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EFFECTS OF THE COMBINATION OF FLUORESCENT LAMPS OF DIFFERENT COLOR ON THE GROWTH OF TOMATO PLANTS

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Introduction

It is well known that there are photosynthesis, photomorphogenesis, phototropism, and phototaxis effects of light on plant growth. Spectral effects have been confirmed experimentally. But the effects of the combination of two- or three- wavelengths of light on plant growth have not been measured. These are important problems in the use of artificial light for plant growth and in light measurement of plant irradiation. The two-light effect for photosynthesis, the Emerson enhancement, have been observed for green, blue and red algae, and the Hill reaction is known for chloroplasts taken out of green plants. This effect will occur in higher green plants, so that the Emerson enhancement occurs by the combination of pigment-enzyme in the chloroplast.

Light effects on photomorphogenesis have been reported for the combination of red and blue, and red and far red. Therefore the writer thinks that a percentage combination of spectral light is necessary for plant growth. The experiments reported here on growth of tomato plant (var. Fukuju-2) were performed with combined red and blue light, red-orange and blue light, and red-blue and green light.

Experimetal Methods

Two growth cabinets $1.5 \times 1.5 \times 1.5$ m were used, each cabinets being able to suspend thirty-three tubes of 40-W fluorescent lamps for the light sources at the ceiling. The fluorescent color lamps used were manufactured by Mitsubishi (Fig. 1).

Experiments were performed with three different light combination:

1) Combination of red and blue light

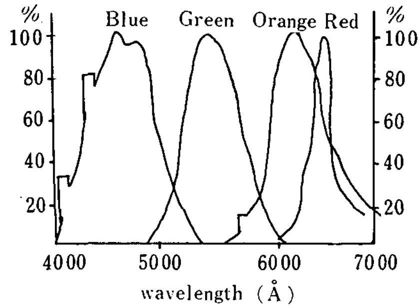

Fig. 1. Spectral curve of Mitsubishi colored fluorescent lamps.

a) 0.015 cal/cm² irradiation
After germinating in darkness (28.0°C) and growing under Toshiba plant-lux (type FLR 40 S/BR/M), tomatoes were exposed for twenty days from the expanded two-leaf stage.

b) 0.031 cal/cm² irradiation
After germinating in darkness and growing under sunlight, tomatoes were exposed for twenty days from the expanded two-leaf stage.

The plants irradiated with 0.015 cal/cm² of red and blue light were grown under Toshiba plant-lux before the light treatment were applied, but after 0.031 cal/cm² irradiation tomatoes were grown under natural sunlight to avoid the effects of artificial light of pretreatment.

2) Combination of red-orange and blue light
The same as treatment 1)–b).

Red light from the fluorescent lamps is narrower than blue light, therefore, a part of red light showing maximum growth with the red and blue combination was exchanged for orange light.

3) Combination of red-blue and green light
The same as treatment 1)–b).

Green light is added to the red and blue light combination showing maximum growth.

The experimental conditions were:

1) Exposure time per day : 16 hours (300–1900 hrs)
2) Temperature day (300–1900 hrs): 25.0°C
night (1900–300 hrs): 17.0°C

Exposure time per day was taken from the experimental results of Dunn, Saito et al., and Arther, and temperature from Went, Saito et al..

Results and Discussion

1) The combination of red and blue light

Length, dry matter, wet weight, stem diameter, and number of leaves after twenty days exposure were measured. Except for the number of leaves, maximum growth was with a high red ratio of 80% of all radiant energy at 0.015 cal/cm^2 irradiation and 88% at 0.031 cal/cm^2 irradiation. The growth disparity caused by pre-treatment light is not large because red ratios showing maximum growth in these experiments are similar.

