The Influences of Planting Density to Aboveground Biomass Distribution of Hybrid Larch

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Abstract: Forest biomass, carbon storage and distribution pattern were the important research content for the forest carbon cycle and terrestrial ecosystems model.Biomass, carbon storage and components distribution were mensurated used by diameter class standards in 4 planting density (2500 N hm^{-2}、3300 N hm^{-2}、4400 N hm^{-2}、6600 N hm^{-2}) of hybrid larch at 11age.The results show that , the order of the biomass and carbon storage of each components was trunk> branch> bark> leaf, stem biomass ratio of total biomass growing by the planting density growing. There was no significant differences among the single components biomass under 4 planting densities. The components biomass were obtained by diameter class measure, the trend was decreased along with the planting density growing, and there was significant differences between components biomass. The components allometric equation of hybrid larch were established with components biomass of 32 different diameters standard wood, and the accuracy were more than 90%. The average carbon storage of hybrid larch each component were 14.00 tC hm^{-2}， 2.43tC hm^{-2}， 5.80tC hm^{-2}， 2.02tC hm^{-2}, and the total aboveground carbon storage was 24.25tC hm^{-2}, the carbon storage of hybrid larch each component were all increased along with planting density decreasing, and there was significant differences between them. This is the first study about the biomass and carbon storage , and bring forward the components allometric equation of hybrid larch in different density, which provides a theoretical basis for the research on the Biomass and carbon storage of hybrid larch in the future.
[Sun Nan, Li Yazhou, Li Meng. The Influences of Planting Density to Aboveground Biomass Distribution of Hybrid Larch. World Rural Observations 2012;4(1):39-44]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). http://www.sciencepub.net/rural. 7

Key words: Hybrid Larch;Carbon Allocation;Carbon Storage;Biomass

Introduction

The forest area accounts for about one thirds of the land area, but it contains 80% of the Ground carbon pool and 40% of the underground carbon pool in the land ecological system, the carbon content is up to 638Gt(1Gt=1 × 109 t), and the biomass carbon is about 283Gt [1]. The research shows that, the forest in the northern Hemisphere has very high holding capacity for carbon fixation[2-4], and plays an important role in fixing in carbon dioxide of the atmosphere and slowing climate warming[5-6].

Forest biomass and distribution pattern were affected by the vegetation composition, forest age, site conditions, plantation characteristic factors effect . The research of carbon allocation of the three kinds of Larix gmelini found that, the percentage of DuXiang- Larix gmelini vegetation to total carbon of ecological system was 13.5%, but the percentage of Cuckoo- Larix gmelini was 63.1%[7]. The total carbon density increase along with forest age even if the similar forest type. The carbon of young forest mainly was soil and clastic carbon library(85-99%), and the older, the carbon mainly was vegetation carbon library (54 – 64%)[8-11], the proportion of the same age northern black spruce in drainage good stand conditions was significantly higher than the drainage bad,but the proportion of soil carbon library was significantly lower [12]. Recent Zhu etc [13] reported that. The total carbon density, vegetation carbon density and its distribution of temperate virgin forest in Changbai mountain were all reduced along with the altitude decreases (700 - 2000m). In addition, the studies have pointed out that the carbon density of young forest of pinus contorta was increases along with stand density[9,14]. Thus it can be seen that, forest carbon density and carbon pattern of distribution was significant different because of regional, forest types and different characteristics, so forest carbon cycle, temporal and spatial variation were made complicated[15-17]. In addition, the uncertainty of the prediction of regional carbon source pattern model and the understanding of driving mechanism were enlarged because of the lack of the related research of stand structure and interference history[18-19].

Based on four different afforestation density of Hybrid Larch, Improve the accuracy of estimates and model simulation of the biomass and carbon reserves of Hybrid Larch by analysising the biomass and its allocation rules of the Hybrid Larch, establishing the allometric equation of Hybrid Larch.

1 Materials and methods

1.1 Regional situation

The experiment was created in 1998 in Jiangshanjiao forest farm, Mudanjiang city of Heilongiang province, Northeastern China, Located in 43°44′54″ N，128°53′16″ E，the altitude is 400 ~ 800m, which is belong to Changbai Mountain of Zhangguangcailing, The topography fluctuation is not obvious, and it is a temperate continental monsoon climate, the average annual temperature is -1.4 ℃. The Annual rainfall is concentrated in June to August about 550mm, and the frost-free period is 120 days to 140 days. Due to the development of longer, the original Korean pine forest vegetation is destroyed seriously, and the existing stand are secondary oak forest, Oak birch, Poplar-birch forest and hard broadly mixed forests。The soil is the typical dark brown soil, which is the cultivation base for the timber forest as the high nutrient content and the good permeability of the soil.

