The K to (Ca+Mg) ratio effect on potassium availability for plants – splitting soil- from plant-related interactions

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The energy of K\(^+\) to (Ca\(^{2+}\) + Mg\(^{2+}\)) exchange in soils, expressed as \(\Delta F\), represents the intensity factor in plant K nutrition. To elucidate whether the ratio K\(^+\)/(Ca\(^{2+}\) + Mg\(^{2+}\)) affects K nutrition of plants through plant physiological interactions, such as competition, or through soil-related interactions, the influence of various ratios of K concentration to (Ca+Mg) concentration on the growth and K uptake of tomato (Lycopersicum esculentum Mill.) plants was examined in soil, perlite, and hydroponic culture.

Nutrient solutions with six combinations of four \(\Delta F\) values (-3500 to -2000 cal mol\(^{-1}\)) and three K concentrations (0.2 to 1.8 mM) were used in a hydroponic experiment. Fertigation with three \(\Delta F\) levels (-3600 to -3214 cal mol\(^{-1}\)) at a fixed K concentration (0.63 mM) and with three K concentrations (0.51 to 1.52 mM) at a fixed \(\Delta F\) value (-3324 cal mol\(^{-1}\)) were used in a soilless perlite experiment. In the soil culture, a clayey soil (62% clay) with \(\Delta F\) values of -5037, -3600 and -3200 cal mol\(^{-1}\) and a sandy soil (92% sand) with \(\Delta F\) values of -3200, -2834 and -2200 cal mol\(^{-1}\) were used with N and P, but no K, fertigation during plant 30-days growth period. The two soils largely differed in their potential buffer capacity (PBC) for K availability, with PBC of 21.4 to 34.2 meq kg\(^{-1}\) (Ca+Mg\(^{0.5}\)K\(^{-1}\)) for the clayey soil and 1.1 to 1.7 meq kg\(^{-1}\) (Ca+Mg\(^{0.5}\)K\(^{-1}\)) for the sandy soil.

In hydroponic culture, at a constant \(\Delta F\) level, biomass yield and K uptake increased significantly (\(P \leq 0.01\)) with increasing K concentration in the nutrient solution, but varying \(\Delta F\) value at a constant K concentration did not result in any significant impact on yield or K uptake by the plants. In the perlite culture, increasing K concentrations in the nutrient solution resulted in a higher K concentration in the youngest mature leaves (\(p \leq 0.05\)), regardless of the \(\Delta F\) value of the solution, whilst decreasing \(\Delta F\) of the solution had no significant impact on plant K concentration or plant growth. In contrast to the hydroponic and soilless culture, for both soils shoot K concentration and shoot dry weight were significantly correlated with the soil \(\Delta F\) level and were affected by soil PBC.

It is concluded that K uptake by tomato plants strongly depends on K concentration in the root-zone solution while the rather large root selectivity for K\(^+\) probably results in rather small effect of the competing cations Ca\(^{2+}\) and Mg\(^{2+}\). On the contrary, in soils, \(\Delta F\) represents the soil-related energy needed for releasing K\(^+\) from its exchangeable positions in the soil. The energy needed for K\(^+\) extraction from the soil is ultimately invested by the plant and is related to the ratio between K\(^+\) and (Ca\(^{2+}\) + Mg\(^{2+}\)) in the soil solution. In soils, the K\(^+\) concentration is dependent on the (Ca\(^{2+}\) + Mg\(^{2+}\)) concentrations, thus the cation exchange and the PBC of the soil affect K nutrition in soils.