EFFECT OF LIGHT ON LEAF INCLINATION OF *TRITICUM AESTIVUM*

I. Monochromatic Light

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Many investigations have been published on the effect of light of different spectral regions on physiological phenomena, including germination, leaf elongation, leaf development, and flowering (Stolwijk 1954, Wassink and Stolwijk 1956, Mohr 1962). Virgin (1962) and Takahashi (1964) reported that the expansion of folding leaves of wheat and rice plants differed greatly due to light of different spectral quality. Inada (1969) and Maeda (1969) have demonstrated that the inclination of leaves in rice plants was regulated by the quality of light. The present experiments investigated the effect of monochromatic light on the inclination of the leaf blade in wheat plants.

MATERIAL AND METHODS

Well matured seeds of medium size of *Triticum aestivum*, variety "Shirasagi Komugi", were soaked in running water for 12 hours at room temperature and spread on moistened sand. The following day, germinating seeds were selected for uniformity and sown in 20×10×3-cm plastic trays containing sand, 40 seedlings per tray. The plants were grown in a growth cabinet, 60×50×45 cm and irradiated from above by 8 fluorescent tubes* containing red, green, and blue fluorescent powders. Blue light was secured from a blue fluorescent lamp filtered with 2 layers of blue cellophane. The radiant energy at plant level was measured by an ISCO spectroradiometer as shown in Fig. 1.

To ensure equal intensities in all the growth cabinets, fewer lamps were used in some instances, and the intensities of the peak of each colored light at plant level was adjusted to 70 erg/cm²/sec by changing the height of the light source. As a control, daylight fluorescent lamps (National realux lamp EDL-50) were used and adjusted to 70 erg/cm²/sec at 550 nm. In other experiments, plants were irradiated with spectral beams from a grating monochromator at Kyoto University.

Plants were exposed to monochromatic light from the fluorescent lamps and the spectral beams, and the leaf blade inclination of the first leaves were examined 10-13 days after germination. Generally, 30-40

* National colored 20W fluorescent lamps of blue (Fl 20B-F with a maximum energy at 440 nm), green (Fl 20G-F with a maximum energy at 535 nm) and red (Fl 20R-F with a maximum energy at 660 nm), Matsushita Electric Co.

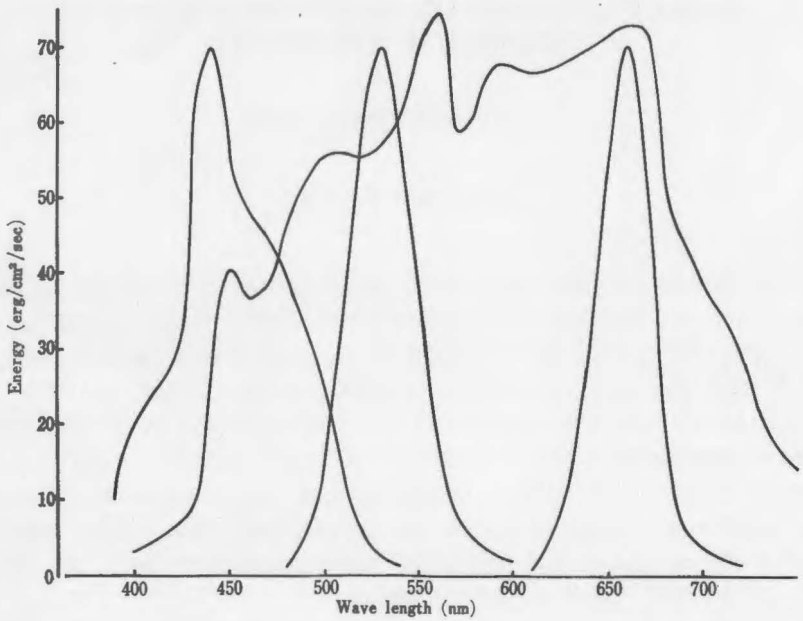


Fig. 1. Radiant energy of fluorescent lamps of blue, green, red and white lights used in the present expriments.

plants were used for one lot of the treatments. To ease observations, the apical parts of the leaf blade of the first leaves were cut off by a scissors, leaving 5 cm of the blade. The angle between the leaf blade and the leaf sheath was measured with a protractor. An increase in the angle indicated a movement of the leaf blade toward the ground, whereas a decrease indicated a more upright position of the leaf blade with respect to the leaf sheath.

