The temperature gradient as the driving force of water and solutions flow in the root

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Abstract

The examination of thermoosmosis in the maize primary root tissue has shown that under the rising temperature gradient (gradT) all flows are declining, which continue also under the gradT levelling between compartments. The permeability coefficients are declining similarly as flows. The reflection coefficient during the rising gradT declines, but it rises during the gradT levelling between compartments. These phenomena depend on the plant age and concentration of the bathing solution.

Introduction

At the absence of a pressure gradient, the difference of temperature in the fluid system causes the water flow through a porous barrier, from one compartment into the other. It is known from the literature that the uptake and transport of water and ions is sensitive to temperature and low temperature reduces especially ion uptake (Pedro *et al.* 1981). Due to temperature gradient concentration changes occurs in the system manifesting themselves subsequently in variations of the osmotic phenomenon for example in osmoregulation (Zimmermann 1982).

It is known that small decline in temperature (few centigrades), produce a relatively large rise in concentration. Electric voltage causes the appearence of current flow and heat flow. Similary, the hydrostatic pressure in the electrolyte stimulate the origin of an current flow as well as of heat flow, but the gradT in the bioelectric system causes the appearence of the electric potential gradient also.

Material and Methods

Measurements of flows (current, diffuse, heat and volume) have been carried out by the method described in detail in a preceding paper (Michalov 1989).

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The measurements was made of primary roots of 3, 4, 5 and 6 d old maize plants (hybrid C-330), raised in distilled water on filter paper, at a temperature of 20 °C and relative humidity 75 %. The roots length and thickness varied: 3-d plants: length 55 - 70 mm, thickness 1.75 - 1.85 mm; 4-d plants: length 80 - 125 mm, thickness 1.70 - 1.85 mm; 5-d plants - length 155 - 180 mm, thickness 1.60 - 1.95 mm; 6-d plants - length 175 - 230 mm, thickness 1.50 - 1.80 mm.

The root, the above ground part having been cut off, was placed into a sample holder so that the cut end was in contact with the solution in the first compartment in which solution temperature was changing in the range from 20 to 30 °C. Temperatures difference between compartments varied from 0 to 9 °C. The tip of the root was in a cooler environment, that is in compartment II. The effect of the temperature gradient upon flows was synchronously identified and registered by the variation of voltage (E), of temperatures (T_1 and T_2), ohmic resistance (R) and of the height of solution columns in the levelling tubes. Numbers of measurements have been approximately 15 for each age and concentration.

The value obtained were substituted a mathematical model (Michalov 1989). By means of it the current, heat and volume flows, the diffuse flow, the permeability and reflection coefficients have been established.

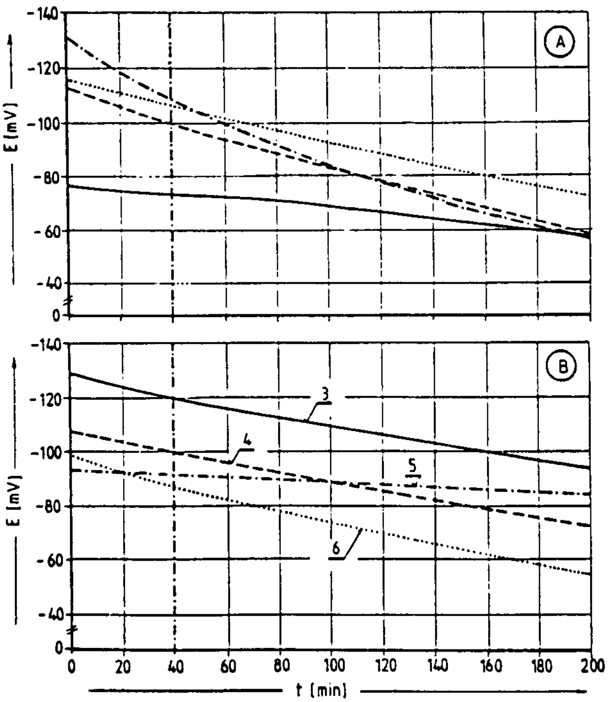

Fig. 1. Changes of electric voltage (E) between two compartments divided by the root after the gradT was established. A - 0.5 % KCl (bathing solution); B - 1 % KCl. Numbers at the curves indicate plant age [d], the perpendicular *dot-and-dash line* indicates time (40 min) in which the gradT reaches maximum. It concurrently indicates the onset of the gradual levelling the temperature between two compartments.

