Phene synergism between root hairs and basal root growth angle for phosphorus acquisition in common bean *(Phaseolus vulgaris L.)*

Miguel, M.A.[1], J. A. Postma[3], and J. P. Lynch[2,*]

[1]Instituto de Investigação Agrária de Moçambique (IIAM), Mozambique.
[2]*Department of Horticulture, The Pennsylvania State University, University Park, PA 16802, USA.*
[3]*Forschungszentrum Jülich, IBG-2: Plant Sciences rm 203, 52425 Jülich, Germany, Phone:+49 2461 61 8687*

[*]*Corresponding author. Email:* JPL4@psu.edu

INTRODUCTION

Phosphorus deficiency is a primary limitation to plant growth in terrestrial ecosystems (Vance et al. 2003). Large areas of tropical and subtropical soils in Africa, Latin America, and Asia have phosphorus availability limited by high phosphorus fixation. The use of phosphorus fertilizer to correct phosphorus deficiencies in the soil represents a partial solution since phosphorus fertilizers are costly, nonrenewable, potentially harmful to the environment, and also less effective because of immobilization by the soil.

Several root phenes enhance phosphorus acquisition, including root architectural phenes for topsoil foraging (Rubio et al. 2003), such as shallow root growth, increased basal root whorl number (Rubio et al. 2003) and adventitious rooting (Ochoa et al, 2006); phenes to enhance soil exploitation include root hair length and density and phosphorus-solubilizing root exudates (Ryan et al. 2001; Bais et al. 2006); phenes for mycorrhizal symbioses (Smith et al. 2004), and phenes that reduce the metabolic cost of soil exploration, such as root etiolation (De la Riva, L., 2010) and root cortical aerenchyma (Postma et al., 2010; Postma et al. 2011; (Fan et al. 2003). It is probable that these phenes interact to influence the phosphorus acquisition of integrated phenotypes. We hypothesize that the utilities of BRGA and RHL/D for phosphorus acquisition are synergetic. Root hairs will be more valuable for phosphorus acquisition if located in surface soil horizons by arising from roots with a shallow growth angle; shallow roots will have greater benefit for P acquisition if they have long and dense hairs.

OBJECTIVES

The purpose of this study was to evaluate and quantify the effect of root hairs and basal root growth angle alone and in combination among closely related genotypes.

MATERIALS AND METHODS

We established a set of field experiments with Recombinant Inbred Lines (RILs) of common bean *(Phaseolus vulgaris L.)* grouped in four distinct root phenotypes: long root hairs and shallow basal roots; long root hairs and deep basal roots; short root hairs and shallow basal roots; and short root hairs and deep basal roots. Plants were grown for 28 days in a CRBD under low and medium phosphorus availability.

RESULTS AND DISCUSSION

Results revealed substantial synergism between the two phenes. Long root hairs increased shoot biomass under phosphorus stress by 89.3% while shallow roots increased shoot biomass by 57.7%. Genotypes with both long root hairs and shallow roots had the greatest biomass accumulation, 298% greater than short-haired, deep-rooted phenotypes. Shoot biomass and phosphorus content of genotypes with long root hairs on deep roots and shoot biomass of genotypes with short root hairs on shallow roots did not differ, but were greater than those of genotypes with short root hairs on deep roots.

Figure 1. Field evaluation of Basal Root Growth Angle (BRGA). Phenotypic variation was confirmed among genotypes contrasting for both Root hairs and BRGA, forming four distinct trait classes.

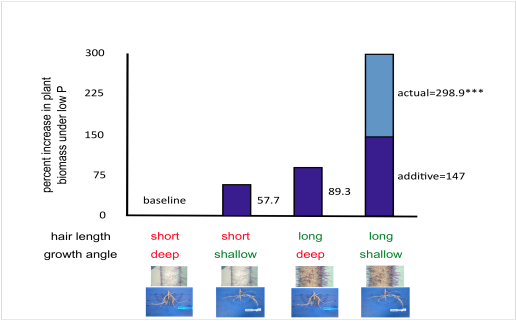

Figure 2. Synergistic effect of Root Hair Length and Density (RHD), and Basal Root Growth Angle (BRGA) among four trait classes composed by four genotypes each. Synergistic effect between RHD and BRGA was significant in low P treatments (at p=0.05).

		Phosphorus Treatment					
		Low P			Medium P		
Trait Class	Genotype	SDW (g)	Avg. SDW (g)	% increase	SDW (g)	Avg. SDW (g)	% increase
Long-shallow	DG53	37.38			42.50		
	DG38	35.11			45.23		
	DG13	33.78	35.42	298.9	39.90	42.54	87.7
Long-deep	DG32	17.23			27.36		
	DG79	16.63			30.75		
	DG52	16.56	16.81	89.3	26.65	28.25	24.7
Short-shallow	DG36	15.54			25.67		
	DG66	13.70			23.81		
	DG64	12.78	14.01	57.7	22.90	24.13	6.5
Short- deep	DG47	10.01			20.14		
	DG19	8.89			24.98		
	DG27	7.74	8.88	0	22.86	22.66	0

Table 1. Percentage of increase of shoot dry weight (SDW) in 12 common bean genotypes grouped in the following trait classes. Plants were grown with low and medium P in the field. Plant samples were collected at 28 DAP. Each value in shoot dry weight of genotype is a mean value of 4 replicates. Percentages were calculated from the average shoot dry weight of short-deep trait class (8.88 g=100% for low P, and 22.66 g=100% for medium P).

CONCLUSIONS

We conclude that the morphological phene of longer root hairs and the architectural phene of shallower basal root growth are synergetic for phosphorus acquisition in the soils with low phosphorus availability.

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