Water and phosphorus uptake in common bean as a function of root architecture

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Abstract

Root system architecture plays an important role in soil resource acquisition. In common bean (*Phaseolus vulgaris* L.), low-P availability can dramatically alter the growth angle of basal roots and the production of adventitious roots, resulting in more shallow root systems. These traits have been associated with genotypic differences in adaptation to low-P soils. While genotypes that have shallow root architectures may be more productive in low P environments, they may be at a disadvantage under water-limited environments. The primary objective of this study was to examine the tradeoffs between a shallow vs. deep root architecture for water and phosphorus acquisition. A stratified pot system was developed for the greenhouse, which employed buffered Al-P media and time-domain reflectometry (TDR) to control phosphorus and moisture levels in surface and subsoil layers of each pot. As expected, preliminary results showed that G19833, the shallow genotype, performed better when P was concentrated in the topsoil, while DOR364, the deep genotype, performed better when water was concentrated in the subsoil. Surprisingly, DOR364 performed slightly better in the treatment with infertile subsoil and dry topsoil. These results warrant further investigation, as root architecture traits that are most desirable for acquisition of a specific resource, may not be the most desirable strategy when multiple resources are co-limiting, particularly in the case of water and P.

Key Words

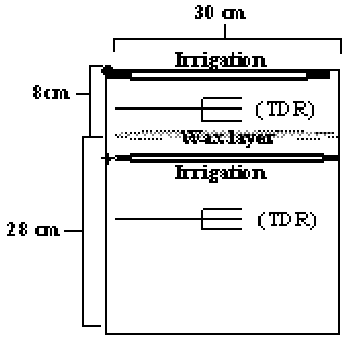
Phaseolus vulgaris, multiple resource acquisition, tradeoffs,

Introduction

Resource acquisition is an important component of plant adaptation and productivity. Most natural environments have suboptimal availability of multiple resources. This is particularly true for resources such as water and phosphorus. Root architecture is an important factor determining belowground resource acquisition (1,2). Since many soil resources are unevenly distributed in space and time and are often subject to localized depletion. Spatial deployment of the root system thus determines the ability of a plant to exploit heterogeneous soil resources (3). In common bean, drought tolerance has been associated with depth of rooting (4), while greater phosphorus acquisition has been associated with increased soil exploration by roots in surface layers (5). Although we are beginning to understand some of the architectural adaptations of roots to individual soil constraints, virtually nothing is known about how root architecture adapts to multiple soil constraints. In this study, our primary objective was to gain a better understanding of the relationship between root architecture and the acquisition of water and phosphorus in common bean.

Methods

A stratified water and phosphorus pot system was developed as shown in Fig. 1. Plants were grown in the greenhouse for 4 weeks and then harvested for root and shoot biomass.



	Treatment				
	1	2	3	4	5
Top layer					
$H_2$0 content	22-28%	22-28%	22-28%	8-12%	8-12%
P-level	(HiP)	(HiP)	(LoP)	(HiP)	(HiP)
Bottom layer					
$H_2$0 content	>28%	>28%	>28%	>28%	>28%
P-level	(HiP)	(LoP)	(LoP)	(HiP)	(LoP)

Fig. 1. Stratified water and phosphorus system. Layers are separated by an impermeable wax layer and are irrigated independently. For each treatment, phosphorus level and water content of each layer was maintained by Al-P buffered media and TDR, respectively.

Results

Genotypic variation for basal root angle exists for common bean is shown to be correlated with phosphorus acquisition and yield under low P conditions (Fig. 2). As expected, G19833 performed better when P was concentrated in the topsoil, while DOR364 performed better when water was concentrated in the subsoil (Fig. 3). Surprisingly, the deep genotype, DOR364, performed better under Treatment 5, the stratified water and phosphorus stress treatment.

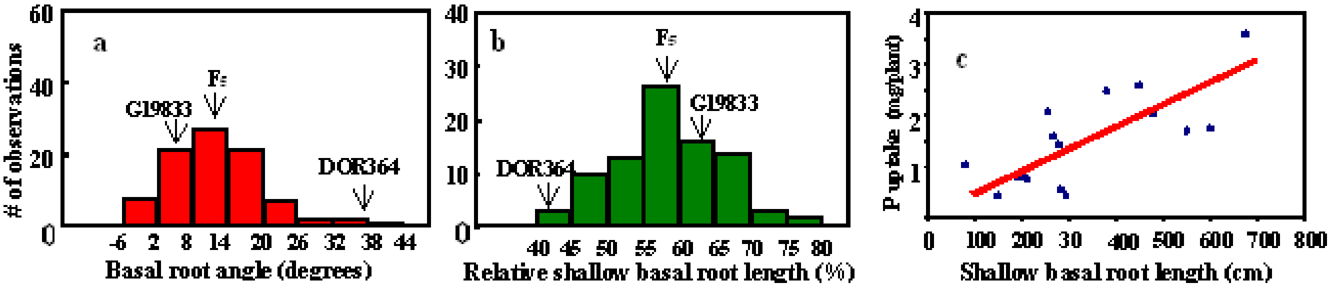


Fig. 2. Segregation distribution of a) basal root growth angle; and b) relative shallow basal root length (SBRL) of F$_5$ recombinant inbred lines (RILs) derived from parent genotypes DOR364 and G19833. c) The relationship of P uptake and SBRL for the same population of RILs (6).

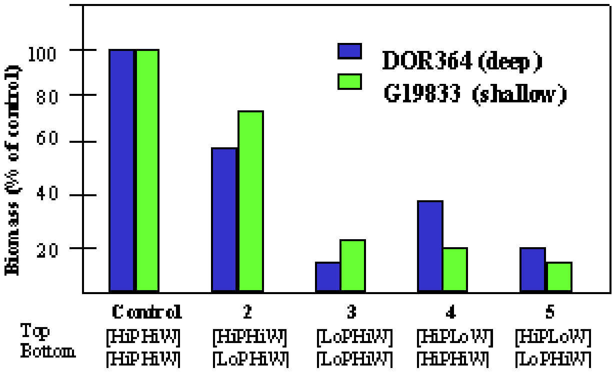


Fig. 3. Shoot biomass relative to control for deep (DOR364) and shallow (G19833) bean genotypes grown 4 weeks in a stratified water and phosphorus system (Fig 1). The dry weights of the control plants are 11.4 and 12.3 g for DOR364 and G19833, respectively.

Conclusions

These initial results support the hypothesis that there are tradeoffs between root architecture form (shallow vs. deep) and function (water vs. phosphorus acquisition). Here shallow-rooted architecture is shown to confer better for phosphorus acquisition and the deep-rooted architecture better water acquisition. The importance of plasticity as an important mechanism for adaptation to multiple resource constraints remains to be seen. Future experiments will build upon the results from these preliminary studies. We hope to confirm genotypic differences in adaptation to water stress and stratified water and phosphorus stress, and to determine the key root architectural traits and the importance of plasticity for water and phosphorus acquisition under co-limiting environments.

References

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