The optimal lateral root proliferation response in maize growing on low fertility soils

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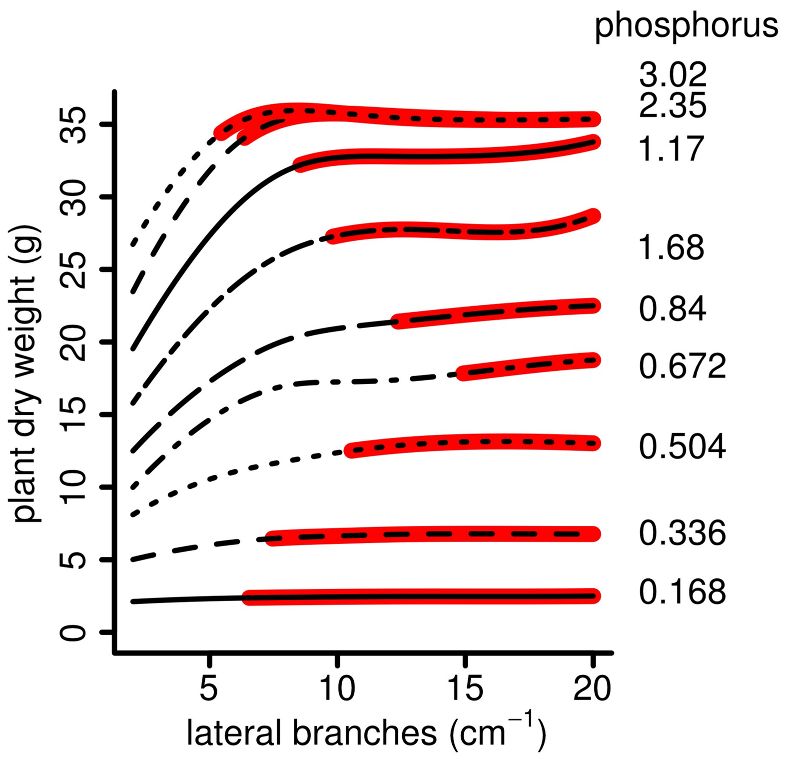

Fig 1: Plant dry weight at 40 d.a.g. given different lateral branching densities and various levels of phosphorus availability

Introduction

According to our previous simulation studies[1] (Fig 1,2) , the optimal lateral root branching density in maize depends on the relative availability of nitrate and phosphorus, strongly differing in soil mobility and the two most growth limiting nutrients world wide. For nitrate acquisition a low branching density is optimal as it allows for exploration of a larger soil domain and reduces root competition, while for phosphorus acquisition a greater branching density was optimal as it resulted in the greatest root length duration in the, relatively phosphorus rich, top soil.

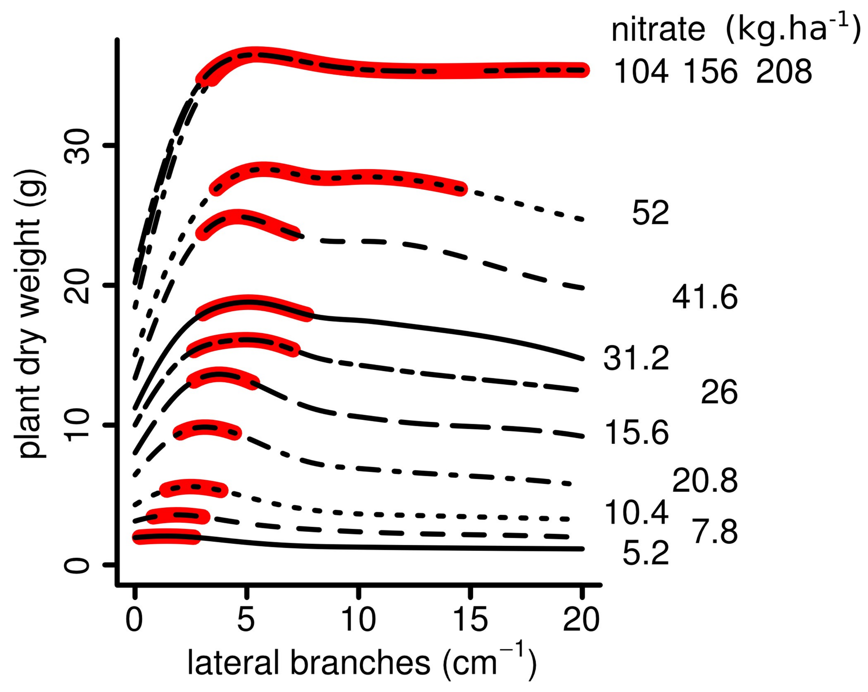

Fig 2: as figure 1 but for different levels of nitrate, assuming phosphorus is not growth limiting.

