

► Keynote presentation

K-1043 Using root architecture models to bridge the gap between the rhizosphere and the whole root system

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The growing, dynamic root system needs to be considered when placing rhizosphere processes in the context of whole plants. Root-rhizosphere processes are, however, incredibly complex. While the complexity of the problem makes it potentially intractable, modelling can play a role in investigating root-soil interactions. Root architecture models in particular, are designed to simulate the way that root systems, and hence the rhizosphere, develop through soil. Individual processes and interactions can then be investigated in relation to the root-rhizosphere maps these models can generate, providing information that is difficult to quantify from experiments.

Root architecture models have been used for a range of different applications with important implications for rhizosphere research, including the generation of dynamic maps water transfer through the soil-root system, accounting for variations along roots and with root type [1]. This work is significant because the hydraulic properties of the rhizosphere impact on a number of important processes, including: water and nutrient transport and uptake over time; soil strength; root-soil contact and microbial populations. Root models have been used to investigate the interaction between root architecture, phosphorus depletion zones and phosphate uptake [2], and for simulating root hair architecture and its impact on phosphorus acquisition [3]. These studies have made an important contribution to understanding the relationship between root architecture and the efficient acquisition of growth-limiting nutrients from the rhizosphere. An architecture model was also used to investigate the interaction between a root exudate, water and nutrient acquisition and root architecture [4], highlighting important differences between resource acquisition at the single root scale compared to whole, dynamic root systems. Another modelling approach generated 3D representations of root-microbial systems [5], showing potential for investigating the spatial relationship between roots and rhizosphere microbial populations. The value of current modelling approaches and future potential for the use of root architecture models for rhizosphere research will be discussed.

[1] Doussan C et al. (2006) Plant Soil, 283.

[2] Ge Z et al. (2000) Plant Soil, 218.

[3] Ma Z et al. (2001) Plant Soil, 236.

[4] Dunbabin VM et al. (2006) Plant Soil, 283.

[5] Brown TN et al. (1997) Ecol. Mod., 99.

► Oral presentations

O-777 A mycorrhizal growth model and its impact on plant phosphorus availabilitySchnepf Andrea¹, Roose Tiina²¹ BOKU.-University of Natural Resources and Applied Forest and Soil Sciences Peter Jordan Strasse 82 A-1190 Vienna Vienna Austria² University of Oxford, Mathematical Institute, Oxford, Oxford Centre for Industrial and Applied Mathematics and Centre for Mathematical Biology, OX1 3LB, UK, Email

Arbuscular mycorrhizal fungi can contribute substantially to plant phosphorus nutrition. Here, we present a mathematical growth model for arbuscular mycorrhizal fungi and compare its contribution to total root uptake determined by a classical Barber-Nye-Tinker model. The model is based on a model for general mycelial fungi (Edelstein, 1982) and describes the development of the extraradical mycelium of arbuscular mycorrhizal fungi in soil. We consider growth due to elongation, linear or non-linear apical branching, hyphal and tip death and anastomosis. A time dependent function for hyphal length density at the interface between root and fungi serves as model boundary condition.

Using this growth model together with information on diameter and phosphorus uptake capability of a single hypha in soil (Schnepf and Roose, 2006), we created a volumetric sink term for hyphal phosphate uptake and introduced it into a classical single root model (Barber, 1995). Assuming that extraradical hyphae can take up phosphorus over their entire length, we found that they dominate overall root uptake after an initial time period when the extent of the extraradical mycelium is larger than the phosphorus depletion zone created by the root. Then, hyphae grow into new, undepleted regions of the soil where they take up phosphorus that would otherwise not have been accessible for the plant. This model provides a quantitative approach to assess the development of the fungal mycelium in soil as well as the contribution of mycorrhizal fungi to plant phosphorus uptake. Comparison with experimental data will help to further improve the model.

Acknowledgements

We acknowledge the FWF Austrian Science Fund (P15749, T341-N13). Andrea Schnepf thanks the Oxford Centre for Industrial and Applied Mathematics and Centre for Mathematical Biology for hosting her stay in 2004/05. Tiina Roose is a Royal Society University Research Fellow.

