ARBORETUM KÓRNICKIE
Rocznik XXIV — 1979

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Dependence of electrical impedance of *Magnolia* shoots on temperature*

INTRODUCTION

Woody plants are characterized by seasonal changes in resistance. For studying this problem most interesting is the period of preparation of plants for the winter colds when intensive biochemical and physical adaptations are taking place. Among many factors responsible for the induction of this adaptation process is the changing temperature (Levitt, 1972; Weiser, 1970). Recently many papers were published in which authors aim at the clarification of the cold resistance process through the study of the electrical properties of plant tissues (Sinjuhin and Burmistrova, 1970; Hayden at al., 1969).

Much data seems to indicate that biological material displays properties similar to semiconductors (negative temperature quotient for electrical resistance, and strong dependence of the resistance on the structure). When establishing the relation between the electrical impedance of a plant tissue and its temperature it is possible to determine its physical state and at the same time observe the change preparing it for dormancy. The purpose of the present paper was to follow these processes in three magnolias differing in resistance to low temperatures.

MATERIALS AND METHODS

Periodicaly during autumn and winter one year old shoots were collected for the experiment from one individual (*Magnolia acuminata* L.) very resistant to low temperatures and from two individuals of (*Magnolia ×soulangiana* Soulange-Bodin), a resistant one H_1 and a frost susceptible one H_2. The shoots collected simultaneously have been placed in a chamber at 20°C for a period of 20 hours and after that electrical impedance

* This work has been partially supported by grant FG-PO-238 from the US. Department of Agriculture ander PL-480.

was measured. Then the shoots were transferred to a chamber with a temperature of 1°C for 4 hours after which the electrical impedance was measured again. The impedance measurements were made in the chambers in which the shoots were stored. For the measurement of electrical impedance two nickelplated steel needles 0.5 mm in diameter and 8 mm long were used as electrodes positioned 10 mm apart and connected with an impedance mater BM 507 supplying an output of 0.2 V at 80 Hz.

In order to obtain a curve expressing the dependance of electrical impedance of shoots on temperature, the studied fragment of the shoot was placed in a Dewar vessel where the temperature was changed gradually from 20°C to −8°C. The temperature reduction was obtained using liquid nitrogen supplied through a copper spiral. The rate of cooling was 3°C/h. The temperature was registered with a Cu-Constantan thermocouple 0.2 mm in diametr. The registration of electrical impedance and temperature of the shoot fragment was made simultaneously using two registrators, TZ-21S and KSP-4 (Fig. 1).

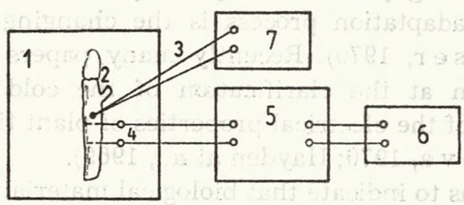

Fig. 1. Diagram of the measuring aparatus

1 — cooling chamber, *2* — twig section, *3* — thermocouple, *4* — electrodes, *5* — impedance meter (BM 507), *6*, *7* — pen recordes

The degree of resistance of magnolias to low temperatures was estimated by the method of electrical admittance (B i a ł o b o k, P u k a c k i, 1974), measured simultaneously with the relation between impedance and temperature. From the studied magnolias 10 one year old shoots were collected and then frozen to a temperature of −30°C for 24 hrs. The difference in the electrical admittance measured before and after freezing in individual shoots was a measure of the degree of injury.