RESULTS

Monochromatic light

To examine the effect of continuous irradiation with monochromatic light, seedlings were subjected to various colored lights at 20°C for 10 days. As the control, two lots of plants were exposed to either continuous illumination with white light or total darkness.

Immediately after the treatments, inclination of the leaf blades were measured.

The inclination of the blade differed greatly due to various colored lights (Table 1). Maximum leaf blade inclination occurred in blue light (94°) and the leaves were horizontal to the leaf sheath. In green and red light and in darkness, however, leaf blades were almost vertical with angles of 13 to 17°. In white light, the angle was 36.9°. Length of

TABLE 1. Effect of continuous monochromatic light at 20°C for 10 days on length and inclination of the leaf blade in wheat plants.

Light quality	No. of plants	Leaf blade length (mm)	Leaf blade inclination(°)
Blue	32	108.1±10.4	93.9±11.7
Green	30	101.8±10.4	17.3± 4.4
Red	34	102.4±10.6	13.2± 3.6
White	36	92.9± 7.5	36.9± 7.9
Dark	36	90.7± 8.9	14.8± 4.7

the leaf blade was nearly the same in all the lots, except for somewhat lower values in white light and darkness.

Duration of monochromatic light

Plants were subjected to continuous irradiation of various colored lights at 20°C for various durations (Fig. 2 and Fig. 3). In blue light,

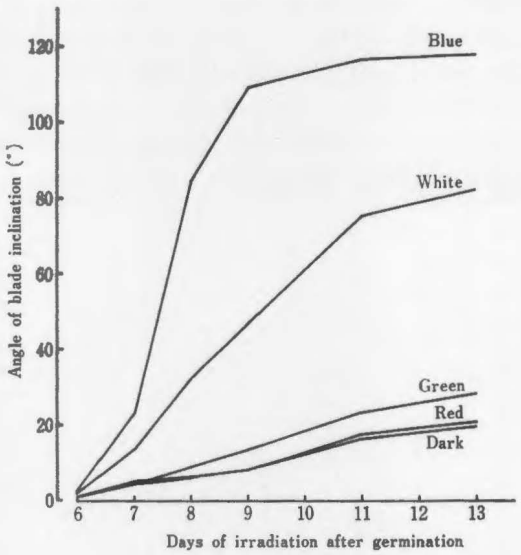


Fig. 2. Leaf blade inclination in wheat plants under continuous irradiation with various colored lights at 20°C.

the inclination of the blade began on the 7th day after germination, and increased rapidly between the 7th and 9th day, reaching a maximum of 120°. In green, red and darkness, the inclination was much smaller with a linear increase throughout the irradiation period. In white light, relatively high values were obtained for the angle of the leaf blade suggesting that the inclination in white light was perhaps attributable to the action of the blue light included in it.

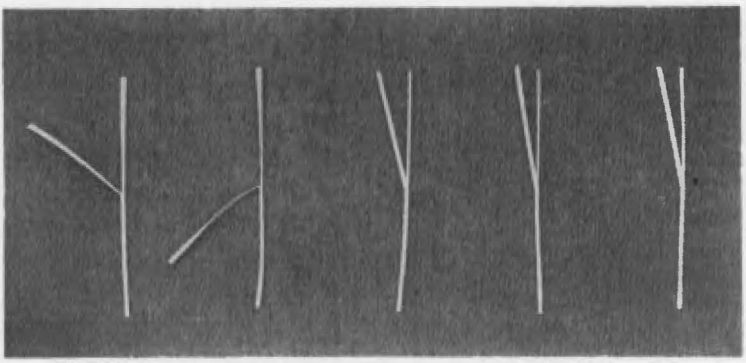
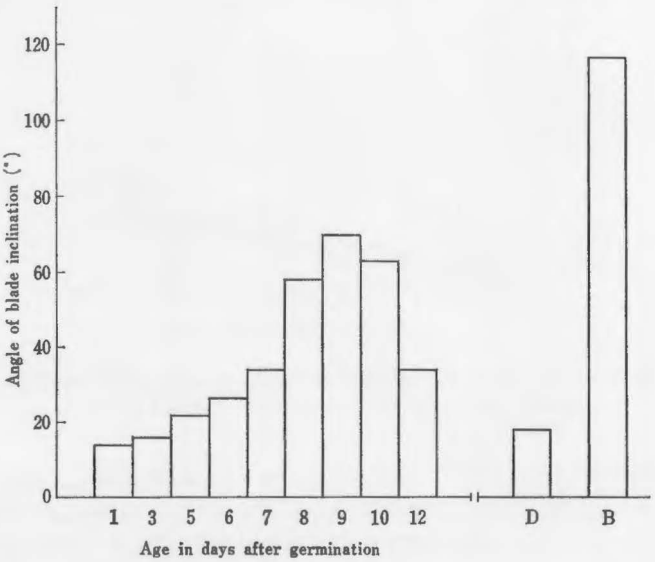


