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Studies on the Growth Response of the Rice Plant to Exogenous Gibberellic Acid

II. Relationship between the Applied Gibberellic Acid and Light in the Different Organs of Rice Seedlings

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Summary

The present paper deals with the relationship between the applied gibberellic acid (GA) and light on the growth of rice seedlings grown under various GA levels and light intensities.

The degree of the effect of GA applied for the recovery of light-induced growth inhibition varied with the variety, organ, GA level, and light intensity. The most prominent effect was observed in the case of the second leaf-sheath. In this organ, the promoting effect of GA increased with the elevation of the GA level and a growth promotion by light appeared in the higher levels of GA (1–100 μg/ml) owing to an interaction between the GA and the light (3,000 lux). Such an interaction was also observed in the lower intensity of light (below 2,500 lux), and a remarkable light-induced promotion appeared with the application of GA (10 μg/ml).

The effects of applied GA and light were different with the age of the organ. In the second leaf-sheath, maximum inhibition by light was observed in 5th day stage in the absence of GA, and maximum promotion owing to an interaction of GA and light was observed in 4th day stage.

From the results, the authors concluded that the GA treatment response curve in this organ was composed of two functions of light, *i.e.*, the promotional and inhibitory action of light.

In the previous paper (1), it was suggested that the relationship between the effects of applied GA and light on the growth of ordinary Japonica rice varieties varied with the organ of the seedlings. But it was not clarified whether such a relationship would come out under various GA levels and light intensities. The present experiments were carried out to elucidate that relationship under various conditions.

Materials and Methods

Three rice varieties, "Boshi-to" (Indica, *normal*), "Sasanishiki" (Japonica, *normal*), and "Waito-C" (Japonica, *dwarf*), which showed low, medium and high sensitivity to GA, respectively, were used as materials. The seeds were harvested in the fall of 1966 and used for experiment from May to October, 1967. The seeds were sterilzied with a 0.1 *per cent* "Uspulun" solution for three hours at room temperature. They were then washed with tap water and placed in a *Petri* dish in darkness at 30°C. When the emerging coleoptile reached about 1 mm in length, uniform seedlings were selected. Five seedlings were placed in a glass tube containing a 1 ml of test solution and incubated under various conditions described hereafter. The length of organ in each seedling was measured after twelve days' incubation periods.

Results and Discussion

Effects of Exogenous GA Levels on the Growth of Seedlings

The experiments were carried out at 30°C under continuous illumination (3,000 lux with white fluorescent lamp) and in darkness, respectively. Six levels of GA (0, 0.01, 0.1, 1, 10 and 100 μg/ml) were used. The results are shown in Fig. 1. The growth of each organ increased with the elevation of GA level in all cases. The growth of the primary leaf and the second leaf-blade were greater in the dark than in the light with the same level of GA. Growth of the second leaf-sheath, however, was greater in the light than in the dark with the higher levels of GA (above 1μg/ml). For comparison of the effects of GA in the light and in the dark, the growth response was calculated as follows; $(L_g - D_g)/D_g \times 100$ (%), where L_g or D_g represents the final length of the organ in the light or in the dark at the same GA level. The positive or negative value obtained indicates the degree of growth promotion or inhibition by light. The results are illustrated in Fig. 2. From the figure, it was indicated that the effects of the various GA levels on the light-induced growth inhibition varied with the variety and organ. In the case of "Boshi-to", the degree of recovery from light inhibition, by using GA, increased with the elevation of the GA level up to 10 μg/ml in the primary leaf and the second leaf-blade. However, with "Waito-C", the GA recovery effect seemed to be independent of the GA level. "Sasanishiki" was of intermediate character. In the second leaf-sheath, however, an interaction between the applied GA and the light was observed in all varieties. An inhibitory light effect was also observed in the lower GA levels, but diminished with the increase of the GA level. In higher levels of GA, the growth in the light surpassed the growth in darkness.

