containing these species are tapering off (Deng et al., 2011; Liu et al., 2017; Wang et al., 2015). It is difficult to recover the population by natural regeneration. So appropriate provenances were introduced in the original region where *Ormosia* populations were disappeared, which is the important method for the *Ormosia* populations restoration.

The shortage of forest resources has been forcing us to explore the ways to improve the forest quality of rare tree species. However, the systematic seedling cultivation techniques was scarce. Artificial cultivation is one of the important ways to rebuild low yield forests and restore forest ecology (Ghosh et al., 2014). The growth rhythms and suitable provenances of seedlings are basis of forest restoration. The growth rhythm of seeding is influenced by the external environment, which is the embodiments of its physiological function (Chen et al., 2014; Gyllenstrand et al., 2007; Mattos et al., 2005). The growth period could be divided by observing and studying the annual growth rhythm of *Ormosia* seedlings. The scientific cultivation measures were formulated for cultivating high quality and strong seedlings according to different growth stages (Zhou et al., 2016). Therefore, understanding of growth rhythms and selection of appropriate provenances of three *Ormosia* species are indispensable to develop effective reforestation strategies, protect biodiversity, and meet the needs of wood-processing industry and human diversity (Cai, 2007; Ye, 2014).

At present, most researches on *Ormosia* species are mainly concentrated on tissue culture (He et al., 2015; Fan et al., 2011), seed reproductive ecology (Peng et al., 2009; Chen, 2016), seed germination (Vargas-Simón et al., 2017; Silva et al., 2014; Foster, 2008), seedling cultivation (Shen et al., 2009; Ye, 2014; Yang, 2011; Feng et al., 2007; Zhu et al., 2015), fertilization measures (Duan et al., 2017; Zheng, 2008) and forest afforestation techniques (Wu et al., 2009; Pan, 2004), while few studies have been performed on the growth rhythm of *O. hosiei*, *O. xylocarpa* and *O. henryi* from different provenances. Hence, this study is aimed to evaluate the growth rhythms and differences of the three species from different provenances for selecting the superior provenances of *O. hosiei*, *O. xylocarpa* and *O. henryi* for priority use and determining appropriate management technique. Our findings will facilitate the cultivation of good seeds, good quality seedlings and planting, and population restoration of these species. It also provides a theoretical basis for ecological restoration and development of timber resources.

2. MATERIAL AND METHODS

2.1 Experiment material

The ripe seeds were collected from October to November in 2014, then they were stored in nylon mesh bags in shade conditions. *O. hosiei* seeds were collected from Jiujiang, Jiangxi Province and Lichuan, Hubei Province, the *O. xylocarpa* seeds were collected from Ruyuan, Guangdong Province and Liping, Guizhou Province, and the *O. henryi* seeds were collected from Longquan, Wuhan, Guilin, Hangzhou and Changsha that distributed in Zhejiang, Hubei, Guangxi, Zhejiang and Hunan Provinces (Table 1).

Table 1 – Summary of the site details for the test provenances of Ormosia species.
Tabela 1 – *Resumo dos detalhes do local para testar as províncias de espécies de Ormosia.*

Provenance	LON (E)	LAT (N)	ALT (m)	AMT (°C)	AR (mm)	FFP (d)	EAT (°C)	EIT (°C)	MAH (%)	SD (h)
O. hosiei										
Jiujiang	113°57′	28°47′	1032	17.6	1446	252	40.9	-6.7	75	1582
Lichuan	108°21′	29°42′	1000	12.9	1301	232	34.3	-10.2	81	1341
O. xylocarpa										
Ruyuan	113°28′	24°77′	1142	20.5	1599	308	40.4	-4.3	77	1644
Liping	109°14′	26°24′	695	15.8	1302	277	37.5	-6.2	83	1257
O. henryi										
Longquan	118°67′	27°71′	1267	18	1438	263	41.5	-8.3	76	1602
Wuhan	114°64′	30°12′	23	17.1	1316	240	39.6	-12.8	75	1808
Guilin	110°66′	26°03′	800	19.1	1888	309	39.5	-3.3	75	1445
Hangzhou	120°10′	30°16′	19	17	1649	245	40.3	-8.4	79	1615
Changsha	112°86′	27°97′	45	17.4	1428	281	40.6	-10.3	79	1623