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 Edelstein, L., 1982, The propagation of fungal colonies: A model for tissue growth. J. theor. Biol. 98, 679 - 701.
 Schnepf A. and T. Roose, 2006, Modelling the contribution of arbuscular mycorrhizal fungi to plant phosphate uptake, New Phytol. 171: 669 - 682.

O-723 Modelling of root exudationNguyen Christophe^{1,2}, Personeni Emmanuelle², Marchal Patrice², Pagès Loïc³¹ INRA TCEM 71, avenue Edouard Bourlaux, BP 81 33883 Villenave d'Ornon France² UMR INPL(ENSAIA)-INRA Agronomie et Environnement Nancy-Colmar, 2 avenue de la forêt de Haye. F54500 Vandoeuvre lès Nancy, France³ Unité de recherche Plantes et Systèmes de Cultures Horticoles. INRA Domaine Saint-Paul - Site Agroparc. F84914 Avignon, France

This work focussed on the modelling of C exudation by roots. Root exudation is the release of low molecular weight organic solutes that passively diffuse from the root cells to the external solution (gross efflux). An active re-uptake of sugars and amino acids also operates and limits the C loss from roots (influx). First, a model was designed to describe the efflux and the influx of C through the surface of an individual apical root segment. The efflux of C ($\mu\text{g C cm}^{-2} \text{ h}^{-1}$) was modelled by a power function of the distance from the apex to simulate the greater release of C at the root tip. The influx ($\mu\text{g C cm}^{-2} \text{ h}^{-1}$) was set proportional to the C concentration in the external solution to simulate the active re-uptake of exudates by the root. Root boxes were designed to grow maize plants and to isolate apical root segments of variable length (L) and diameter (d) to obtain different root surface areas ($S=\pi Ld$). Plants were exposed to full light ($200 \mu\text{moles m}^{-2} \text{ s}^{-1}$) or to shade ($40 \mu\text{moles m}^{-2} \text{ s}^{-1}$) to manipulate C availability. The root segments were allowed to exude in a CaCl_2 solution for 5, 15, 30, 60, 120 and 180 min. The kinetics of root exudation were used to parameterise the model. The model gave satisfactory fits ($R^2 = 0.74$). The estimated gross efflux was $5.2 \mu\text{g C cm}^{-2} \text{ h}^{-1}$ at the apex and decreased importantly between 0-5 cm. For the region located at 5-25 cm from the root tip, the mean gross efflux was around $1.8 \mu\text{g C cm}^{-2} \text{ h}^{-1}$. Shading of plants had little effect on exudation of individual roots, indicating that further work is needed to understand the link between exudation and C availability. Then, the exudation of C at the plant scale was modelled by applying the parameterised gross efflux function to the growing root system simulated by the root architecture model of Pagès and Pellerin (1996). The simulated cumulative exudation was $4.9 \text{ g C plant}^{-1}$ at the flowering stage (860 growing degree-days) or 392 kg C ha^{-1} (8 plants m^{-2}). By considering the root diameter, the root length and the number of root apices, this model may contribute to understand changes in plant exudation mediated by modifications of the root architecture and morphology. The advantages and limitations of the model are discussed.

Pagès, L., Pellerin, S., 1996. Study of differences between vertical root maps observed in a maize crop and simulated maps obtained using a model for the three-dimensional architecture of the root system. Plant and Soil 182, 329-337.

O-677 Rhizosphere management for disease control: the significance of root system architecture

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Soil-borne plant disease is a recurrent and recalcitrant problem in crop production and there exists an urgent need for the development of reliable disease control. These patho-systems are characterized by the spread of the pathogen as it responds to dynamical changes in the density and distribution of roots within an inherently heterogeneous soil environment. The study of soil-borne disease is notoriously difficult, largely due to the opacity of soil that imposes considerable restrictions on the way in which data can be collected. Moreover, there is currently no theoretical framework available that can deal with such a complicated and heterogeneous system. Hence practitioners and scientists still adopt a largely empirical approach to disease control. In this paper we formulate testable hypothesis for the invasion of pathogens through root systems by combining (i) epidemiological concepts (e.g. pathozone dynamics that summarize the spatio-temporal transmission of disease); (ii) a theory for the spread of diseases on networks; (iii) novel experimentation that enables the non-destructive visualization of root growth.

