Analysis of Climatic Factors Influencing Walnut Distribution in the Main Producing Areas of Yunnan Province

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Abstract　Using the data of 11 climatic factors on 40 counties in the main producing areas of walnut of Yunnan Province，we analyze the impact of various climatic factors on the distribution of Yunnan walnut. The results show that Yunnan walnut has a great expectation on temperature and moisture. Temperature，including average temperature in January，average temperature in July，the average annual temperature and accumulated temperature≥10 ℃，has the greatest impact on the distribution of Yunnan walnut，and is the primary dominant factor；moisture，including annual rainfall and average relative humidity，has a great impact on the distribution of Yunnan walnut，and is the secondary dominant factor.
Key words　Yunnan walnut，Climatic conditions，Major influencing factors

Walnut has a long history of cultivation in Yunnan Province，and Yunnan walnut ranks first in China in terms of both yield and quality[1]. Yunnan as a major producer of Chinese walnut now has a production area of walnut of 1. 22 million hm², with the output reaching 0. 3 million t and output value reaching about 6 billion yuan[2]. Yunnan walnut is large in the size and thin in its shell，with high kernel yield and oil content. It has good quality，good taste and rich nutrient，so it is deeply favored by domestic and foreign consumers and the products are competitive. Yunnan has unique natural conditions for planting walnut，world-class variety resources，long history of cultivation，and good industrial and technological base，so Yunnan walnut has a pivotal position in the world walnut industry[3]. The walnut tree requires not much on environment，so its geographical distribution is wide，but the suitable habitat conditions can help obtain high yield walnuts. Therefore，this study analyzes the climatic factors influencing the main producing areas of walnut in Yunnan Province，to determine the climatic factors most suitable for the growth of Yunnan walnut，in order to provide a scientific basis for the reasonable zoning and planting of Yunnan walnut.

1　Research methods

1. 1　Data collection　In order to survey the walnut production and area in the prefectures and cities of Yunnan Province，we select the regions with the walnut annual output of over 20 000 t（including Dali，Chuxiong，Lincang，Baoshan and Nujiang）as the analysis samples for the main producing areas of walnut in Yunnan Province. Through the relevant meteorological data from the local Forestry Bureau and Bureau of Meteorology，we collect 30 years of

meteorological data in 40 main producing counties，including the average temperature in January，the average temperature in July，the average annual temperature，extremely low temperature，extremely high temperature，accumulated temperature ≥10 ℃，annual rainfall，the annual sunshine hours，evaporation，average relative humidity and frost-free period[4].

1. 2　Statistical analysis method　Using statistical analysis software SPSS18. 0，we carry out principal component analysis of 11 meteorological factors，to determine the main meteorological factors influencing the distribution of Yunnan walnut. Determination of the optimal distribution range：FWHM formula（ $PWH_i = 2. 354S_i$ ）is used to calculate the optimum range，namely the upper limit of the optimum range is $X_i + 0. 5 \, PWH_i$，and the lower limit of the optimum range is $X_i − 0. 5PWH_i$，where X_i is the average value of index i，and S_i is the standard deviation of index i[5].

2　Results and analysis

2. 1　Climatic factors in the main producing areas of Yunnan walnut　According to the light，heat，water and air needed by the plant growth，we select 11 main meteorological factors which can represent local climatic features in the main producing areas of walnut，and collect the data. And the results are shown in Table 1.

2. 1　The relationship between Yunnan walnut distribution and climate

2. 1. 1　Temperature. The heat indicators for Yunnan walnut distribution include average temperature in January，average temperature in July，the average annual temperature，extremely low temperature，extremely high temperature，and accumulated temperature≥10 ℃. As can be seen from Table 2，the optimum heat conditions for Yunnan walnut distribution are：average temperature in January（9. 195 ℃），and the optimum range（6. 230 ℃ − 12. 160 ℃）；the average temperature in July（21. 428 ℃），and the optimum range（19. 089 ℃ − 23. 766 ℃）；the average annual temperature（16. 36 0 ℃），and the optimum range（13. 604 ℃ − 19.

