

A STUDY ON THE ECOLOGICAL CLIMATES OF SOME FAMOUS TEA GROWING AREAS IN HIGH MOUNTAINOUS REGIONS OF CHINA

Huang Shoubo (黄寿波)

(*Zhejiang Agricultural University, Hangzhou 310029, PRC*)

ABSTRACT: The tea tree [*Camellia sinensis* (L) Kuntze] is one of the world's economic crops. It is an especially important crop for southern China. Environmental factors related to the tea yield and quality in some high mountain areas of China are identified in this paper. These factors are: geology, topography, climate, hydrology, soil and vegetation. Climatological factors are the most important. Using data collected from meteorological stations which are situated at the summit and the base of high mountains, this paper discusses ecological climatic problems in growing tea in China. The ecological climatic characteristics of the famous tea areas mainly included are as follows: more amounts of clouds and fog, less percentage of sunshine, abundant rainfall and high relative humidity in the air, temperatures that rise and fall slowly, daily and annual temperature ranges that are smaller, more days that are suitable for tea growing and low wind speeds in the lee-sides and valleys of mountains. All of these factors are favorable for growth of tea trees.

KEY WORDS: the famous tea growing areas, high mountains, ecological climate

China is the origin of tea plants^[1] and has a history of 3,000 years in cultivation of them^[2]. Distribution regions of tea plants have been expanded to 946 counties in 19 provinces of China. At present, the tea plant in China is being distributed from 94° E longitude in Milin of the Xizang Autonomous Region to 122° E longitude on the east coast of Taiwan Province, covering a total of 28° longitude. In the broad areas from 18° N latitude (Hainan Island) to 37° N latitude (Rongcheng County in Shandong Province) covering 19° latitudes, the tea plant is extensively distributed. According to the statistics of 1985, there have been 458.14 million kg in the yield of tea made in China. The tea output of China is the second largest in the world^[3].

I. CLIMATIC CHARACTERISTICS OF SOME FAMOUS TEA GROWING AREAS IN HIGH MOUNTAINOUS REGIONS

The locations, altitudes, and ecological climatic characteristics of the most famous tea growing in high mountainous areas in China are on Table 1 as follows:

Table 1 The location and altitude of famous tea growing in some high mountainous areas in southern China

Name of province	Name of mountain	Name of station	Latitude	Longitude	Mountain elev.(m)	Garden elev.(m)	Name of the famous tea produced
Zhejiang	Tianmu	Changhua	30° 11'	119° 13'	168.5	500—900	Tianmu Qingding Tea
		Tianmushan	30° 21'	119° 25'	1496.9		
Zhejiang	Guancang	Xianju	28° 52'	120° 44'	50.0	600—900	Huading Yunwu Tea Yandang Baiyun Tea
		Guancangshan	28° 49'	120° 55'	1373.9		
Anhui	Huangshan	Tunxi	29° 43'	118° 17'	146.7	800—1000	Huangshan Maofeng Tea
		Huangshan	30° 08'	118° 09'	1840.8		
Fujian	Jiuxian	Yongchan	25° 20'	118° 16'	188.0	700—1000	Anxi Tieguanyin Tea
		Jiuxianshan	25° 43'	118° 06'	1650.0		
Jiangxi	Lushan	Jiujiang	29° 45'	115° 55'	32.2	500—1000	Lushan Yunwu Tea
		Lushan	29° 35'	115° 59'	1164.0		
Hunan	Hengshan	Hengyang	26° 56'	112° 30'	103.0	600—1000	Anhua Songzhen Tea
		Hengshan	27° 15'	112° 45'	1265.9		
Hubei	Wufeng	Enshi	30° 16'	109° 22'	437.2	400—800	Enshi Yulu Tea
		Wufeng	30° 10'	110° 37'	908.4		
Sichuan	Emei	Emei	29° 36'	103° 30'	447.3	700—1500	Emei Erui Tea
		Emeishan	29° 31'	103° 21'	3047.4		

1. Abundant Rainfall and High Relative Humidity in the Air

The original areas of tea plants are those in the Yunnan—Guizhou Plateau and areas that are adjacent to the mountains^[1]. Tea grows well in the warm and humid climate^[4,5,6]. During the period of growth of the new shoots, abundant rainfall, intermittent fair and cloud weather, or sunshine by day and rain by night, along with high humidity help the tea leaves to remain tender, have more contents and better quality^[7]. Test results showed that after sprinkler irrigation in tea plantations during midsummer the soil and air temperature were reduced while the soil moisture and atmospheric humidity were both increased, the tea quality was improved.