Smarter roots

Roots supposedly optimize the branching density according to the heterogeneous environment they grow in and adapt their response according to their future needs for the various nutrients. **The question is: What response to heterogeneity in soil nutrients is actually smarter than no response, and what information is needed for a 'smarter' branching strategy?**

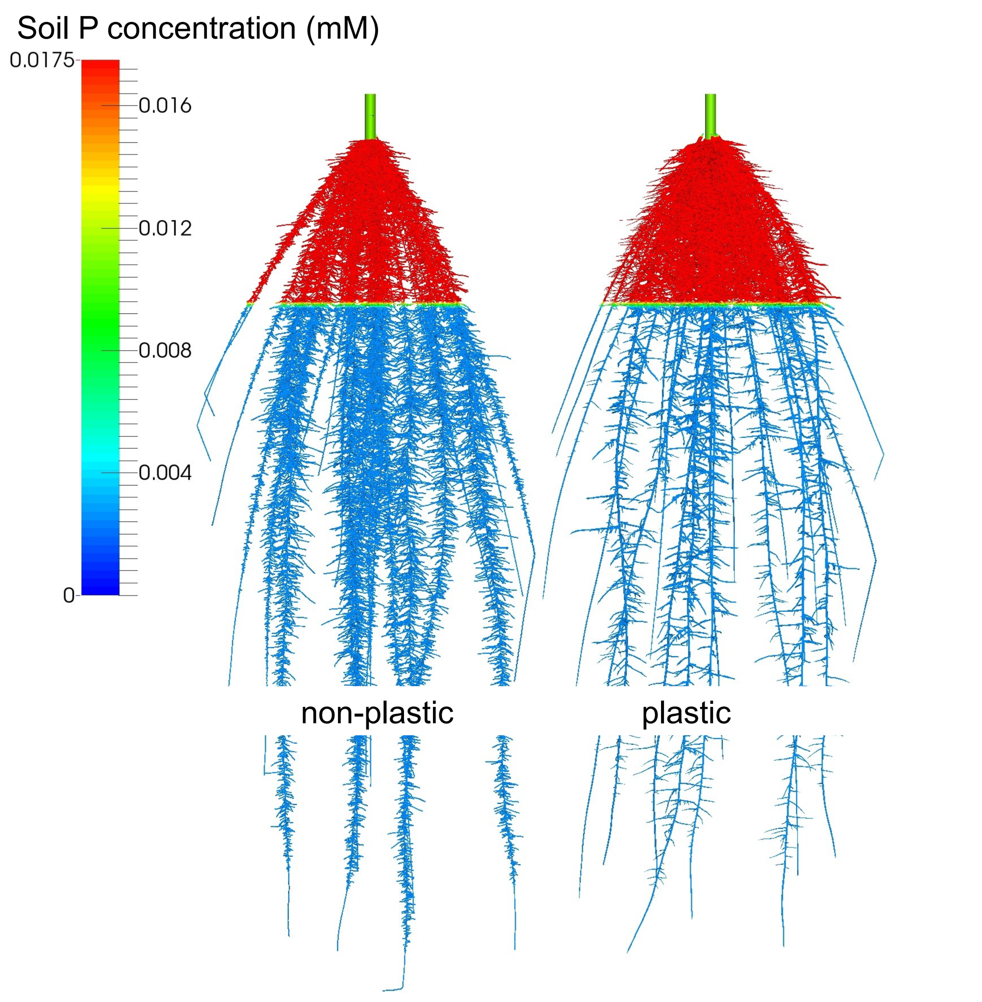

Fig 3: Rendering of plastic and non plastic root system at 40 d.a.g. Heat map colors encode the initial P concentration that roots experienced and responded to.

