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BRIEF COMMUNICATION

Effect of potassium, and abscisic and indole-3-acetic acids, on maize root xylem exudation and potassium efflux

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Abstract

The influence of potassium sulfate, abscisic acid (ABA) and indole-3-acetic acid (IAA) solutions on xylem exudation rate and potassium efflux from the apical cut end of root tips of intact maize (*Zea mays* L. cv. Dnepropetrovskaya) seedlings was studied. Foliar application of 5 mM K_2SO_4 considerably stimulated the exudation rate. The application of ABA and IAA (1 mM) also induced a high rate of xylem exudation, K^+ efflux being simultaneously increased.

Additional key words: potassium recycling, water uptake, *Zea mays*.

Potassium plays an important role in establishing a favourable osmotic gradient between the external solution and the fluid in the root xylem vessels. K^+ absorption by the root system and its presence in xylem fluid is connected with water absorption. The important physiological role of K^+ in plants consists in the increase of the osmotic component of the root pressure (Zyalalov and Gazizov 1989). Increase in potassium concentration promoted xylem exudation from the excised roots of some plants (Zyalalov *et al.* 1994). Exogenously applied ABA affects xylem exudation by its influence on volume flow (J_v) and solute flow (J_s) velocity. In some cases ABA already increased exudation several minutes after treatment (Humble and Raschke 1971), while in other cases ABA stimulation was observed after 1 h (Van Steveninck and Van Steveninck 1988). On the other hand, inhibition of exudation by ABA was observed in excised roots (Behl and Jeschke 1979). Because ABA production is enhanced by water stress, any effect that ABA might have on the absorption function of the roots is of great importance to plant water balance.

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Auxin activates the cation channels of the plasmalemma permeable for both Ca^{2+} and K^+ ions (Pineros and Tester 1995). Therefore IAA might play an important role in plant water relations (Blatt and Theil 1994). Hormone treatments were carried out mainly on the root zone, *i.e.* hormones were added to the nutrient solution, and the xylem flux rates were measured on excised roots. Therefore, the aim of this paper was to determine if treatment of shoots with ABA and IAA can regulate water uptake and potassium recycling.

The experiments were conducted with 7 to 10-d-old seedlings of maize (*Zea mays* L. cv. Dnepropetrovskaya). After germinating in darkness on moistened filter paper for 3 d, the seedlings were mounted in drilled holes in special plastic holders and transferred to containers (5 dm^3 capacity, 25 plants per container) with continuously aerated, 1/4 strength Hoagland-Arnon nutrient solution. Plants were grown under controlled conditions: 14-h photoperiod, irradiance of 15 W m^{-2}, day/night temperature of 25/18 °C and relative humidity of 60 %. Then seedlings were placed in the chamber divided into separate compartments (3 seedlings per compartment), the above-ground parts were covered by plastic transparent pots, lined with moistened paper, to create almost 100 % air humidity around the plant foliage. Cotton splints saturated with 5 mM potassium sulfate (0.2 mg of potassium per splint) and 1 mM ABA or IAA were put on two expanded leaves of experimental plants. Control plants were treated with distilled water.

The xylem exudate was collected from the apical cut end of the root tip (3 - 5 cm from the root apex) of intact plants exposed to 100 % air humidity, which suppressed the transpiration and raised hydrostatic pressure in the xylem vessels. It has been shown that composition of this exudate is analogous to the composition of the unbroken xylem vessel fluid (Solovev and Verenchikov 1987). Calibrated glass capillary was attached (with the help of thin rubber tube) on the apical cut ends of root tips. Readings were generally taken at 15 min intervals. Exudate was analyzed with a flame photometer *Flapho-var* (*Carl Zeiss*, Jena, Germany). In order to estimate the amount of K^+ uptake through the leaf surface we analyzed the content of the K^+ retained in the cotton splints and on the leaf surface after the experiments. For this purpose the splints were soaked off in distilled water, the surface of treated leaves was washed with distilled water and the "wash-out" obtained was analysed with the flame photometer.

After 60 min, potassium treatment of the shoots sharply increase in 60 min both the exudation rate from the root tip and the K^+ efflux in the xylem exudate (Fig. 1). The mean K^+ concentration in the exudate from control plants was 35 mM and 38 - 43 mM from seedlings treated with K_2SO_4-solution. In this experiment potassium not only increased exudation rates within 60 min after application, but it also caused a considerable promotion of exudation during the following day. The mean K^+ concentration in the exudate during the following day increased to 75 - 85 mM from treated plants. The analysis of potassium content in splints after the experiments showed that approximately 40 - 80 μg of K^+ from splints was transported across the leaf surface (from 200 μg of the initially applied K^+).

The application of ABA and IAA significantly stimulated the rate of exudation (2 - 2.5 fold); moreover the response was induced within 30 min after application. In

addition, ABA and IAA supply to the leaves of plants caused 1.5-fold promotion of K^+ efflux in the exudate (Fig. 2).