Fig. 3. Inclination of the leaf blade in wheat plants subjected to continuous irradiation of various colored lights at 20°C. Photographed 9 days after germination.

Seedling age

In the experiments mentioned above, blue light was most effective in causing the inclination of the first leaf blade when wheat plants were subjected to continuous irradiation for 10 days after germination, especially from the 7th to 9th days. To obtain more detailed information of the effect of the age of the seedlings, plants were cultured at 20°C in darkness. At various times thereafter, plants were subjected to blue



D: Total darkness for 13 days
B: Continuous irradiation of blue light for 13 days

Fig. 4. Effect of seedling age on leaf blade inclination of wheat plants irradiated with blue light for 24 hours at 20°C.

light for 24 hours, and then moved back to 20°C in darkness. As the controls, two lots of plants were cultured either in continuous irradiation of blue light or in total darkness throughout the experiment. Observations of leaf blade inclination were made 13 days after germination.

The inclination responses to blue light differed according to the age of the seedings (Fig. 4). Leaf inclinations increased up to the 9th day after germination, but subsequently the effect of light diminished. Maximum response was obtained on the 9th day after germination, when the laminar joint of the first leaves was 1 to 2 cm in length above the top of the coleoptile sheath. However, even on this day, the inclination was only half of that in plants continuously irradiated with blue light for 13 days.

Time of irradiation

Nine-day-old dark-grown seedlings were exposed to blue light for 0 to 48 hours. After the treatment, the seedlings were transferred to darkness and the inclination responses were examined 11 days after germination. The promotive effect of blue light on blade inclination (Fig. 5) appeared if the duration of the blue light irradiation was 8 hours or

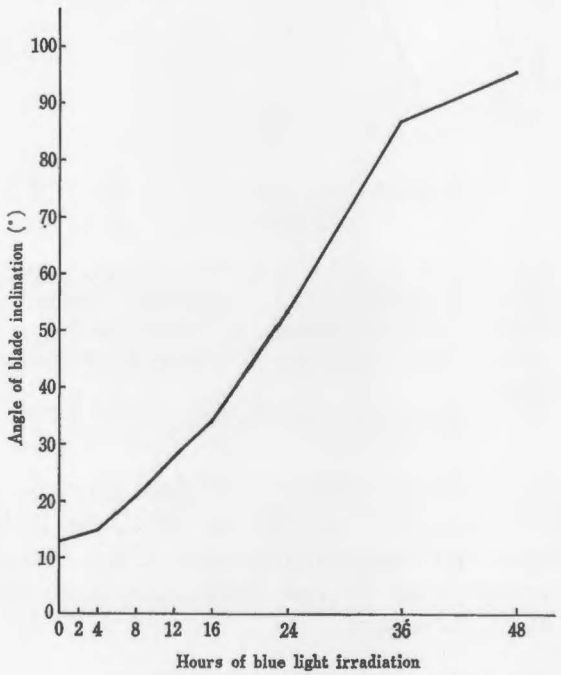


Fig. 5. Effect of duration of irradiation with blue light on the leaf blade inclination of wheat plants. Plants were cultured at 20°C for 8 days under darkness and then exposed to blue light for various hours.

more, and increased with increasing duration of blue light. When the plants were exposed to blue light for 48 hours, blade inclination was nearly the same (93.6°) as if plants were kept in continuous blue light for 13 days (Fig. 4).

