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The Effects of Gibberellic Acid on the Growth of Rice Plant under Different Temperatures

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Summary

The growth response of japonica rice (cv. *Sasanishiki*) to applied gibberellic acid (GA_3) was studied in outdoor phytotrons which were maintained at 17/12, 24/19 and 30/25°C (day/night).

At 30/25°C, the plant height and leaf length were markedly increased by a foliar spray of 0.1% GA_3, but the leaf breadth, chlorophyll concentration of leaf-blades and nitrogen levels of shoots were reduced. The total leaf area, chlorophyll content of leaf-blades and nitrogen content of shoots were also decreased. The dry weight of the treated shoots increased by GA_3 due to an increased growth of leaf-sheaths and stems.

At 17/12 and 24/19°C, the treated plants had a greater leaf area and a higher content of chlorophyll and nitrogen although their concentrations were lower than those of the untreated plants

It has been known that the grain yields of cereals are often decreased by an application of gibberellic acid (GA_3), although the growth of the leaves and stems are greatly promoted (1). Blacklow (2) showed that the foliar growth of grasses was increased by GA_3 at low temperatures during winter. We have reported the growth response of rice plants to different levels of GA_3 application (3). The grain yields were increased with 10 ppm of GA_3 applied repeatedly during the reproductive stage resulting from an increase of total leaf area and of the number of spikelets per panicle and per plant. While with the heigher concentrations of GA_3 (50 to 1,000 ppm), the grain yields were decreased because of a decreased total leaf area and of a smaller number of panicles with heigher percentages of degenerated flowers and unripened grains.

In the present experiments, the growth responses of rice plants to GA_3 under different temperatures were examined in an attempt to find the possibilities of utilizing GA_3 application for rice culture.

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Materials and Methods

A japonica type of rice, cv. *Sasanishiki* was used. This is the most common variety in our region where the growth of rice plants are sometimes checked by a cool climate in the early growing season. Seedings at the 6.1 leaf stage were transplanted to 1/5,000 *a* Wagner's pots on May 27, 1971, 2 plants per pot. The fertilizers composed of each 0.6 g of N (NH_4), K_2O and P_2O_5 were applied to the paddy soil in pots before transplanting. After the plants were grown outdoors for 11 days, the total 48 (16 pots for each room) pots were transferred into 3 phytotrons on June 7, which were maintained at 17, 24 and 30°C day-temperatures, the night-temperatures being 5°C lower than each day-temperature. Day-time was from 6 am to 6 pm. Immediately after the transfer, 8 pots in each phytotron received a 4 ml of 1,000 ppm of GA_3 solution application (Kyowa fermentation Co.) per plant by foliar spray. The rest 8 pots remained untreated. At 15 days after the treatment, plants were sampled for measuring the leaf area and chlorophyll content of leaves and for chemical analysis, i.e. nitrogen by semimicro Kjeldahl method, total sugar and starch by Murayama's method (4), and chlorophyll by IRRI's method (5) using a spectrophotometer.

Another group of 18 pots were sprayed with 1,000 ppm of GA_3 on June 7. The plants were grown outdoors where the daily mean temperature was arround 18°C. At 0, 2, 5, 8, 16 and 32 days after the treatment, each 2 to 4 plants were sampled, frozen, and stocked at -20°C till being extracted with 70% acetone. The methods of extraction, fractionation and bioassay were almost the same as those reported by Suge (6). The gibberellin activities of the extracts in the acid fraction were seperated with thin-layer chromatography using a mixture of isopropanol, ammonia and water (10:1:1 v/v) as developing solvent. The chromatogram was divided into ten segments, and the eluates were tested on the rice seedlings. The total gibberellin activities in the eluates were indicated as μg equivalents calculated from the dosage response curve of synthetic GA_3.