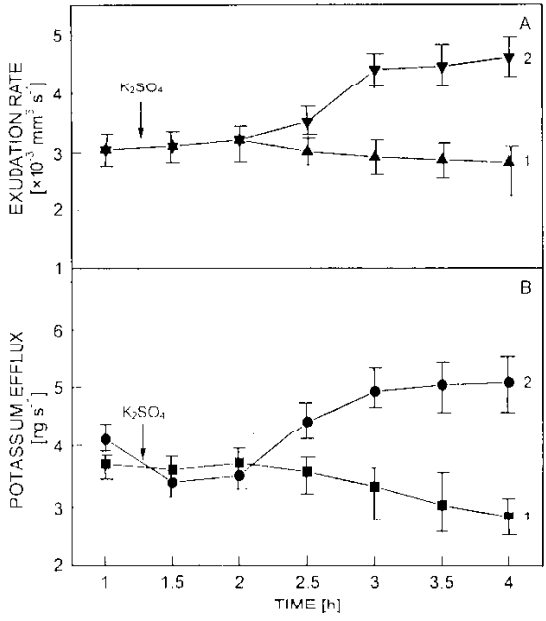

Fig. 1. The xylem exudation rate (*A*) and potassium efflux (*B*) from the apical cut end of the maize root tip (1 - control, 2 - the leaf treated with 5 mM K_2SO_4, ↓ - the moment of K_2SO_4 solution application to the leaves). Means ± SD of six replicates.

The treatment of the leaves with K_2SO_4 resulted in an increase of exudation and K^+ efflux in the xylem exudate. These results are in full agreement with our views about the connection between absorption and long-distance transport of K^+ with water (Zyalalov 1979, Zyalalov and Gazizov 1989). The increase of K^+ content in the xylem exudate under the influence of exogenous K_2SO_4 indicates that the exogenous K^+ enters the phloem elements and transfers to the root in a basipetal direction, passes into the xylem vessels and then is carried back by the xylem flow. The increase of exudation under the influence of K_2SO_4 might be due to the fact that potassium, having entered into the root, contributes to its osmotic potential. The lag-time of the effect (almost 1 h) is comparable with the transfer rate of mineral nutriemts through the conductive elements of plants. The increase of K^+ efflux, and also that of the exudation rate continue for a long time.

Introducing K^+ into the plant and thus increasing water absorption by the root can optimize its water balance. This was shown by the increase of water content in the leaves of *Fagopyrum esculentum* L. under the influence of K_2SO_4 foliar spray in field experiments (Gazizov *et al.* 1995).

According to Glinka (1980) the promotive effect of ABA on exudation involves an increase in hydraulic conductivity (L_p) and the release of ions (especially K^+) from the vacuoles to the cytoplasm and from the symplasm to the xylem, thus increasing the osmotic potential of xylem sap. The fairly rapid stimulating effect of ABA (a lag of about 30 min) on water uptake by roots might be caused by its influence on plasmalemma permeability. Our data point to an increase in water diffusional permeability of root cell membranes under the influence of ABA supplied to the leaves as measured by the NMR technique (unpublished data). Increase of K^+ efflux with the xylem exudate may suggest ABA-induced release of K^+ ions in the xylem vessels similar to ABA-induced fluxes of K^+ from stomatal guard cells.

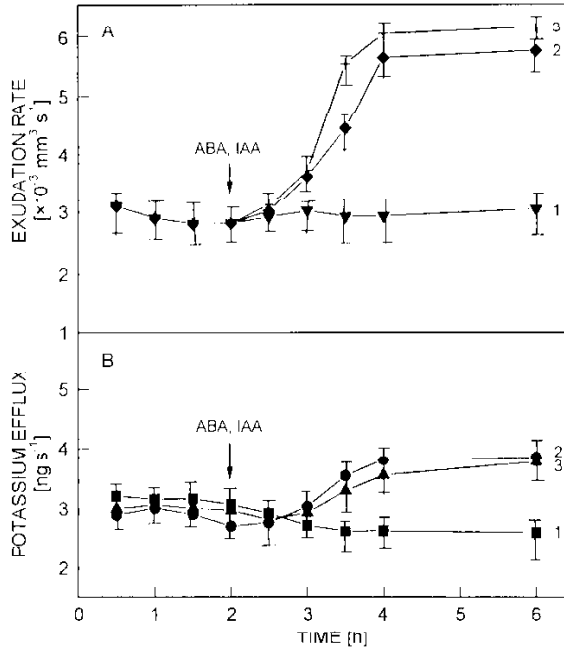

Fig. 2. The influence of ABA and IAA on the xylem exudation rate (*A*) and potassium efflux (*B*) from the apical cut of the maize root tip (1 - control, 2 - leaf treated with 1 mM ABA, 3 - leaf treated with 1 mM IAA, ↓ - the moment of ABA and IAA application to the leaves). Means ± SD of six replicates.

The basis of the promotive effect of IAA on the exudation might be the coupling of H^+ efflux from cells with K^+ influx. Increase in uptake of some ions (including K^+) by the root system was observed under the influence of IAA.

Thus, the potassium treatment of shoots allows us to fill up the circulative flux by K^+ and to intensify water absorption by the root. ABA and IAA exogenously applied to the shoots enhance the exudation rate and K^+ content in xylem vessels and so influence potassium recycling in plant organs.

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