When we compare famous teas growing in high mountainous areas of China with tea plantations at the base of the mountains, we see that the precipitations and rainy days from April to September (the period for picking tea leaves) or for all year are greater in the high-

er areas. For example, annual precipitations increased by 200–800mm, annual rainy days increased by 20–70 days (Table 2).

Table 2 The precipitations and rainy days in some meteorological stations in southern China

Name of mountain	Name of station	Annual precipitation (mm)							Annual rainy days
		Apr.	May	June	July	Aug.	Sept.	Year	
Tianmu	Changhua	147.2	196.8	214.8	139.2	165.2	139.7	1417.7	159.2
	Tianmushsn	157.4	224.2	217.5	160.9	223.9	204.1	1653.2	184.0
Guacang	Xianju	129.0	193.9	238.9	113.5	117.8	154.2	1339.9	160.3
	Guacangshan	158.2	258.3	283.2	176.0	281.7	382.5	2178.6	194.1
Huangshan	Tunxi	207.5	272.4	297.9	154.4	111.7	103.7	1642.8	155.2
	Huangshan	246.8	347.6	353.4	294.3	281.7	200.6	2339.4	181.9
Jiuxian	Yongchun	122.5	244.4	318.2	238.9	257.1	165.3	1685.5	152.9
	Jiuxianshan	143.6	246.7	303.2	168.7	253.5	225.8	1822.1	204.6
Lushan	Jiuijiang	168.7	217.9	233.9	132.8	109.5	70.5	1396.8	142.9
	Lushan	211.2	287.3	286.1	187.7	177.2	153.0	1833.6	166.8
Hengshan	Hengyang	181.8	234.1	154.1	89.7	100.4	47.6	1353.0	153.8
	Hengshan	233.9	404.2	264.5	168.7	172.5	172.3	2231.9	182.1
Wufeng	Enshi	115.9	187.3	185.6	234.2	178.9	156.4	1424.8	164.8
	Wufeng	140.5	187.4	195.1	265.9	204.4	129.1	1460.8	165.6
Emei	Emei	92.9	140.3	164.5	364.1	450.8	164.1	1593.8	187.2
	Emeishan	114.8	179.7	241.0	412.6	486.7	239.6	1958.9	264.0

2. More Amounts of Clouds and Fog, and Scattered Light Proportion to Total Radiant Intensity

Table 3 shows that the average relative humidity of the tea plantation in the high mountain areas are higher than those of the mountain bases. Generally speaking, the tea plantation of high mountains was 2–11 percent higher than tea plantation at the base of the mountains. It was above 5 percent in the warm season (from April to September) and in the high mountainous areas with good natural vegetation. This provided favorable conditions for tea planting and improving tea quality.

The new shoots of tea plants developing under conditions of scattered light are the tea leaves which remain tender have more contents and better quality. The more direct the light, the easier the fibres of tea leaves become old.

Generally, in the subtropical hills and mountains of China, sunshine decreases with the elevation. Take for example, the annual percentages of sunshine decreased by 1–4 percent (Table 4). Under a definite elevation, foggy days increase with the elevation of the

Table 3 Average relative humidity in the air at some meteorological stations in southern China

Name of mountain	Name of station	Apr.	May	June	July	Aug.	Sept.	Year
Tianmu	Changhua	79	81	82	79	80	82	79
	Tiaumushan	81	82	85	88	89	88	79
Guacang	Xianju	79	80	84	79	77	79	78
	Guacangshan	82	85	87	86	87	91	83
Huangshan	Tunxi	80	81	82	78	78	78	79
	Huangshan	81	82	84	91	89	84	76
Jiuxian	Yongchun	79	81	84	78	79	77	77
	Jiuxianshan	89	91	93	90	90	91	87
Lushan	Jiujiang	80	80	80	76	77	77	75
	Lushan	81	82	82	82	83	82	77
Emei	Emei	75	74	77	82	82	82	80
	Emeishan	86	88	86	88	89	91	86

mountain, especially during the period for picking tea. The increasing rate is 15–20 days 100m⁻¹ in the most of the mountains in China. One of the main reasons how "Yunwu Tea of the high mountain" has evolved is because there are more amounts of clouds and fog than the percentage of sunshine.