LON = longitude, LAT = latitude, ALT = altitude, AMT = annual mean temperature, AR = Annual rainfall, FFP = Frost free period, EAT = extreme maximum temperature, EIT = extreme minimum temperature, MAH = mean relative air humidity, SD = sunshine duration. All of the data are from National Meteorological Information Center (http://data.cma.cn).
LON = longitude, LAT = latitude, ALT = altitude, AMT = temperatura média anual, AR = chuva anual, FFP = período livre de frio, EAT = temperatura máxima extrema, EIT = temperatura mínima extrema, MAH = humidade do ar média, SD = duração do sol. Todos os dados são provenientes do Centro Nacional de Informações Meteorológicas. (http://data.cma.cn).

2.2 Experiment site

This study was conducted in the greenhouse of Jiangxi Academy of Forestry, Jiangxi Province, China (115°49′E, 28°44′N). The region is dominated by humid monsoon climate of subtropics with a mean annual temperature of 18.0°C and mean annual precipitation of 1600-1700 mm. The extreme maximum temperature is 40.1°C in summer and the extreme minimum temperature is -9.7°C in winter. The annual average sunshine time is 1723-1820 hours. The rainfall periods are 147 to 157 days.

2.3 Seedling cultivation

The experimental field was established in December 2014. The seedbed with a width of 100 cm and a height of 40 cm was sterilized with carbendazim diluted 500 times. In March 2015, the seeds were soaked in water at 40 °C for 6 to 8 hours and seeds displaying obvious expansion were sowed a dibble method at a spacing of 5 cm × 10 cm (Shen and Zhai, 2001). They were cover with 1 cm of yellow soil. The yellow soil is the soil without stone and roots and taken from > 20 cm depth. Then the seedbeds were covered by an arched bamboo shed (overlying 50% shade net on arched bamboo strip) to keep the seedbeds moist and cooling and shading of growing environment. Weeding, irrigation, and pest control were implemented regularly, according to normal management production processes.

2.4 Measurements

After sowing, seedlings were observed every 2 days until they were more than 90% of the first leaf of seedling unfolding, which the seedling stage was determined. Thirty seedlings of each provenance in stationary plots were studied. The height of seedlings was measured with a steel tape (accuracy of 0.1 cm), every 20 days (but adjusted to 10-30 days based on weather changes) till October and the last time in the end of December since they grew slowly in winter. As the growth of the ground diameter is small and the increase is not obvious, the ground diameter of the seedling stems was measured with a digital vernier caliper (accuracy of 0.01 cm) only when the height growths were almost stopped.

2.5 Statistical analysis

The logistic curve was simulated for the dynamic growth of the seedling height from different provenances (Dong, 2007). The fitting equation of the logistic curve is:

$$y = \frac{k}{1 + ae^{-bt}} \quad \text{(Eq. 1)}$$

Where y is the growth increment of the seedling height, t is the growth time, a and b are the undetermined coefficients, k is the limit value of the seedling height growth under the given conditions.

Take the derivative of formula (1) for several times, and two inflection points of the growth rate that is the fastest can be obtained (Kuang et al., 2014):

$$t_1 = \frac{1}{b} ln \frac{a}{2+\sqrt{3}} \quad \text{(Eq. 2)}$$

$$t_2 = \frac{1}{b} ln \frac{a}{2-\sqrt{3}} \quad \text{(Eq. 3)}$$

In formula (2) and (3), *t1* and *t2* are the dividing points from the germination to the fast-growing stage and from the fast-growing stage to the slow growth stage respectively, and the period between *t1* and *t2* can be regarded as the fast-growing stage. The growth stages of various provenances were divided according to the growth data obtained.

The mean height of each measurement stage, the mean ground diameter of the last measurement and the corresponding standard error were calculated. We conducted the significance test of differences on the average height and ground diameter of one-year-old seedlings of *O. hosiei* and *O. xylocarpa* by means of T test and of *O. henryi* by means of one-way ANOVA and LSD method. All statistical analyses were performed on SPSS 20.0.

3. RESULTS

3.1 Model simulation of seedling height growth rhythm of Ormosia species

Combining the seedling height data, the seedling height growth rhythms of *Ormosia* species of different provenances were simulated by the logistic model. The results exhibited during the growth period of *Ormosia* seedlings in the first year, the dynamic height growths presented a slow-fast-slow trend and fitted a “S” growth curve by the logistic mathematical model. The achieved highly significant fitting level ranged from 0.820 to 0.994 (Table 2).

