Utilization of Light Quality in Shading Culture of Tea Plants

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As the shading culture has been practiced in Japan since old days with the purpose of improving the quality of green tea, many studies on changes of various characters and chemical components of tea leaves induced by the shading treatment have already been worked out[2,6]. In the past, reed screens or rice straw-mats were used for the shading culture, but in recent years synthetic materials such as lawn cloth screen come to be widely used. These covering materials reduce light intensity without changing the spectral composition of light. More recently, agricultural films or synthetic fiber materials both having the photoselectivity have been developed, and the utilization of these materials is being studied even for other crops than tea.

In 1972 to 1974, studies on the effect of light quality on growth and chemical components of new shoots as well as quality of tea and on the practical utilization of light quality for improving the tea quality were carried out[1,4,5]. Some of the interesting results will be presented in this paper.

Growth response of tea plants to light quality

Shading, in general, manifests various effects on growth and chemical composition of new shoots of tea. To determine the spectral band responsible for causing such effects, tea plants were grown in color-boxes equipped with different filters which can remove specific spectral bands[3] (Table 1 and Fig. 1). The

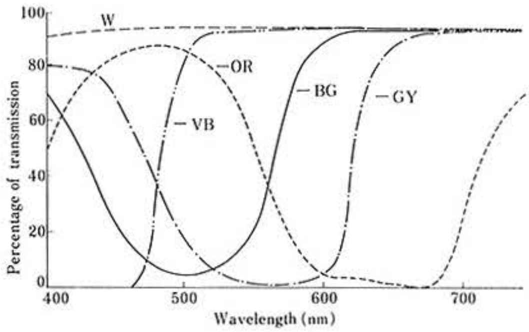

Fig. 1. Spectral transmission curves of plastic filters used for removing specific spectral bands.

Table 1. Kinds of plastic filters used

Color	Light treatment		Thickness (mm)	Transmittance of solar radiation* (%)
White	Control	(W)	3	94
Yellow	Minus violet-blue	(—VB)	2	79
Red	Minus blue-green	(—BG)	2	63
Purple	Minus green-yellow	(—GY)	2	41
Blue	Minus orange-red	(—OR)	2	39

* Transmittance of photosynthetically active solar radiation

Table 2. Effect of the removal of specific spectral bands from natural light on the growth of new shoots

	Light treatment			
	W	−VB	−GY	−OR
Length of new shoot (cm)	10. 5[b]	14. 2[a]	10. 0[b]	10. 9[b]
Number of leaves with new shoot	5. 2	5. 4	5. 1	4. 7
Fresh weight of new shoot (g/shoot)	0. 77[b]	1. 03[a]	0. 71[b]	0. 58[c]
Leaf area (cm^2/leaf)*	14. 2[b]	16. 5[a]	11. 5[c]	13. 8[b]
Thickness of leaf (mm)*	0. 229	0. 219	0. 238	0. 223

Note: The values with a, b, c in the table show significant differences from one another at 5% level.
* Measurement was made of the 3rd leaf, counted from the base of shoot.

neutral film was used to make the light intensity in each box as equal. The color-box used in the field was 1 m long, 0.5 m wide, and 1 m high and was equipped with a small fan on its side-wall to blow air into the box for preventing the temperature rise. In addition, small color-boxes were used in growth cabinets to examine the growth response under artificial illumination.

1) Growth response of new shoots

Tea plants heavily pruned in the spring were covered by color-boxes and sprouting and growth of new shoots were examined. In this experiment, photosynthetically active irradiation was adjusted to be at 40% of natural light. Growth of new shoots after the newly sprouted shoots were skiffed in August is shown in Table 2. In the −VB plot, length and weight of new shoots and leaf size were found greater than those in other plots, particularly the leaves in the −VB plot curved outwards apparently with increased wrinkles and luster and decreased leaf thickness. In general, these changes are induced by so-called shading treatment which does not change the spectral composition of light as in the case of W plot. However, these changes were enhanced by the removal of the violet and blue band from the visible radiation.

Tea plants at the time of first flushing in the spring were also covered by color-boxes described above, and growth process of new shoots was examined. New shoots were slightly longer in the −VB plot, and tended to be shorter in the −BG and −OR plots than in the W plot. In the −VB plot, the leaf area increase continued for a longer period than in other plots (Fig. 2). The −BG plot also showed a tendency of large leaves, while the leaf area increase ceased relatively soon in the −OR plot.

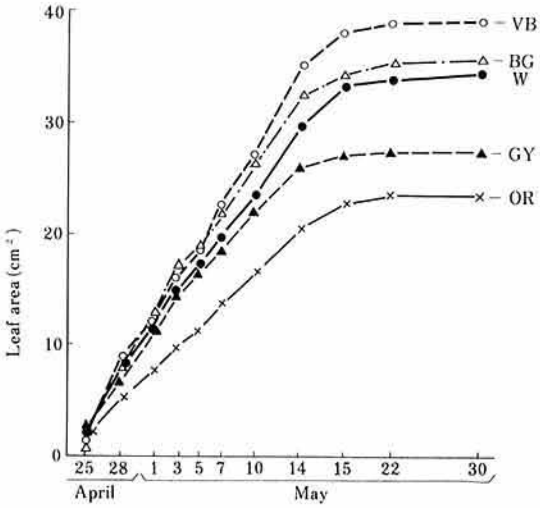

Fig. 2. Effect of the removal of specific spectral bands from natural light on the development of leaf area.
Note: Measurement was made of the 3rd leaf counted from the base of shoot.