The samples were setted in 4 kinds of planting density(2500 tree/hm^2, 3300 tree/hm^2, 4400 tree/hm^2, 6600 tree/hm^2) which were created in 1998 with two years old Ⅰlevel seeding of Hybrid Larch of Qingshan forest farm, the area was about 12hm^2, and the statistical features of the sample data was shown in table 1.

Table 1 The basic characteristics of hybrid larch

planting densities/N hm^{-2}	Survival rate/%	Existing rate/%	Existing number /N hm^{-2}	DBH/cm	H/m	HT/m
2500	92.71	92.58	2315 (672)	10.3 (2.6)	8.32(0.75)	9.68(0.66)
3300	89.32	75.82	2502 (332)	9.8 (2.5)	8.18(0.70)	9.69(0.66)
4400	92.91	69.08	3038 (521)	9.1 (2.6)	8.3 (0.49)	9.7 (0.69)
6600	92.39	55.52	3667 (625)	8.3 (2.6)	8.24(0.95)	9.75(0.93)

*Value for the standard deviation in brackets（n=12）

1.2 Experimental Design

Determination of biomass: In four kinds afforestation densities of hybrid larch larch, setting 12 standard area in every density, and examing every wood in it. The diameter was in order of 2-16cm and divided into 8 diameter class, in which fell 1 standard wood and the total was 32. Determinationed the fresh weight of the standard wooden trunk, bark, branches, leaves of the standard wood, selected some and dryed at 65 ℃ to constant weight, calculated the dry weight of each componen and the plant biomass, getted each componen percentage of plant biomass using 1m section" stratified cutting method". Obtained each componen biomass of the stand according to each componen biomass of the standard wood and the DBH of the stand.

Determination of the biomass carbon: Estimated the aboveground biomass of the hybrid larch using allometric equation which was setted in this research. Calculated the biomass carbon of the hybrid larch using the carbon rate of larch (the leaves, branches, the trunk 0.492 0.504 0.467, an average of 0.469) [20].

1.3 Data Analysis

Set allometric equation: Setted the components allometric equation of hybrid larch in different density using standard wood trunk, bark, branch and leaf biomass and D (diameter at breast height), and diameter at breast height-tree height (D^{2}H) making a correlation analysis, and tested them by the total relative error (RS), average system error (E) and relative error of absolute value (RMA) and average prediction accuracy (P), the computation formula is:

$$RS = \frac{\sum wi - \sum wi'}{\sum wi'} \times 100\%$$

$$E = \frac{\sum \frac{wi - wi'}{wi'}}{n} \times 100\%$$

$$RMA = \frac{\sum \left| \frac{wi - wi'}{wi'} \right|}{n} \times 100\%$$

$$P = 1 - \frac{ta \cdot \sqrt{\sum (wi - wi')^2}}{\overline{w} \cdot \sqrt{n(n-T)}} \times 100\%$$

Where wi is the measured values, wi' is the estimated value, n is the number of samples, T is the parameter's number of the regression model, ta is the critical value when the confidence level a is 0.05.

Established the allometric equation by nonlinear regression of the SPSS15.0 statistical analysis software and examined the effect of afforestation density on the components of biomass and distribution pattern of the Hybrid Larch.

2. Results and Analysis

2.1 The influence of planting density to forestry measurement factors

The average DBH of 2500 N hm^{-2}, 3300 N hm^{-2}, 4400 N hm^{-2}, 6600 N hm^{-2} is 10.0cm, 9.5 cm, 8.7 cm , 7.9 cm, the effect of afforestation density on the average DBH is very distinct ($F_{3,48}$=24.6，P < 0.001) and no significant effect to the basal area（P>0.05）, the basal area of the four afforestation densities is 19.4 m hm^{-2}、18.8 m hm^{-2} 、19.64 m hm^{-2}、19.87 m hm^{-2} (Figure 1).

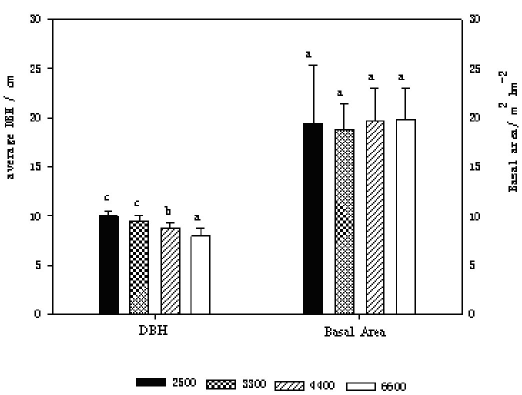

Fig.1 The influence of planting density to forestry measurement factors

2.2The influence of planting density to aboveground biomass

No difference of afforestation density on biomass of hybrid larch was proved by variance analysis (P > 0.05), the biomass of the leaf, the bark, the branches, the trunks and the total aboveground of the four kinds of planting density of Hybrid Larch was fluctuations in 11.23～12.00 t hm^{-2}、5.05～5.25 t hm^{-2}、11.23～12.00 t hm^{-2} 、29.31～30.53 t hm^{-2} and 50.40～52.67 t hm^{-2} respectively (Figure 2).

