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The Chemical Composition of Xylem Sap in *Vitis vinifera* L. cv. Riesling During Vegetative Growth on Three Different Franconian Vineyard Soils and as Influenced by Nitrogen Fertilizer

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Cuttings of grapevine (*Vitis vinifera* L. cv. Riesling clone B 68) grafted on SO4 (Selection Oppenheim No. 4) rootstocks were grown in pots with three different soils from Franconian vineyards derived from different geological formations (namely, Loess, Muschelkalk (shell lime), or Keuper). Additionally, the influence of N-fertilizer treatment was investigated. From the midrib of leaves six to eight of the sole shoot, xylem sap was collected simultaneously by pressurizing the rhizosphere during the vegetative growth phase. The chemical composition of xylem sap was determined and compared with that of the aqueous soil extract. In Muschelkalk soil, carbon, nitrogen, and calcium were present in the greatest concentrations. Sulfur, boron, magnesium, sodium, and potassium were greatest in Keuper, and the concentrations in Loess soil were intermediate. Aqueous extraction of the soils resulted in a two-fold greater concentration of total solutes in Keuper extract compared with Muschelkalk, and more than threefold than in Loess. The apparent volume flow was greatest in the middle leaves along the shoot and in plants grown on Keuper; additionally there was a tendency for fertilizer treatment to increase flow. The concentrations of mineral ions in xylem sap were the same in all the leaves of a shoot of grapevine. An important exception was the supply to the leaves of amino acids, which increased in concentration along the transpiration stream and were greatest in the youngest leaves (particularly in non-fertilized plants). Potassium was the dominant cation in xylem sap and was greatest in plants grown on Keuper. Concentrations of sodium and calcium were increased in non-fertilized plants, but not significantly in vines grown on Muschelkalk. In xylem sap, nitrate was the major anion, followed by malate. Nitrate concentration was greatest in plants grown on Muschelkalk, while malate was greater in plants grown on Keuper. Chloride, sulfate, and phosphate concentration in sap were increased by fertilizer treatment. Abscisic acid was markedly increased in xylem sap of non-fertilized plants grown on Loess and Muschelkalk and was discussed as a signal for nutrient limitation. If Keuper was the substrate it was also increased by fertilizer treatment. Of the organic N-compounds, glutamine was the largest fraction. On the basis of the relation of nitrate to total N in xylem sap, it could be assumed that about 40% to 75% of nitrate reduction took place in the shoots. In general, soil type had only a moderate effect on the chemical composition of the xylem sap compared with the effect of N-fertilizer.

KEY WORDS: grapevine (*Vitis vinifera* L. cv. Riesling), cations, anions, abscisic acid, xylem sap, soil (geological formation)

Leaves and other shoot parts are supplied with mineral nutrients and organic products of root uptake and metabolism (organic forms of N, organic acids, phytohormones) via the xylem. One of the first steps in this process is the secretion/loading of ions into the xylem by the stellar parenchyma [32]. The composition of the soil solution has a marked influence on the composition of the xylem sap. For example, the relative concentrations of nitrate or ammonium generally have large effects on the composition of the transport fluids in plants [1,4,5,22,23,29,30] as have concentrations of other ions such as K^+, Mg^{++}, and Ca^{++}.

Grapevine is an old agricultural plant and the quality of wine is the object of much debate [31]. While many factors including cultivar, climate, agriculture methods, *etc.* play roles in determining quality, soil type (including fertilizer) plays a major role [31]. The chemical and physical properties of soils influence the wine in numerous ways, but mostly indirectly since grapes are supplied largely by the phloem during ripening [15]. Recent studies have highlighted the circulatory nature of xylem and phloem [8,10,12,13,22,25,26]. In general, the composition of xylem sap reflects both mineral and water uptake and also the general nutrition status of the plant. In addition, xylem sap is the major means of transport of abscisic acid (ABA), a major hormonal signal of drought and salinity, from roots to shoots [7]. Therefore, the xylem is not only responsible for solute exchange, but also for transport of root to shoot signals. ABA is considered to be an

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