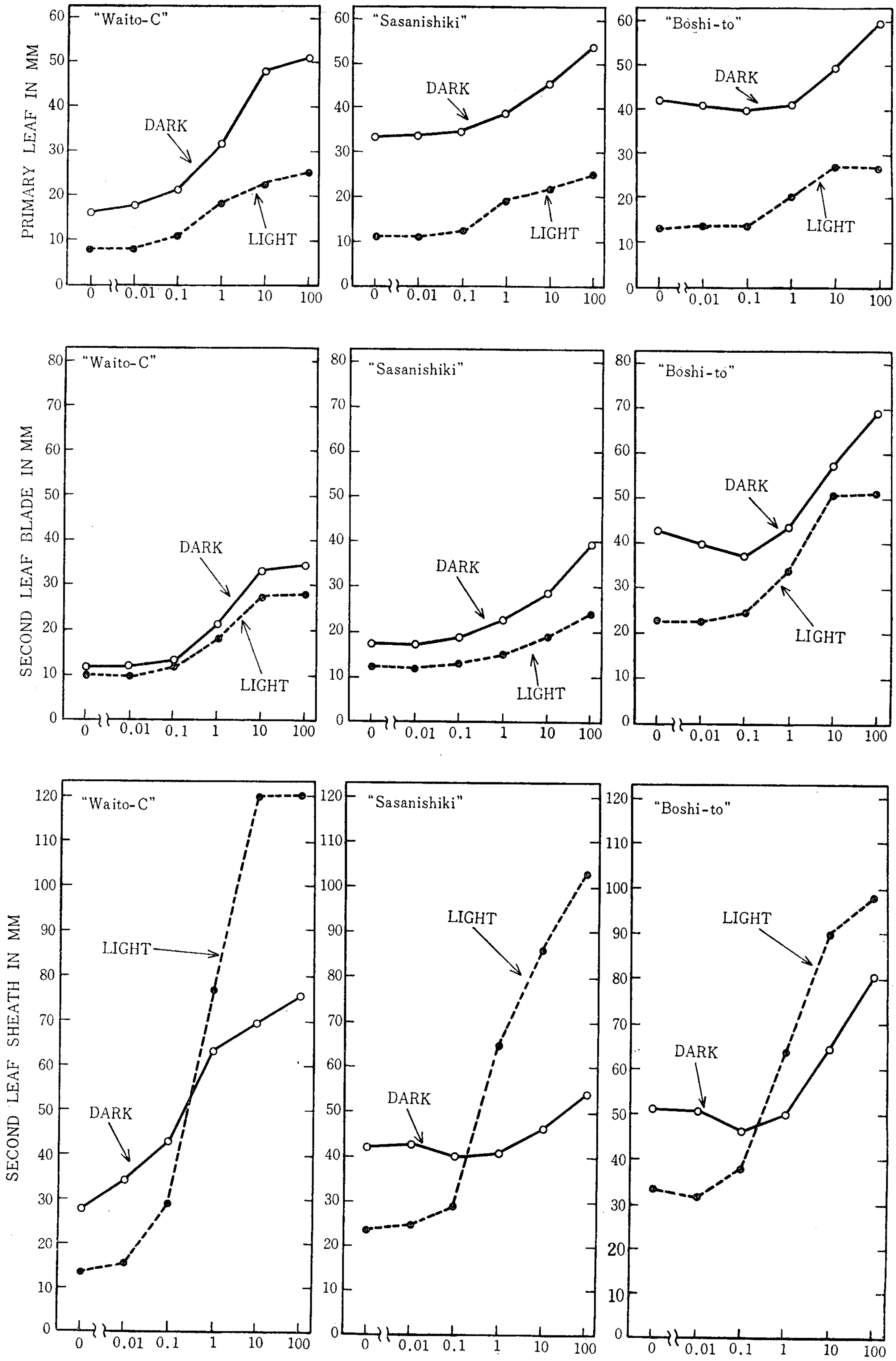

FIG. 1. Elongation of different organs of rice seedlings to various doses of GA (0, 0.01–100 μg/ml) in the light (3,000 lux) or in darkness. Length of the organs were measured after 12 days' incubation periods. Note: Waito-C (Japonica, *dwarf*), Sasanishiki (Japonica, *normal*), Boshi-to (Indica, *normal*).

