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学 位 論 文 要 旨

SUMMARY OF DOCTORAL THESIS

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題目 Title: Physiological mechanisms related to silicon-induced improvement of water uptake in sorghum seedlings under water stress
（水ストレス下のソルガムにおける吸水能の改善に関わるケイ酸の作用機作）

Silicon application can alleviate both biotic and abiotic stresses, including water stress. It has been reported that silicon application enhanced drought tolerance of sorghum seedlings [*Sorghum bicolor* (L.) Moench]. This enhancement was ascribed to higher photosynthetic rate and stomatal conductance due to improvement of leaf water status under water stress. In the most past studies, water relation characteristics related to this effect of silicon were measured only at midday after a specific period of water stress. However, these characteristics closely interact, and vary both diurnally and over the course of an extended period of the stress. Therefore, it is important to consider the dynamics of the changes in the characteristics for better understanding of the silicon-induced improvement of leaf water status under water stress. The objective of this study was to determine the effect of silicon application on dynamics of the changes in water relation characteristics related silicon-induced improvement of leaf water status, and elucidate the relevant physiological mechanisms. To meet these objectives, two experiments were conducted.

1) Diurnal variations in photosynthesis, stomatal conductance and leaf water relations in sorghum grown with or without silicon, under water stress.

Sorghum seedlings (cv. Gadambalia) were grown hydroponically in two different silicon concentrations (0 and 1.78 mM) and two levels of water stress (with and without polyethylene glycol 6000). Water stress was imposed to the seedlings from 10 days after sowing (DAS) with increasing its level in response to the seedling growth. Water stress reduced dry weights of the seedlings at 15 DAS. The reduction in dry weight became more pronounced at 23 DAS, but this was ameliorated by silicon. Similar effects of silicon application were also observed in photosynthetic rate and stomatal conductance; the silicon-induced reduction of these physiological traits was ameliorated by silicon application. Silicon-applied seedlings showed higher photosynthetic rate and stomatal conductance throughout the daytime compared with the seedlings grown without silicon under water stress. However, leaf water potential changed little throughout the daytime, and was little influenced by silicon application. In the relationship between stomatal conductance and leaf water potential under water stress, leaf water potential was maintained by closure of stomata in seedlings grown without silicon and by

opening of stomata in silicon-applied seedlings. The reduction of water uptake was also ameliorated by silicon application under water stress. These results suggested that the application of silicon ensured provision of water to the leaf by enhancing water uptake rate under water stress. These effects of silicon occurred soon after exposure to water stress.

2) Effect of silicon application on sorghum root responses to water stress

Sorghum seedlings were grown under similar growth conditions and using the same treatments described above. To analyze how silicon improves water uptake rate under water stress, we investigated the root responses of sorghum seedlings to silicon application. The reduction in dry weight due to stress was alleviated by silicon application, accompanied by an increase in root water uptake. Silicon application decreased the osmotic potential of the roots without affecting their water content. These results showed that silicon application positively induced osmotic adjustment in sorghum roots. This silicon-induced root osmotic adjustment could be linked to the increase water uptake under the water stressed condition. From an assessment of root solutes, the osmolytes responsible for this osmotic adjustment were soluble sugar and amino acids (alanine and glutamic acid), not minerals such as potassium. Root anatomical traits such as the diameter and number of the xylem vessels, which are related to water transport, were not affected by the silicon application. These results suggested that the effect of silicon application on water uptake was ascribed to silicon-induced root osmotic adjustment by soluble sugar and several amino acids (alanine and glutamic acid).

Conclusion

In this thesis, it was demonstrated that silicon application increased stomatal conductance through the alleviation of reduction in water uptake rate throughout the daytime under water stress. This ameliorative effect of silicon application on water uptake was ascribed to root osmotic adjustment by soluble sugar and several amino acids (alanine and glutamic acid).