116 ℃); accumulated temperature≥10 ℃ (5360.760 ℃), and   the optimum range (3967.319 ℃ - 6754.201 ℃).

Table 1   11 main climatic factors in the main producing areas of Yunnan walnut

Counties (districts)	The average temperature // ℃			Extremely low tempera-ture // ℃	Extremely high tempera-ture // ℃	Accumulated temperature ≥10 ℃	Annual rainfall mm	The annual sunshine hours // h	The annual evaporation mm	The annual average relative humidity %	Frost-free period // d
	January	July	Whole year								
Yongren	10.0	22.9	17.7	-4.4	37.7	5 919.1	839.8	2 803.7	2 689.4	64.0	48.2
Dayao	8.9	20.5	15.7	-6.1	33.0	4 860.5	795.7	2 499.5	2 682.1	64.0	62.7
Yuanmou	14.9	26.3	21.7	-0.8	42.0	7 986.0	630.2	2 630.3	3 510.3	55.0	1.0
Yaoan	8.0	20.5	15.3	-8.4	34.0	4 790.5	770.3	2 445.2	2 450.6	68.0	71.0
Mouding	8.4	20.9	15.7	-7.3	34.3	4 921.4	851.7	2 447.8	2 039.6	70.0	74.0
Nanhua	7.6	20.2	14.9	-8.4	33.3	4 590.2	822.6	2 410.9	1 926.8	73.0	77.4
Chuxiong	8.3	20.8	15.7	-4.8	33.0	4 941.2	829.4	2 351.2	2 031.1	71.0	63.7
Wuding	7.2	20.7	15.1	-6.4	33.9	4 703.7	987.7	2 312.4	2 072.7	75.0	67.5
Lufeng	8.2	21.6	16.1	-5.5	34.2	5 214.0	908.1	2 232.1	1 959.4	75.0	56.6
Shuangbo	8.8	19.2	15.0	-4.4	31.0	4 624.3	917.1	2 390.0	1 979.1	72.0	29.4
Zhenkang	11.7	23.0	18.8	-2.1	36.3	6 870.2	1584.7	1 913.6	1 565.5	81.0	13.9
Fengqing	10.4	20.8	16.6	-0.9	32.7	5 604.2	1329.0	2 073.0	1 874.9	73.0	16.8
Yongde	11.9	20.4	17.4	0.0	32.1	6 216.0	1283.3	2 224.8	1 882.8	69.0	13.5
Yunxian	12.5	23.8	19.5	-1.3	37.7	7 109.0	906.4	2 212.0	2 302.2	73.0	2.7
Cangyuan	10.8	21.4	17.4	-4.3	34.4	6 126.2	1772.3	1 901.0	1 625.6	82.0	11.3
Mengding	14.5	25.6	21.7	2.2	41.2	7 848.0	1530.4	2 140.5	1 626.3	80.0	0.0
Gengma	11.6	23.1	18.8	-3.2	36.6	6 723.3	1331.8	2 161.0	1 607.7	78.0	17.5
Shuangjiang	12.7	23.8	19.6	-2.1	37.4	7 135.0	1012.9	2 230.3	2 282.5	75.0	13.1
Lincang	10.9	21.3	17.3	-1.3	34.1	6 063.3	1170.5	2 118.2	1 676.3	73.0	38.3
Jianchuan	4.6	18.9	12.4	-10.7	33.5	3472.8	755.3	2 399.9	2 022.2	70.0	112.1
Eryuan	6.8	20.0	14.0	-8.1	31.8	4 104.0	748.0	2 431.3	1 947.9	69.0	102.9
Heqing	6.5	19.2	13.6	-11.4	33.4	4 029.3	960.7	2 310.8	2 026.2	65.0	99.3
Yunlong	6.6	20.9	14.6	-8.5	34.9	3 941.2	819.2	1 975.5	1 756.9	71.0	105.5
Yangbi	8.8	21.4	16.2	-2.8	34.6	5 245.7	1 033.4	2 222.5	1 752.8	72.0	70.2
Yongping	8.1	21.4	15.8	-4.4	33.8	5 085.4	966.0	2 133.3	1 679.8	75.0	72.8
Dali	8.2	20.0	14.8	-4.2	31.9	4 671.8	1 062.4	2 285.1	1 976.6	69.0	72.5
Binchuan	9.6	23.7	18.0	-6.4	38.2	5 918.1	568.3	2 706.3	2 544.5	63.0	73.9
Midu	8.9	21.5	16.3	-6.8	34.5	5 174.6	748.4	2 570.1	2 131.9	69.0	54.4
Xiangyun	8.1	19.7	14.7	-6.5	31.9	4 473.0	797.4	2 577.1	2 406.8	68.0	52.0
Weishan	8.1	21.2	15.7	-4.6	33.5	4 862.7	796.1	2 284.7	2 049.0	70.0	75.4
Nanjian	12.2	23.9	19.1	-1.1	35.6	6 783.7	707.2	2 459.9	2 968.0	63.0	28.3
Tengchong	7.8	19.5	14.9	-4.2	30.5	4 639.7	1 477.9	2 080.6	1 589.7	79.0	82.9
Baoshan	8.1	20.8	15.5	-3.8	32.3	4 904.1	967.1	2 362.9	1 619.4	75.0	90.0
Longling	7.4	19.8	14.9	-4.8	30.7	4 690.8	2 105.7	2 063.9	1 460.3	85.0	67.0
Changning	7.3	20.4	14.9	-5.1	31.6	4 649.9	1 233.0	2 223.4	1 684.2	81.0	56.2
Longyang	13.9	26.3	21.3	0.2	40.3	7 775.0	774.0	2 329.7	2 039.8	71.0	8.4
Gongshan	7.5	21.2	14.5	-2.5	35.7	4 343.0	1 724.8	1 299.6	1 255.4	78.0	65.0
Fugong	9.6	23.4	16.9	-2.8	37.1	5 484.9	1 433.5	1 371.5	1 232.4	80.0	51.8
Lanping	3.2	17.8	11.2	-10.2	31.7	3 198.7	1 003.2	2 008.4	1 592.1	74.0	115.1
Lushui	9.2	19.3	15.1	-0.5	32.5	4 735.9	1 213.9	2 063.9	1 635.9	70.0	44.8