Previously, we demonstrated and tested experimentally that thresholds for invasion can be obtained for epidemics in spatially structured populations based upon concepts derived from statistical physics. Here we use the same theory to interpret the consequences of the spatial distributions of roots in soil for the spread of disease. The starting point of our approach is the quantification of the spatial and temporal dynamics of root systems. Sectional images of living wheat roots were obtained non-destructively by whole-body computer tomography X-ray scanning (X-ray CT). The root systems were scanned at various depths to quantify the changes of inter-root distances with depth and time. The spatial distributions are interpreted in the light of a potential for spread of a fungal pathogen, initiated from a soil propagule and subsequently realised through root-to-root transmission, making use of the epidemiological concept of the pathozone. We demonstrate that at a given depth, the spread of a pathogen can switch from non-invasive (forming small, isolated disease patches) to invasive to spread with time. We discuss how the framework can be used to evaluate control strategies

O-611 Modelling effective behaviour of maize root under water scarcity

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Numerous models exist for predicting soil/root water fluxes. As most of them have been developed based on empirical observations, they are often able to properly describe root water uptake under normal conditions. However, it is known that such models perform much worse under stress conditions for which additional fitting parameters are usually needed.

Firstly, we investigated the performance of a very detailed mechanistic model, which solves the water fluxes in three dimensions in both the soil matrix and the xylem network. We compared stochastic simulations performed with that model to field observation of water distribution in a maize field at the end of the growing season. This allowed us to define a parameter set able to describe the soil-plant system under stressed conditions.

Secondly, since this approach is not efficient for large scale modeling, we tried to assess an effective parameterization of the system, based on observation and the detailed modeling runs. We investigated the potential of compensation modeling approaches to adequately reproduce the effective behavior of the soil-plant system. Finally, we propose several criteria to parameterize effective compensation approaches from small scale root and soil hydraulic properties.

O-451 Modelling arsenic transport and speciation in the rhizosphere in the presence of goethite with the novel computer model RhizoMath

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Most of the numerous different approaches for modelling transport processes in the rhizosphere disregard speciation in soil solution. However, problems dealing with trace elements such as arsenic, which can be present as arsenate or arsenite and which competes for binding sites with other oxyanions, can only be solved with coupled speciation-transport models. This contribution presents the novel rhizosphere transport model RhizoMath and its applications with a special emphasis on the reactive transport of arsenic in the rhizosphere. RhizoMath is based on the mathematical package MATLAB and the geochemical code PHREEQC. The chemical speciation is calculated by PHREEQC separately from the transport equations solved in MATLAB. The model consists of two main modules: (i) the initialization module determines certain parameters which describe the chemical speciation in the solution before a plant is introduced in the system with performing inverse modelling; (ii) the coupled speciation and transport module solves the problem of plant uptake, transport and speciation in the rhizosphere by alternating transport and speciation calculations for each time step. The computer code was verified against the output of other rhizosphere transport models within their domain of applicability.

The model development and calibration were conducted using a compartment system experiment as reference. In this system *Zea mays* was grown under controlled conditions on an artificial quartz substrate spiked with known amounts of nutrients and arsenate and with increasing amounts of goethite. The root compartment was separated from the bulk soil compartment by a nylon net. Soil solution samples were taken weekly by micro suction cups aligned horizontally at well defined distances from the nylon net, which is regarded as root surface.

Results are presented on the ability of RhizoMath to reproduce measured gradients and changes in soil solution composition with time and increasing distance from root surface. Beside this, some theoretical scenarios are also going to be presented and the major challenges and future needs of modelling trace element dynamics in the rhizosphere are going to be pointed out.

RhizoMath is intended to be applicable by researchers with different backgrounds as it is easily controllable via its graphical user interface. The authors can be contacted at the meeting for a copy and a small introduction to the usage of RhizoMath.

