Calcium Localization within Live Oat Leaves Using a Semiconductor Detector Assembly*

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Summary. Pathways of movement of foliar-applied ⁴⁵Ca in young oat leaves are localized by means of in-vivo β spectrometry with a semiconductor detector assembly. The shift of the maximum energy of the observed spectra to the lower-energy region, which is a function of the thickness of the tissue layer between an internal ⁴⁵Ca source and the detector, is the most reliable and easily interpretable parameter for ⁴⁵Ca localization. Transport of foliar-applied Ca occurs in the vascular bundles. The major part of the transported Ca moves out of the conducting tissue and accumulates in the mesophyll and epidermis cells. The passage from the transport to the accumulation phase is a rapid process. These results are compared with those obtained by histoautoradiography.

Introduction

One of the major drawbacks in physiological studies on the role of mineral elements in plants is the lack of information concerning localization of ionic action sites and pathways of movement.

Histoautoradiographic studies (GIELINK et al., 1966; MYTTENAERE et MOUSNY, 1966) have brought a partial solution to some of the localization problems involved. The information provided by means of this technique is, however, strictly limited to the sampling time. This implies that histoautoradiography constitutes a reliable method for detecting accumulation sites of a given element in the tissue (RINGOET et al., 1968). An extensive sequence of histoautoradiographs is, however, needed to demonstrate pathways of movement.

In order to render possible a combined and non-ambiguous analysis of ⁴⁵Ca movement (RINGOET et al., 1967) and localization within the living tissue of young oat leaves a new technique, which makes use of semiconductor detectors, has been developed at this laboratory (RECHENMANN et DE SWAART, 1964). The method already announced in an earlier paper (RINGOET et al., 1967) and presented here in more detail, is based upon the fact that pulse charges released by semiconductor counters are proportional to the energy of the incident particles and that these detectors can therefore be used for spectrometric

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measurements (BOSCH et al., 1962). A semiconductor detector spectrometric assembly of high stability and of great efficiency and resolution has been built especially for this purpose.

**Materials and Methods**

*a) Principle of the Method.* The localization method described here is based upon the following principle: the energy loss of $\beta$ particles in an absorbing layer (e.g., plant tissue) placed in front of an isotopic source (e.g., $^{45}$Ca), varies with the thickness and the chemical composition of the layer. In the experimental conditions presented here, the energy loss produces a change in the shape of a continuous spectrum (e.g., $^{14}$C, $^{45}$Ca, $^{35}$S) recorded through such a layer, and a general shift towards the lower-energy region of this spectrum. On the basis of theoretical considerations and preliminary experiments, the shift of the maximum energy of the spectrum has been chosen as the most reliable and easily interpretable parameter for measuring the thickness of a plant tissue layer. Depending on the maximum energy of the isotope ($^{45}$Ca: 254 keV) and on the resolution of the spectrometric assembly, a fairly accurate estimation of the tissue thickness can be obtained. In the same way it is possible to measure the distance between a "radio-active source" in a living tissue and the detector at its surface or, in other words, to estimate the depth at which an isotope is located in biological material.

When a spectrum belongs to the group of "allowed spectra" (e.g., $^{45}$Ca), it is known that its maximum energy for an ultra-thin source in vacuum is given by the intersection with the energy-axis of the linear representation of this spectrum by Fermi-Kurie plots [SIEGBAHN, 1965, Chap. 8 (A) par. 7, Chap. 24 (A)]. Various experimental factors (presence of an absorbing layer, thickness of the source, its backscattering) can affect the linearity of the plots (Fig. 4). Under such circumstances, the maximum energy may be determined by extrapolation of the plots to the energy-axis in the high energy region of the spectrum.

*b) Semiconductor Detector Spectrometric Assembly.* The detector equipment used for in-vivo localization of $^{45}$Ca is a highly stabilized semiconductor detector assembly represented by the block diagram in Fig. 1. A detector, of the surface barrier type, is set inside a double

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1 The validity of this extrapolation has been shown by the satisfactory agreement between results of systematic measurements of the maximum energy through layers of known thickness and the corresponding theoretical values calculated according to the Landau equation. A detailed study of these results and of the factors affecting the use of this rather delicate method will be published later on.

2 Ortec SBBJ 007 or detector built in the Laboratoire de Physique des Rayonnements et d'Electronique Nucléaire (Direction: Prof. A. COCHE) of the CRN in Strasbourg-Cronenbourg, France.