6 SUMMARY

Objective of the presented study has been the investigation of transport paths for the plant hormone abscisic acid (ABA) through root-tissue into the xylem vessels under different external conditions. Furthermore, the ABA-effect upon the hydraulic conductivity was to be analysed and the link between water flow and transport of that hormone investigated.

The experimental work of the presented study has been able to show, for the first time, that a phytohormone like ABA can be transported apoplastically into xylem vessels by solvent-drag of the water flow. In a recent paper of Wan and Zwiazek (2000) this proposition has already been confirmed. Similar results have been found by Steudle (1993) for nutrient ions.

For ABA, a bypass-flow throughout the whole cell wall apoplast, including lipophilic barriers like exo-and endodermis, could be demonstrated. This may be due to the particular properties of the 264 Da ABA-molecule: (i) the small diameter of the molecule (8 to 11 nm) and (ii) the high lipophily of the uncharged ABA under physiological conditions. Conclusively, a penetration of apoplastic barriers is supposed to be possible.

Furthermore, this study shows the development of such lipophilic cell wall-nets should have significant influence on apoplastic ABA-transport-properties. The formation of an exodermis in maize, as it occurs under natural conditions, was able to reduce the ABA-flow into the xylem by factors of 2 up to 4. As, simultaneously, the root-hydraulic conductivity was decreased by the same rate, the root-to-shoot ABA-signal, the phytohormone concentration in the xylem, remained constant. The information about the root-water-status addressed to the guard cells has not changed, therefore.

In the natural environment even an increase of this signal is to be expected, as exodermal layers are no uptake-barriers for the tissue-produced ABA. On the contrary, an exodermis will retard the leakage of ABA to the rhizosphere.

At the same time, roots are more effectively adapted to drought because water loss from exodermal roots is also reduced significantly.
Apoplastic barriers are, therefore, beside membrane-located transport-proteins, the important parameters for determining root-transport-properties for water and solutes.

The contribution of the apoplastic component to the entire ABA-transport depends on the plant species investigated, the actual transpiration- or water-flow rate and on external conditions like high ABA-concentrations in the root tissue (e.g. after drought), pH of the rhizosphere, and the nutrient status of the plant.
Increased radial water-flow, raised ABA-contents of the root tissue, and a low pH of the rhizosphere intensified the apoplastic bypass-flow under physiological conditions.
Low water-transport rates, low ABA tissue-contents, alkaline pH-values in the rhizosphere and ammonium as the only N-source, on the other hand, increased the symplastic contribution to the ABA-transport.

In the presented study, the controversal dispute concerning the ABA-effect on root hydraulic conductivity could be settled. ABA raises cell hydraulic conductivity (Lp) for 2 h with a maximum after 1 h of ABA-application. This results in an increased Lp_r (hydraulic conductivity of intact root systems), directed by a similar time-pattern. So, by ABA plants are able to reversibly optimise the cellular transport path of water to support the plant under mild drought stress with sufficient water.
However, if water deficiency continues, plants again close this additional symplastic pathway. This transient ABA-effect explains both stimulating and inhibiting ABA-actions, as known from literature.
At the beginning of a stress situation ABA induces by an increased water flow a self-intensifying root-to-shoot-signal. Thus, in an effective way the leaf achieves a sufficient amount of ABA in order to close the stomata. A reduction in transpiration follows. Further continuous stimulation of the symplastic water transport path would be without any physiological meaning.
Membrane structures, responsible for regulating this mechanism may be ABA-responsive water channels (aquaporins) in the plasma membrane. It has been

shown that the receptor for regulating these channels is localised inside the cortical cells of maize roots and highly specific for (+)-cis-trans-ABA.

Signal transduction for this short-time effect is not mediated by intensified aquaporin-transcription, but there may be evidence of ABA-induced regulation by channel activation (phosphorylation) or by incorporation of aquaporins into cell membranes.

The transport of abscisic acid is a complex process modified by environmental conditions, root anatomy, coupled with the water flow, and variable by itself. Customary ideas about a simple hormone diffusion are not apt to describe this complex process anymore.

Plants possess an ABA-transport system, which is fast, effective, and adaptable to changing environmental conditions.