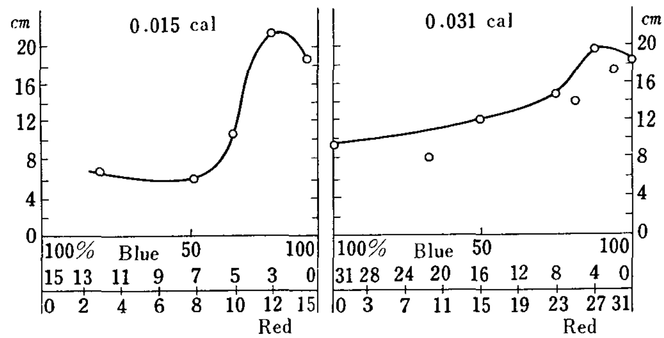

Fig. 2. Lengths of tomato plants exposed the combination of red and blue light.

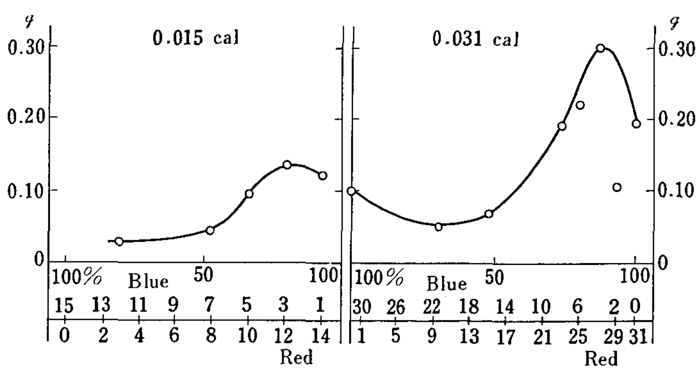

Fig. 3. Dry matter of tomato plants exposed the combination of red and blue light.

For tomato plant length, indicating photomorphogenesis effects, the following results appeared:

a) Maximum tomato lengths at 0.015 cal/cm^2 or 0.031 cal/cm^2 irradiation showed no large differences.

b) Lengths at 0.031 cal/cm^2 irradiation in the high blue ratio are greater

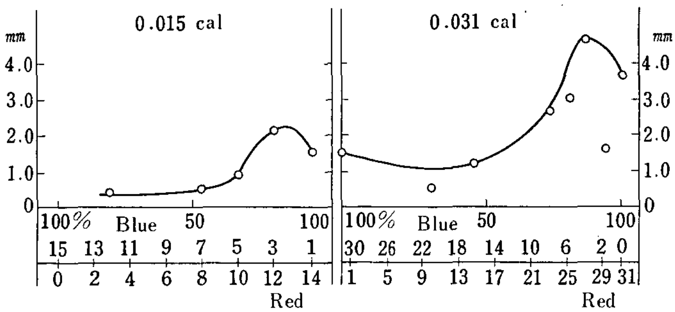

Fig. 4. Fresh weight of tomato plants exposed the combination of red and blue light.

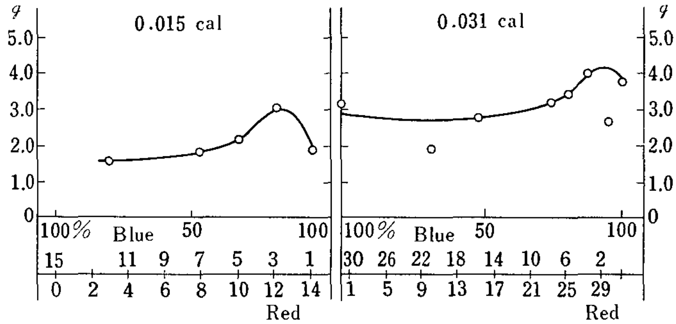

Fig. 5. Stem diameters of tomato plants exposed the combination of red and blue light.

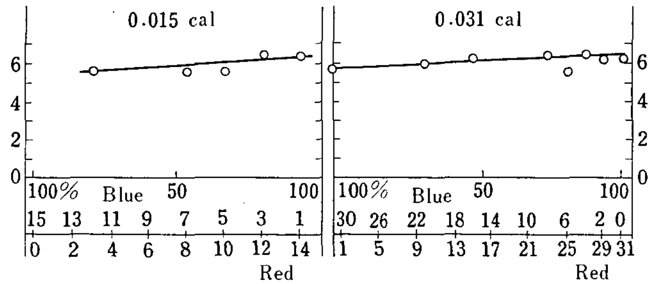

Fig. 6. Number of leaves of tomato plants exposed the combination of red and blue light.

than at 0.015 cal/cm^2.

c) These two facts account for the greater curvature in Fig. 2 for 0.015 cal/cm^2 irradiation.

