Effects of Air Temperature on the Growth of New Shoots and Quality of Green Tea

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Growing season of tea plants is generally from April to the end of September in Japan. However, there are considerable regional variations with date of flushing and plucking, showing from 2 to 4 pluckings in a year. As to the quality of green tea, the first crop of tea, harvested in April–May, is regarded to be the best, followed by the second and third crops harvested in the summer season.

Since such regional variations with time of sprouting new shoots and the seasonal differences in tea quality are considered to be caused by differences in climatic conditions, especially air temperature, the author has examined effects of air temperature (it's upper limit, lower limit and optimum range) on the growth of new shoots, and the accumulated air temperature from the sprouting to plucking stage. In addition, effects of air temperature during the period of new shoot growth on tea quality were studied by examining contents of amino acids and tannin, the components contributing to tea taste (hereafter referred to taste components), and by histological examinations.

Maximum, minimum, and optimum temperature for new shoot growth

Using tea plants growing in Wagner pots (1/5000 are), growth rate of new shoots was studied under controlled temperatures in growth cabinets with natural light. As shown in Fig. 1, no growth occurred at 5°C, while the growth was faster at higher temperature in the range of 10°–25°C and was retarded at the temperature above 30°C. No varietal difference was recognized in this relation.

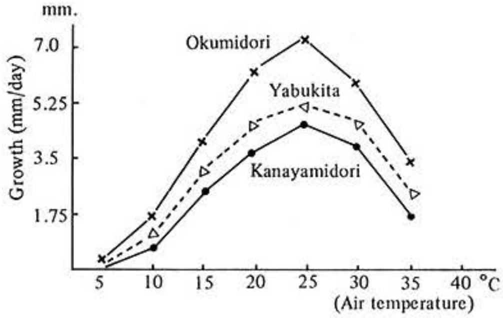

Fig. 1. Growth of young shoot in relation to air temperature

Therefore, it can be regarded that for the growth of new shoots the minimum temperature is 10°C, the optimum temperature is about 25°C, and the temperature higher than 30°C is inhibitive.

Air temperature at the sprouting stage, and number of days and accumulated temperature from sprouting to plucking

Yearly variations of sprouting date observed during 16 years with a green tea variety, Yabukita, at Kanoya, Shizuoka Prefecture, were examined. The result showed that the earliest date was 28 March, and the latest was 15 April, with a mean date of 4 April. In each year, the sprouting occurred immediately after the week in which daily mean temperature exceeded 10°C.

Earliness and lateness of sprouting of varieties seem to be caused by different intensities of dormancy of winter buds.

Number of days, accumulated temperature, and average temperature, each for the period from sprouting to plucking of each crop are shown in Table 1. Number of days from sprouting to plucking was about 33 for the first crop, about 19 for the second crop, and about 18 for the third crop. The accumulated temperature was 460°C, 380°C and about 460°C, respectively. The lowest value for the second crop suggests that the temperature (about 20°C) at this time was most effective.

Using yearly data, the relationship between the mean temperature in the period from sprouting to plucking and the number of days required for that period was examined as given in Fig. 2. It shows negative correlations for the first and second crops, indicating that the longer time was required to reach the plucking in years with lower temperature. In case of the third crop, however, the yearly variation was small, and number of days required to reach the plucking was effected by other factors than temperature.

Accumulated temperature required for the expansion of one new leaf was estimated to be 90°–100°C, and that requqired for the initiation of sprouting after the preceding plucking was approximately 500°C for each crop.

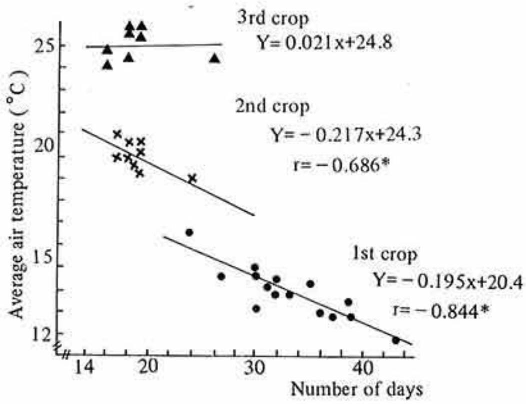

Fig. 2. Relation between average temperature and number of days from flushing to plucking

Temperature at growing time and green tea quality

With new shoots growing at 4 levels of temperature, 15°, 20°, 25°, and 30°C (night temperature was set to be lower by 5°C) in

Table 1. Date of flushing between and plucking in each crop season, and relation between number of days and accumulated or average air temperature

