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ACCELERATION OF MANGANESE UPTAKE BY RICE PLANT GROWN UNDER UNFAVORABLE TEMPERATURE OR LIGHT CONDITION

By

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The rice cultures in the districts of Hokkaido and Tohoku, namely the north eastern part of Japan, have been frequently damaged by unusual cool weather in summer. It is, therefore, an important problem to elucidate the nutrio-physiological behaviors of rice plants grown under the cool weather conditions. However, until about a decade ago it was very difficult to control artificially the environmental conditons such as light or temperature for plant growth. Thus the artificial irrigation of cool water was used as the sole method for investigation of this kind of cool damage and some workers (1, 2, 3) showed that the nutrient uptakes of rice plants were markedly reduced by the treatments of the irrigation of cool water.

As a result of the remarkable developments in the field of engineering, it became recently possible to control the temperature or light for the plant growth to some extent (4). The experiments described below were also carried out in the temperature-controlled greenhouse established by the Tohoku University in 1955.

It is the purpose of this paper to report the acceleration of manganese uptake by the rice plant growing under such unfavorable environment as low temperature or shade. This report is a part of the studies on the cool damage of rice plant in Japan.

Materials and Methods

Norin No. 16 of the rice plant (*Oryza sativa* L.) with a weak cool resistance was used as the experimental material. Two plants of 30 days seedling were transplanted in each of the Wagner's pots (1/5000 *are*) containing Minamikoizumi alluvial soil which was fertilized with 0.5 g. of N, P, and K, respectively. Prior to the low temperature or the shade treatment, these plants were cultivated under normal condition in the open air. At the stage of maximum number of tillers, these plants were exposed to three unusual environments as (a) low temperature, (b) shade, and (c) low temperature and shade for one to three weeks, respectively. Some plants were continuously grown under the normal condition for the control. The average temperature of the normal condition was 27 °C.

The low temperature treatment was examined in the temperature-controlled greenhouse of about 80 percent of relative humidity at 17°C.

The shade treatment was carried out in a wooden frame with about 50 percent of intensity of sun light, this was made by covering the frame with a bamboo blind in the open air. The average temperature in the frame was 27 °C.

The low temperature and shade treatment was performed in the dark room connected with the greenhouse, in which the temperature was controlled at 17° C, and the doors of the dark room were allowed to open to receive about 50 percent of light intensity in the greenhouse. To equalize the acceptable quantities of light by the plants, the positions of these plants growing under the shade environment were alternately changed every day.

After one to three weeks, the tops of these plants were harvested as samples for determination of the amounts of nutrients which have been taken up by them. These samples were immediately killed in an air forced dry oven at 80 °C for 30 minutes and the drying of these samples was continued at 50 °C for three days. Then these dried samples were weighed and pulverized for analysis. After wet or dry ashing, the amount of each of the elements in these samples was determined with the following analytical methods;

N ; semi-micro Kjeldahl.
P ; Allen's colorimetric.
K ; flamephotometric, with Lange's apparatus.
Ca ; volumetric, with potassium permanganate.
Mg ; colorimetric, with thiazole yellow.
Si ; gravimetric.
Fe ; colorimetric, with *o*-phenanthroline.
Mn ; colorimetric, with potassium periodate.

Results

Growth: The changes in dry weight of the tops of rice plants harvested at one, two, and three weeks after the start of the treatment are shown in Table 1. It is confirmed that the increases of dry weight of the rice plants are noticeably retarded by treatments such as the low temperature, the shade, and the low temperature and shade. It is also observed that the longer the duration of these treatments, the larger the differences of dry weight between these treated rice plants and the control ones.

Table 1 Changes iu dry weight of tops of rice plants grown under various environments for one, two, and three weeks.

Treatments \ Weeks	1	2	3
Control	20	29	35
Low temperature	15	19	24
Shade	15	22	25
Low temperature and shade	16	10	10

* Figures represent g. per plant.

At one week, the dry weight of each of these treatments showed about 70 percent of that of the control.

The changes in dry weight in the low temperature and the shade treatments showed nearly the same trends even at two or three weeks. On the other hand, the dry weight of the low temperature and shade treatment markedly decreased at two and three weeks, and it showed less weight than that of one week treatment, and consequently it is supposed that under such excessive unfavorable condition the dry weights of the rice plants are reduced because of the decrease in photosynthetic activity in addition to the consumption of the substrates by respiration and probably from the release of carbohydrates from them (5).

Mineral nutrient content: Mineral nutrient contents in the tops of the rice plants at one week after the beginning of the treatment are shown in Table 2. In both of the low temprature and the shade treatments, each of these

Table 2 Changes in mineral nutrient contents in tops of rice plants grown under various environments for one week.

Treatments \ Elements	N	P	K	Ca	Mg	Si	Mn	Fe
Control	430	114	515	28	30	815	4.71	3.41
Low temperature	466	108	519	24	30	841	10.33	2.69
Shade	602	108	555	24	32	976	8.63	2.92
Low temperature and shade	538	122	599	31	35	1066	10.77	2.91

* Figures represent mg. per plant.

contents of nitrogen, potassium, magnesium, silicon, and manganese was more than that of the control, whereas phosphorus, calcium, and iron contents were not. On the other hand, in the case of the rice plant grown under the low temperature and shade environment the contents of mineral nutrients except for iron, were more than those of the control. It is of interest that the uptake of most of the nutrient elements by the rice plants growing under such unfavorable environments was enhanced, nevertheless the dry weight of these rice plants was less than that of the control, and it is supposed that this enhanced nutrient uptake was caused by the stimulative effect arisen from sudden exposure to unfavorable temperature or light condition for rice plants at the stage of maximum number of tillers.