Results

Changes of electric voltage through the maize root as a result of the acting gradT: GradT considerably affects the electric voltage between the two compartments separated by a barrier - the root (Fig. 1). This effect also depends on the concentration of the KCl solution applied. At the stage of rising temperature in compartment II in the case of a 0.5 % KCl solution, electric voltage attains the negative values through the tissues of the primary root of 5-d old plants. This voltage also declines during the rise of the gradT. In the case of 0.5 % KCl solution electric voltage drops most slowly in 3-d old and 6-d old plants. In the case of the 1 % solution the situation is reverse. The values are highest in 3-d old plants, followed by the values of 4, 5 and 6 d-old plants. In this case it is the primary root of the 5-d old plants that exhibits the least dependence on the gradT.

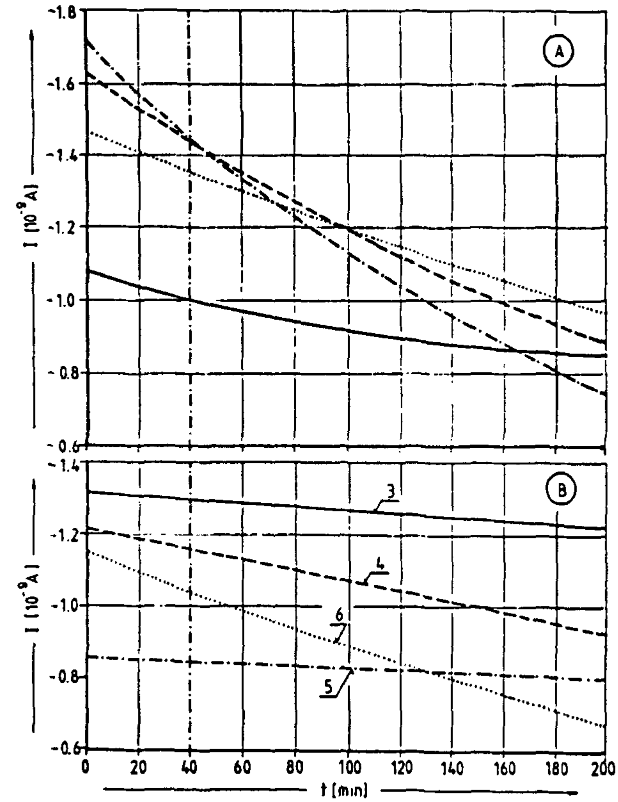

Fig. 2. Changes of current flow (I) through tissues of the maize primary roots in consequence of gradT. Bathing KCl solution concentrations in the A and B segments as well as the other symbols indicate the same as in Fig. 1.

Changes of current flow under the influence of gradT: Due to gradT the current flow decreases (Fig. 2). The declining rate depends on the concentration of the bypassing solution. In the case of a 0.5 % solution, the decline is the highest in 5-d old plants, the lowest in 3-d old plants. With a 1 % solution this dependence exhibits another feature. The lowest gradient is exhibited by tissues of 5-d old plants, the highest by 6-d old plants. In 3-d old plants the decline is small, but the current flow values are the greatest. In the case of current flow, the tissues of the primary root differ markedly in current conductance. It is interesting that the character of decline does not change while temperatures are levelled between the compartments, that is when the medium cools down in compartment II.

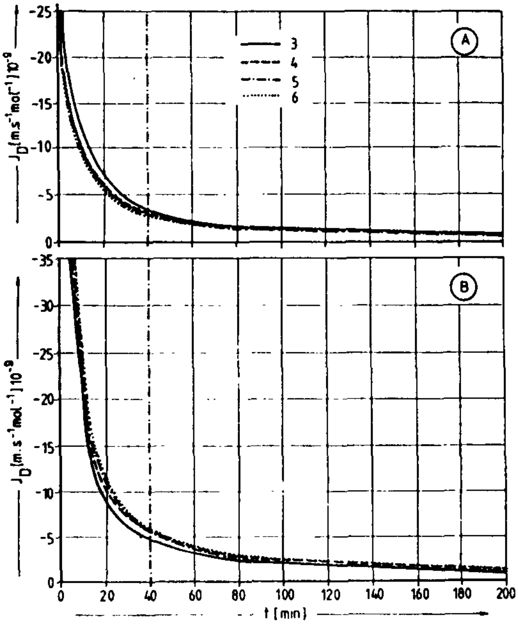

Fig. 3. Changes of diffuse flow (J_D) through tissues of the maize primary roots in consequence of gradT. Bathing KCl solution concentrations and other symbols as in Fig. 1.