3.2 Comparison of the height growth rhythm of *O. hosiei* of different provenances

The seedling growth period of Jiujiang provenance was from Apr. 16 to Dec. 30 for 257 days with 46.52 cm of the accumulated growth increment, and Lichuan provenance was from Apr. 7 to Nov. 1 for 208 days with 27.90 cm of the accumulated growth increment (Table 3). Because the initial growth rate was slow, the seedling height growth of both Jiujiang and Lichuan provenances were not different obviously, while the fast-growing stages of these two provenances were quite different (Figure 1A). For the fast-growing stage of *O. hosiei* seedlings, the duration of Jiujiang provenance had lasted from June 25 to October 1 for 98 days, with 28.65 cm of the net height increment concomitantly and 40.19 cm of total accumulated increment (Table 3). The *O. hosiei* seedlings of Lichuan provenance entered into the fast-growing stage was mid-May, with 17.56 cm of the net height increment concomitantly and 24.10 cm of total accumulated increment (Table 3). The *O. hosiei* seedlings tended to grow slowly after October (Figure 1A; Table 3). Lichuan provenance were inclined to grow gently and stop in November while the seedlings of Jiujiang provenance hardly grew at the end of December (Figure 1A; Table 3).

3.3 Comparison of the height growth rhythm of O. xylocarpa of different provenances

It differed greatly in the growth of *O. xylocarpa* seedlings between Ruyuan and Liping provenances in the first year. The seedlings of Liping provenance grew much better than those of Ruyuan provenance during

Table 2 – Logistic equations of the seedling height of *Ormosia* species of different provenances in the first year.
Tabela 2 – *Equações logísticas em altura de mudas das espécies de Ormosia de diferentes províncias no primeiro ano.*

Species	Provenance	Logistic equations	R2
O. hosiei	Jiujiang	$y=47.071/(1+32.247e^{-0.027t})$	0.934
O. hosiei	Lichuan	$y=30.678/(1+7.856e^{-0.021t})$	0.820
O. xylocarpa	Ruyuan	$y=24.143/(1+24.436e^{-0.027t})$	0.911
O. xylocarpa	Liping	$y=66.888/(1+321.081e^{-0.043t})$	0.976
O. henryi	Longquan	$y=27.206/(1+20.956e^{-0.022t})$	0.917
O. henryi	Wuhan	$y=20.968/(1+18.26e^{-0.023t})$	0.872
O. henryi	Guilin	$y=23.161/(1+3.959e^{-0.013t})$	0.994
O. henryi	Hangzhou	$y=15.125/(1+8.212e^{-0.019t})$	0.980
O. henryi	Changsha	$y=17.575/(1+47.81e^{-0.028t})$	0.922

Table 3 – Height growth status and growth periods of *Ormosia* seedlings of different provenances in the first year.
Tabela 3 *– Status de crescimento em altura e períodos de crescimento de mudas de Ormosia de diferentes províncias no primeiro ano.*