Results

Plant height, tiller number and leaf number

GA_3 markedly increased the plant height at all temperature regimes. For instance, the height of the treated plants at 17°C reached almost the same height of the untreated plants at 24°C (Table 1). At 30°C, the elongation of both leaf and stem internode was promoted by the treatment, whereas at 17 and 24°C the internode elongation was not increased. The previous work (7) conducted outdoors (daily mean temperature was arround 20°C) showed the occurrence of internode elongation only by the continuous application of high levels of GA_3 (1,000 ppm). From these results it may be suggested that the plants grown at a

TABLE 1. *The Effects of GA_3 on the Height, Tiller Number and Leaf Number of Main Stem of Rice Plant grown under Different Temperatures.*

Day-temperatures, °C	17		24		30	
GA_3	Untreated	Treated	Untreated	Treated	Untreated	Treated
Plant height, cm	28.5	53.0	58.5	97.5	65.5	115.0
Number of tillers	4.8	3.8	5.5	4.4	6.4	5.4
Leaf stage	9.2	9.0	10.1	9.8	10.5	10.2

high temperature are in a state more sensitive to GA_3 than at a low temperature concerning stem elongation.

The tiller number and leaf number of the main stem were slightly decreased by the GA_3 treatment at all temperatures (Table 1). The average number of leaves per plant for untreated and for treated plants at 17, 24 and 30°C were 14.8, 15.6; 10.2, 13.6; 18.3, 15.4, respectively.

Leaf size

The leaf length was conspicuously increased by GA_3 at all temperatures, but the breadth was generally decreased, especially at a high temperature. By the treatment, the mean and the total leaf areas were decreased at a high temperature, but increased at lower temperatures, the tendency being more evident in the total leaf area, since the number of leaves per plant decreased in the former but increased in the latter environment (Fig. 1).

Chlorophyll content

The chlorophyll concentration of leaf-blades was reduced by GA_3 at all temperatures (Fig. 2). However, the chlorophyll content of whole leaves at 17 and 24°C was increased by the treatment due to an increased total leaf area, while it was markedly decreased at 30°C with a concomitant decrease of total leaf area.

Nitrogen content

The nitrogen concentration of the leaf decreased with the application of GA_3 to a greater extent at high temperatures (8, 9), (Fig. 3). This decrease of nitrogen concentration was accompanied with an increase of dry matter production of the shoot (Fig. 5). At 30°C, both dry weight and nitrogen concentration of leaf-blades were decreased by the GA_3 and much of the absorbed nitrogen accumulated in the leaf-sheath and stem. At 17°C, the dry matter increase was accompanied with slight increase of nitrogen content resulting from the greater amount of nitrogen absorption by the treatment. At higher temperatures, the GA_3 did not promote nitrogen absorption together with an increase of dry matter, thus resulting in a lower concentration of nitrogen. Both concentration and content of soluble-

