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Evolutionarily stable strategies for nutrient foraging and below-ground competition in plants

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ABSTRACT

Question: How do differences in uptake kinetics caused by varying conditions of interspecific competition influence the evolutionarily stable root production strategies of plants?

Mathematical method: We present a game-theoretic model that investigates trade-offs between efficient nutrient harvest and neighbour pre-emption as evolutionarily stable strategies. The model builds upon previous game-theoretic models by incorporating potential differences in uptake capacity among competing plants, and by extending the model to interspecific competition.

Key assumptions: We assume that plants exhibit plasticity in growth that is informed by cues in the environment. We also assume that soil resources are limiting while light is not limiting to plant growth, and root costs increase linearly with root biomass. Finally, we assume a spatially implicit soil environment with infinite mixing of nutrients.

Conclusions: The model predicts plants should invest primarily in efficient nutrient harvest when soil fertility is low, per-root costs are high or uptake ability is low. Under these conditions, the plants produce fewer roots when neighbours are present compared with when grown alone. Alternatively, when soil fertility is high, per-root costs are low or uptake ability is high, the plants should invest heavily in more roots than are necessary to harvest available nutrients, thus pre-empting their neighbours. Under these conditions, the plants produce more roots compared with when grown alone.

Keywords: asymmetric game, best response curve, evolutionarily stable strategies, evolutionary game theory, interspecific competition, plant–plant competition, root games.

INTRODUCTION

Plants compete for nutrients in soil with their roots. This below-ground competition can often be more intense than above-ground competition and reduce plant performance by more than an order of magnitude (Wilson, 1988; Casper and Jackson, 1997; Schenk, 2006; Lamb and Cahill, 2008). Competitive effects are also often variable among species, leading to variable conditions of competitive intensity (Keddy *et al.*, 1994; Goldberg *et al.*, 1999; Thorpe *et al.*, 2011). The strong negative effects of root competition, and variable root allocation strategies among species, mean that

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