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[Short Report]

Involvement of Silicon in the Senescence of Rice Leaves

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Silicon is thought to have positive effects on the growth of rice plants (Takahashi et al., 1990 ; Wener and Roth, 1983), but its physiological function is not fully understood. Our previous comparative studies on the effects of silicon on dry-matter production of ten rice cultivars suggested that the positive effects of silicon were attributable to maintenance of photosynthesis and protection of chlorophyll from destruction in aging leaves (Agarie et al., 1992). Although it is not clear whether the phenomena is senescence or necrosis, apparent senescence is often observed as a typical symptom of Si-deficiency (Wener and Roth, 1983). To our knowledge, there are few studies on the preventative effect of silicon on these phenomena. These symptoms are conspicuous under high temperature conditions with low humidity (Wener and Roth, 1983). This suggests that the maintenance of an appropriate water status in leaves might be an important aspect in the role of silicon in the prevention of photosynthetic depression and chlorophyll destruction in leaves. The aim of the present study is to elucidate the role of silicon in senescence without the secondary effects of desiccation. Our data show clearly that silicon is associated with prevention of the progress of senescence in leaves.

Rice plants (*Oryza sativa* L. cv. Koshihikari) were grown hydroponically in nutrient solution containing 100 ppm SiO_2 or in nutrient solution without SiO_2. The procedure for hydroponic culture has been described previously (Agarie et al., 1992). However, in the present study, plants were grown in a box (2 m×2 m×2 m) covered with plastic sheeting. A plate filled with water was placed in the box to humidify the inside, and plants were placed on the plate in the resulting moderate humidified conditions. The leaves on the main culms that had been grown with and without Si for 30 to 40 days were used for the present study. Senescence was induced by placing the whole plants in a growth chamber maintained in darkness at a temperature of 30°C and a relative humidity of 95%. Photosynthetic O_2 evolution rate (OER) was monitored polarographically by the procedure described by Ishii et al. (1977). In the study of the effect of short term treatment of Si-deficiency, plants grown with Si for 40 days were cultured in nutrient solution without Si for 1 to 3 days. After the Si-deficient treatment, the plants were transplanted to the pots filled with the nutrient solution with Si and then placed in a growth chamber maintained in darkness at a temperature of 30°C for 3 days to induce senescence. OER was then measured.

Figure 1 shows the changes over time in OER in the second leaves after the start of dark treatment. In leaves of plants grown in the solution without Si (-Si), OER remained stable for two days and then decreased markedly, almost to zero on the third day. On the other hand, in leaves of plants grown in nutrient solution with 100 ppm SiO_2 (+Si), OER remained above 50% of the initial value for more than four days but fell to zero on the fifth day. These results show clearly that silicon prevented the progress of senescence. To our knowledge, this is the first report that silicon delays senescence in rice leaves. The progress of senescence is influenced by several factors. For example, growth regulators such as cytokinin and ethylene delay and accelerate senescence, respectively (McKersie et al., 1988). The amount of accumulated assimilates in senescent leaves translocated to sites of plant growth (Mae and Ohira, 1981) and ability to protect tissue from environmental stress are also associated with the progress of senescence (Sacher, 1957). In the present study, since plants were cultured under moderately humidified conditions and senescence was induced in leaves by placing whole plants in the dark under humidified conditions, water stress was probably minimized. Therefore, differences in the progress of senescence between +Si and -Si plants presumably reflected differences in the levels of these endogenous factors (i.e., growth regulators or accumulated assimilates) which had been established by accumulation of silicon before induction of senescence.

To investigate the effect of silicon on senescence without these influencing factors, +Si plants were cultured in nutrient solution without Si for several days just before the start of the induction of senescence, and OER

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Abbreviation : OER, photosynthetic O_2 evolution rate.