RESULTS AND DISCUSSION

Figure 2 represents the recording of shoot impedance as the temperature declines from 20°C to −8°C. Initially we observe a very gradual increase in impedance as the temperature declines. At a temperature of −2°C a sudden break in the curve is caused by the crystallization of water in the intercellular spaces. Then the curve increases rapidly attaining

380 Kohms at −8°C. The point of supercooling observed on the curve is a known phenemenon occurring always as plant tissues are being cooled (Quamme et al., 1972; Burke et al., 1976). The value of the electrical impedance in plant tissues as measured by a current of low frequency

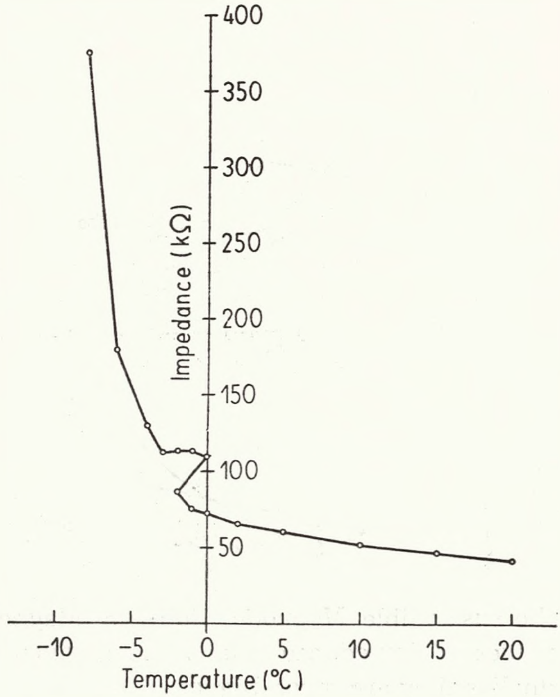

Fig. 2. The influence of temperature on the electrical impedance of a *Magnolia* shoot

depends primarily on the concentration of dissociated ions, on their mobility (particularily of sodium and potassium) in the channels within the cell walls (Hayden et al., 1969). The passage of current through the cytoplasm is inhibited by the high values of the electrical resistance and capacity of cell membranes.

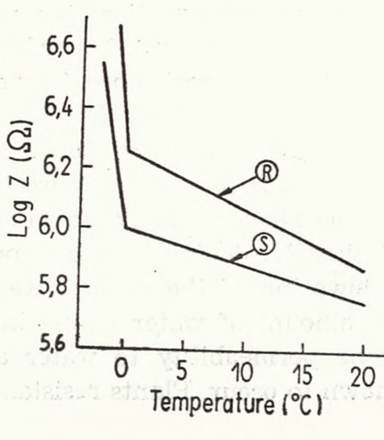

Fig. 3. Log impedance — temperature curves in shoots of *Magnolia*×*soulangiana*, R — resistant and S — susceptible to low temperatures

Expressing the temperature dependent impedance of shoots in a logarythmic for we obtain an almost straight-linear relation (Fig. 3). The graph represents the regression of the logarythmic impedance on temperature for two hybrids of Magnolias differing in resistance to frost. The curve obtained for the resistant individual H_1 is more steep than that for

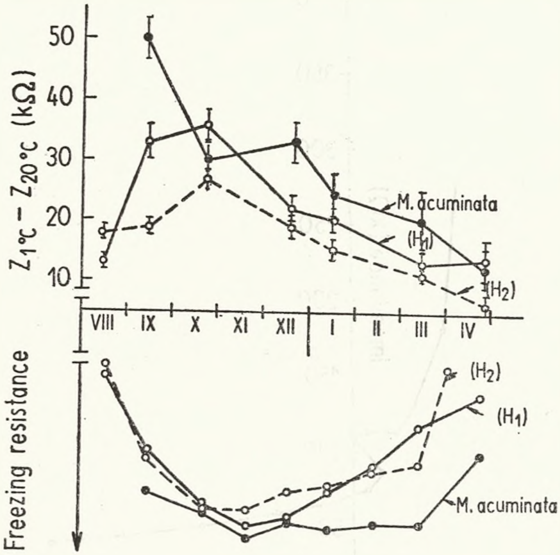

Fig. 4. Sesonal changes in the differencies of *Magnolia* shoot impedance between temperatures of 1°C and 20°C, in relation to corresponding to freezing resistance. The vertical lines indicate the standard error of each point

the susceptible *Magnolia*. Both the Magnolias differ also in the absolute values of impedance relative to a given temperature. In resistent Magnolias they are much higher.