► **Poster presentations****P-498 Verification and intercomparison of reactive transport codes to describe root-uptake**Nowack Bernd¹, Mayer K. U.², Oswald S. E.³, Van Beinum W.⁴, Appelo C. A. J.⁵, Jacques D.⁶, Roose T.⁷¹ Empa - Materials Science and Technology Lerchenfeldstrasse 5 CH-9014 St. Gallen Switzerland² Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, Canada³ Hydrogeology Department, UFZ Centre for Environmental Research, Halle/Saale, Germany⁴ Central Science Laboratory, York, UK⁵ Hydrochemical Consultant, Amsterdam, The Netherlands⁶ Vito, Flemish Institute for Technological Research, Mol, Belgium⁷ Centre for Mathematical Biology and Oxford Centre for Industrial and Applied Mathematics, Oxford, UK

Several mathematical models have been developed to simulate processes and interactions in the plant rhizosphere. Most of these models are based on a rather simplified description of the soil chemistry and interactions of plant roots in the rhizosphere. In particular the feedback loops between exudation, water and solute uptake are mostly not considered, although their importance in the bioavailability of mineral elements for plants has been demonstrated. The aim of this work was to evaluate three existing coupled speciation-transport tools to model rhizosphere processes. In the field of hydrogeochemistry, such computational tools have been developed to describe acid-base and redox reactions, complexation and ion exchange, adsorption and precipitation of chemical species in soils and aquifers using thermodynamic and kinetic relationships. We implemented and tested a simple rhizosphere model with three geochemical computational tools (ORCHESTRA, MIN3P, and PHREEQC). The first step was an accuracy analysis of the different solution strategies by comparing the numerical results to the analytical solution of solute uptake (K or Ca) by a single cylindrical root. All models are able to reproduce the concentration profiles as well as the uptake flux. The relative error of the simulated concentration profile decreases with increasing distance from the root. The uptake flux was simulated for all codes with less than 5% error for K and less than 0.4% for Ca. The strength of the codes is that they can also be used to investigate more complex and coupled biogeochemical processes in rhizosphere models. This is shown exemplarily with simulations involving both exudation and uptake and the simultaneous uptake of solute and water.

P-603 A mathematical model for nutrient uptake by root branching structures

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In this talk I will present a hierarchy of models that enable the evaluation of the levels of nutrient and water uptake by branched root systems from partially saturated soil. In particular, the models take into account the simultaneous on uptake of highly buffered nutrients and water from the soil. First I will present a model for nutrient uptake by a single cylindrical root that will be non-dimensionalised and solved analytically (Roose et al. 2001). The second stage model treats water uptake and transport by the different subbranches in the root system (Roose & Fowler, 2004a). The main finding of the analysis is that some subbranches are less effective at taking up water and transporting to the shoots than main tap roots due to their anatomical structure. Finally, the root water uptake models will be combined with nutrient uptake models in order to evaluate nutrient concentration gradients in the soil (Roose & Fowler, 2004b). Using this final model I will show that previous models by Barber, Tinker and Nye can systematically underestimate the phosphate uptake, due to their oversimplified approach in dealing with root branching structure. I will show how this discrepancy can be remedied without the need for extensive three dimensional computer simulations. In particular, I will discuss how the rigorous application of the method of spatial averaging can give better estimates for phosphate uptake by field crops. Whilst the spatial averaging presented in Roose & Fowler (2004b) does introduce approximations, it does so without neglecting any necessary root structural effects.

Roose, T., Fowler, A. C. & Darrah, P. R. (2001) Mathematical model of plan nutrient uptake. *Journal of Mathematical Biology* 42, 347-360.Roose, T. & Fowler, A. C. (2004a) A model for water uptake by plants. *Journal of Theoretical Biology* 228, 155-171.Roose, T. & Fowler, A. C. (2004b) A mathematical model for water and nutrient uptake by roots. *Journal of Theoretical Biology* 228, 173-184.**P-690 Effect of soil resistance at soil-root interface on root water uptake**Schröder Tom¹, Javaux Mathieu², Vanderborght Jan², Vereecken Harry²¹ Forschungszentrum Juelich ZAM Leo-brandt-strasse 52425 Jülich Germany² ICG-IV

