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Investigating Phylogenetic Relationships between Roots and Soil for Understanding Plant-Soil Interactions

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Introduction

Roots have a high level of responsiveness to changes in environmental cues, which is known as developmental plasticity. Endogenous rhythms control root system development genetically, but it is heavily influenced by biological (competition and symbiosis with other organisms), chemical (nutrient availability, oxygen supply, pH), and physical properties of its environment. The root system's architecture, or three-dimensional shape, is largely determined by the distribution and diversity of individual root apical meristems [1].

The physical properties of the soil, particularly its mechanical resistance to penetration, have a strong influence on the development of plant root systems. The interaction between mechanical soil stresses and root growth is of particular interest to many communities, including agronomy and soil science, as well as biomechanics and plant morphogenesis. Root apices, unlike aerial organs, must exert growth pressure to penetrate dense soils and reorient their growth trajectory to overcome obstacles such as stones or hardpans or to follow the tortuous paths of soil porosity. In this review, we present the main macroscopic field investigations of soil-root physical interactions and combine them with simple mechanistic modelling derived from model experiments at the scale of centimetres. Roots absorb the water and mineral nutrients from the soil that the shoot requires. Roots also ensure the plant's anchorage in the soil and provide a stable foundation for shoot emergence. Despite their interdependence, roots and shoots of the same plant organism live in very different environments [2].

A root system is made up of different root types depending on the plant species and age: primary or seminal root(s), adventitious roots, and/or lateral roots. The primary or seminal root(s) emerge during seed germination after being established during embryogenesis. Adventitious roots form on organs other than the liver. Roots, such as a leaf or stem Lateral roots, which form post-embryonically on roots, usually make up the majority of the root system. Whatever its type and composition, root system architecture is the result of lateral root emission and the growth of individual axes. In contrast to what occurs at the stem apex, root growth and lateral [3,4].

Since then, extensive and comprehensive reviews and books in soil science and agronomy have described the interaction between physical soil properties and root growth and architecture. The goal of this review is to combine these macroscopic approaches to the physical interaction of soil and roots with simple mechanistic modelling derived from model experiments at the scale of the individual root apex. The first section of this review summarises the key features of roots, root systems, and soils. Then, using observations of root response to growth in compact soils, we describe their interrelationship. The second section focuses on model experiments that investigate the various mechanisms involved in the root apex's response to local mechanical stresses. Root apices, in particular, are subjected to axial, radial, and frictional forces [3].

The root meristematic zone is surrounded by a root cap in the majority of plant species. The root cap is made up of a central region called the columella and a lateral root cap that surrounds it. The columella is made up of statocytes, which are gravity sensing cells with starch-rich organelles called amyloplasts. The root cap of some plant species, such as Arabidopsis thaliana, extends far along the flanks of the root apex. Despite the fact that the size of the root cap remains constant, this root tissue is constantly renewed. Close to the dormant center, root cap stem cells generate cells that, after a few divisions, differentiate into columella or lateral cap cells.

The nature of the soil or substrate influences the root-foraging strategy, resulting in different root architectures and physiological responses in plants. Deep loamy soils, artificial composts, or even model substrates like vermiculite or agar gels will require different rooting strategies than shallow soils over bedrocks or massive hardpans. Changes in growth direction (tropisms) or root system development (architectural features such as lateral root formation) are influenced by the mechanical stress field experienced by the root apices of growing roots, in addition to environmental cues such as water or nutrients. These stress fields are influenced by the soil or growth medium.

Description

Soil bulk density increases soil strength. Agronomists commonly use the term dry soil bulk density, which is defined as the mass of dry soil divided by the total soil volume. Soil strength increases with compaction, with soil bulk density ranging from 1.24 g/cm^3 for loose soils to 1.38 g/cm^3 for dense soils, and up to 1.52 g/cm^3 for very dense soils. Texture, clay mineral type, organic matter content, and moisture content all influence soil compaction resistance. Soil compaction is caused in part by external loads exerted by wheels under tractors or tillage machinery, as well as animal trampling [5].

The majority of penetrometers are made up of a metal probe with a conical tip attached to a cylindrical shaft. The probe diameter ranges from about 0.1 mm for a small needle penetrometer to more than 10 mm for a large field penetrometer, but it is usually around 1 mm, which is comparable to the diameter of many crop roots such as maize or peas. A relieved shaft with a diameter smaller than the cone basis is frequently used to reduce friction and adhesion between the soil and the shaft.

Conclusion

Although it goes without saying that soil compaction makes soil stronger, water content is a different soil characteristic that also significantly affects soil strength. As soil water content drops, soil strength rises. Soil behaviour can change from being brittle solid to plastic-ductile as a result, and the reported mechanisms of root penetration will be entirely different after drying. When the expanding root pushes through the soil, low water content soils behave like brittle solids and can crack under the pressure.

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Conflict of Interest

There is no conflict of interest by author.

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