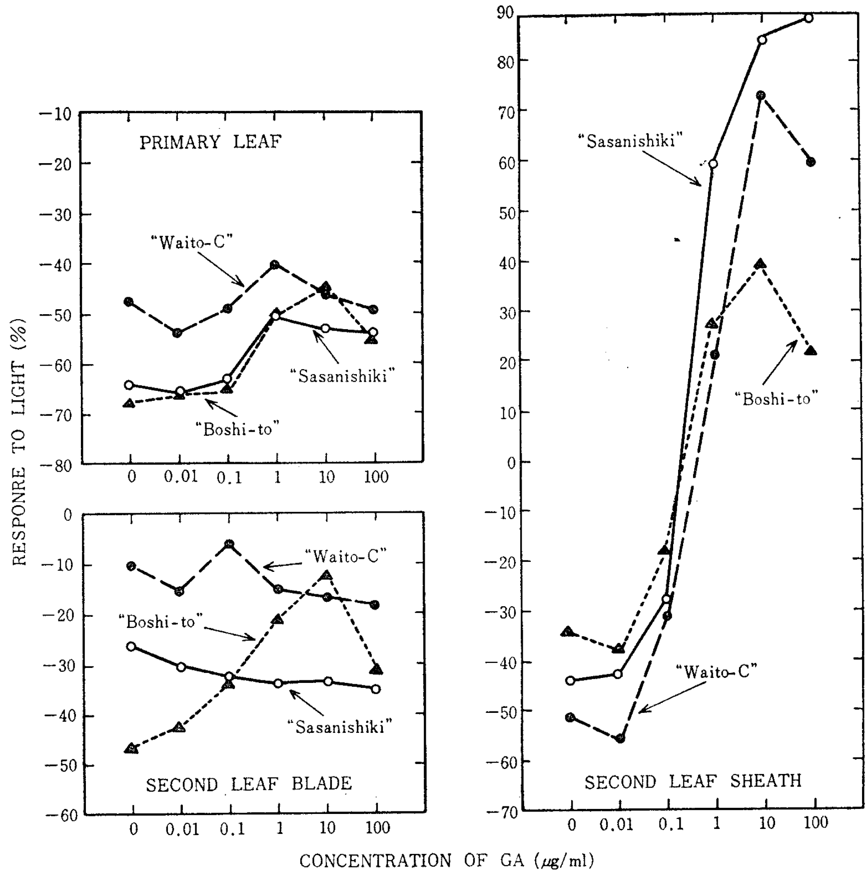

FIG. 2. Response of different organs of rice seedlings to light at each GA level. The growth response was calculated as follows; $(L_g - D_g)/D_g \times 100$ (%), where L_g or D_g represents the final length of the organ in the light or in the dark at the same GA level.

Experimental condition is the same as in Fig. 1.

The Effects of Applied GA on the Growth of Seedling under Various Light Intensities

The effects of applied GA (10μg/ml) were studied under several light intensities (0, 50, 2,500 and 5,000 lux with white fluorescent lamp). "Sasanishiki" was used. The results are shown in Fig. 3. The figure indicates that the growth promoting effect of GA can be recognized at any light intensity regardless of the kind of organ. However, the degree of GA effect varied with the organ, *i.e.*, low in the second leaf-blade, medium in the primary leaf and high in the second leaf-sheath. For comparison of GA effects among various light intensities, the ratio of the growth increase with GA treatment to the growth of water control (—GA) was calculated at each level of light intensity, respectively. The results obtained are illustrated in Fig. 4. The growth response value of the primary leaf was higher than that of the second leaf-blade, and the values were nearly constant at all light intensities. Therefore, the GA action in these organs was thought to be independent of light intensity. But the growth response of the second leaf-sheath increased