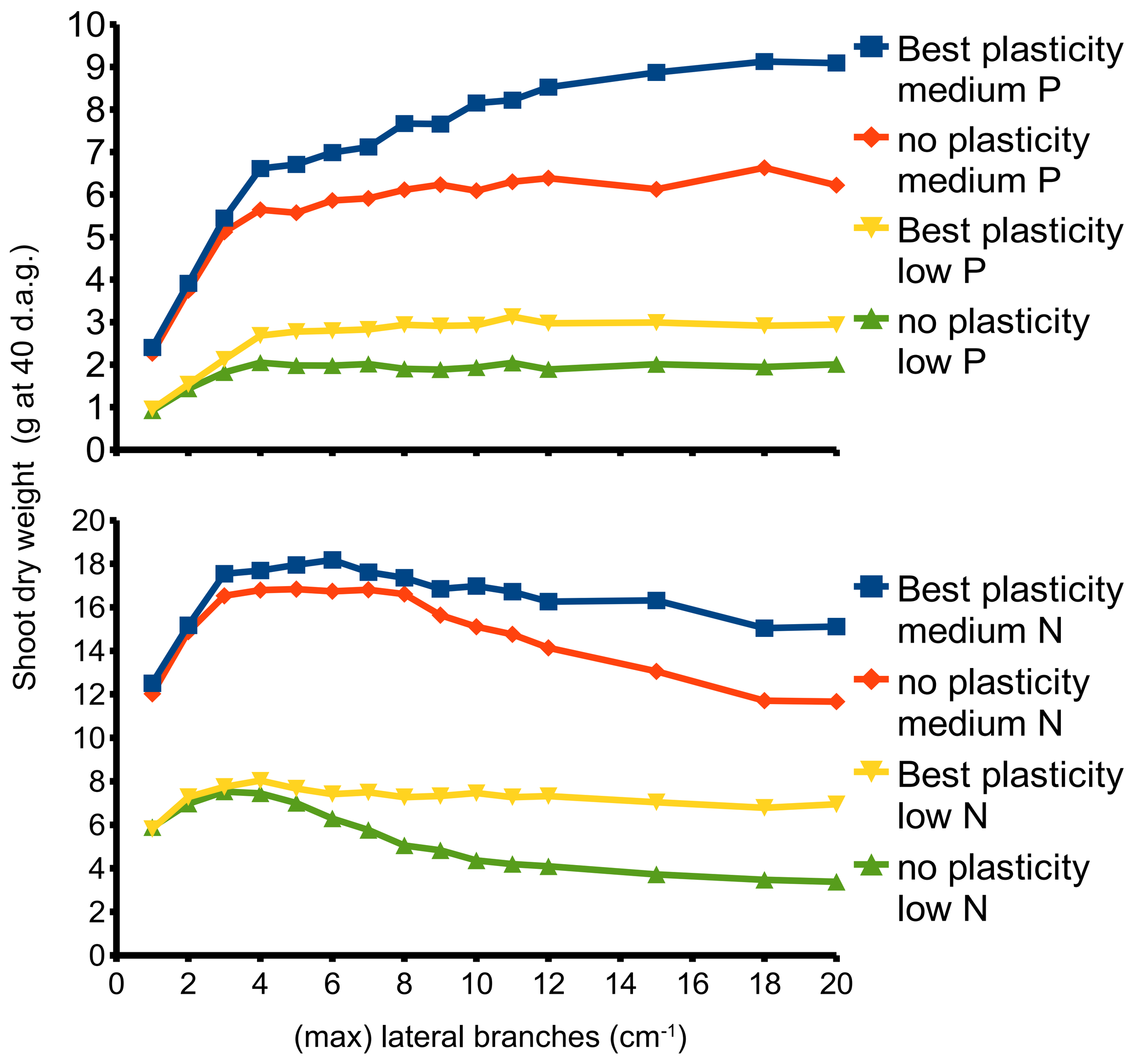

Fig 4: Shoot dry weight at 40 d.a.g. for P limited (top) and N limited (bottom) growth. Plotted are lines for non-plastic roots with branching density as on the x-axis, and the best plasticity response for which the maximum branching density was as on x-axis.