The changes during natural hardening and dehardening processes are given in (Fig. 4). It shows the differences in impedance of *Magnolia* shoots between temperatures at 1°C and 20°C in subsequent months. Below the corresponding resistance of shoots to low temperatures is plotted. In the resistant Magnolias it can be observed that over the studied period there is a greater change in impedance with temperature. In all three Magnolias this relation has its maximum during the first stage of hardening, after which it declines gradually parallel with the drop in frost resistance. It needs to be pointed out that this relation clearly differentiates the resistant and susceptible Magnolias. It turned out that tissues react most strongly to temperature when the processes leading to frost resistance are just starting.

The above presented data seem to indicate that during the first stage of plant hardening both metabolic and physical changes are taking place. A lowering of the general water content in the tissues, and increase in the amount of water bound in the cytoplasm and the increase of membrane permeability to water are the most significant physical changes known to occur. Plants resistant to low temperatures appear to be characterized by greater dynamics of these changes. These examples however do not explain the relation observed for the plants resistant and susceptible to frosts. Since resistant plants are characterized by an increased permeability of membranes to water one can suspect that during the lowering of the shoot temperature to 1°C there occurs an expulsion of water from the protoplasm to the intercellular spaces. This causes a substancial lowering of the molar concentration of dissociated ions in the canals and at the same time the ionic conductivity of the plant tissues is lowered as can be measured by a current of low frequency. This gives in increase in impedance at a temperature of 1°C.

The mobility of ions which determines conductivity depends on their hydration and on the structure of the water. As the temperature declines the degree of association of water molecules is on the increase. A lowering of the water temperature from 20°C to 0°C leads to an almost doubling of the water molecules associated by hydrogen bonding into clusters (House, 1974). The number of such clusters is correlated with the density of polar groups in the membranes the number of which also increases with frost resistance (Weiser, 1970). Since the total water content in all the *Magnolia* shoots is roughly the same, it is suggested that electrical impedance and frost resistance depend on the physical state of water and on membrane permeability.

SUMMARY

The effect of temperatures 20°C and 1°C on the electrical impedance of one year old shoots of a single *Magnolia acuminata* and two individuals of *Magnolia×soulangiana* have been studied during winter rest. A much stronger effect of temperature on the impedance has been found in individuals resistent to low temperatures than in susceptible ones. This relation is dependent on the season and is best observed during periods of increased resistance of magnolia shoots to frost.

I would like to thank Professor dr Stefan Białobok for his interest in, and supervision of my work.

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PAWEŁ PUKACKI

Zależność impedencji elektrycznej pędów magnolii od temperatury

Streszczenie

W czasie spoczynku zimowego badano wpływ temperatury na impedancję elektryczną jednorocznych pędów *Magnolia acuminata* L. i dwóch osobników *Magnolia*× ×*soulangiana* Soulange-Bodin. W miarę jak temperatura tkanek pędów obniża się rośnie impedancja mierzona prądem niskiej częstości (80 Hz). Stwierdzono, że wartość obliczonej różnicy impedancji pędów dla temperatur 20°C i 1°C jest najwyższa w okresie wysokiej odporności roślin na mrozy (listopad) i jednocześnie koreluje z indywidualną odpornością magnolii na niskie temperatury. Zmiany w przepuszczalności błon komórkowych oraz w stosunkach wodnych tkanek roślinnych są dyskutowane.

ПАВЕЛ ПУКАЦКИ

Зависимость электрического импеданса побегов магнолии от температуры

Резюме

В период состояния зимнего покоя исследовалось влияние температуры на электрический импеданс однолетних побегов *Magnolia acuminata* L. и двух особей *Magnolia*×*soulangiana* Soulange-Bodin. По мере уменьшения температуры тканей побегов растет импеданс измеряемый током низкой частоты (80 Hz). Констатировано, что подсчитанная разница импеданса побегов для температур 20° и 1°C является самой высокой в период большой устойчивости растений к морозам (ноябрь) и одновременно обнаруживает корреляцию с индивидуальной устойчивостью магнолий на воздействие низких температур. В статье рассматриваются также изменения в проницаемости клеточных мембран и состояние воды в растительных тканях.