15 Electrochemical Potential around the Plant Root in Relation to Metabolism and Growth Acceleration

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15.1 Introduction

In order to keep our globe in a natural state, the protection of plants becomes more important in our future life. Practically, it is desired to provide suitable environmental conditions for plants to grow. In higher plants, the roots play an important role in their growth since the uptake of all the nutrition, including water, is done through the root (Bibikova and Gilroy 2003). This means that control of the chemistry of the environment around the roots is the key factor for plants to grow strongly.

Recently, electrochemical signal detection for the intact higher plants around the roots has been investigated. For example, Iwabuchi et al. (1989) observed the electric patterns around growing cress roots. They reported that a change in the electric patterns was brought about by the growth of the root in a given environment. Toko and coworkers reported on the occurrence of current flow around plant roots (Ezaki et al. 1988), the current flow picture outside the root being shown to be related to growth. Miwa and Kushihashi (1992) reported on the stereoscopic electric current density picture around the root. Their current flow picture was constructed on the basis of the measured spatial assumption of the presence of an active ionic flow. They expected H^+ accumulation in the region of the growing position of the root. However, neither the ionic concentration profile nor the time dependence of the potential profile appears to have been studied in detail for the root surface during growth. It is interesting to measure directly the ionic concentration profiled during the growth.

Electrochemistry can afford to control the electric field near the plant root as desired. If the electrochemical potential is applied to the root, the signal is supposed to be sensed near the interior of the root, which may possibly stimulate the growth of the plant. We found that growth was accelerated by the application of DC or square wave voltage to the root of a bean radicle planted in a culturing bath (Mizuguchi et al. 1994). It is worthwhile to study how the growing intact plant root is related to the presence of the substance which originates the potential distribution around the root surface. The ATP cycle

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is suggested to take part in the growth rate change. This implies that the plant growth is influenced dynamically not only by the concentration of the chemical entities, but also by the profile of electrochemical potential distribution in connection with ATP cycles.

In this context, this article will introduce our work at first on the relation of the potential distribution and the ionic entities around the root, especially paying attention to the proton concentration, followed by showing proton concentration image around the root during the growth and how the proton concentration affects the growth, leading to the effective potential application to the root for accelerating the growth, and finally the investigation of the mechanism of the growth acceleration will be shown.

15.2 Potential distribution around root of seedling in culturing solution

15.2.1 Introduction

Investigation of the relationship between the plant metabolism and the electrochemical potential near the root surface is of great interest to an electrochemist. To allow for easier measurement, due to its large root size, we adopted a bean sprout which was laid down in the culturing solution as the specimen and the potential near the root of the sprout was measured by constructing a measuring device where position of the probe micro-electrode could be moved precisely around the root. The potential distribution map was constructed, which can be correlated to the ion concentration distribution map, based on the Henderson equation.

Takeuchi at al. (1994) found the presence of a large negative potential well in the growing tip region. In addition, the lateral root is an important organ for plant growth, since the growth rate of a plant is roughly proportional to the effective surface area of its roots (Bibikova and Gilroy 2003). It is important to observe the potential in the lateral roots emerging region. A striking feature of the lateral root is that it makes it possible to observe all the changes from the initial period of germination. The lateral root begins to grow from a lateral root primordial whose metabolic activity during segmentation is expected to extend out to the root surface as an electrochemical signal. The emerging of lateral roots plays an important role in plant growth, and the potential change during the emerging of a lateral root attracted our attention. The potential and ionic concentration distributions were measured precisely at the lateral root emerging point. Observation showed the appearance of a negative potential well preceded the initiation of an emerging lateral root (Watanabe et al. 1995).

In this section, the precise measurement of the potential distribution around the root surface will be shown in connection with the measured