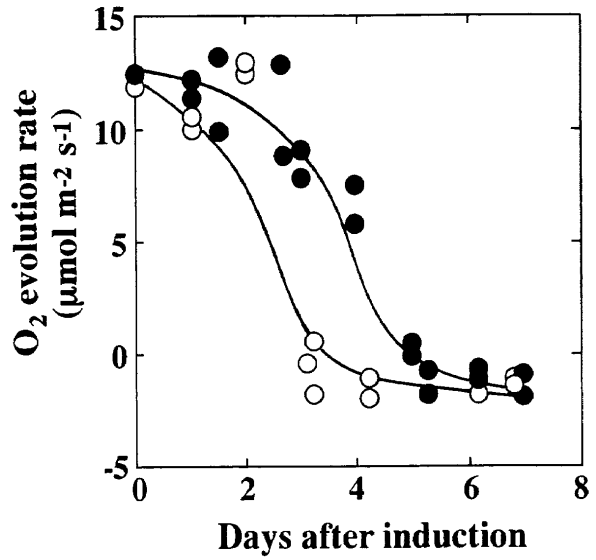

Fig. 1. Changes over time in photosynthetic O_2 evolution rate (OER) of leaves of plants grown with Si (●) and without Si (○) during the dark-induced senescence. The OER was measured on the second leaves from the uppermost fully expanded leaves on the main culms. Note that the OER of leaves grown without Si became almost zero on the third day, whereas it remained above 70% of the initial value in leaves grown with Si.

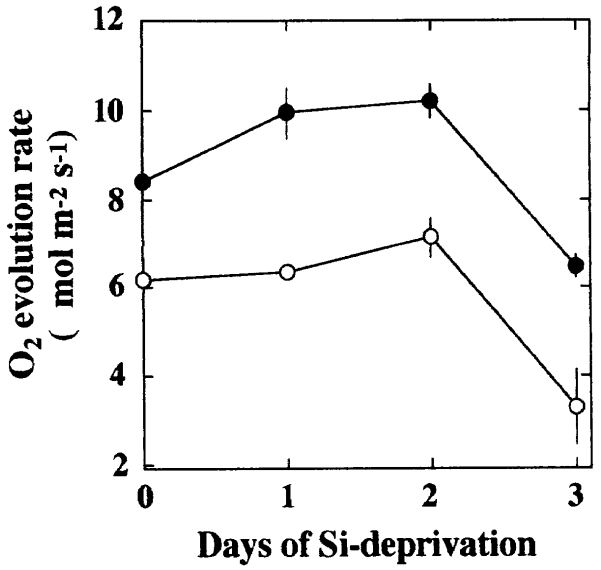

Fig. 2. Effects of short-term deprivation of silicon on photosynthetic O_2 evolution rate (OER) in leaves of plants grown with Si. Plants grown with Si for 40 days were cultured in nutrient solution without Si for 1 to 3 days just before the start of senescence induction. The OER in the second (●) and fourth (○) leaves from the uppermost fully expanded leaves on the main culms was measured on the third day from the start of the senescence induction. Note that the O_2 evolution rate was reduced by the Si-deprivation treatment. Data are mean values from three separate experiments ± SE.

on the third day from the start of the induction of senescence was measured as an index of the degree of senescence. The OER on the third day was decreased by the Si-deficient treatment (Fig. 2). The tendency was more prominent in the fourth (aged) leaves. These results show clearly that senescence was accelerated by short-term silicon deprivation. The plants used in the experiment had been grown in nutrient solution with Si before the Si-deficient treatment. Therefore, acceleration of senescence by Si-deficient treatment may be caused by changes in physiological status in rice plants resulting from interruption of the application of silicon. Silicon appeared to have no effect on the progress of senescence when Si was applied to detached leaf discs (unpublished data). These results indicate that the effects of Si-deficiency occur within a few days and continuous application of silicon to the root system may be essential for maintenance of photosynthetic activity in rice leaves even when plants have accumulated silicon.

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