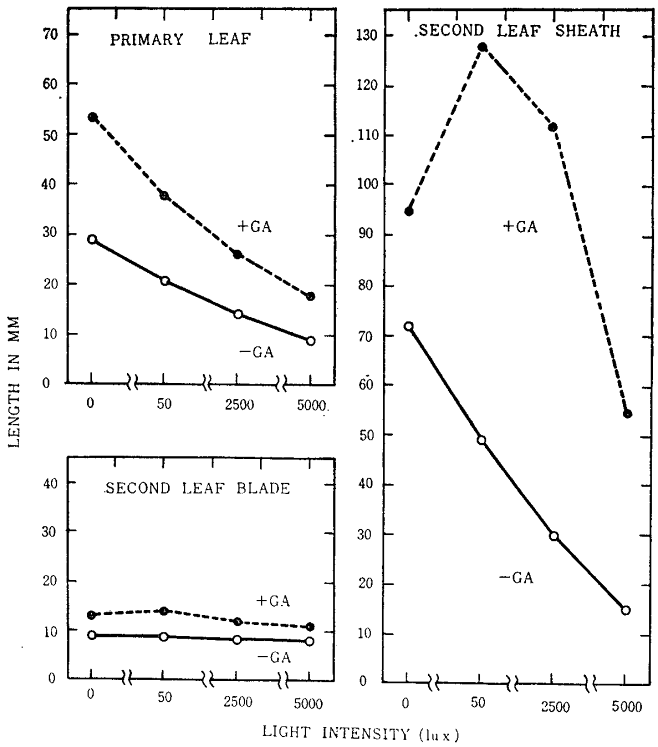

Fig. 3.

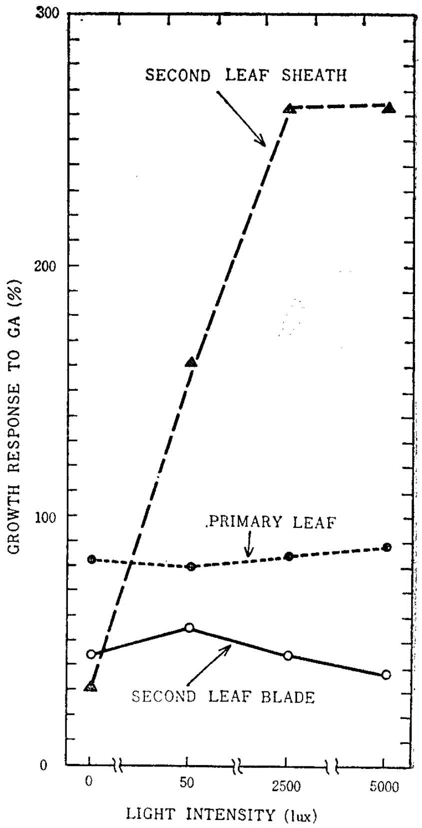

Fig 4.

FIG. 3. Elongation of different organs with or without GA (10 μg/ml) at various light intensities (0, 50–5,000 lux). Sasanishiki (Japonica, *normal*) was used.

FIG. 4. Growth response of different organs to GA at various light intensities. Growth response is indicated as per cent increase of control length (−GA) at each light intensity. Experimental condition is the same as in Fig. 3.

rapidly with the elevation of light intensity (up to 2,500 lux) and then settled to a difinite level. These facts suggest the presence of an interaction between applied GA and light (under weak light conditions) in the case of the second leaf-sheath.

Effect of the Applied GA on the Growth of Seedlings Exposed to Light at Different Ages

The above-mentioned experiments were carried out in continuous light or dark conditions during the incubation period. However, the sensitivity to light of seedlings was thought to vary with the age of the seedlings. The present experiment was undertaken to clarify the effects of light exposure at different ages upon the growth response to GA. The light exposure was given by interrupting the dark incubation period with an illumination of 24 hours (3,000 lux with white fluorescent lamp) at designated times as shown in Fig. 5. The higher dose of