On the other hand, plants grown under the blue, yellow, red, or white inflorescent lamps in growth cabinets showed that the leaf area increase continued for a longer period under the yellow and red light, but the leaves were thinner with less number of stomata per unit

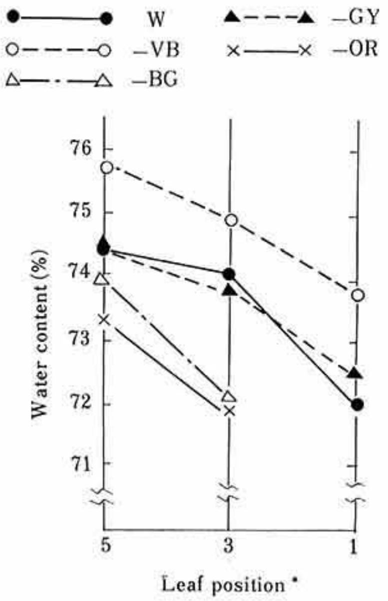

Fig. 3. Effect of the removal of specific spectral bands from natural light on the water contents of new leaves.
* Counted from the base of shoot

leaf area than under other light. This result is consistent with the results obtained from the −VB plot above. Thus, it can be considered that yellow and red light are closely related to the leaf area expansion.

2) Effects on chemical components of new shoots

Water content of new shoots grown in color-boxes was measured at each leaf position (Fig. 3). Although water content generally decreased with the maturing of leaves, the water content in the −VB plot was higher at each leaf position than other plots. The same tendency was observed in other experiments. Total nitrogen and tannin contents also decreased with the maturing of leaves as in the case of water content, but there were some variations according to leaf position. With the third leaf, the −VB plot showed a slightly higher content of total nitrogen and a lower content of tannin than the W plot. However, a higher water content of leaves and a longer duration of leaf area expansion in the −VB plot indicate a retarded leaf maturation, a significant phenomenon from the viewpoint of quality improvement of green tea.

3) Effects on photosynthesis of leaves

Photosynthetic rate of leaves grown in the natural light was measured under blue, green or orange light. As the light intensity used was below the light-saturation point, the photosynthetic rate increased with an increase of the irradiance. When compared at the same light intensity, the rate was in the order of orange, green and blue light.

Next, the photosynthesis of leaves grown in color-boxes was measured under the white light or the light in which the leaves had grown. Leaves grown in the −VB light gave similar photosynthetic rate as leaves grown in the white light when measured under the white light or the −VB light. But the rate decreased markedly when measured under the −OR light. Leaves grown in the −OR light gave always very low rate under any light at the time of measurement.

Practical application of light quality

Based on the above results, practical application of light quality was studied by using various photoselective covering materials.

1) Utilization of photoselective films for the forcing culture

As the forcing culture using films is being practiced in some warm areas of Japan, several studies were undertaken to utilize photoselective films for that culture. Yellow film having the above-mentioned −VB property and neutral film of the W property, having the same degree of transmittance as the yellow film were used to cover tea field. The yellow film gave higher yield of first plucking and better green tea quality than the neutral film. The use of both films in combination caused a further reduction in light intensity and much better quality of tea. As compared to aventurine films now being popularly used, the yellow film gave slightly lower yields but apparently better quality.

2) Utilization of photoselective covering materials in the shading culture

Although the effectiveness of yellow films is proved from the above results, it is practical to use net-like covering materials, rather than to use films, for the shading culture aiming at quality improvement. As the net woven of black tape is already put into the practical use, the net woven of yellow tape or interwoven of both yellow and black tapes was produced for a trial. Six kinds of them with varying ratio of yellow to black tape were used for the experiment. The higher the ratio of yellow tape, the less is the transmittance of violet-blue band.

On 24 April, these nets were applied to tea fields, and after 14 days new shoots were plucked and the yields of green leaves and their quality of green tea were examined. As given in Fig. 4, yields of all treated plots were lower than that of the untreated plot, but the plots covered by nets interwoven of yellow tape outyielded the black tape plot (N100), so far being used. Quality of tea in the former plots was better than that of N100 plot except YN70 plot.

Thus, it becomes apparent that the nets interwoven of yellow tape are very effective in improving tea quality and preventing yield decreases caused by the shading. Further examinations are being in progress on these photoselective nets with different rates of shading.

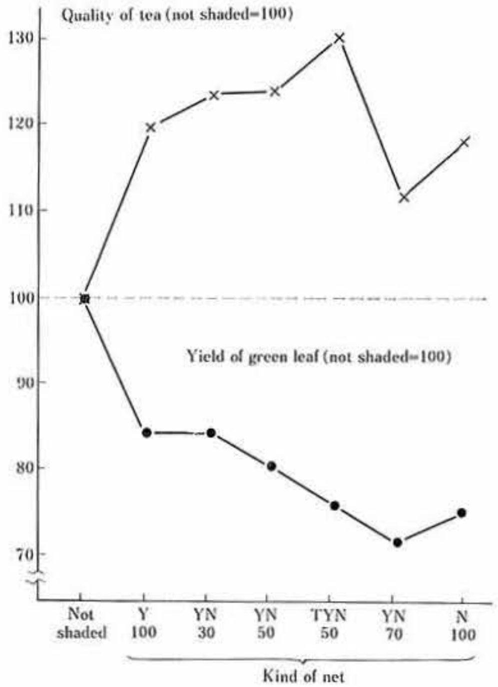

Fig. 4. Effect of polyethylene nets interwoven of yellow and black tapes on yield and quality of tea

Note:
- Y100 : Net woven of yellow tape only
- YN30 : Net interwoven of 30% yellow tape and 70% black tape at regular intervals
- YN50 : Net interwoven of 50% yellow tape and 50% black tape at regular intervals
- TYN50: Net made of 10 cm yellow and 10 cm black tape bands
- YN70 : Net interwoven of 70% yellow tape and 30% black tape at regular intervals
- N100 : Net woven of black tape only

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