Temperature

In the previous experiments, the plants were cultured at 20°C. To determine the effect of temperature, plants were cultured at 20°C in darkness for 8 days and subsequently subjected to blue light treatment for 48 hours at temperatures varying between 10 and 35°C (Fig. 6). Immediately after the treatment, the inclinations of the first blades were measured.

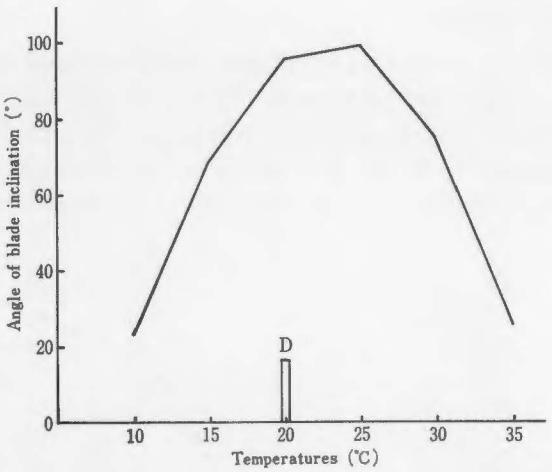


Fig. 6. Influence of temperature on the leaf blade inclination of wheat plants irradiated by blue light. Plants were cultured at 20°C in darkness for 8 days and then subjected to blue light irradiation at various temperatures for 48 hours.
D: cultured under total darkness at 20°C for 10 days.

The optimal temperature for the blue light effect on leaf inclination ranged from 20°C to 25°C. At 10° and 35°C, the inclination respone was greatly reduced and was similar to that of the dark control at 20°C. This effect of temperature on leaf blade inclination is similar to the effect on linear stem elongation.

Spectral beams from a grating monochromator

To obtain more detailed information on the spectral regions effective in the inclination response, plants were irradiated with monochromatic light from a grating monochromator at Kyoto University. Monochromatic

light beams of the same intensity (625 erg/cm²/sec) were obtained by partly shading the light beams, as measured with a spectroradiometer (Model SRP, Iio Electric Co.) (Konishi, 1972). Plants in plastic trays were grown in vermiculite in darkness for 8 days at 20°C and were arranged on the irradiation stage. Ten plants were irradiated with the monochromatic light beams (10 nm wave length) from 400–820 nm for 18–40 hours. The inclination responses were examined immediately after the treatments (Fig. 7).

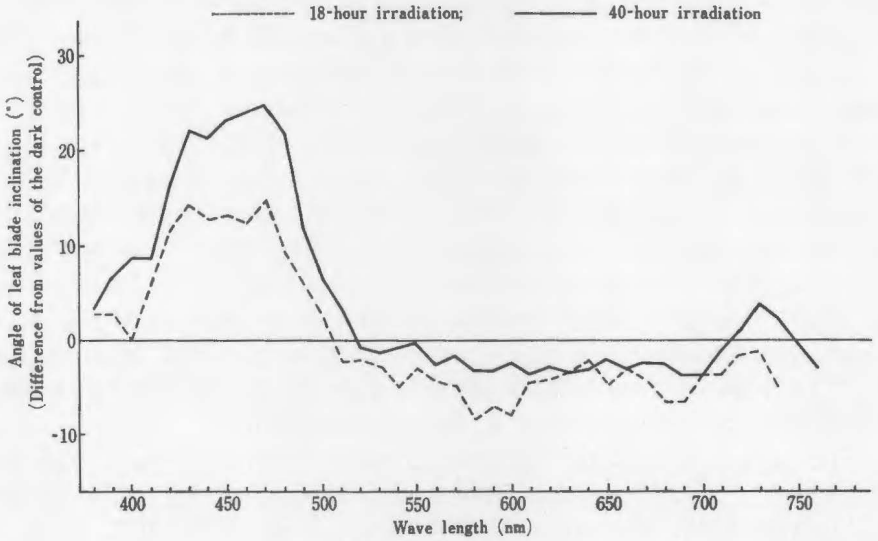


Fig. 7. Action spectrum of leaf blade inclination in wheat plant. Plants were cultured at 20°C under darkness for 8 days and then subjected to monochromatic light beams from grating spectroirradiator at 20°C for 18 and 40 hours. As the control, plants were cultured at 20°C under darkness.