The geometrical coupling of the water flow between soil and root based on a mathematical description of the root water uptake at a very detailed scale is a challenge. Indeed, at such a scale, there is a possible large water potential gradient resulting from the plant water demand, which may lead to an important non-linear soil resistance. When 3-D models are used to simulate flow in the soil matrix and in the xylem network, this additional soil resistance at the soil-root interface level may be important to consider, especially under water scarcity conditions. This can either be taken into account by enhancing the derived numerical coupled 3D soil-root model or by analytical approximations applied to the continuity equation describing water flow in the soil (Richards equation). Enhancing the numerical model leads to a more accurate solution in which smaller elements are used to solve the derived system of equations describing water flow (and solute transport) in the soil. The computational time, however, will increase enormously. An analytical approach is favourable, because it is fast and the parameters can easily be monitored and handled. The derived analytical solution is successfully compared to methods found in literature, which are always extreme cases of the common solution derived here. Furthermore, a numerical implicit finite difference model with implicit linearization of the non-linear terms is derived which is successfully compared to the analytical solution as well. The analytical approach is built into the code of the 3D soil-root model. Comparisons are made by comparing the enhanced 3D model with the former 3D model which uses a simplistic coupling of the soil-root water flow without taking the soil resistance around a root into account. Furthermore, the enhanced model is compared to the numerical enhancing method (smaller elements). Finally, the decoupled numerical soil-root model is transformed into a coupled model to achieve faster results and make the code more manageable for adaptation.

P-635 Manganese influx and its depletion in the rhizosphere of different crops grown on Mn deficient soil

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Manganese deficiency in field crops has been reported worldwide, which often limits crop growth and results in decreased crop yield. Crops differ widely in their Mn efficiency. The crop having more roots, less shoot growth rate, and a low internal requirement and a high Mn influx is expected to be more Mn efficient. Crops grown under Mn deficiency conditions can obtain higher Mn influx if there is stronger decrease in Mn concentration at the root surface because of more efficient uptake kinetics. To study Mn influx and its depletion in the rhizosphere of different crops, greenhouse experiments were conducted at PAU, Ludhiana, India using Mn deficient loamy sand soil having pH 8.3, CaCO_3 4.7 g kg^{-1} soil and DTPA-extractable Mn 2.7 mg kg^{-1} soil. Soybean (*Glycine max.* L cv. SL 295) and moong (*Vigna mungo* cv. SML668) during summer 2004 and wheat (*Triticum aestivum* L cv. PBW 343), raya (*Brassica juncea* L. cv. PBR 91) and chickpea (*Cicer arietinum* cv. GPF 2) during winter 2004-05 were grown. Under Mn deficiency conditions, soybean produced 94% of its maximum shoot dry weight (SDW) with only 60% of its maximum root length (RL) at 35 days of growth. However, moong had 81% of its maximum RL and it produced 89% of its maximum SDW. At maturity moong and soybean produced 85 and 72% of their potential grain yield, respectively. Considering relative grain yield as a criteria of Mn efficiency, moong was more Mn efficient than soybean though soybean produced maximum SDW at 35 days of growth. Both the crops could obtain almost similar Mn influx under Mn deficiency conditions. Among winter crops, raya was more Mn efficient than wheat and chickpea as it produced 86% of its maximum SDW with similar RL under Mn deficiency conditions at 35 days of growth. Even at maturity raya produced 83% of its maximum grain yield compared with 75 and 53% by wheat and chickpea. Raya could decrease Mn concentration at root surface to a lower value creating 9.5 and 2.6 times more concentration gradient at the root surface than that of chickpea and wheat, respectively. The higher Mn efficiency of raya resulted from its more efficient uptake kinetics as raya could obtain 10.5 and 2.1 times higher Mn influx than chickpea and wheat, respectively, even under Mn deficiency conditions.

