Modelling nutrient and water acquisition of root systems: Under which conditions root system architecture is relevant

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Root system architecture can determine the acquisition efficiency of water and nutrients from the soil and an well adapted root system architecture may therefore of crucial importance for the competitive strength of single plants in plant communities and for yield formation and yield stability of crops. Under conditions where either water or nutrient supply is a key limiting factor, higher "carbon investments" into the root system may me "profitable" if this leads to an increase of carbon assimilation that balances out the *per se* negative effect of an enhanced root growth on the carbon gain of the shoot and the harvested organs. A proper analysis of the conditions where altered root system architecture may be beneficial is therefore a prerequisite for any effort to alter specific root traits, either by traditional or molecular breeding methods.

Root system architecture influences the uptake efficiency of water and nutrients by altering the transport distances from the bulk soil to the entry point of the resource into the plant, i.e. the root surface and by the ratio of uptake rates to total root length or root surface. The degree of sensitivity of the yield to root architectural traits is therefore in close correspondence with the degree of mobility of the resource. For highly mobile resources, like the soil water and the nitrate ion under wet soil conditions small amounts of roots may be satisfy the demand of the growing plants. Under these conditions the knowledge of the rooting depth over time may be sufficient for characterising the uptake efficiency of a root system. For immobile resources like phosphate, on the other hand, the problem of uptake efficiency reduces to questions of the ratio of the total root length to the nutrient uptake rate and the physiological efficiency per unit root length. The spatial arrangement of the roots then plays a minor role.

The most interesting case from the viewpoint of root system architecture, however, is the case of a "medium" mobility in combination with high uptake rates per unit root length. This situation is most common for nitrate under moderate to severe dry soil water contents and low rooting densities ($<0{,}5$ $cm\cdot cm^{-3}$), typical for the subsoil. Under conditions of a high evaporative demand and when water uptake is restricted in the region of the rooting front also water uptake may be influenced by the spatial arrangement of the roots. And, in addition, for the problem of inter- and intraspecific competition for belowground resources, also the case of the "medium mobile" resource is the most interesting one.

The most recent branch of root growth models, 3 dimensional, rule- or Lindenmayersystem based, offer the possibility to delineate complex root system distribution patterns from relatively few parameters and simple production rules. In combination with process models, they may allow to identify environmental and management conditions, where the root system architecture of current genotypes is suboptimal. In order to combine these complex structural models with the appropriate process models, however, they have for practical reasons to be degraded to two or one dimensional models incorporating the small scale variability by means of statistical parameters.