Species	Provenance	Growth period	Time	Du	Ai	Ni	Ri
O. hosiei	Jiujiang	Emergence	04/16-05/16	30	3.84	3.84	8.26
	Early growth	05/16-06/25	39	11.54	7.7	16.55	
	Fast growing	06/25-10/01	98	40.19	28.65	61.58	
	Late growth	10/01-12/30	90	46.52	6.33	13.61	
	Stagnation	12/30-	-	-	-	-	
O. hosiei	Lichuan	Emergence	04/07-04/21	14	4.48	4.48	16.04
	Early growth	04/21-05/13	22	6.54	2.07	7.41	
	Fast growing	05/13-09/14	124	24.1	17.56	62.93	
	Late growth	09/14-11/01	48	27.9	3.8	13.61	
	Stagnation	11/01-	-	-	-	-	
O. xylocarpa	Ruyuan	Emergence	04/28-05/19	21	2.72	2.72	11.34
	Early growth	05/19-06/15	27	7.66	4.94	20.56	
	Fast growing	06/15-09/21	98	22.22	14.56	60.62	
	Late growth	09/21-12/12	82	24.01	1.79	7.47	
	Stagnation	12/12-	-	-	-	-	
O. xylocarpa	Liping	Emergence	05/04-06/15	42	3.82	3.82	5.71
	Early growth	06/15-07/19	34	30.41	26.6	39.77	
	Fast growing	07/19-09/18	61	65.11	34.7	51.88	
	Late growth	09/18-12/30	103	66.88	1.77	2.64	
	Stagnation	12/30-	-	-	-	-	
O. henryi	Longquan	Emergence	05/05-05/12	7	2.54	2.54	9.4
	Early growth	05/12-06/24	43	8.96	6.42	23.75	
	Fast growing	06/24-10/22	120	25.23	16.26	60.15	
	Late growth	10/22-01/18	88	27.04	1.81	6.71	
	Stagnation	01/18-	-	-	-	-	
O. henryi	Wuhan	Emergence	05/05-05/17	12	2.53	2.53	12.12
	Early growth	05/17-06/16	30	7.19	4.66	22.26	
	Fast growing	06/16-10/07	113	19.51	12.32	58.92	
	Late growth	10/07-12/29	114	20.91	1.4	6.7	
	Stagnation	12/29-	-	-	-	-	
O. henryi	Guilin	(Emergence)					
	early growth	04/02-04/12	10	5.23	5.23	24.76	
	Fast growing	04/12-10/31	202	18.26	13.03	61.75	
	Late growth	10/31-01/16	78	21.11	2.85	13.49	
	Stagnation	01/16-	-	-	-	-	
O. henryi	Hangzhou	(Emergence)					
	early growth	05/08-05/19	11	3.22	3.22	21.47	
	Fast growing	05/19-10/04	138	13.97	10.75	71.66	
	Late growth	10/04-01/02	90	15	1.03	6.87	
	Stagnation	01/02-	-	-	-	-	
O. henryi	Changsha	Emergence	05/29-06/12	14	2.06	2.06	11.72
	Early growth	06/12-07/07	25	9.39	7.33	41.7	
	Fast growing	07/07-10/09	94	17.32	7.93	45.15	
	Late growth	10/09-01/14	97	17.57	0.25	1.42	
	Stagnation	01/14-	-	-	-	-	

Du = duration time (d), Ai = accumulated increment (cm), Ni = net increment (cm), Ri = ratio of net increment in total increment (%). Since the fast-growing stages of *O. henryi* of Guilin, Guangxi provenance and Hangzhou, Zhejiang provenance occur earlier, no distinction between the emergence and early growth stage whose period is short and ambiguous.
Du = tempo de duração (d), Ai = aumento acumulado (cm), Ni = aumento líquido (cm), Ri = rácio de aumento líquido no aumento total (%). Como os estágios de rápido crescimento de *O. henryi* de Guilin, província de Guangxi e de Hangzhou, província de Zhejiang ocorrem mais cedo. Não há diferença entre o estágio de surgimento e o crescimento inicial, cujo período é curto e ambíguo.

the whole year (Figure 1B). The seedling growth period of Liping provenance was from May 4 to Dec. 30 for 240 days with 66.88 cm of the accumulated growth increment, and the seedling growth period of

Ruyuan provenance was from Apr. 28 to Dec. 12 for 228 days with 24.01 cm of the accumulated growth increment.

For *O. xylocarpa* seedling of Liping provenance, the early growth stage was from mid-June to July 18 that lasting 34 days, with 26.60 cm of a net height increment (Table 3). The duration of the fast-growing stage was from Jul. 19 to Sep. 18 for two months with 34.70 cm of a net height increment, and an extreme growth occurred in the end of August which had presented nearly 9.86 cm of increment in height for 10 days, then after Sep. 18, the seedlings grew slowly and stopped (Figure 1B). Nevertheless, contrast to the seedlings of Liping provenance, the seedlings of Ruyuan provenance got a low-growing speed at the beginning with the 7.66 cm of accumulated increment before they entered into the fast-growing stage, which was preeminently lower than those of Liping provenance (Figure 1B). The fast-growing stage could be identified from Jun. 15 to Sep. 21 for 98 days along with 14.56 cm of a height growth increment (Figure 1B; Table 3). The seedlings of the late growth stage were late September and terminated growth in the middle of December (Figure 1B).