2.1.2   Moisture and humidity. The moisture and humidity indicators for Yunnan walnut distribution include annual rainfall, annual evaporation, and annual average relative humidity. As can be seen from Table 2, the optimum moisture conditions for Yunnan walnut distribution are: annual rainfall (1054.235 mm), and the optimum range (645.998 - 1462.472 mm); annual evaporation (1978.918 mm), and the optimal range (1441.058 - 2516.777 mm); annual average relative humidity (72.2 00 %), and the optimal range (65.032% - 79.368%).

2.1.3   Light conditions. The main light indicator for Yunnan walnut distribution is the annual sunshine hours. The average val-

ue is 2241.448 h, and the optimum range is 1893.014 - 2589.881 h.

2.2   The major climatic factors influencing Yunnan walnut distribution   We carry out principal component analysis of the 11 climatic factors influencing the main producing areas of walnut in Yunnan Province, and the results are shown in Table 3 and Table 4.

As can be seen from Table 3, the contribution rate of the first principal component and the second principal component is 54.723%, 30.616%, respectively. The cumulative contribution rate of the first two principal components reaches 85.339%, fully reflecting the main information of various climatic factors influen-

cing walnut distribution, so we choose the first two principal components for analysis. As can be seen from Table 4, in the first principal component, average temperature in January, average temperature in July, the average annual temperature and accumulated temperature ≥ 10 ℃, have large load value, so the first prin-

cipal component mainly reflects the temperature conditions; in the second principal component, annual rainfall, and annual average relative humidity have large load value, indicating that the second principal component mainly reflects the moisture conditions.

