論文の内容の要旨

生産・環境生物学専攻

平成29年度博士課程進学

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論文題目 Studies on a Functional-Structural Model for Determination of P-uptake and Utilization in Upland Rice（陸稲におけるリンの取り込みおよび利用効率を定量化するための機能構造モデルに関する研究)

Chapter I Introduction and Research Objectives:

The upland rice growth situation in general terms is discussed, as well as its general importance in the overall food situation in the world. Emphasis is focused on how upland rice is of high importance for South Saharan Africa (SSA), before focusing on the many underlying issues plaguing the yield production of the area, particularly focusing on phosphorus (P) deficiency. It is explained how this problem is exacerbated by the low income of the farmers living in the area, who are mostly subsistence farmers.

P-deficiency tolerant upland rice is described, and a general review of the qualities of these resilient rice varieties is given. Special focus is shown on DJ123, an *aus* sub-species coming from Bangladesh. An in-depth review of the architecture of rice roots is also given, with emphasis in P uptake.

The existence of mathematical models and computational simulations of rice and rice growth is described, and emphasis on how studies have not yet addressed the effect of differences in S-type length and density in the presence of root hairs is made. The lack of an upland rice model including all fine structures and a root distribution pattern not affected by spatial limitations in root proliferation was discussed.

This research explains the process of development of an individual functional-structural plant model for studying traits in upland rice that can affect phosphorus uptake, as well as display various results that were obtained thanks to the use of said model, and how these results can be used to further expand the knowledge of crop growing in phosphorus deficient conditions.

Chapter II: Cost-benefit analysis of the upland-rice root architecture in relation to phosphate: 3D Simulations highlight the importance of S-type lateral roots for reducing the pay-off time.

The process of obtaining data for the development of the architectural and structural part of the model is discussed, as well as the development of the model itself, starting from the reasons DJ123 upland rice variety was selected as the initial target variety to the model's completion, including sensitivity analysis and comparisons with observed plants. Afterwards, the process by which the previously completed structural-architectural model receives new phosphorus uptake in order to be able to fully be called a functional-structural model is explained. Parameters and details about Phosphorus uptake are shown, and sensitivity analysis, uptake simulations, and root cost-efficiency modeling results are also explained. Utilizing the newly developed model, a P cost vs uptake analysis was made, and general effectiveness of each type of root was obtained. The results allowed us to conclude about the great importance of having root hairs and S-type (short) lateral roots for phosphorus uptake, especially in P-deficient conditions.

Chapter III: Biomass and P uptake analysis of upland-rice roots simulation with angle distribution variations per layer: Advantages of medium reaching roots for uptake during low water conditions.

The necessity of having a more comprehensive model was discussed. As a way of making the analysis more accurate and able to cover more scenarios, water-nutrient interactions were selected to be included next. One of the most famous water transport mechanic simulations is J. Simunek's SWMS_3D model. Being a free public use code, it was utilized as a module inside the OpenSimRoot system. The SWMS_3D model's internal mechanics are explained briefly, before describing the new data utilized to update the model's environmental and soil parameters. After confirmation that the model was working correctly, simulations utilizing diverse root angles and environment conditions were conducted, and analysis for length, weight, surface area, biomass, P uptake were done for 10 cm layers. Conclusions for the effectiveness of short, middle, and deep roots in terms of P uptake were drawn.

Chapter IV: Phosphorus Deficiency Stress Effects on Plant Growth: Plant Functional-Structural Models aid in the Determination of Optimal Nutrient Concentrations for Growth.

The drawbacks of a static architectural model are touched upon, and the advantages of having a two-way interaction between plant and environment are described. Rather than a model with growth rates hardcoded to be unmovable, models with growth rates that can be modified due to abundance or lack of resources are more flexible and can be applied in many more scenarios. Data that has been used before is revisited, and new parameters were created in order to increase the width of environments and soils the model can work with. Experiments with variations on soil conditions were done in order to determine optimal soil P concentrations and the effects of P deficit stress on growth and uptake.

Chapter V: Conclusions and looking forward

Modeling plants to produce results has been relatively successful, and shows good promise as a tool for analyzing and obtaining data that is unfeasible, or sometimes impossible to obtain through normal experimentation. Even the most time-consuming and heavy model calculations take less than a day to complete, which is much less than the months a normal field experiment would take. The only considerations are a need for ample data in order to make accurate predictions.

While OpenSimRoot has proven itself to be a good base for creating models for root architecture and measuring uptake from the soil, with more time and resources, upgrades can be done in order to make this model more accurate, have visual shoot architecture, and/or making it more accessible and easy to use for everybody.