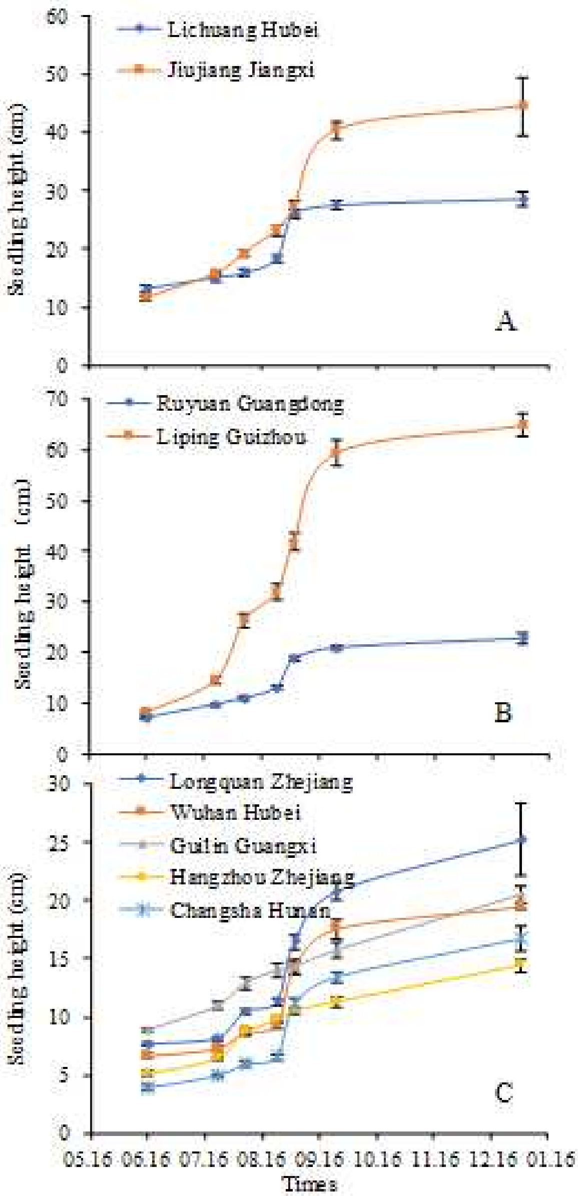

Figure 1 – Height growth dynamic of *O. hosiei* (A), *O. xylocarpa* (B), and *O. henryi* (C) seedlings from different Provenances.

***Figura 1** – Dinâmica de crescimento em altura de mudas de O. hosiei (A), O. xylocarpa (B) e O. henryi (C) de diferentes províncias.*

3.4 Comparison of the height growth rhythm of O. henryi of different provenances

For all investigated provenances of *O. henryi*, the growth rate of each stage of different provenance were inequable (Figure 1C). At the early growth stage, the seedling height of Changsha provenance was the highest with 9.39 cm, followed by the Longquan provenance, Wuhan provenance, Guilin provenance and Hangzhou provenance with the 8.96 cm, 7.19 cm, 5.23 cm and 3.22 cm of height, respectively (table 3). The seedlings of Guilin provenance were the earliest ones who entered the fast-growing stage (Apr. 12), whereas those of Hangzhou provenance were on May 19, of Wuhan provenance and Longquan provenance were in the mid and late June respectively, and of Changsha provenance were the latest (Jul. 7) (Table 3). The net height increment of Longquan provenance was the largest (16.26 cm), followed by that of Guilin (13.03 cm), Wuhan (12.32 cm), Hangzhou (10.75 cm) and Changsha (7.93 cm) provenance (Table 3).

3.5 Comparison of one-year-old seedling growth increment for Ormosia species

Significant discrepancies in the height and the ground diameter of one-year-old *O. hosiei* seedlings of different provenances were recognized ($P < 0.05$). The heights of one-year-old *O. hosiei* seedlings of Lichuan provenance were in the range of 9.50 - 33.80 cm, averaging 28.54 ± 1.15 cm, which was 16 cm shorter than those of Jiujiang provenance. To the contrary, the average seedling ground diameters of Lichuan provenance were 0.10 cm thicker than those of Jiujiang provenance (Table 4).