Changes in nutrient contents in the tops of the rice plants grown under various conditions for two weeks are given in Table 3. Rice plants in the low

Table 3 Changes in mineral nutrient contents in tops of rice plants grown under various environments for two weeks.

Treatments \ Elements	N	P	K	Ca	Mg	Si	Mn	Fe
Control	440	138	603	44	39	1181	7.24	5.78
Low temperature	419	108	543	40	33	891	14.90	2.49
Shade	492	137	669	57	52	1296	14.56	5.24
Low temperature and shade	384	75	372	25	25	820	13.16	2.12

* Figures represent mg. per plant.

temperature or the low temperature and shade treatment, as compared with the control, were less in the contents of most of the nutrient elements except for manganese, and especially the contents of numerous nutrients in the rice plant grown under the low temperature and shade environment were even less than those of rice plant at one week after the start of treatment under the same condition. It is considered that most of the nutrient elements which had been already taken up were depleted out of the plant because of the decrease of metabolic activities which are closely connected to maintenance of the absorbed nutrients in the plant (6, 7). Iron content in both of these treatments was only one half of the control. In contrast with many other nutrient elements, manganese content in these treated rice plants amounted to about twice the quantities of that of the control, namely, manganese uptake by the rice plant was markedly enhanced under the unfavorable low temperature or feeble light condition.

On the other hand, the rice plant which was grown under the shade environment for two weeks contained more quantities of nutrient elements than those of the control. Manganese content in this treatment also showed twice the values as compared with that of the control.

The results obtained in the rice plants which were grown under various unfavorable environments for three weeks essentially showed nearly the same trends to those in the two weeks treatments.

Discussion

It is generally recognized that mineral nutrient absorption and accumulation of the plant occur closely connected with the active metabolic processes such as respiration (8), photosynthesis (9), and protein synthesis (10). Consequently, when the growth of the plant was retarded by exposure under unfavorable environment the nutrient uptake was also reduced. The results of the experiments on the nutrient uptake of the rice plants which have been performed by means of the artificial irrigation of cool water or the shading (1, 2, 3, 11) also agree with this opinion.

However, in the present experiment it was found that the pattern of nutrient uptake of the rice plant significantly varies according to the growth stage at the beginning of treatment and the duration of exposure to unfavorable environment change. Furthermore it was revealed that manganese uptakes by rice plants grown under unusual environments such as the low temperature or the shade remarkably increase compared with those of most other nutrient elements.

The stimulative effect on the nutrient uptake which was found in the rice plants grown under the low temperature, the shade, or the low temperature and shade environment for one week was observed at the stage of maximum number of tillers, but it has not been seen at the early vegetative growth stage hitherto. In the shade environment this stimulative effect was continuously observed for a relative long period and it seems to be closely related with an abnormal elongation of the rice plant growing under such feeble light condition. Thus, it is supposed that this stimulative effect was caused by the biological function for maintaining the growth under unfavorable conditions though the true mechanism is obscure at the present. It is also suggested that the ability induced by this function develops according to the growth stage of rice plant proceeds from the early vegetative growth to the maximum mumber of tillers and under the low temperature or the low temperature and shade environment the ability is lost as the duration of exposure to these unusual conditions is prolonged, but in the rice plant grown under the shade environment it is maintained for a fairly long time.

The acceleration of manganese uptake by the rice plant found in the present experiment was also observed in the rice plant grown under the low temperature environment at the early vegetative growth stage in the series of this investigation. Accordingly this phenomenon seems to belong to different absorption mechanism from most other nutrient elements. That manganese uptake by the plant was markedly affected by its available amount in the medium has been reported by a number of workers (12, 13), that is, manganese content in the plant is nearly proportional to the amount of the available one in the medium. Although the symptom of manganese excess in the plant have been observed in many species and it was explained that this symptom occurs by excessive accumulation of the element in the plant (12), however, it did not appear in the case of the rice plants grown under the low temperature or the feeble light condition. Furthermore that the appearance of the excess symptom in the rice plant occurred at higher manganese concentration in the plant than the results of the present experiment was noted by a few workers (14, 15). Antagonistic action between manganese and iron have been described by many investigators (15, 16), however, from the fact that manganese uptake increased even then iron uptake by the rice plant grown under the shade environment was not much reduced, the possibility of antagonism between both of these elements is excluded in the present experiment. In conclusion, it is presumed that the rice plant actively uptakes manganese against the unfavorable environments.

Summary

1) At the stage of maximum number of tillers, rice plants grown in the soil culture were exposed to unusual environments such as the low temperature, the shade, or the low temperature and shade for one to three weeks.
2) Uptakes of nitrogen, potassium, magnesium, silicon, and manganese by rice plants grown under these unfavorable conditions rather increased at one week after the start of these treatments in comparison with the control plant which was cultivated under the normal condition, but the uptakes of phosphorus, calcium, and iron did not increase.
3) Except for manganese, the uptakes of most of the nutrient elements were reduced at two and three weeks under the low temperature or the low temperature and shade environment. On the other hand, the uptakes of a number of mineral nutrient elements still increased under the shade condition.
4) Manganese uptake by the rice plant was markedly increased under these unfavorable environments and it amounted, in contrast with many other nutrient elements, to about twice the quantities of that of the control.

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