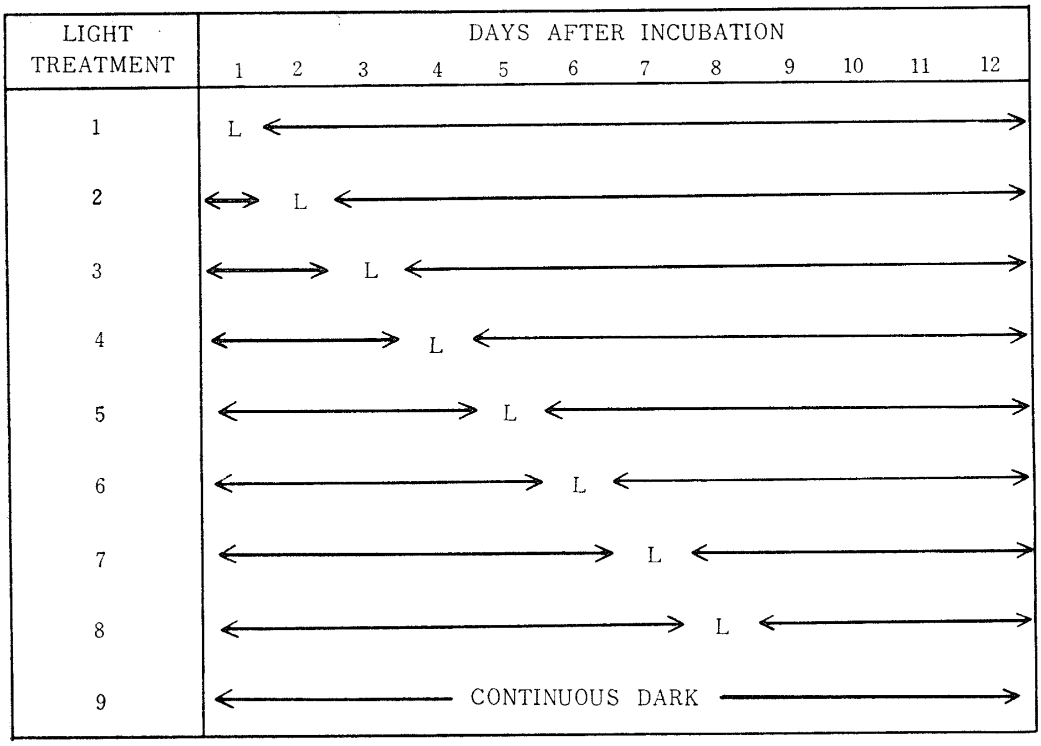

FIG. 5. Light treatment at different ages of plant.
Seedlings were treated with or without GA (100 μg/ml) at the start of incubation and exposed to light (3,000 lux, white fluorescent lamp) for 24 hours at designated periods. The length of different organs of the seedlings were measured after 12 days' incubation periods. Note; Light exposure is indicated as **L**.

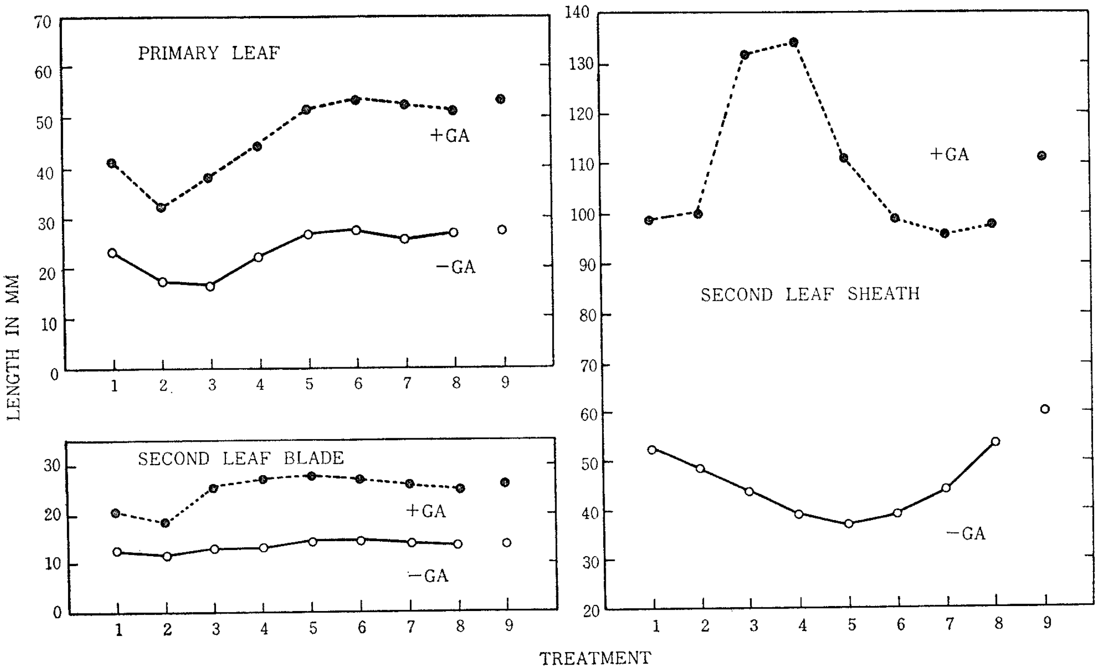

FIG. 6. Elongation of different organs with or without GA (100 μg/ml) exposed at designated periods as shown in Fig. 5.