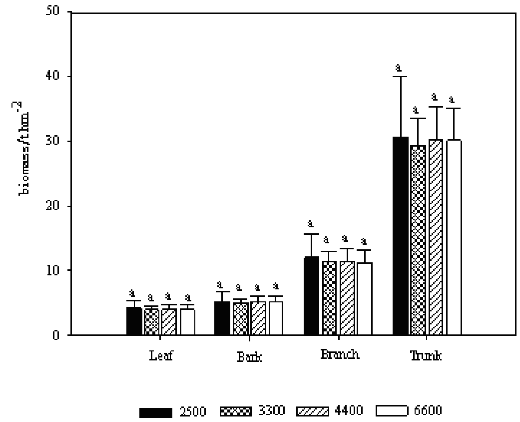

Fig. 2 The influence of planting density to aboveground biomass

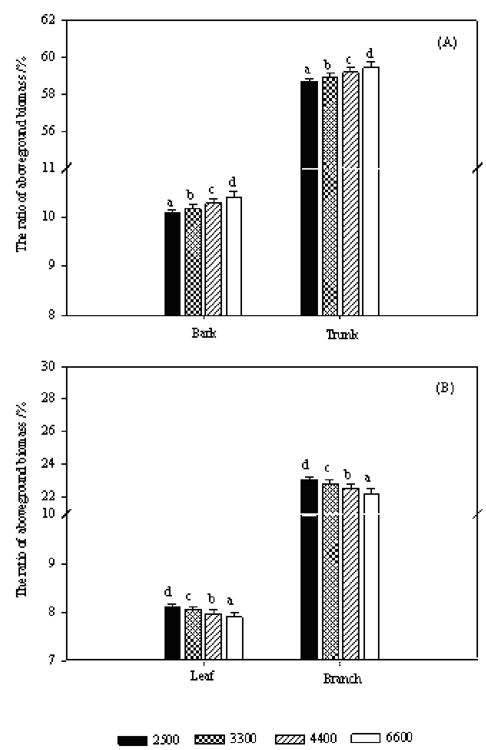

Fig. 3 The influence of planting density to aboveground biomass allocation

2.3 The influence of planting density to aboveground biomass allocation

The percentage of the leaves, the bark, the branches, the trunk to total biomass aboveground of the four kinds of afforestation densities of Hybrid Larch fluctuated 7.90～8.12%、10.08～

10.41%、22.22～23.07%、and 58.73～59.48%. The proportion of the bark and the trunk of 2500 N hm^{-2} to total biomass aboveground was the minimum, and the branches and the leaves' was the maximum. The proportion of the bark and the trunk of 6600 N hm^{-2} to total biomass aboveground was the maximum, and the branches and the leaves' was the minimum. So the proportion of the bark and the trunk increased according to the afforestation densities, the branches and the leaves were just the opposite (Figure 3). The differences of afforestation density on the allocation pattern of forest biomass aboveground was significant by variance analysis（$F_{3,47} = 26$, $P < 0.001$）.

2.4 Allometric equation of hybrid larch

The correlation coefficient of two kinds of mathematical models were more than 0.97, and the F were more than $F_{0.05}(1,31)$ or $F_{0.01}(1,31)$,it can be showed that forest components (D, D^2H) were significantly related to the corresponding components of biomass. The precision of the two regression equations on estimating single wood biomass of hybrid larch was accurate because the standard error is less than 0.40, that can be gained from the significant inspection. The various components of the Hybrid Larch biomass (W) were significantly related to diameter(D) and diameter - height (D^2H), especially the correlation coefficient of the regression equation of the total biomass aboveground was more than 0.99 (table 2), and it has high practical value.

Tab2 Allometry equation and inspection parameters of Components

Components	a	b	R	F	SE	RS	E	RMA	P
$\ln W = a' + b \ln D$									
Trunk	-2.642	2.23	0.992	1901.9	0.185	0.59%	1.62%	13.01%	94.66%
Bark	-4.141	2.12	0.991	1585.9	0.193	0.10%	1.40%	14.33%	93.51%
Branch	-4.288	2.526	0.985	1004.5	0.288	4.60%	4.00%	22.05%	90.59%
Leaf	-5.192	2.468	0.977	643.0	0.352	1.49%	5.07%	25.80%	90.94%
Total	-2.260	2.298	0.994	2407.6	0.170	0.42%	1.26%	12.50%	95.07%
$\ln W = a' + b \ln(D^2H)$									
Trunk	-3.705	0.921	0.996	3419.6	0.138	0.91%	0.94%	9.76%	94.81%
Bark	-5.153	0.875	0.994	2612.5	0.151	0.70%	0.99%	11.58%	93.18%
Branch	-5.441	1.034	0.981	761.2	0.330	6.90%	5.42%	26.64%	87.01%
Leaf	-6.358	1.017	0.979	702.2	0.338	2.63%	4.78%	24.98%	89.70%
Total	-3.344	0.947	0.995	3135.2	0.149	1.16%	0.81%	12.47%	93.47%

