EXCHANGE ACIDITY OF WHEAT AND PEA ROOTS IN SALT SOLUTIONS
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SUMMARY

The pH of salt solutions of different kinds and concentrations was lowered when roots of starved peas (Pisum sativum) and wheat (Triticum aestivum) plants were submerged. This pH decrease seems to be primarily caused by cation exchange. The metal cations of the salts displace hydrogen ions on the root surface. The root surface functions as a cation exchanger in a way that can be predicted by the ordinary ion exchange laws.

Effects of concentration, valency, and hydration of salt cation were demonstrated in the experiments. These exchange properties of the roots are marked and consistent at + 20°C as well as at + 0.5°C with N₂-gas bubbling. At 0.5°C the cell metabolism is reduced to a minimum and no active uptake or release of ions from the roots can occur.

The exchange acidity of the roots increased with the salt concentration and with the valency and hydration in the order: M⁺ < M²⁺ < M³⁺ and Li < Na < K; Mg < Ca < Ba.

INTRODUCTION

The root hairs and the young parts of plant roots are provided with an outermost zone of mucigel with negative charge, and inside this is a wall of cellulose, hemicellulose and pectic material with carboxyl, COOH, as cation exchanging groups. The root surface therefore behaves as a cation exchanger, adsorbing cation nutrients from the surrounding soil solution and to some extent also by contact exchange direct from the soil particle surface. The cation exchanging properties as determined by the CEC value vary strongly with the plant species, as well as with the plant age. The non-metabolic cation exchange between plant root and soil solution may be formulated as

Root-H + M⁺ (sol.) → Root-M + H⁺ (sol.)
and as a consecutive reaction the replacement of $M^+$ from the soil particles by $H^+$:

$$\text{Soil-M} + \text{H}^+ (\text{sol.}) \rightarrow \text{Soil-H} + \text{M}^+ (\text{sol.})$$

This process leads to a slow and gradual pH drop in the soil solution and a corresponding decrease of the base saturation of the soil, if not counteracted or balanced by other processes, like chemical weathering, or by nutrient application.

If the ion exchange between the root surface and the soil solution, as formulated above, is governed by the same laws as are valid in non-living systems, it can be concluded that the H-ion replacement and the pH drop should increase with the salt concentration and with the adsorption energy of the cation $M$. Consequently, the exchange acidity created when plant roots are immersed in a neutral salt solution should increase with the valency of $M$, that is $M^+ < M^{2+} < M^{3+}$, and decrease in an opposite direction to the hydration degree of $M$.

In addition to this non-metabolic exchange acidity the plant roots produce acidic environment by exuding many different organic acids and carbonic acid as metabolic products. Nightingale observed so low pH as 2.8–3.0 close to the roots.

Washüttl demonstrated pH drop after immersion of excised barley roots in distilled water, KNO$_3$ solution and Hoagland solution and explained the pH change as a result of loss of metabolic products and different uptake of cations and anions.

The purpose of the present investigation was to study the relationship between the exchange acidity of wheat and pea roots and the kind and concentration of neutral salt solutions. The experiments were designed to show whether this ion exchange follows the general laws governing the influence of salt concentration, cation valency and degree of ion hydration. The experiments were run at 20°C and, to suppress the effect of root metabolism, also at 0.5°C. Chlorides of Li, Na, K, Mg, Ca, Ba, and La and nitrate of Ca were used in concentrations of 0.001–0.100 N (gram equivalents per litre).