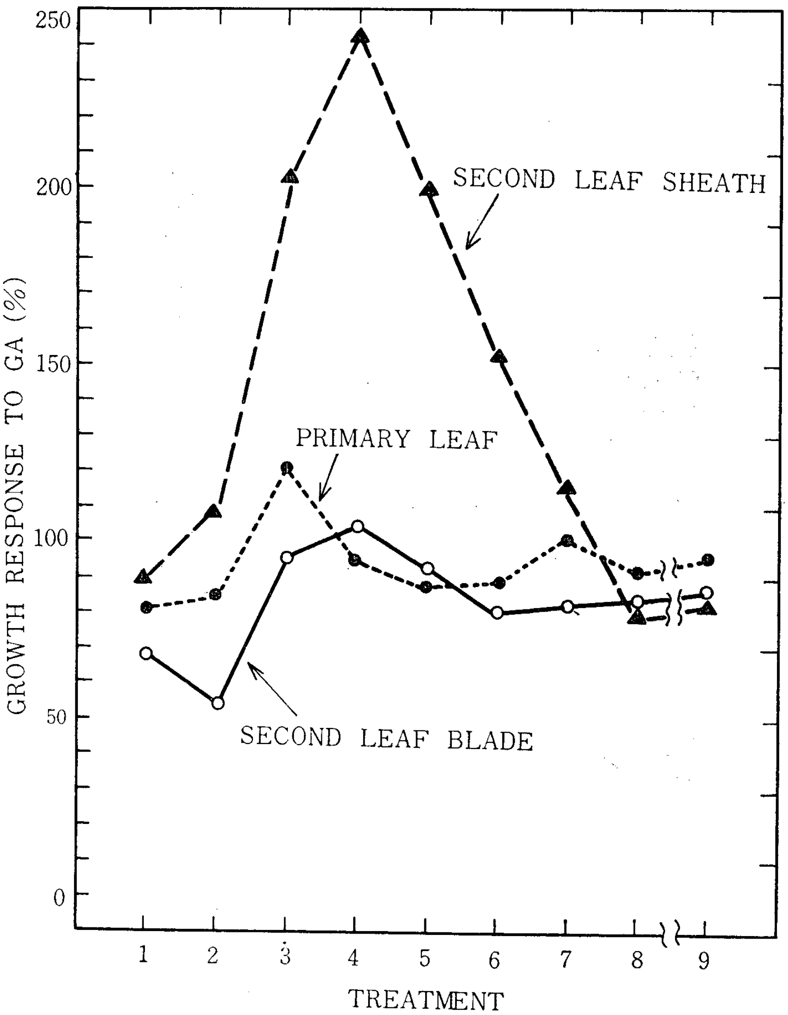

Fig. 7. Effects of light exposure at different ages of plant on the growth response of seedlings to GA (100 μg/ml). Growth response is indicated as per cent increase of control length (−GA) at each treatment. Experimental condition is the same as in Fig. 5.

GA (100 μg/ml) was applied at the start of incubation, and the growth of the organs were measured after twelve days' incubation. "Sasanishiki" was used. The results are illsutrated in Fig. 6. The growth response of the organs at each light treatment are shown in Fig. 7. From the results, growth inhibition by light were recognized even with a 1st day treatment in all organs, but the degree and duration of sensitivity varied with the organ. Maximum growth inhibitions were attained by 2nd or 3rd day treatment in the case of the primary leaf and the second leaf-blade, and by 5th day treatment in the second leaf-sheath.

Similar results were obtained by Hamada (2) indicating that maximum growth inhibition was attained by an early growth stage exposure in each organ.