The heights and the ground diameters of one-year-old *O. xylocarpa* seedlings of different provenances were obviously different from each other ($P < 0.05$). Notably, the heights of one-year-old *O. xylocarpa* seedlings of Ruyuan provenance were correspondingly lower than those of Liping provenance for the former were in the range of 7.00 - 29.30 cm, averaging 22.90 ± 1.03 cm, whereas the latter were 64.86 ± 2.30 cm averagely with the minimum value of 22.00 cm up to 87.00 cm. Besides, the ground diameters of one-year-old *O. xylocarpa* seedlings of Ruyuan provenance were ranging from 0.23 cm to 0.75 cm, 0.30 ± 0.01 cm averagely, significantly less than those of Liping provenance ($P < 0.05$) whose the maximum value was 0.75 cm and the minimum value was 0.23 cm, 0.47 ± 0.03 cm averagely (Table 4).

The heights and the ground diameters of one-year-old *O. henryi* seedlings of different provenances were significantly different. The seedling heights of Wuhan, Hangzhou and Changsha provenance were 12.48 ± 0.22 cm, 11.40 ± 0.50 cm and 12.73 ± 1.03 cm respectively, which were apparently lower than those of Guilin and Longquan provenance ($P < 0.05$). The one-year-old *O. henryi* seedlings of Longquan provenance were the tallest (8.60 - 31.50 cm) whose average value was 21.24 ± 3.09 cm and the ground diameter was 0.32 ± 0.04 cm averagely. However, the ground diameters of one-year-old *O. henryi* seedlings of Guilin provenance were markedly coarser than those of other provenances ($P < 0.05$) because the average ground diameter was 0.36 ± 0.03 cm, the maximum value was 0.62 cm and the minimum value was 0.32 cm (Table 4).

4. DISCUSSION

4.1 The seedling growth rhythm of *Ormosia* species

Through the model simulation and the actual monitoring, the date consistent with the growth stages were determined by calculating. We found that the stages of the height growth of *Ormosia* seedlings could be roughly divided into five stages: emergence stage (before Jun.), early growth stage (Jun.), fast-growing stage (from Jul. to Oct.), late growth stage (from Nov. to Dec.) and stagnation stage (after Jan.).

Among the five stages, the height growth of *Ormosia* seedlings during the first year presented a slow-fast-slow trend in the light of the data of net increment. It differed greatly in the start and stop time and the duration of every growth stage of different provenances, so did the corresponding growth increment. The fast-growing stage had the largest proportion on the net growth increment and the longer duration that up to a maximum of 202 days (Table 3).

The seedlings of *O. hosiei* were the earliest to sprout (averagely 17 days after sowed), followed by *O. xylocarpa* (averagely 35 days) and *O. henryi* (averagely 38 days). The accumulated growth increment of O. xylocarpa in the first growing year was the largest (averagely 45.50 cm) while *O. henryi* was the least (averagely 20.33 cm).

The growth rhythm of species and provenances is different, which is related to their growth characteristics

Table 4 – Comparison of the seedling height and ground diameter of one-year-old *Ormosia* species from different provenances.
Tabela 4 – *Comparação da altura e diâmetro do solo das mudas de espécies de Ormosia com a idade de um ano de diferentes províncias.*

Species	Provenance	Height (cm)			Ground diameter (cm)		
		Mean	Max	Min	Mean	Max	Min
O. hosiei	Jiujiang	44.44±4.98b	62.70	7.00	0.55±0.05a	0.75	0.18
O. hosiei	Lichuan	28.54±1.15a	33.80	9.50	0.67±0.09b	1.00	0.30
O. xylocarpa	Ruyuan	22.90±1.03a	29.30	7.00	0.30±0.01a	0.45	0.17
O. xylocarpa	Liping	64.86±2.30b	87.00	22.00	0.47±0.03b	0.75	0.23
O. henryi	Longquan	21.24±3.09a	31.50	8.60	0.32±0.04ab	0.52	0.17
O. henryi	Wuhan	12.48±0.22b	21.80	7.60	0.28±0.02a	0.50	0.25
O. henryi	Guilin	20.45±0.78a	28.56	8.33	0.36±0.03b	0.62	0.32
O. henryi	Hangzhou	11.40±0.50b	12.80	8.70	0.29±0.01ab	0.34	0.24
O. henryi	Changsha	12.73±1.03b	12.60	4.00	0.30±0.02ab	0.36	0.19

Lowercase letters on the right superscript indicate the statistical difference between the measurement index and provenances ($P < 0.05$).
Letras minúsculas à direita significam a diferença estatística entre o índice de medição e as províncias.