The total relative error of the various components of Hybrid Larch were all within 2%, except the model of the branch, whose total relative error was slightly higher than 4% in the $\ln W = a' + b \ln D$. The prediction accuracy of the trunk and bark were all more than 93%, the branch and leaf were also more than 90% even though the RMA were bigger. In general, the accuracy of this model was higher. The total relative error of the various components of Hybrid Larch were all within 3%, except the model of the branch was 6.90% in the $\ln W = a' + b \ln(D^2H)$, the RMA of the branch and the leaf were bigger, but the prediction accuracy of the various components were more than 85% (table 2).

2.5The influence of planting density to carbon storage

The orders of carbon storage of the various components of Hybrid Larch were as follows: trunk> branch > bark > leaf, the same as the biomass, the average carbon storage of the various components were14.00tC hm^{-2}, 2.43tC hm^{-2}, 5.80tC hm^{-2}, 2.02tC hm^{-2}, and the total carbon storage aboveground was 24.25tC hm^{-2} (Figure 4) , The differences of afforestation density on the total carbon storage, the trunk carbon storage, the bark carbon storage, the branch carbon storage and the leaf carbon storage were significant by variance analysis ($F_{3,5533}$=230.868, $F_{3,5533}$=182.159, $F_{3,5533}$=259.447, $F_{3,5533}$=322.005, $F_{3,5533}$=454.680, $P < 0.001$). The total carbon storage, the branch carbon storage and the leaf carbon storage increased according to afforestation densities decrease, The total carbon storage, the branch carbon storage, the leaf carbon storage and the bark carbon storage of 2500 N hm^{-2} were 25.63 tC hm^{-2}, 6.28 tC hm^{-2}, 2.48 tC hm^{-2} and 2.64 tC hm^{-2}, all the biggest of the four afforestation densities, and the biggest carbon storage of the trunk was 4400 N hm^{-2}（14.52 tC hm^{-2}）, The total carbon storage, the branch carbon storage and the leaf carbon storage of 6600 N hm^{-2} were 23.17 tC hm^{-2}, 5.00 tC hm^{-2} and 1.78 tC hm^{-2}, all the smallest of the four afforestation densities. The smallest carbon storage of the trunk was 3300 N hm^{-2}（13.36 tC hm^{-2}）, and the smallest carbon storage of the bark was 4400 N hm^{-2}（2.26 tC hm^{-2}）(Fig. 4).

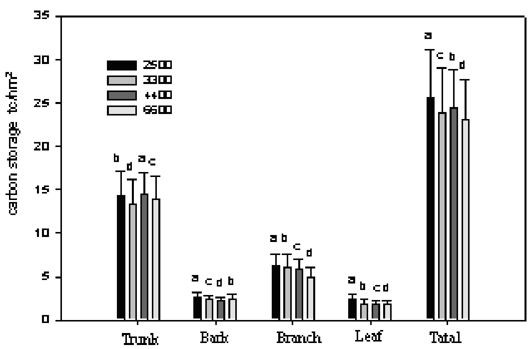

Fig4 Carbon storage of components in different density of hybrid larch

3 Conclusion and Discussion

There were significant difference among different afforestation densities of Hybrid Larch even though the age was small (age 12 years). Afforestation densities was the important factor for wood species and material productivity because the diameter growth increased according to afforestation densities decrease.

There were not significant difference for biomass aboveground and significant difference for the allocation pattern of the biomass aboveground of Hybrid Larch among different afforestation densities. The percentage of the bark and the trunk to the biomass aboveground increased according to afforestation densities increase, and the percentage of the branch and the leaves increased according to afforestation densities decrease[21]. The percentage of the bark, the trunk , the branches and the leaves of the maximum afforestation densities were 1.20 times, 1.09 times, 0.83 times and 0.79 times more than the minimum, so increasing stand density moderately is favorable to improve dry biomass.

Density control is the important technical control measures for forest cultivation, sometimes Hybrid Larch artificial stand grew malnutrition just because of failed to control reasonable on time to stand densities of Hybrid Larch in the production practice, so density control reasonable is the important technology link to cultivating big diameter material, to improve stand quality, production, and to increase stand carbon storage.

Acknowledgements

This study was financed by the project for Technical plan of Heilongjiang province of China,No.GA09B202-02, "Study on the improved variety and directed breeding technology of the high quality wood construction material forest".

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1/22/2012