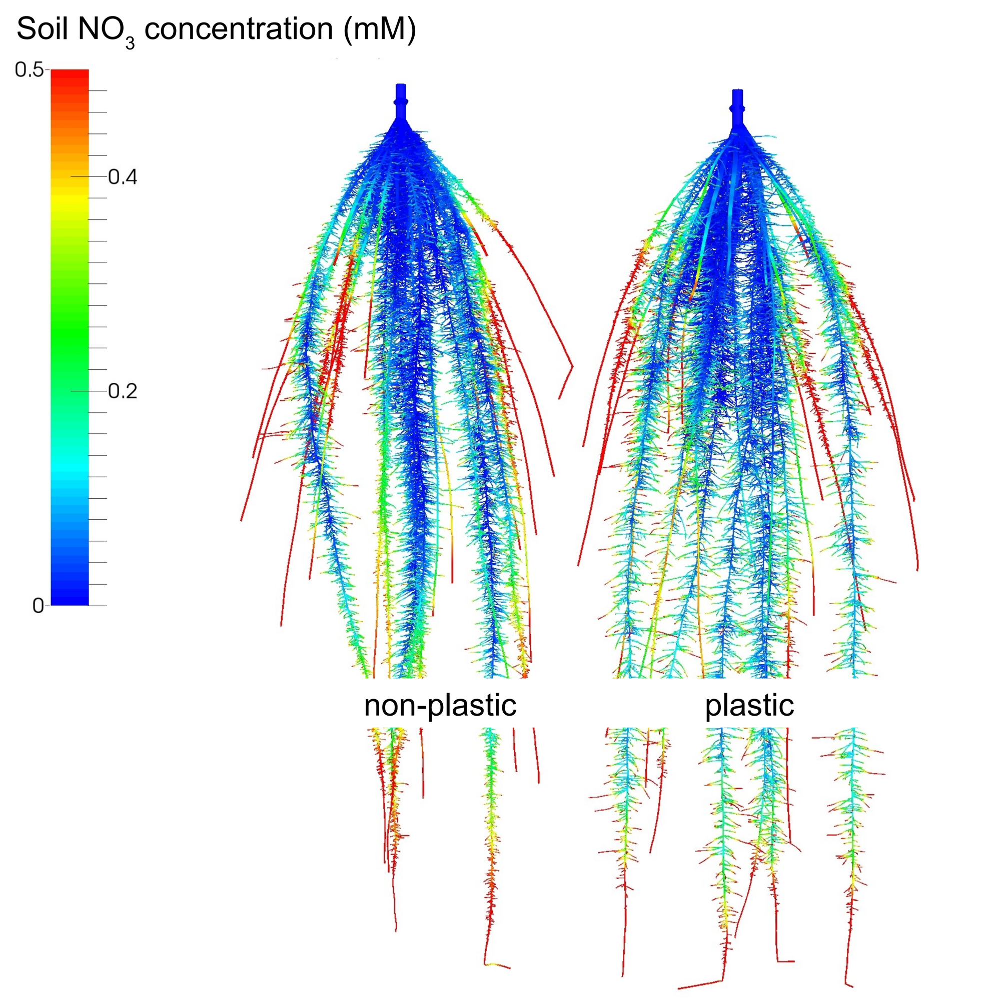

Fig 5: as fig 3, but for plants limited by N and responding to N availability in the soil. Heat map colors encode the N concentrations at 40 d.a.g. at the root surface.

Time vs space

Plants may face a tradeoff between elongation and branching, that is between exploration of new (deeper) soil layers or increased foraging intensity of nearby soil domains. Branching results in greater root densities locally and will speed up the depletion of the local nutrient resources, but may go at the cost of finding new resources, i.e. root branching maybe a short term strategy, while extension of major axis maybe a longer term strategy? In the end it may all depend on the life cycle strategy of the plant and it's competitors.