P-509 A quantitative analysis of root citrate exudation as a mechanism of aluminium resistance in maizeMariano Eduardo Dal Ava¹, Meeussen Johannes C. L.², van Riemsdijk Willem H.³, Menossi Marcelo⁴¹ University of Campinas PO Box 6010 13083-875 Campinas Sao Paulo Brazil² Energy Research Centre (ECN), 1755 ZG Petten, The Netherlands³ Department of Soil Quality, Wageningen University, 6700 EC Wageningen, The Netherlands⁴ Department of Genetics and Evolution, University of Campinas, 13083-875 Campinas, SP, Brazil

The aluminium (Al)-stimulated release of organic anions (OA) by plant roots as a mechanism underlying resistance to Al has been intensively evaluated in the last years. Studies on the physiology of this root process strongly supported the role of OA in a mechanism of protection against Al. However, they also raised the question whether quantitatively the amounts of OA that can accumulate in the rhizosphere are high enough to complex a significant fraction of the local Al. In the current work we aimed to answer this question. We combined experimental with modelling work to test if the amounts of citrate released by roots of maize (*Zea mays* L.) are adequate to explain resistance to Al.

We used a mathematical model to describe the diffusion of mainly citrate and Al in a root-mucilage-culture solution system and to predict the complexation of Al at the local conditions. Values of some model variables were based on observed experimental data whereas values of others were taken from literature. For the simulations, a constant flux of 25 nmol citrate/ m^2/s at the root surface was imposed as the driving force. Release of citrate was assumed to take place only at the epidermal cell layer of a root placed in a 40 μM Al solution.

According to our model predictions, relatively high concentrations of citrate (~ 80 μM) develop quickly near the surface of the root as a result of the constant production and release of citrate by the cells. The activity of the Al^{3+} species, assumed here to be the only toxic form of Al, was significantly reduced at the outer root surface.

The citrate released by the epidermal cells could also diffuse in the root apoplast towards the centre of the root. Because of the relatively small volume of the root apoplast and of the slower diffusion of molecules in this space than in the outer root space (i.e. mucilage + outer solution), concentrations of citrate reached in the apoplast (~ 130 μM) were higher than in the outer root space (< 80 μM). While the citrate accumulated near the outer root surface lowered significantly the local activity of Al^{3+} ions, the citrate accumulated in the apoplast showed to be very important to protect this space from the Al^{3+} ions that continued to cross the mucilage layer and enter the root cortex.

P-1059 Roots model calibration to describe root length density for rainfed rice using soil profile root impactsRadanielson Ando¹, Dusserre Julie², Chopart Jean-Louis³, Audebert Alain¹¹ CIRAD BIOS TAA-06/01 34398 Montpellier France² CIRAD Persyst TA B-69/01³ CIRAD Persyst TA B-05/01

Roots system parameters as root length density, average diameter of roots and rate of soil explored for water or nutrients are necessary to understand the root system function but are difficult to measure in the field. On simple practical solution is to use the in-situ counts of root impact per unit surface on soil profiles (trench-profile method) to calculate the root length density (RLD). An improved model based on the roots impact (NI) and preferential root orientation (anisotropy) was developed and validated on maize by Chopart and Siband (1999). The objective of our work was to calibrate and validate this model on rainfed rice system. The experimentation had taken place in two experimental sites in Antsirabe, Madagascar (2006) and Bouaké, Ivory Coast (1998 and 1999). Cultivars and soil were specific to the country. Observations had done at the end of flowering stage (130 DAS) in Madagascar and at 30, 50 and 70 DAS in Ivory Coast. Root impacts were obtained with the root profile method. Roots anisotropy and orientation were measured with undisturbed cubes of soil, based on the NI in all oriented cube planes. The root length was measured in the enclosed volume using WinRhizo software through root image scan.