Item	Crop season		
	1st crop	2nd crop	3rd crop
Flushing date	4. Apr.±5.6	6. June±4.6	17. July±6.3 days
Plucking date	6. May±4.4	25. June±4.9	4. Aug.±6.3 daps
Number of days from flushing to plucking date	33.2±5.0	18.8±2.1	18.4±2.2
Accumulated temperature in each crop season	460.2°C±42.1	378.3°C±33.3	462.4°C±56.4
Relation of the number of days to the accumulated temperature	Y=7.53X+210.2 r=0.893**	Y=15.27X+91.2 r=0.961**	Y=24.13X+18.4 r=0.941**
Average temperature	13.9°C±1.15	20.2°C±0.67	25.2°C±0.71
Relation of the number of days to the average temperature	Y=−0.195X+20.37 r=−0.844**	Y=−0.217X+24.28 r=−0.686*	Y=0.021X+24.8 r=0.066
Number of days from plucking to next flushing date	29.4±2.2	22.0±2.6	
Accumulated temperature from plucking to next flushing date	520.0°C±38.1	502.0°C±70.3	
Relation of the number of days to accumulated temperature	Y=14.67X+8.87 r=0.863**	Y=24.1X+27.7 r=0.897*	

Note: r: correlation value. 0.01**, 0.05*

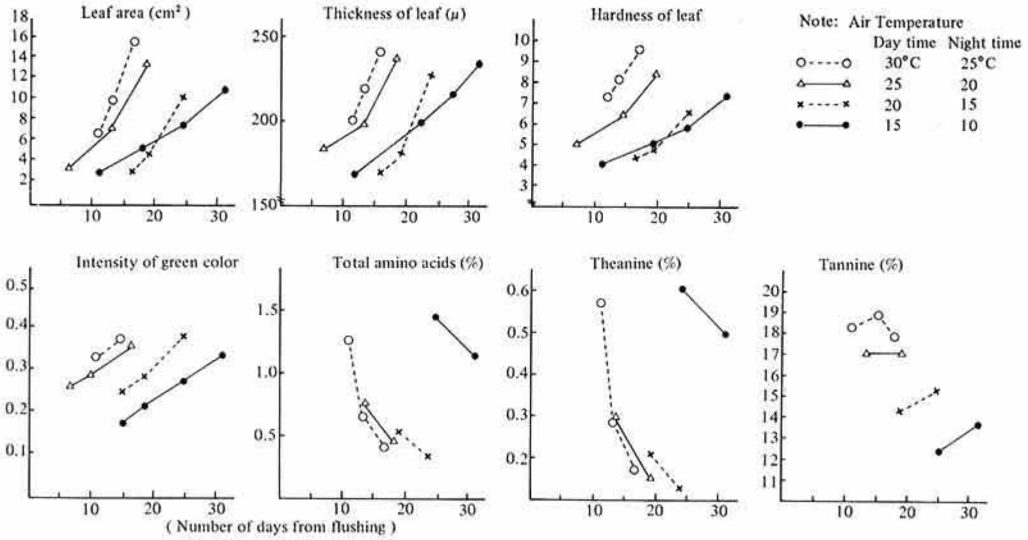

Fig. 3. Characters of young shoots in relation to air temperature

growth cabinets with natural light, morphological features and contents of taste-bearing components were examined following the growth process. The results are shown in Fig. 3.

The higher the temperature, the faster the enlargement and thickening of new leaves, resulting in an increased physical hardness. The new leaves tended to increase faster their green coloration at higher temperature. At the temperature below 15°C, they remained to be yellowish for a considerably long period.

As clearly shown in Fig. 3, contents of taste components such as theanine and total amino acids decreased more rapidly, while the content of tannin which gives a bitterness increased more at high temperature.

Microscopic examination revealed that high temperature promoted the thickening and vacuolization of parenchyma cells, thickening and lignification of sclerenchymatous fibre cells, and development of xylems in the stems of new shoots.

It can be considered that these morphological changes together with the above-mentioned chemical changes such as decreased amino acid and increased tannin contents may cause the lowering of green tea quality under high temperature conditions.

Growth and content of taste components as effected by diurnal change of temperature

It is generally said that teas produced in mountainous areas are of better quality, which is presumably related to the diurnal change of temperature. To prove it, growth and contents of taste components of new shoots were examined under the following temperature treatments, using growth cabinets with natural light:

Plot	Daytime	Night
1	20°C	20°C
2	27	20
3	20	10
4	25	15

(mean temperature is same as plot 1)

As shown in Fig. 4, the growth of new shoots was slightly promoted by high daytime temperature, but growth was same when the mean daily temperature was same, whether with or without diurnal change of temperature.

Growth status and contents of taste components are given in Table 2, which indicates

Table 2. Growth and taste components of young shoots as effected by diurnal range of temperature

	Temperature		Growth of young shoot			Taste component	
	Day time	Night time	Number of shoot	Weight of a shoot	Banjhi rate	Amino acid	Tannin
(A)	20°C	20°C	385	0.25(g)	41.9(%)	3.19(%)	8.6(%)
	20	10	435	0.27	21.8	3.96	10.3
(B)	20	20	360	0.27	74.2	2.74	11.4
	27	20	367	0.25	55.0	2.96	11.8
(C)	20	20	395	0.27	61.5	3.16	8.6
	25	15	375	0.29	60.8	3.36	10.1

that the presence of diurnal change of temperature gives higher contents of amino acids and tannin, and low daytime temperature combined with the big diurnal change of temperature improves green tea quality.