Table 4 Fog days and percentage of sunshine in some meteorological stations in southern China

Name of mountain	Name of station	Foggy days							Percentage of sunshine						
		Apr.	May	June	July	Aug.	Sept.	Year	Apr.	May	June	July	Aug.	Sept.	Year
Guacang	Xianju	1.0	0.5	0.7	0.3	0.0	0.3	10.1	37	35	33	60	64	53	45
	Guacang	22.7	24.9	26.1	24.5	26.8	27.5	285.7	40	33	34	56	49	41	42
Huangshan	Tunxi	3.6	2.7	3.8	2.7	3.2	3.6	52.2	35	35	41	61	62	55	45
	Huangshan	22.3	24.0	23.4	26.1	25.4	24.0	255.9	35	33	30	40	40	39	41
Lushan	Jiujiang	0.9	0.5	0.1	0.2	0.1	0.4	7.9	34	36	43	61	62	51	44
	Lushan	18.9	20.5	16.1	12.4	15.0	16.3	190.6	35	35	37	56	53	49	44
Hengshan	Hengyang	2.3	1.3	0.7	0.1	0.1	0.2	18.7	28	28	42	67	62	53	38
	Hengshan	23.8	25.3	21.3	14.8	20.4	20.5	249.3	27	19	36	61	41	46	37
Wufeng	Enshi	2.1	2.3	1.6	1.0	1.5	1.5	49.1	28	27	36	45	53	41	37
	Wufeng	6.6	5.2	5.6	3.0	3.1	4.4	57.4	31	31	40	50	53	41	36
Emei	Emei	1.1	0.5	1.1	2.9	2.8	1.8	29.5	30	29	28	39	42	25	27
	Emeishan	27.6	28.2	26.1	29.1	28.8	28.4	323.4	34	23	20	28	27	24	31

In the mountainous regions, at a definite elevation, because the amount of clouds and foggy days are more, and the percentage of sunshine is less, the ratio of scattered light intensity (*S*) to direct light intensity (*D*) increases. The higher the *S* / *D* value is, the better the tea quality. Ultraviolet light of sun spectra deeply influences tea quality. Less ultraviolet light is favorable for better tea quality. Ultraviolet light intensity is less in the elevated areas with more clouds and fog.

3. Slower Temperature Rising and Falling, and Smaller Daily and Annual Temperature Ranges Are More Suitable For Tea Growing

The tea plant is one of the typical subtropical plants. It grows well in a warm and hu-

mid climate. The author^[8] shows that heat flux has much influence on the growth and development of tea plants and yield of made tea, and that light intensity and humidity are also related to tea quality. In the mountainous regions, air temperature, daily and annual temperature range, frostless season, growing period of tea plants, and the accumulated temperature decreases with the rise in elevation (Table 5). For this reason, the output of tea leaves in most mountainous areas of China, decrease as the elevation increases^[9]. But, under a given elevation range, the natural quality of tea in the mountainous areas increases with the rise in elevation. To get the best economic benefit, a suitable range in height must be chosen. This range is called the relative superiority layer for cultivation of tea plants. This range of elevation varies from 140m to 450m on the Tianmu Mountain of northern Zhejiang Province, from 200m to 600m on Guacang Mountain in mid Zhejiang Province, and from 300m to 750m Longquan Mountain in southern Zhejiang Province^[10].

Table 5 Thermal conditions recorded in some meteorological stations in southern China

Name of mountain	Name of station	Mean air temperature (°C)						
		Apr.	May	June	July	Aug.	Sept.	Year
Tianmu	Changhua	15.0	19.8	23.4	27.6	27.2	22.9	15.5
	Tianmushan	9.0	12.9	16.4	20.2	19.4	15.1	8.8
Guacang	Xianju	16.7	21.6	24.2	28.7	28.7	25.1	17.4
	Guacangshan	10.3	14.0	17.1	21.0	20.1	16.3	10.1
Huangshan	Tunxi	16.2	20.8	24.4	28.3	27.8	23.6	16.3
	Huangshan	7.9	11.7	14.8	17.8	17.4	13.8	7.7
Jiuxian	Yongchun	20.0	23.6	25.6	28.2	27.8	26.1	20.5
	Jiuxianshan	12.5	15.5	17.2	19.2	18.7	16.4	12.1
Lushan	jiujiang	16.4	21.5	25.5	29.4	29.0	24.5	17.0
	Lushan	11.4	15.6	19.2	22.6	21.9	17.9	11.4
Wufeng	Enshi	16.4	20.5	24.3	27.2	26.7	22.7	16.4
	Wufeng	13.3	17.4	21.0	24.2	23.4	19.2	13.1
Emei	Emei	18.1	21.7	24.1	26.3	25.7	22.1	17.2
	Emeishan	3.3	6.2	8.9	11.9	11.3	7.9	3.1

