Root growth and calcium uptake in relation to calcium concentration

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Summary The purpose of the present work has been to investigate the influence of calcium supply on root growth in barley. The plants were grown in pots, in which the upper part was a sand-perlite mixture and the lower part a test solution with varying calcium concentration (10^{-6} - 10^{-2} M CaCl_2). The two parts were separated by a peat layer impeding a calcium transport from the upper to the lower part.

The growth of the roots in the test media was examined daily by counting the total number of roots and the number of roots with laterals. The development of the number of roots had an exponential course at all calcium concentrations and was enhanced by increased calcium concentration. At harvest it was found that the size of the roots (length and dry weight) decreased with decreasing calcium concentration to a certain extent.

Introduction

Calcium-ions are the only ions which were considered to be essential for root growth, because calcium-ions are not translocated in the phloem sap^{2,11,15}. Therefore, calcium-ions have to be continuously supplied to the root meristems. This process requires an adequate and continuous uptake of calcium-ions and a difference in water potential, creating a flow of solutes and water in the cell walls and in the xylem^{8,15,19}.

Plants are adequately supplied with calcium-ions, when the activity ratio of calcium-ions to the total sum of cations in the soil solution is larger than 0.15^{1,4}.

When the total amount of calcium is limited as can be the case in sandy and/or acid soils or when per cent saturation with calcium on the colloids at the actual pH is too low in the colloidal soils^{4,6,21,22}.

In soil areas with unfavourable conditions for root growth, the ageing of roots proceeds more rapidly due to retardation of root extension and suberisation closer to the root apex^{5,7,9}.

When root growth in the subsoils is restricted, the plants are less drought resistant and thereby more sensitive to the fluctuations in environmental conditions, which are normally occurring in the field.
This will influence the further root growth, as especially young roots are able to transport calcium-ions through the endodermis cell walls to the xylem.

Generally, the influence of calcium-ions on root growth has been investigated in water culture experiments with seedlings or in field experiments in acid or solonetzic soils with mature plants.

The purpose of the present study has been to examine the influence of the calcium-ion supply on root growth in young plants without the harming effects of low pH-value (pH > 3.6) and without any competition from other cations.

Three experiments were designed to investigate to which extent root growth is influenced by the calcium supply. A peat layer, forming a calcium barrier, was inserted between the top soil and the test medium in order to establish a separation with respect to calcium concentration and to avoid transportation of calcium-ions adsorbed in the root cortex from upper soil to test medium.

Due to the immobility of calcium-ions in the phloem sap, isolation of the test medium from the upper soil was the only necessary arrangement previous to the investigations of the influence of calcium-ions on root growth.

Materials and methods

Micropot technique

A micropot technique, which is a modified Stanford and DeMent technique, was developed. The pots were filled with a sand-perlite mixture and the bottom of the pots was replaced by a layer of peat. The peat had previously been brought to equilibrium with a CaCl₂ concentration corresponding to the test medium concentration.

Barley (Hordeum vulgare L., cv Nordal and in exp. 2 cv Welam as well) was pregerminated for one day in a cotton cloth moistened with tap water. The seeds were then placed at a depth of two cm in the micropot with the sand-perlite layer. They were covered with sand and the top soil was supplied with adequate amounts of water and nutrients.

As soon as the first roots had grown through the peat layer in one of the pots all micropots were placed in test pots in contact with the test media. The experimental setup is shown in Fig. 1.

Three experiments were performed as shown in Table 1. Dissolved nutrients were supplied to the top of the micropots five times during the experimental period. The amount of macro-nutrients supplied is stated in Table 2. Micronutrients were supplied in all three experiments (in μM per pot): 0.78 MnSO₄, 0.32 ZnSO₄, 0.06 CuSO₄, 0.58 H₃BO₃, 0.008 Na₂MoO₄ and 1.84 Fe-Na₂-EDTA.

Before use all materials and bottles were cleaned by placing them in a bath of acid (40% H₂SO₄) for one day, then rinsed with distilled water three times and air dried.

Test solutions

Calcium-ions are susceptible to precipitations and ion-pair formations with anions as sulphate, phosphates and bicarbonates. Because chloride and nitrate ions were the only anions added to the test solutions, the influence of ion-pair formations and precipitations could be neglected.