(biological, ecological and forest characteristics). The time of emergence and growth duration were directly affected by species, provenances, and planting sites (Chen et al., 2014; Tang, 2013; Peng et al., 2009). The growth rhythm of plants can self-regulate with the climate change, which indirectly reflects the adaptability of plants.

Comparing all the *Ormosia* species experimented, it was demonstrated that the *O. xylocarpa* seedlings of Liping provenance had a biggest height growth rate in the first year (more than 60 cm averagely), followed by *O. hosiei* seedlings of Jiujiang provenance (more than 40 cm averagely) and Lichuan provenance (nearly 30 cm averagely) (Figure 1; Table 3), which may be a cause of high heritability on different species (Sudan et al., 2018) and genetic diversity on different provenances of the same species (Zhao et al., 2008; Zhang et al., 2012). Besides, *O. henryi* seedlings reflected to be the shortest (most of them were between 15-30 cm) and grow the most slowly among three *Ormosia* species (Figure 1) which corresponds with other studies (Cai, 2007; Chen et al., 2014; Tang, 2013). Among these *Ormosia* species, the *O. xylocarpa* seedlings of Liping provenance grew the most optimally (Figure 1). *O. hosiei* of Jiujiang provenance and *O. henryi* of Longquan provenance are also the best choice for artificial cultivation in future. Different provenances have different physiological characteristics, which will inevitably affect their growth.

Considerable differences on the provenances of the same species accompanying the geographic and climatic variables lead to different growth states (Lukkarinen et al., 2009). Different geographical conditions have different climate, so the variation tree species have different tolerance to Jiangxi climate. Extreme climate change (for instance extreme maximum temperature showed up, air humidity increased sharply) may produce some morphological variation of forest trees (García-Plazaola and Becerril, 2000; Gratani et al., 2003; Kaleem et al., 2010), and change their photoperiod and photosynthesis (Kalita and Titlyanov, 2013; Yuan et al., 2017). It is still worth to explore further what are the main factors leading to growth differences among different provenances: genetic factors or environmental factors?

4.2 Cultivation Measures

According to their growth rhythm, it is effective to take cultivation measures timely characterized the growth of different stages (Fan et al., 2013; Santelices et al., 2015), so the cultivation procedure should be implemented before the end of Spring by adopting conservation measures such as covering the seedling shed and irrigating adequate water regularly etc. (Jiang and Xiaoli, 2016; Luis et al., 2004). The mixed fertilizer with low nitrogen and high phosphorus should be applied properly at the end of June to promote the growth of roots laying the foundation for the fast-growing stage (Huang et al., 2015). What should be carried out in the key fast-growing stage from July to September is to spray the mixed fertilizer of high nitrogen, low potassium and low phosphorus, irrigate fully and weed comprehensively to maximize the seedling growth rates. After October, all management measures to facilitate the seedling growth should be stopped except to promote the lignification and prevent frostbite as the seedling growth is stepping into the sclerosis period.

5. CONCLUSIONS

The dynamic height growths of one-year old *Ormosia* seedlings presented a slow-fast-slow trend that fit a “S” growth curve by the logistic mathematical model (highly significant fitting level ranged from 0.820 to 0.994). Five stages were broadly divided: emergence stage (from Apr. to May.), early growth stage (Jun.), fast-growing stage (from Jul. to Oct.), late growth stage (from Nov. to Dec.) and stagnation stage (after Jan.). From the growth of the first year, *O. xylocarpa* seedlings of Liping provenance, *O. hosiei* seedlings of Jiujiang provenance and *O. henryi* of Longquan provenance are the most suitable to be cultivated in Nanchang, Jiangxi by artificial afforestation. However, the growth of seedlings will be affected by many factors, such as water and fertilizer management, need to be further studied in the future.

6. ACKNOWLEDGMENTS

This study was supported by the Key Research Program of Jiangxi Academy of Forestry Sciences (2017511201) and the Key Research and Development Program of Jiangxi province (20161BBH80065). Thanks are due to Shaoping Hu for wholeheartedly aids in investigation process, to Jinshan Ye for valuable help of collecting data, to Huamei Lin for assistance with the nursery management and to Professor Shengquan Que for protection from diseases and insect pests.

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