Table 2　The range of climate indicators on the main producing areas of Yunnan walnut

Indicators	Mean	Standard deviation	FWHM	Optimum range	
				Lower limit	Upper limit
Average temperature in January // ℃	9.195	2.519	2.965	6.230	12.160
Average temperature in July // ℃	21.428	1.987	2.338	19.089	23.766
The average annual temperature // ℃	16.360	2.342	2.756	13.604	19.116
Extremely low temperature // ℃	−4.468	3.170	3.731	−8.199	−0.736
Extremely high temperature // ℃	34.473	2.786	3.279	31.193	37.752
Accumulated temperature ≥ 10 ℃ // ℃	5360.760	1183.892	1393.441	3967.319	6754.201
Annual rainfall // mm	1054.235	346.845	408.237	645.998	1462.472
Annual sunshine hours // h	2241.448	296.035	348.434	1893.014	2589.881
Annual evaporation // mm	1978.918	456.975	537.860	1441.058	2516.777
Average annual relative humidity // %	72.200	6.090	7.168	65.032	79.368
Frost days // d	55.874	32.646	38.424	17.450	94.299

Table 3　The principal component contribution rate of climatic factors influencing the main producing areas of walnut

Principal component	Eigenvalue	Contribution rate // %	Cumulative contribution rate // %
1	6.020	54.723	54.723
2	3.368	30.616	85.339
3	0.701	6.375	91.715
4	0.356	3.239	94.953
5	0.238	2.164	97.117
6	0.143	1.304	98.421
7	0.089	0.805	99.226
8	0.057	0.522	99.748
9	0.016	0.147	99.894
10	0.010	0.089	99.984
11	0.002	0.016	100.000

It can be concluded that the main climatic factors influencing Yunnan walnut distribution are temperature and moisture, and temperature has a greater impact on Yunnan walnut distribution than moisture.

Table 4　The load of principal component of climatic factors

Climatic factors	The first principal component	The second principal component
Average temperature in January	0.978	0.069
Average temperature in July	0.930	−0.040
The average annual temperature	0.991	0.024
Extremely low temperature	0.784	0.402
Extremely high temperature	0.828	−0.112
Accumulated temperature ≥ 10 ℃	0.985	0.069
Annual rainfall	0.004	0.916
Annual sunshine hours	0.105	−0.861
Annual evaporation	0.387	−0.854
Average annual relative humidity	−0.149	0.903
Frost days	−0.874	−0.236

3　Conclusions and discussions

The optimum range of climatic factors influencing the main producing areas of Yunnan walnut is as follows: the average annual temperature (13.604 ℃ – 19.116 ℃); average temperature in January (6.230 ℃ – 12.160 ℃); average temperature in July (19.089 ℃ – 23.766 ℃); accumulated temperature ≥ 10 ℃ (3967.319 ℃ – 6754.201 ℃); annual rainfall (645.998 – 1462.472 mm); annual average relative humidity (65.032% – 79.368%). Walnut has high requirements on heat and moisture, which is consistent with the findings of He Chunyan[6] and Han Huabai[7]. Principal component analysis shows that temperature (including average temperature in January, average temperature in July, the average annual temperature, accumulated temperature ≥ 10 ℃) has the greatest impact on Yunnan walnut distribution, which is the primary dominant factor; moisture (including annual rainfall and annual average relative humidity) has a great impact on Yunnan walnut distribution, which is the secondary dominant factor. The topography and climatic conditions are complex and diverse in Yunnan Province. As a main producing province of walnut, Yunnan should carry out scientific and rational evaluation of the main factors affecting the distribution of walnut in the production, to efficiently develop Yunnan walnut industry.

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