Name of mountain	Name of station	Annual range	Days		Mean air temp(>10°C)	
			>30°C	>35°C	Days	Accumu.temp
Tianmu	Changhua	24.7	92.6	35.9	226.7	4840.0
	Tianmushan	23.1	0.1	—	147.5	2522.7
Guacang	Xianju	23.3	95.0	73.5	249.2	5524.3
	Guacangshan	22.0	—	—	165.0	2868.7
Huangshan	Tunxi	24.6	94.1	32.0	236.4	5151.0
	Huangshou	21.2	—	—	138.7	2176.2
Jiuxian	Yongchan	16.4	118.6	16.9	319.0	6951.9
	Jiuxianshan	15.3	—	—	192.1	3186.2
Lushan	Jiujiang	25.3	84.2	25.0	239.8	5394.7
	Lushan	23.0	1.5	—	170.0	3223.2
Wufeng	Enshi	22.3	81.0	17.7	250.3	5212.6
	Wufeng	22.4	34.9	—	199.4	3872.9
Emei	Emei	19.3	55.8	2.8	266.7	5490.3
	Emeishan	18.0	—	—	48.8	586.4

The author^[3] reported that in the spring when the daily mean air temperature was 10—12°C, the shoots start in most varieties of tea plants. The suitable temperature for the new

shoots to grow then is about 22°C. When the air temperature is above 30°C in the day time, or below 14°C at night, the new shoots slow down or stop growing. The ecological climate of famous tea areas in some high mountainous areas of China have more amounts of clouds and fog, higher relative humidity, smaller daily temperature ranges, slower dropping of temperature in the autumn, and less days with an average temperature above 30°C and 35°C. All of those factors are favorable for better tea quality and growth.

The best season for tea quality in tea plantations in the plains of China is the Spring. Tea quality of summer tea is the second best, and the quality of autumn tea is third. In the tea plantations of high mountains, air temperature in the summer is lower, and so high temperature weather damage and drought weather damage usually do not occur. Therefore, the new shoots of tea plants can normally grow in summer, making tea quality of the high mountains better in summer and autumn.

4. Smaller Wind Speed

Wind is one of the ecological factors of the tea plant. It influences the growth, development, yield and quality of tea plants. In the mountainous regions, the wind speeds and the amount of daily gales increases with the rise in elevation. For example, the average wind speed at a meteorological station on the mountaintop is two to four times greater than the meteorological station at the foot of the mountain. The annual number of gale days has increased over eleven times. But the tea plantations of famous teas grown in high mountainous regions are situated in the lee-sides or valleys of mountains. Tree forests are distributed around the tea plantations, thus reducing the wind speeds of the plantations.

II. ANALYSIS AND DISCUSSION

The tea quality has been associated with manifold factors. These factors are: targets of the production, environmental factors and artificial factors. Close relationship exists between the environmental factors around the tea plantations, and the actual tea quality⁽¹¹⁾. The major environmental factors which affect the quality of tea are: geology, landforms, climate, soil, vegetation, and so on. The climatic factors are of great importance in the environment. Light intensity, temperature, and humidity not only influence the growth and development of the tea plants, but also influence the quality of the tea.

The ecological climatic characteristics of famous tea growing in some high mountainous areas in China are as follows: greater amount of cloudy and foggy days, less percentage of sunshine, abundant rainfall, high relative humidity, more scattered light, slower increases and decreases of temperatures, smaller temperature variation, more days that are suitable for tea growing plants, no high temperature damage or drought damage, and lower wind speeds. Among those climatic factors, greater amounts of cloudy and foggy days, and high relative humidity are some of the main reasons how "Yunwu tea of the high mountains" has been formed. The ecological climatic characteristics above are similar to those in the

original areas of tea plants^[12], so the tea quality is very good.

In order to improve tea quality in China, various measures must be taken. From the view point of ecology, suitable areas for tea plantations should be chosen taking full consideration of the ecological conditions of the tea plants culture, because a close relationship exists between the ecological environment of the tea plantation and the tea's natural quality.

Meteorological calamities of the tea plant have a major influence on the growth, development, yield and quality of tea plants. The main meteorological calamities of tea plants in China are freezing injury, frost injury, drought, high temperature, water-logging, snow, and hail. Among these calamities, freezing injury, drought, and high temperature are the greatest influences on the tea quality of China. Therefore, various measures must be taken to protect the tea plants against such meteorological calamities. The measures are very important for protecting, maintaining, and increasing tea quality.

In the tea producing regions along the middle and lower reaches of the Changjiang (Yangtze) River, the rainfall amount is abundant in the spring. During the harvest period of spring tea, more cloudy and rainy days, intermittent fair and cloudy weather, sunshine by day and rainfall by night, and high humidity, help to produce good quality spring tea^[13]. The quality of spring tea is much better than the quality of summer and autumn tea. For this reason, raising the proportion of spring tea and limiting the proportion of summer and autumn tea are favorable for quality of tea all year round. In order to increase the quality of summer and autumn tea we can use the tea plantation sprinkler irrigation system for a simulated ecological climate to that of "Yuzwu tea of the high mountains".

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