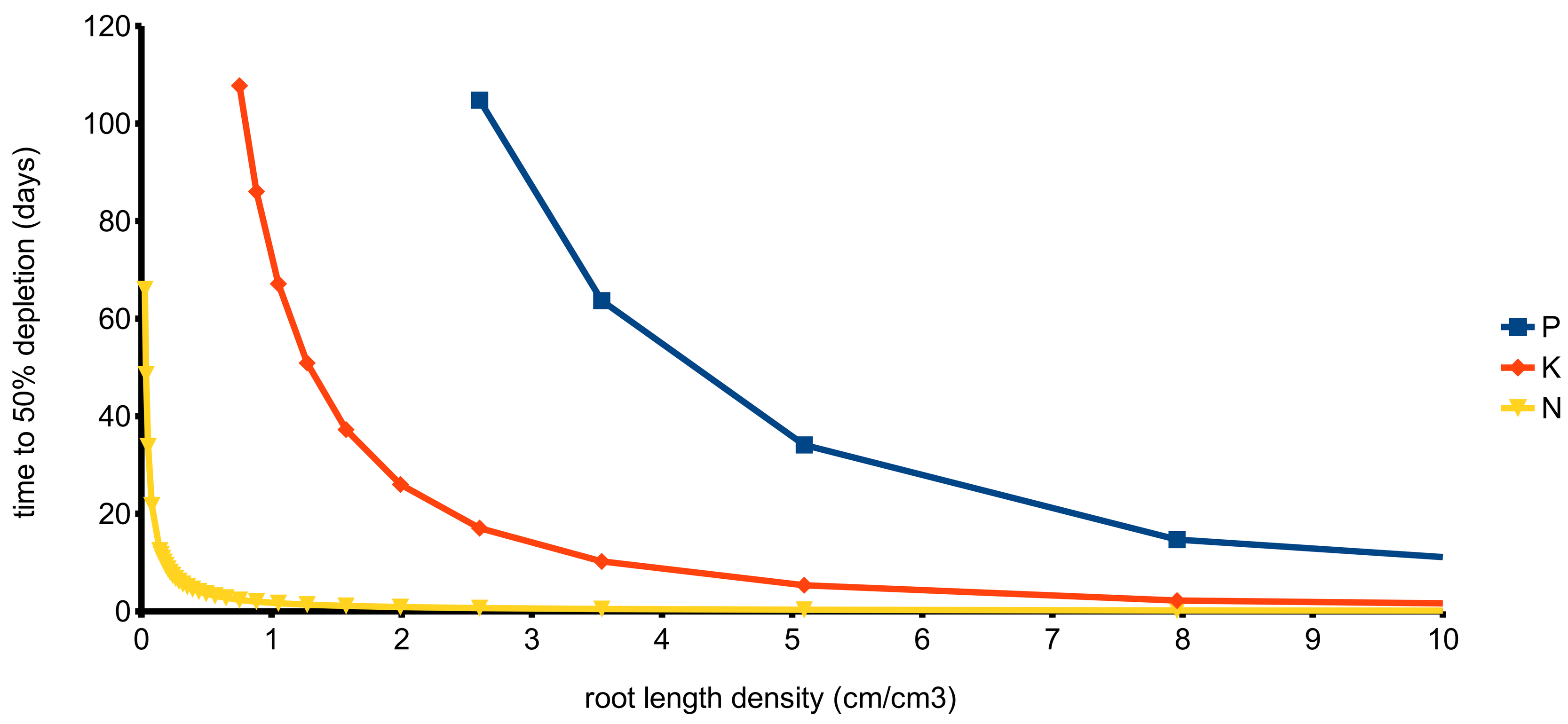

Fig 6: The time it took to deplete half of the available nutrients, as simulated by the Barber-Cushman model. Soil resources are faster depleted when the root length density increases (x-axis), but increases in root length density may go at the cost of decreases elsewhere.

Conclusion

The optimal lateral root proliferation response for phosphorus seems to be simply placing more roots in phosphorous rich soil domains. The definition of phosphorus rich, however, is a relative one, and it is not clear what the standard should be. An optimal root proliferation response for nitrate seems much more complicated and may not involve branching as much as it may involve root elongation. An optimal branching response to nitrate concentrations might require integration of various parameters related to soil nitrate availability, mineralization rates and the plant life cycle.

1. Postma et al. 2014 Plant Phys 166(2): 590-602