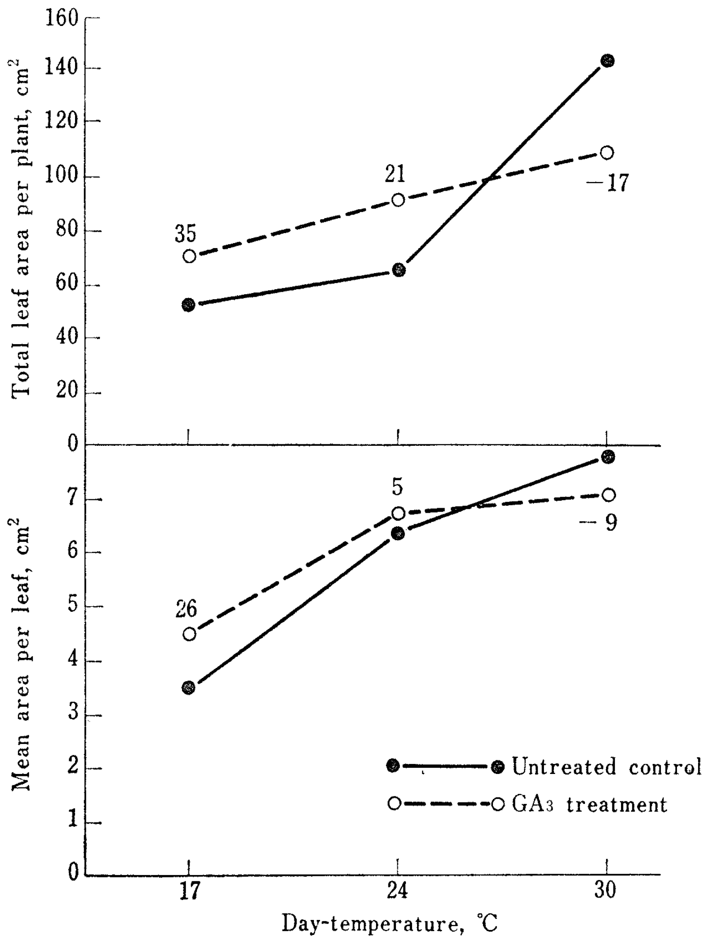

FIG. 1. Effects of GA_3 on the mean area per leaf and the total leaf area per plant. Figures represent percentage increase by the treatment.

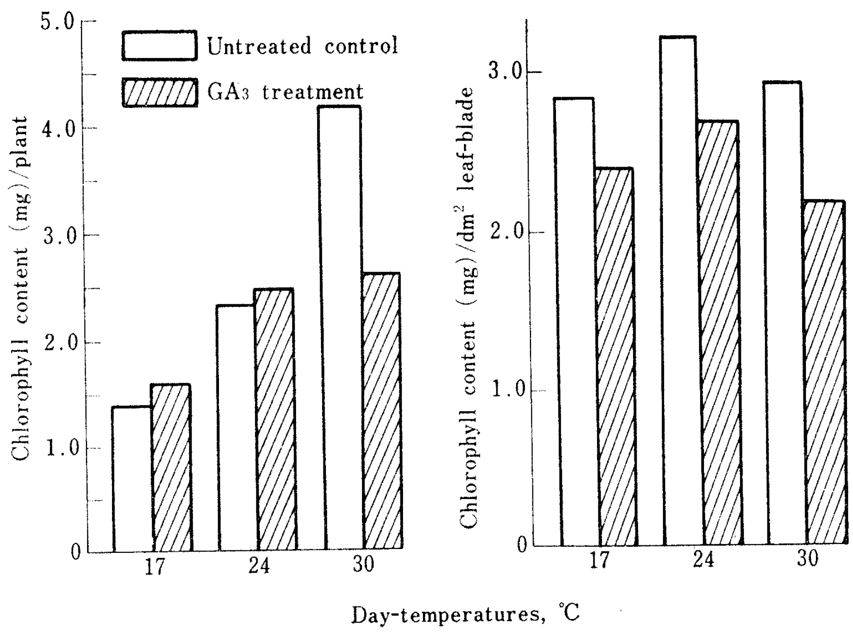

FIG. 2. Effects of GA_3 on chlorophyll contents per plant and per unit leaf area.

