審 査 の 結 果 の 要 旨

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The body of his research thesis was divided into seven chapters. In the introductory Chapter 1, some background information related to the research topic is summarized and main research questions are formulated.

The 2nd Chapter describes the experimental methodology used to obtain plant growth and soil parameters, which are needed as inputs for the development of the functional-structural root model. A remarkable feature is that many input parameters describing root development were obtained from field experiments. This data set had been published with Daniel Gonzalez as a co-author (Wissuwa, Gonzalez et al. (2020) Plant & Soil).

The 3rd Chapter provides details of the model development process, and this includes considerations regarding the choice of the modeling framework, data processing steps to turn measured traits into input variables for the model, and an outline of the architectural elements modeled. Here the remarkable feature is the inclusion of root hairs as individual structures rather than as a simple approximation. The accuracy of the model was then compared to measured data from field and greenhouse studies.

In Chapter 4, this was followed up by utilizing this new 3-D root growth model to simulate P uptake over time. A sensitivity analysis identified influential model parameters such as length of L-type lateral roots and a cost-benefit analysis comparing the amount of P needed to develop a root of a certain type with the amount of P uptake contributed by that root over time concluded that the finer root structures are most cost-effective, with recovery times of only one day compared of up to 28 days for larger crown roots. Results of chapters 3 and 4 have been published in Gonzalez et al. (2021), Frontiers of Plant Science. In the remaining chapters the base model is expanded to include water movement and content as a second soil factor that interacts with the availability of P for plant uptake.

Chapter 5 describes the model additions/extensions needed to include the factor water and the problems that needed to be solved to achieve this. Once the operability of this extended model was confirmed, simulations of water and P uptake were conducted for hypothetical root systems differing in root growth angle (shallow - intermediate (normal) – steep). Contrasting water regimes, of which one simulated drought conditions, were added as a 2nd factor. Contrary to expectations changes in root angle did not have large effects on P uptake.

In Chapter 6, to test hypotheses why this may have been the case, additional simulations were conducted with more than a single plant. This introduced the factor inter-root competition and led to much faster depletion of water and stronger effects of root angles on water and P uptake. Data from Chapters 5 and 6 is being summarized in a new manuscript to be submitted shortly.

The final chapter provides a general summary and an outlook on research questions to be addressed in the future based on the knowledge created in the present thesis. These research results are of academical and practical significance and accordingly, all members of the doctoral thesis defense committee recognized that this research is equivalent to a doctoral thesis and all referees recommended that a doctorate will be awarded to Gonzalez Lozano Guillermo Daniel.