Harvesting time and green tea quality

The quality of the first crop is regarded in Japan to be superior to that of the second and third crops. To make clear whether is it due to climatic factors or repeated pluckings, the first, second and third crops were harvested from the same plants growing under constant temperature of 18° and 23°C (night temperature was set to be lower by 5°C) in growth cabinets, and their growth and taste components were examined.

As shown in Table 3, growth rate was higher in the 23°C plot than in the 18°C plot for each crop, but fresh leaf yield was greater in the 18°C plot except for the first

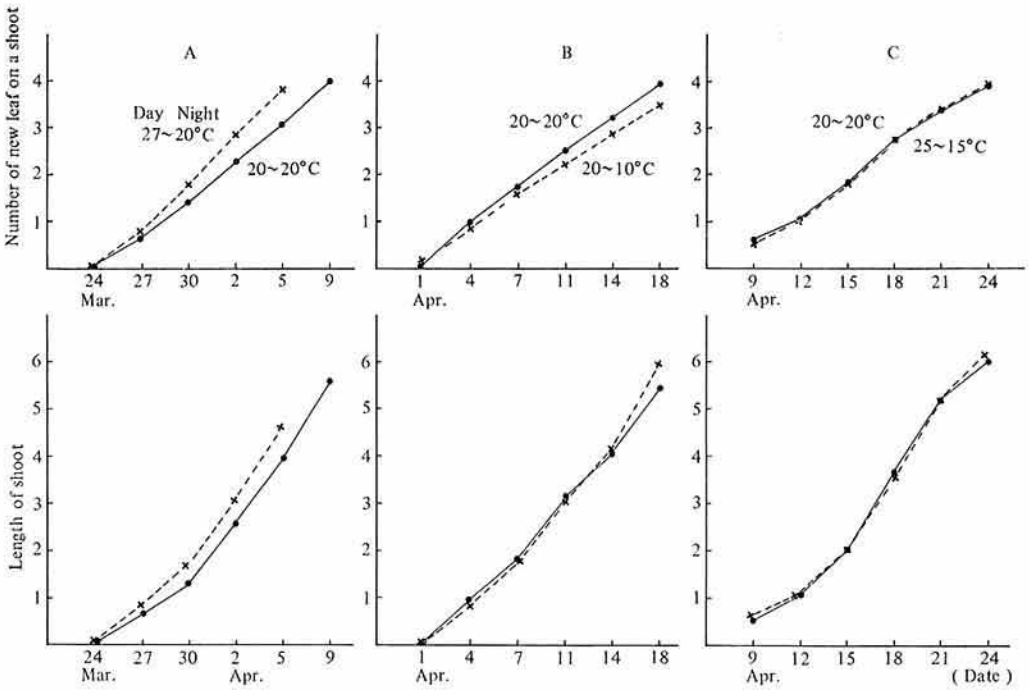

Fig. 4. Growth curve of young shoot at each temperature

Table 3. Growth of young shoots, yield of green leaves and taste components of tea grown at two different temperatures

Item	Temperature					
	18°C in day. 13C° in night			23°C in day. 18°C in night		
	1st crop,	2nd crop,	3rd crop	1st crop,	2nd crop,	3rd crop
Flushing date	20. March	27. May	26. June	20. March	3. May	7. June
Plucked date	19. Apr.	24. June	18. Aug.	7. Apr.	20. May	24. June
Number of days in each growing season	30	28	23	18	17	17
Banjhi rate (%)	55.1	29.8	26.5	75.9	54.7	63.3
Weight of a shoot (g)	0.39	0.58	0.50	0.35	0.58	0.43
Yield of green leaves (g)	37.7	93.0	91.0	39.5	81.0	85.0
Total nitrogen (%)	6.49	5.83	5.83	6.49	5.74	5.15
Tannine (%)	7.4	12.3	12.8	8.4	14.8	14.9
Total amino acids (%)	2.97	1.93	1.80	2.33	0.97	1.42
Theaninn (%)	1.76	0.98	0.76	1.34	0.48	0.53
Arginine (%)	0.10	0.09	0.34	0.10	0.01	0.04
Aspartic acid (%)	0.22	0.19	0.14	0.26	0.12	0.16
Glutamic acid (%)	0.38	0.25	0.24	0.27	0.16	0.25
Serine	0.24	0.24	0.19	0.23	0.11	0.10

crop.

Content of amino acids was low at high temperature for each crop. At the same temperature, the first crop showed the highest content, while the second and third crops tended to show lower contents. On the contrary, tannin content was high at high temperature and it increased in the second and third crops.

Based on these results, the lower quality of the second and third crops can be attributed to the decreased amino acid content and other changes caused by temperature rise and repeated plucking.

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