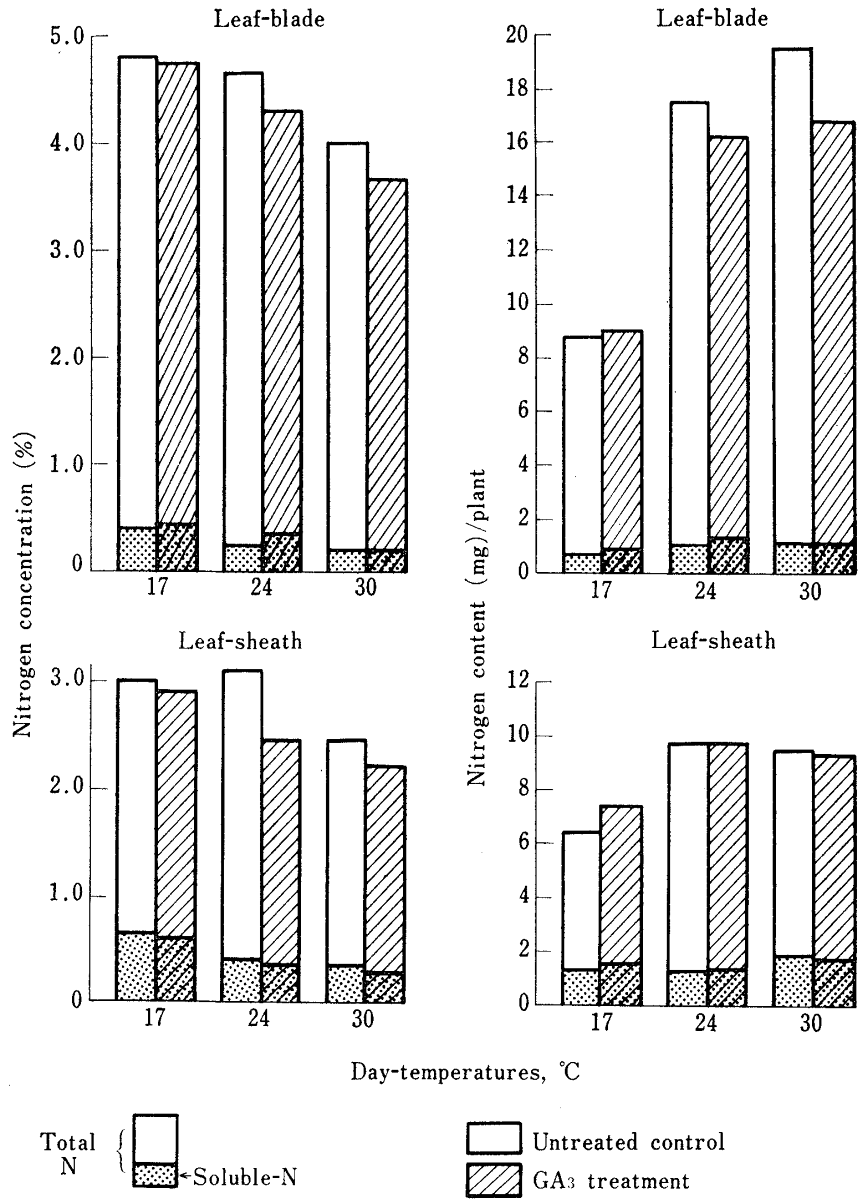

FIG. 3. Effects of GA_3 on nitrogen content of leaf.

nitrogen of leaf-blades and their sol-N/total-N ratios were increased by the treatment at all temperatures.

Carbohydrate content

The GA_3 application decreased both starch and total sugar concentrations in the leaf-sheath and stem (8, 10). The starch concentration in the leaf-sheath and stem increased with the decrease of temperature (Fig. 4) (9).

