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Development of a Quantitative Evaluation Method of Plant Response in Salt Stress for High-Quality Crop Production Using Microwave Sensing

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Summary

Part I

Quantitative estimation method of plant adaptation responses to saline environment using microwave sensing.

In this study, in order to develop an estimation method of plant adaptation responses to a saline environment using microwave sensing, plants which have different salinity tolerances were examined after being grown hydroponically and exposed to a saline environment for 2, 4 or 6 weeks. Experimental results showed the dielectric relaxation spectra changed as the plant leaves adapted to the saline environment, and there were three main types of spectral change pattern. The plants associated with each of the three types of spectral change pattern did not correlate with the conventional classification of salinity tolerance of the plants (as sensitive crop, moderately sensitive crop, moderately tolerant crop and tolerant crop), suggesting there are patterns of spectral change peculiar to each variety of plant. The patterns of change in dielectric properties on the Cole-Cole plots showed that the dielectric properties of all plant materials changed toward those of a halophytic plant after exposure to a saline environment, as if the plants tried to become halophytic plants. The relationship between dielectric properties of plant leaves and water potentials also showed a similar phenomenon. In addition, the relationship between loss tangent and water potential had a nearly linear relationship. Experimental results showed the potential of using microwave sensing for quantitative estimation of plant adaptation responses to a saline environment and the degree of salinity of the environment in the rhizosphere.

Part II

Development of a quantitative evaluation method of plant response in salt stress for high-quality crop production.

1. Effect of residual salinity on spinach growth and nutrient contents in polder soil.

In this study, the effect of residual salinity in polder soil on plants was investigated, in order to develop a value-added plant production method. Spinach plants were subjected to a saline environment by adding diluted artificial seawater to the soil of reclaimed land with 23.5 g m^{-2} ammonium sulfate at NaCl conversion concentrations of 0, 0.05 and 0.10 mol L^{-1}. Diluted seawater equal to the amount of the maximum water holding capacity of the soil was added to the soil three weeks after germination. Afterward, the moisture content of the soil was maintained at about 40% during the experiment. The plants were harvested 4 weeks after starting the saline treatment. The growth of the plants, measured by parameters such as leaf width and number of leaves, was

almost the same, and the fresh weight of both shoots and roots increased compared to the control plants at NaCl treatment concentration of 0.05 mol L^{-1}. Na ion in spinach increased with increase in NaCl treatment concentration, but K, Ca, Mg and Fe ions showed little change. Spinach grown in polder soil contained a large amount of cations, soluble saccharide, L-ascorbic acid and polyphenol compared with field cultivated spinach. Essential amino acid content increased with increase in NaCl concentrations compared with the control. It is well known that the effect of γ-amino butyric acid (GABA), an inhibitory neurotransmitter in humans, has physiological functions such as relaxation, increasing immunity and reducing blood pressure. Spinach cultivated in polder soil contained extremely large amounts of GABA, about 200 times compared with field cultivated spinach regardless of NaCl treatment concentration. Nitrate ion and oxalic acid ion decreased at NaCl concentrations of 0.05 and 0.10 mol L^{-1}, and that nitrate ion level was less than EU standards (250 mg/100gfw harvested 1 April to 31 October and 300 mg/100gfw harvested 1 November to 31 March). In conclusion, experimental results showed that spinach plants cultivated under the appropriate residual salinity in polder soil might have potential to increase the amount of production and nutrients and to decrease components harmful to humans at same time.

2. Production of high quality muskmelons using salt stress treatments.

The objective of this research is to develop a new method to produce high quality muskmelon fruits using plant adaptation responses to a saline environment. Muskmelons (*Cucumis melo* L.) were grown in soil culture on a strawberry bench in a greenhouse to determine the optimum strength and timing of the salt treatment. Muskmelon growth from seeding to harvest was divided into three stages, Stage I (transplanting to pollination), Stage II (pollination to fruit net development) and Stage III (fruit net development to harvest). In this study, the salt treatment was conducted at Stage III, because the basic quality of the muskmelons was almost determined during Stage II. In the salt stress treatment six different levels of NaCl concentration were used, with 3 liters of solution per plant: 0 mmol L^{-1} (water stress treatment), 30 mmol L^{-1} (1,800 ppm), 60 mmol L^{-1} (3,500 ppm), 90 mmol L^{-1} (5,300 ppm) and 120 mmol L^{-1} (7,000 ppm). The salt stress treatment was conducted only once, immediately after the end of Stage II. Experimental results showed that the salt stress treatment of 60 mmol L^{-1} produced the best quality muskmelons, which had highest sugar content. The external quality, size and weight of fruits were similar compared with the case of water stress treatment. All salt stress treatments achieved higher sugar content than with the water stress treatment.

Part III

Development of nondestructive plant stress sensor.

The low-cost nondestructive plant stress sensor which had simple structure and operability was developed. Experimental result showed that this plant stress sensor could detect the degree of salt stress and water stress in tomato plants quantitatively. Concerning this invention, two patents were applied.