Changes of diffuse flow under the influence of gradT: The effect of the gradT upon diffuse flow is relatively great and very weakly differentiable with regard to the age of plants (Fig. 3). The rate of diffuse flow decline depending on the gradT is relatively high and rises with the concentration of the bathing solution. Decline continues also in course of temperatures levelling in the compartments.

Changes of heat flow brought about by the gradT: The effect of the gradT upon heat flow through the root tissues does not differ esentially in plants of various age (Fig. 4A). It depends on concentration and volume flow, at a higher concentration heat flow is slower than at a lower concentration of the bathing medium. Just as the current flow, the heat flow also declines during gradT levelling.

Changes of volume flow due to the effect of the gradT: The influence of the gradT upon the volume flow is smaller than upon the diffuse flow (Fig. 4B).

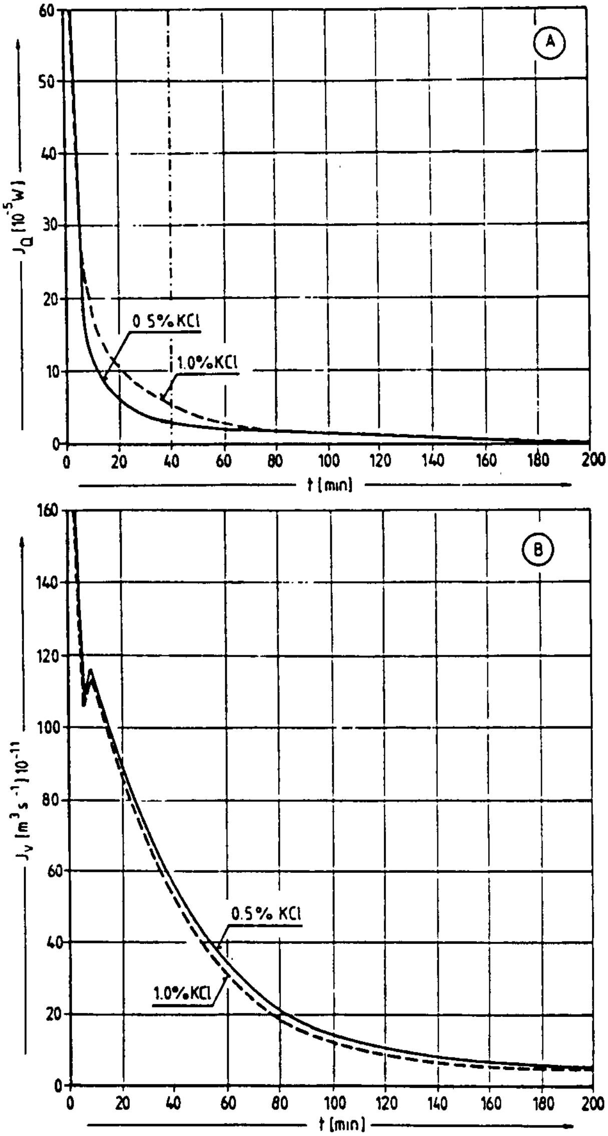

Fig. 4. Changes of heat flow (J_Q- segment A) and volume flow (J_V - segment B) through tissues of the maize primary root brought about by the acting gradT. KCl solution concentrations and other symbols as in Fig. 1.

The difference with respect to the plant age is similarly minimal. The volume flow decline depending on variations of the gradT is relatively high within the first 5 min. In course of the next 5 min decline changes into rise and approximately in the 8th minute volume flow drops again and continues to decline also in course of temperature levelling.

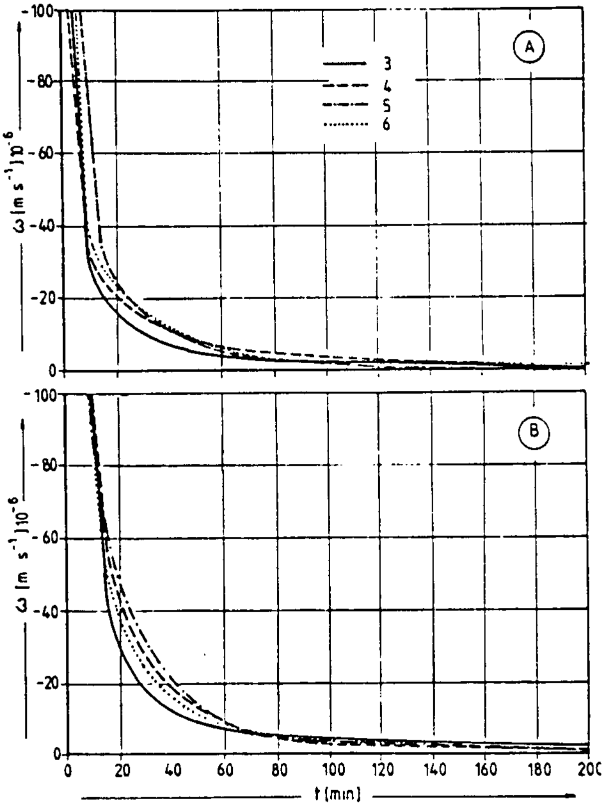

Fig. 5. Changes of the permeability coefficient (ω) of the primary maize root tissues due to the acting gradT. KCl solution concentrations and other symbols as in Fig. 1.