Dry matter production

At all temperatures GA_3 increased the shoot dry weight (Fig. 5). However,

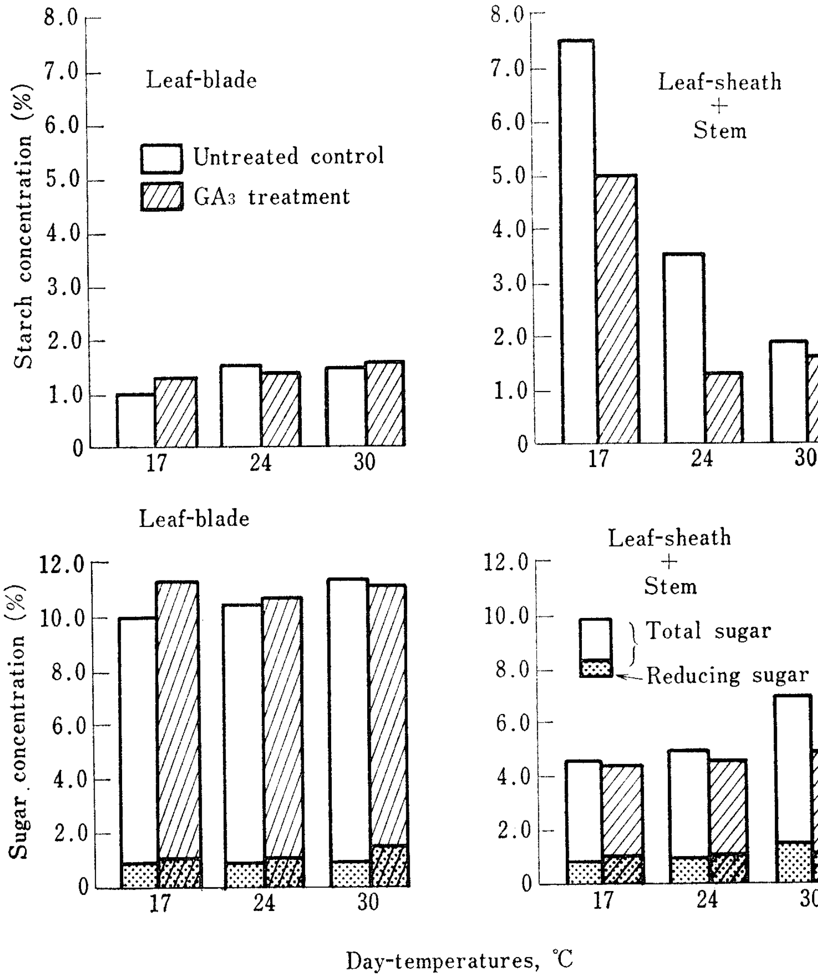

FIG. 4. Effects of GA_3 on starch, total and reducing sugars concentrations (dry weight basis) of leaf-blade and leaf-sheath+stem.

the increased parts are different with different temperatures, i.e. leaf-blade and -sheath at 17°C, leaf-sheath at 24°C, leaf-sheath and stem at 30°C, respectively.

Gibberellin activity

A high activity of gibberellin existed in the treated plant soon after the application but dropped rapidly during the first two days thereafter (Fig. 6). Suge (11) reported that only 0.5% of the applied GA_3 was recovered from the treated rice plants 10 days after the treatment. These results suggest that supplied GA_3 is very unstable in rice plants, although Zeevaart (12) reported its longer persistency in Bryophyllum plants. Therefore, repeated applications may be necessary for maintaining the activity at an appropriate level at least in rice plants.

Discussion

It has been known that GA_3 increases leaf area but often decreases chlorophyll content per unit leaf area (13, 14). Similar results were obtained in the experiment.

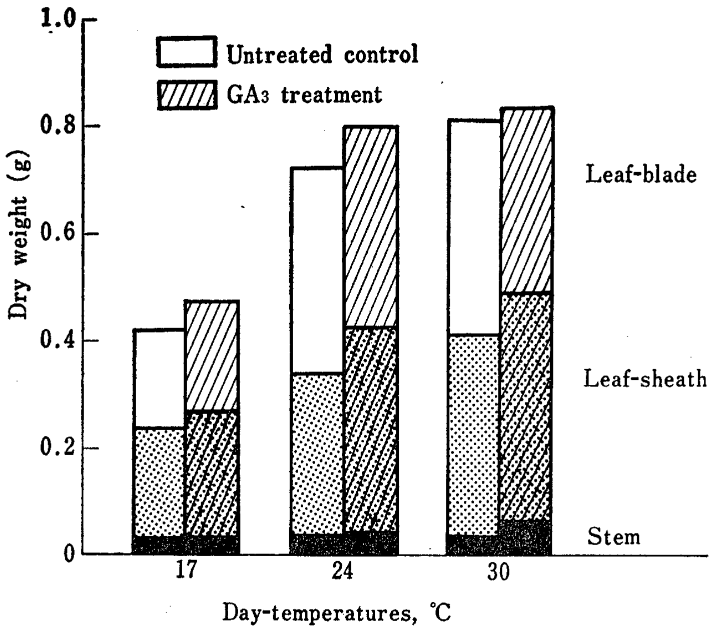

FIG. 5. Effects of GA_3 on the dry weights of leaf-blade, leaf-sheath, and stem per plant.

