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Effect of water quality on the leaching of potassium from sandy soil

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Abstract

When potassium (K^+) fertilizers are applied to soil, K^+ is subject to displacement through the soil profile. More generally, the application of K^+ fertilizers to sandy soils with low clay content and small buffer capacity, in which K^+ does not interact strongly with the soil matrix, results in localized increases in K^+ concentration in the soil solution. Losses of K^+ depend on the concentration of calcium (Ca^{2+}) as a competing ion in the leaching water and the amount of water that passes through the soil. In this study, we examined the adsorption and movement of applied K^+ in columns of sandy soil. Glass tubes, 4.8 cm in diameter and 40 cm in length, were packed with either native soil or Ca^{2+}-saturated soil. The resulting 10-cm-long column of soil had a bulk density of 1.65 g cm^{-3}. Native soil was leached with distilled water and $CaCl_2$ solutions of various concentrations. In the Ca^{2+}-saturated soil, a pulse of K^+ was leached with $CaCl_2$ solutions of various concentrations or distilled water. Increasing the $CaCl_2$ concentration from 3 to 15 mM resulted in earlier breakthrough, a higher peak concentration of K^+, and greater amounts of leached K^+. The breakthrough curve for K^+, when leached with distilled water, showed very low concentrations and was more delayed than the other treatments. In Ca^{2+}-saturated soil, the amount of K^+ leached increased as Ca^{2+} concentration increased, with up to 54% of the added pulse K^+ being removed from 10 pore volumes (Pv) (387 mm) of 15 mM $CaCl_2$. The presence of Ca^{2+} in irrigation water and soil minerals able to release Ca^{2+} is important in determining the amount of K^+ leached from soils. Large amounts of K^+ are leached from soils in areas where crops are irrigated with water that contains significant concentrations of Ca^{2+} and other cations.

Keywords: Leaching; Potassium; Native potassium; Water quality; Iran

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1. Introduction

The fate of the nutrient K^+ has received less attention than that of nitrogen or phosphorus. The chemistry and fertility of K^+ in arid and semi-arid regions are poorly studied because soils in these regions are generally well supplied with K^+; however, soils that are intensively cropped become progressively depleted in plant-available K^+. The forms of K^+ in soil, in order of their availability for leaching, are solution, exchangeable, non-exchangeable and mineral (Martin and Sparks, 1985; Sparks and Huang, 1985). Exchangeable and solution forms are primarily involved in leaching.

The application of K^+ fertilizers to most sandy soils with low clay content and small buffer capacity, in which K^+ does not interact strongly with the soil matrix, results in localized increases in K^+ concentration in the soil solution; subsequently, K^+ is leached by rainfall or irrigation water. In arid and semi-arid regions, the leaching of K^+ is enhanced by the presence of calcite and gypsum (Jalali and Rowell, 2003). In addition to clay type and content, organic matter content and the amount of applied K^+ (Johnston et al., 1993), the leaching of K^+ is also dependent on the concentrations of other cations, especially Ca^{2+} in the soil solution. The source of Ca^{2+} for displacing K^+ is either saline solution (Rowell, 1985) or the weathering of soil minerals (Shainberg et al., 1981), especially those that contain gypsum and calcite. Calcium is the dominant cation in soil water and at the exchange sites, and competes with K^+ for exchange sites when K^+ fertilizers are applied to the soil.

Johnston and Goulding (1992) suggested that approximately 1 kg K^+ ha^{-1} was lost for every 100 mm of rainwater leached through the soil in the field, but this value may be larger if K^+ is displaced with a solution that contains a higher concentration of Ca^{2+} ions. Johnston et al. (1993) studied a sandy loam soil and measured 20–80 kg ha^{-1} leaching of K^+ from the soil profile over 1.5 years. Heming and Rowell (1997) analysed chalky soils in laboratory studies and measured leaching of 9 and 74 kg K^+ ha^{-1} following leaching equivalent to 1 year of throughflow in the field.

It is important to note that the leaching of K^+ in arid and semi-arid regions is different to that in temperate regions. A characteristic of arid and semi-arid regions is low rainfall and the necessity of irrigation. The shortage of quality water resources is becoming an important issue in arid and semi-arid regions of the world. In these regions, the availability of non-saline river or canal water is limited and prioritized to supplying urban areas (Beltran, 1999). Ground-water is commonly the only source of irrigation, although its quality is usually low because of limited rainfall and high rates of evaporation. Thus, there is an increasing need to irrigate using low- to medium-quality ground-water.

Irrigation with water in which the concentrations of Ca^{2+}, Mg^{2+}, and Na^+ are higher than those in high-quality water leads to an increase in K^+ desorption and leaching (Meiri et al., 1984; Feigenbaum and Meiri, 1988). This K^+ may be more readily available to plant roots, but it is also easily leached down beyond the root zone. Feigenbaum (1986) reported losses equivalent to 90–300 kg K^+ ha^{-1} when 430 mm solutions containing 5 and 50 $cmol_c\,l^{-1}$ of mixed NaCl–$CaCl_2$ were applied to soil columns in the laboratory. Bar-Tal et al. (1991) showed that irrigation water with high salinity can leach native and applied K^+ from the soil. Jalali and Rowell (2003) reported losses equivalent to 29–387 kg ha^{-1} when 780 mm of distilled water was applied to calcite- and gypsum-bearing soil columns in the laboratory. Therefore, an increase in K^+ concentration can be expected in ground-water within infiltration areas subjected to agricultural land use. Such increases