The reason was thought to be that the tomato plant is saturated at low radiant energy, but this was not confirmed, so that the two-light reaction on photomorphogenesis has not been examined enough. The reason that plants at 0.031 cal/cm^2 irradiation are taller than at 0.015 cal/cm^2 is the increase of photosynthesis ratio at high energy.

The dry weights which represented photosynthesis show a different curve to length. Dry weights at 0.031 cal/cm^2 irradiation are twice those at 0.015 cal/cm^2 in all combinations. At 0.031 cal/cm^2 irradiation there is a large maximum growth, and this maximum growth is located at the same light combination as the maximum length. These facts are conjectured to be superimposed for two light combination and it may relate to the absorption spectra of photosynthetic pigment and to the transfer of enhancement energy.

In any case, the tomato plant showed maximum growth where the percentage of red light is 80–88% of the total radiant energy.

2) The combination of red-orange and blue light

It is desirable that each fluorescent color lamp used in these experiments have the same wavelength width, but red is narrower than blue according to the catalogue from Mitsubishi colored lamps. Therefore, growth was measured where the wavelength width was expanded to be the same as the blue. In this experiment a part of red which showed maximum growth at 0.031 cal/cm^2 irradiation was replaced with orange. The results are shown in Table 1.

TABLE 1. Effect of the combination of red-orange and blue ligth on the growth of tomato plats.

Light condition	Length (cm)	Dry metter (g)	Fresh weight (g)	Stem diam. (mm)	No. of leaves
Red 0.027 cal/cm^2 Blue 0.004 cal/cm^2	18.3±0.9*	0.12±0.03	2.4±0.3	3.5±0.6	6.4±1.6
Red 0.017 cal/cm^2 Orange 0.009 cal/cm^2 Blue 0.004 cal/cm^2	14.0±1.6	0.08±0.09	1.7±0.3	3.0±0.4	6.0±0.5

* Mean ± standared deviation

The growth with red-orange and blue light is less than with red and blue light, so that there is no effect that expand red wavelength width. That is to say the tomato plant does not require so wide range of red wavelength.

3) The combination of red-blue and green light

The growth due to green light added to the combination of red and blue light which showed maximum growth is given in Table 2.

The intensity of green light is 0.005 cal/cm^2, nevertheless it did not affect tomato plant growth. It is said that the effect of green light is not large. This fact has been reported by many authors and is understood to be because the pigment of the plant leaf does not absorb green light. But there is a publication that tomato plants grow very well in daylight from which green light has been removed so that the negative effect of green light must be considered. These experiments do not show it.

TABLE 2. Effect of the combination of red-blue and green light in the growth of tomato plants.

Light condition	Length (cm)	Dry matter (g)	Fresh weight (g)	Stem diam. (mm)	No. of leaves
Red 0.018 cal/cm^2 Blue 0.003 cal/cm^2	17.9±2.8	0.17±0.03	3.2±1.5	3.7±0.2	6.0±0.5
Red 0.018 cal/cm^2 Blue 0.003 cal/cm^2 Green 0.005 al/cm ^{2}	18.8±2.5	0.16±0.02	3.1±1.3	3.9±0.6	6.0±0.5

Summary

The effect of a combination of fluorescent color lamps on the growth of tomato plants (var. Fukuju–2) was investigated.

Under the combination of red and blue fluorescent lamps, the growth was maximum when the ratio of red was 80–88% of all radiant energy. In this combination, if a part of the red was exchanged to orange light in order to spread the range of wavelength, the growth of tomato plants became smaller. From this experiment, it became clear that the range of red wavelength required was not wide.

The addition of green light to the maximum growth ratio of red and blue light did not increase growth. So, it is recognized that green light has no effect on growth of tomato plant.

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