Leaf blade inclination increased in wavelengths of 400 to 500 nm in the 18-hour treatment, as compared with the inclination of the dark control.

In the 40-hour treatment, the inclination response was similar to the 18-hour treatment, with wavelengths of 380–510 nm effective. No or negative response was found in the spectral regions longer than 520 nm. However, a very weak response appeared in a 40-hour treatment in wavelengths between 720 and 750 nm.

These results proved that blue light is effective in causing the inclination of leaf blade in wheat plants, similar to the results with variously colored fluorescent lamps.

DISCUSSION

Irradiation with blue light increased the inclination angles of the first leaves of wheat plants. In green and red light, the inclination was small and near the same as that in darkness. In white light, however, relatively high values were obtained, due probably to the effect of blue light included in white light. The inclination of the leaf blade showed the maximum response when the plants were exposed to blue light at 20-25°C and at the age of 9 days after germination. Blue light irradiation of 8 hours or more was required to cause the inclination response, and 48-hour irradiation was enough to bring about the maximum response.

In rice plants, Maeda (1969) studied the effect of visible light of low energy (about 20 erg/cm²/sec) on lamina inclination and reported that an inhibitive effect on the lamina inclination of the 2nd leaves in etiolated seedlings were observed at all wavelengths of visible light by irradiation of 5 min/day for 7 days. On the other hand, Inada (1969) reported that the inclination angles of rice leaves were increased by blue light irradiation (14,500 erg/cm²/sec), but only slightly by green, orange, red, or white light; these results are similar to those reported in the present experiments with irradiation intensities of about 5000 erg/cm²/sec. The present results and Maeda's may be due to the difference of the duration and the intensity of light irradiation.

The action spectrum for phototropism and photonasty has been determined by many workers (Fortanier, 1954, Stolwijk 1954, Wassink and Stolwijk 1956, Shropshire and Withrow 1958, Mohr 1962, Veen and Meijer 1962). In phototropism, some investigators reported that the blue part of the spectrum is the most active region and photoreceptor consists of one or more yellow pigments, such as a carotinoid and riboflavin. Shropshire and Withrow (1958) demonstrated that the active photoreceptor in the phototropic tip-curvature of *Avena* is a yellow pigment, probably a carotinoid in nature, having absorption maxima at 410 to 415, 440 to 445 and 470 to 475 nm. Photonastic reactions of stems and leaves in various plants have been activated by red part of the spectrum (Veen and Meijer 1962). Virgin (1962) reported that the expansion of folding leaves in wheat plants was brought about by red light irradiation.

In wheat plants, wavelengths between 380-510 nm were effective in leaf blade inclination, with peaks at 430 nm and 470 nm. This is similar to results with rice plants (Inada, 1969) which were influenced by wavelengths shorter than 550 nm with peaks at 420-440 nm and 460-480 nm. Thus, the action spectrum of photonastic reactions in ricc and wheat plants is remarkably a similarity to the action spectrum of phototropic reactions but differs from light reactions in stem and leaves in some other plants.

SUMMARY

The effect of monochromatic light on the inclination of the leaf blade was investigated in *Triticum aestivum*.

1) Blue light was effective in causing the inclination of the leaf blade of the first leaves.

2) In blue light, the inclination of the leaf blade began at the 7th day after germination, and increased rapidly and showed almost the maximum value 9 days after germination. When the plants were exposed to continuous irradiation of blue, green, red, white light and to total darkness for 13 days after germination, the angles of the leaf blade were 117.7°, 21.1°, 82.7° and 20.0°, respectively.

3) Blue light irradiation of 8 hours or more was effective for leaf blade inclination. The leaf blade showed almost the maximum inclination response when the plants were exposed to blue light for 48 hours at the age of 9 days after germination.

4) The optimal temperature for the blue light effect on the inclination ranged from 20° to 25°C.

5) In experiments with spectral beams, the spectral regions effective for the inclination were in the wavelengths between 380 and 510 nm, with a marked response at 430–480 nm.

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