Roots studies were confronted to a high variability which caused by the soil and the methods used to separate soil and roots. The modelling technique based on root impact could be an alternative to minimise this variability and characterized roots system. Roots length density model was confirmed as $\text{RLD} = \text{NI} \cdot \text{CO}$ with CO the roots orientation coefficient. This model could give us a good estimation of roots system in the soil. Results showed an isotropic roots development in the both sites. However, the experimental coefficient (CE) presented differences according sites. For Ivory Coast situation, the experimental coefficient followed a linear function with the distance of the root impact from the stem base (DP). Number of roots was higher in Madagascar this relation was parabolic. This model will be helpful to study root system, but more experiments are needed to confirm these results and get its robustness with other varieties which get different deeper root system, soils and climatic environments

P-1148 Evaluation of the role of root exudates in phosphorous uptake of maize in a low p soil using a simulation model

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Our work has hypothesized that maize produces organic acids, which could increase P solubility. The objectives of this research were to quantify the P active root exudates released in to the rhizosphere of maize using a mechanistic model. To test this hypothesis, field experiments were conducted in an Alfisol. Treatments consisted of three P levels i.e. P-0 (no P), P-50 (50 mg P kg⁻¹ soil) and P-400 (400 mg P kg⁻¹ soil), and two levels of the fungicide benomyl application (0 and 500 kg ha⁻¹). Four harvests were made to cover whole growing season and at each harvest different soil, plant and microbiological parameters were determined. In the early growing season, the P influx of maize was dependent on soil solution P . At this growth stage and at low P supply the effect of arbuscular mycorrhiza (AM) was rather large. At high P supply, the contribution of AM to P influx showed a decrease. During middle and at the end of the growth cycle P influx increased sharply and was not dependent on P supply. At these growth stages, the effect of AM was largest at low P supply. With out or low AM infection and at low P level, the P influx was 62% of that with AM. Groundnut, during early growth period showed a similar behaviour as maize at middle growth satge and without AM reduction of P influx, which was to an extent of 67%. In middle and at the end of the growth cycle P influx was found to be related to P supply, degree of AM infection had no influence. In absolute terms AM is more important at maximum growth in the middle of the growth season for maize and only early growth season for groundnut. However, in relative terms AM is more important in early growth season for both the crops. It is evident from the present investigation that the higher measured than calculated P influx of maize could be explained by less than 10 % through mass flow and diffusion, by about 35 % through arbuscular mycorrhiza and the remaining 60 % might be due to P deficiency-induced exudation.

P-1061 Modelling of an indicator of phosphorus availability according to pH variations: application to a cambisol

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Understanding the bioavailability of phosphorus (P) is a major scientific challenge because plants can influence soil processes to promote its growth by increasing the solubility of P. Precipitation/dissolution and adsorption/desorption are geochemical processes that can control P-concentrations in soil solutions. In this study, we intended to characterize the influence of artificial pH variations on processes controlling P availability. An approach combining chemical extractions and geochemical modelling was used to study the speciation of P in the solid phases of a Mediterranean chromic cambisol exhibiting a neutral pH (7.2). We adjusted the pH in sub-samples to twenty six levels ranging from acidic to alkaline conditions (pH=3 to 10). Three samples set to different pHs (5.08, 6.04 and 6.80) were used to grow durum wheat. All the samples were analysed with CaCl₂ extraction as a surrogate for aqueous P in soil solution.

The CD-MUSIC model was used to simulate P sorption based on CaCl₂ extracts. We showed that concentrations and variations in P-CaCl₂ as induced by pH change can be quite accurately modelled by using generic parameters for P sorption onto reference oxides and by accounting for the sorption of Ca²⁺ on soil exchangers. Results can be further improved by optimizing some parameters. The fit between simulated and measured P-CaCl₂ was quite good ($r = 0.70$ and $RMSE = 0.034 \text{ mg.kg}^{-1}$). This confirms that available P in the studied soil was controlled by sorption processes. Depending on the pH, goethite, ferrihydrite, Al-oxides and clays (kaolinite and illite) can contribute in a significant proportion to the total P adsorbed in this soil. The modifications of the adsorption capacity of minerals and P surface complexes can explain the effect of the pH on P-CaCl₂. For soils in contact with plants, modelling further showed us that the increase in P-CaCl₂ observed can be explained by considering citrate exudation and competitive sorption, on top of pH variations. This model must be validated in other P-deficient soils before being integrated within more complex models that cope with the different processes controlling P-bioavailability.