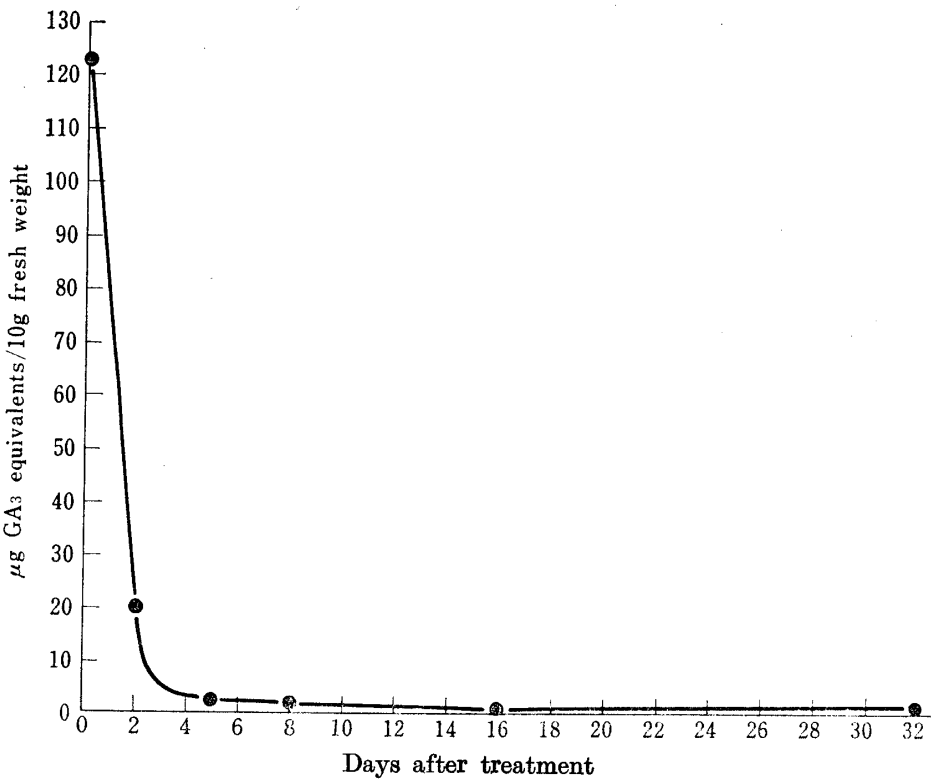

FIG. 6. Changes in gibberellin activities of treated plants.

This decrease of chlorophyll content per unit leaf area may be due to the effect of dilution by the increase of leaf area, or to a decrease of quantity of chlorophyll itself, as suggested by Brian (13). Masuda *et al.* (14) supported the former possibility. However, the present results may allow either possibility, since the decrease of chlorophyll content was accompanied with the decrease of leaf area at 30°C and with the increase at 17°C.

The shoot growth was promoted by GA_3 at all temperatures. However, the distribution of assimilates was differentially affected with different temperatures. The growth of leaf-blades was increased by GA_3 at 17°C but decreased at 30°C where a greater growth of leaf-sheaths and stems was observed.

At the low temperature of 17°C, the GA_3 increased the total nitrogen content of leaf-blades because of their greater dry weight, although it decreased the concentration. The treated plants at 17°C had greater leaf area with a greater amount of chlorophyll, thus being in a state more productive of dry matter than the untreated plants. Although GA_3 decreased the starch accumulation in the leaf-sheath due to an increased consumption of carbohydrate for promoted growth, the rate of starch decrease at 17°C was relatively small probably due to an increased photosynthesis (10). They formed longer leaves and greater plant height, reaching almost the same height as the untreated palnts at 24°C, without any sign of spindly growth. Therefore, it may be possible to use GA_3 to promote rice growth under low temperatures. In this case, repeated application of GA_3 of lower concentrations than that used in this experiment may be more effective to avoid a spindly growth when the temperature rises and to maintain the GA_3 content of the plant at an appropriate level.

Under optimal temperature for growth of rice plants of 30°C, the GA_3 decreased the mean and the total area of leaves, their dry weight, and nitrogen and chlorophyll contents, resulting in spindly growth with much consumption of reserve carbohydrates. GA_3 application under optimal temperature conditions may, therefore, be useless for rice cultivation. This may coincide with the fact that no other case of GA_3 application except that applied at young panicle formation stage at a very low concentration which does not affect stem elongation has been effective for increasing grain yields (3, 8).

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