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Plant root architecture: A trade-off between tolerance to competitors and potential growth

H. Salinas, E. Veneklaas, P. Poot, E. Trevenen and M. Renton

School of Biological Sciences, University of Western Australia, Crawley, Australia
email: hugo.salinasmatus@research.uwa.edu.au

Abstract: Competitive ability of species can be understood as their tendency to suppress the growth of neighbours (competitive effect), and resist suppression from others (competitive response). Plant species differ in their competitive ability due to their different traits, for example root architecture. However, our understanding of the effect of root architecture on competitive ability is limited due to challenges in empirically measuring and controlling root systems. Allocating biomass to roots will be beneficial to a plant if the costs are compensated by benefits that eventually lead to greater production of reproductive biomass. The costs and benefits of any particular root biomass allocation and root- morphology strategy are likely to depend on the number and position of competing neighbours, and thus traits that maximise fitness under no competition could reduce fitness under competition. We hypothesised that species adapted to low levels of competition will generally have a higher ability to suppress the growth of neighbours than species adapted to higher levels of competition, but a lower ability to resist suppression from neighbours.

We used a functional-structural root model to simulate the development of roots with different architectural traits. This model runs on a daily time step and represents roots as a set of connected nodes, with growth being simulated with the addition of new nodes. Roots take up water (assumed to be the limiting resource) from the surrounding substrate. Increase in plant biomass is assumed to be proportional to the amount of water acquired by the root system. A fraction of the obtained biomass is allocated to root and the remainder to above-ground biomass. The model includes a number of parameters that define various architectural and allocation traits; using different values for these model parameters results in different root biomass allocation and root-architecture strategies. The functional-structural root model was coupled with an evolutionary algorithm to find combinations of architectural parameters (which we can call “genotypes”) that maximised above-ground biomass in a range of different competition scenarios. These competition scenarios included a target plant developing alone or surrounded by one, two, three or four neighbours. The performance of the target plant was evaluated by assuming that the final above-ground biomass of the plant was a proxy for reproductive fitness. Finally, we conducted virtual competition experiments using plants of the optimal genotypes in different competition scenarios.

Our results support our hypothesis that the negative effect of competition on above-ground biomass is greater on genotypes selected under lower competition. However, plants with these genotypes had higher maximum above-ground biomass, and a higher competitive effect. These results suggest that there is an intrinsic trade-off between maximising biomass under low-competition, and resistance to competition. Our results could have important theoretical implications, suggesting that differences in root architecture could be a mechanism for maintaining diversity in communities and could also be important when considering competitive vs cooperative trait selection in agriculture.

Keywords: *FSPM, evolutionary algorithm, individual-based model, plant ecology, plant competition*