The application of GA was effective in decreasing the light-induced inhibition in all cases. A striking growth promotion was attained by 3rd or 4th day treat-

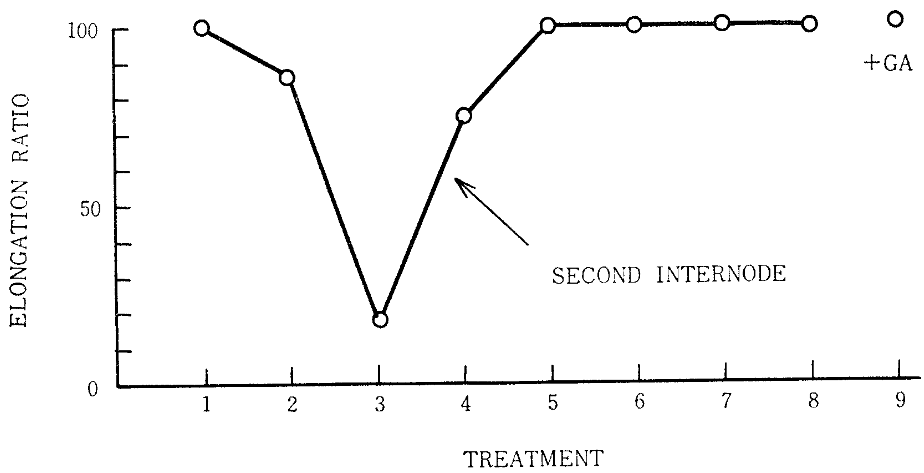

FIG. 8. Effect of light exposure at different ages of plant on the growth response of the second internode to GA (100 μg/ml). Growth response is indicated as the ratio of elongated plants to total plants used at each treatment. Experiment condition is the same as in Fig. 5.

ment in the case of the second leaf-sheath, *i.e.*, one day earlier than that of maximum growth inhibition. As shown in Fig. 7, the growth response to GA was not so high on the primary leaf and the second leaf-blade, but in the second leaf-sheath a prominent response having a peak at the 4th day treatment was observed.

The second internode is located below the second leaf-sheath, and they are closely related to each other histologically. Therefore, in this experiment, elongation of the second internode was measured. The results are shown in Fig. 8. No elongation was observed in the dark or in the light without GA treatment. The elongation appeared with GA treatment, but this effect in some plants was masked by the effects of the light exposure. The ratio of elongated plants to total plants used is indicated as *per cent* of total plants in each treatment, respectively. All the plants elongated in 1st or 5th to 8th day treatment. Miximum inhibition was observed in 3rd day treatment, *i.e.*, one day earlier than that of maximum growth promotion observed in the second leaf-sheath. In the 4th day treatment, the elongation of the second internode was slightly inhibited by light, but a remarkable elongation of the second leaf-sheath was observed. Therefore, the growth promotion of the second leaf-sheath was considered to be independent to the growth inhibition of the second internode by light.

There is a large number of investigation concerning the relationship between the applied GA and light (3-5). Lockhart (6-8) reported that the stem growth in peas was depressed by light and this light-induced inhibition was overcome by applied GA, and that the dark-grown plants showed little or no response to GA. In other species, however, the growth response to GA appeared even in the dark (9).

In the present experiment, the primary leaf and the second leaf-blade of dark-grown rice seedlings showed nearly the same response to GA as those of light-grown plants. These results suggest that the promoting effect of GA is independent of the inhibitory effect of light.

In the second leaf-sheath with water control, an inhibitory effect having a peak at the 5th day stage was observed. In higher levels of GA, however, another growth response curve having two peaks of maximum and minimum was obtained (Fig. 6). It has been known that quality as well as quantity of the response to light are dependent on the age at the time of exposure (10-13). From these results, The authors consider that the response curve with GA treatment is composed of two functions of light, *i.e.*, the promotional and inhibitory action of light of which the maximum are located in the 4th and 5th day stage, respectively.

In the case of the other organs, no promoting effect of light was observed, but the authors consider that the possibility of the existence of a promoting effect of light remains to be solved.

Maeda (14–15) reported that red light irradiation (30 min./day) inhibited the elongation of the second internode of the rice seedling. However, this inhibition was overcome with applied GA. And the light exposure promoted the elongation of the second leaf-sheath which was even more enhanced with GA treatment. Then he suggested that the mechanisms of the elongation of the various organs in a rice plant differed from each other. The present data support this suggestion.

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