The effect of the gradT upon the permeability of primary maize root tissues: The permeability declines vigorously with the rising gradT, most in the youngest plant (3-d old), least in 5-d old plants. Permeability decline slows down with the rising concentration of the bathing solution. It is of interest that permeability at the primary root of 6-d old plants declines faster than in 5-d old plants and in the case of a higher solution concentration it comes close to the permeability values of 3-d old plants (Fig. 5).

The effect of the gradT upon reflection coefficient of primary maize tissues: The reflection coefficient of tissues decline vigorously as the result of the rising gradT and they increase while the gradT declines. The concentration of the solution exerts a great effect upon this proceses. With a 0.5 % solution it is the reflection coefficient of the primary root tissues of 5-d old plants that declines the most, of 3-d old plants that declines least vigorously. When temperatures between compartments are levelled, the situation is the same, it grows the most slowly in the case of 3-d old plants and the most quickly with 5-d old plants. With the 1 % solution this is reverse, except of 3-d old plants (Fig. 6).

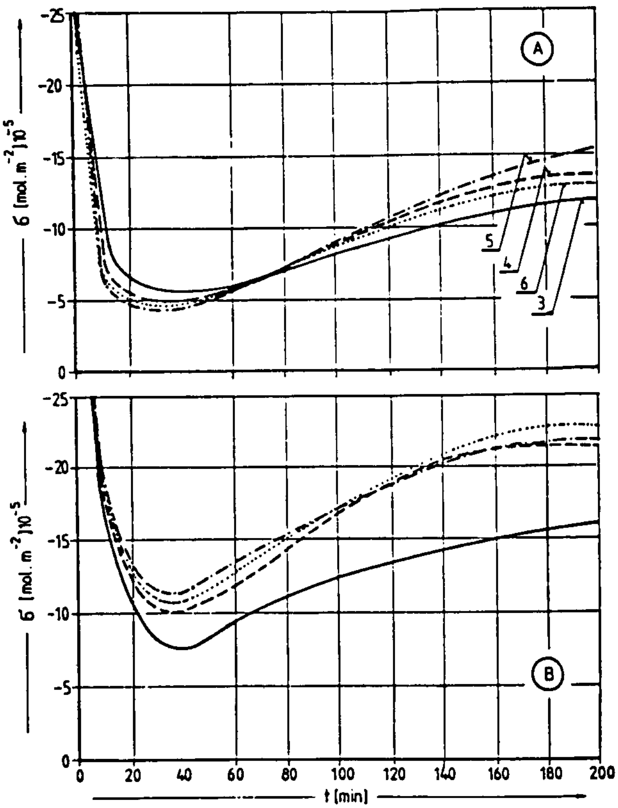

Fig. 6. Changes in the reflection coefficient (σ) of the maize primary root due to acting gradT. KCl solution concentrations in both parts of Fig. and other symbols as in Fig. 1.

Discussion

Due to rising gradT all four flows (current, diffuse, volume and heat) decline relatively quickly and this decline did not stop at the time of gradT decline. The results differentiate according the plant age, especially as far as electric gradients are concerned. The primary root tissues of the 3-d old plant was least affected by the gradT if the bathing medium is a 0.5 % KCl solution and 5-d old plant if the bathing solution is 1 % KCl.

The situation is clarified by the permeability and reflection coefficients. The permeability coefficient indicates the declining rate of water and ions permeation through the primary root tissues during the rise and the subsequent decline of the gradT. The reflection coefficient of the primary root tissues decline rapidly with the rising gradT and increase again in course of its levelling. Probably, the flows cannot be regenerate when temperatures are being levelled. This connects with the decline of the transport driving force.

Both coefficients illustrate the changes in dependence on the plant age and on the concentration of the bathing KCl solution.

The findings obtained confirm the effects of temperature upon the transport phenomena in roots observed by Zimmermann (1982), Pedro Bravo and Uribe (1981) from the physical viewpoint.

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