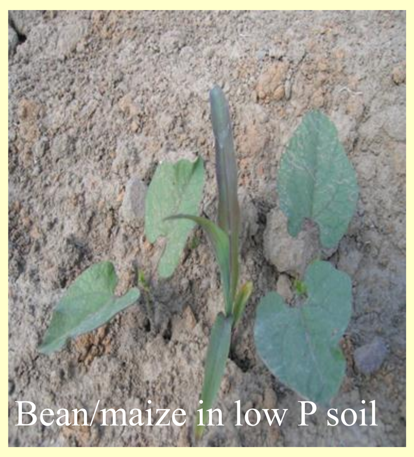
IMPACTS OF PHOSPHORUS-EFFICIENT COMMON BEAN (*PHASEOLUS VULGARIS*, L.) LINES ON AGROECOSYSTEM PRODUCTIVITY AND SUSTAINABILITY.

Soares A. Xerinda[1*], Jonathan P. Lynch[2], and Peter Kleinman[2]. [1]Instituto de Investigação Agrária de Moçambique (IIAM), Av. FPLM no. 2698, P.O. Box 3658, Maputo, Mozambique. [2]The Pennsylvania State University, 102 Tyson Building, University Park, PA 16802, USA.. *soaxer@hotmail.com

INTRODUCTION

Common beans are a centerpiece of the daily diet for more than 300 million people, especially the poor, with global harvest of 18 million tons (CIAT 2010), yet the yields are very far from the potential due to low P availability in most soils. Low phosphorus availability is a primary constraint to plant growth on earth (Lynch and Deikman, 1998), and P is the most frequently deficient nutrient for bean production in more than 90% of humid tropics. Plant adaptations to increase nutrient acquisition under low fertility soils (e.g. shallow basal roots, high and long root hairs), especially low P, have been reported as increasing growth of root and shoot biomass in several studies (Lynch and Brown, 2001). Common bean with shallow roots has superior acquisition of P when it is more concentrated in the topsoil compared to deep rooted bean. The impact of root shallowness on erosion, symbiotic N2 fixation and maize-bean competition on agroecosystem productivity was evaluated in several trials conducted at the Penn State University, Mozambique and South Africa from 2006 to 2011.



MATERIALS AND METHODS

- A study was conducted in a low phosphorus Ustox in Mozambique to evaluate the effect of shallow-rooted bean genotypes on alleviation of water erosion including reduction in runoff water, sediment and P in runoff water. The treatments included two shallow-rooted genotypes and deep-rooted genotypes which are Recombinant Inbred Lines (RILs) from the same population, and bare soil.
- The second study was conducted at Lichinga (Mozambique) in 2008 and at Ukulima (South Africa) in 2010 to test the hypothesis that P-efficient common bean genotypes have better nodulation and better N_2 fixation than conventional genotypes. Ten genotypes of two P-efficiency categories were grown with two phosphorus levels and inoculation/liming combinations.
- The third study examined the root competition effects of maize/bean polycultures with four bean genotypes varying in root shallowness under high and low P in two field trails at Penn State University agriculture research farm in 2006 and 2010. Appropriate statistical methods of experimental, treatment designs and analyses were used to evaluate the results.

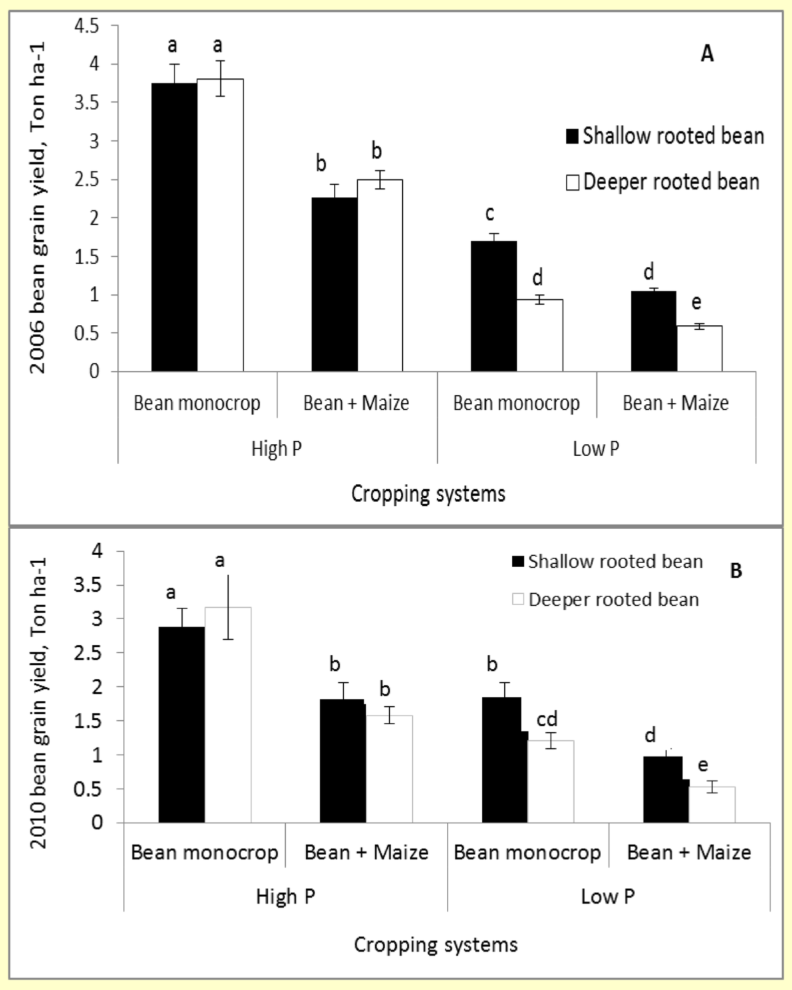
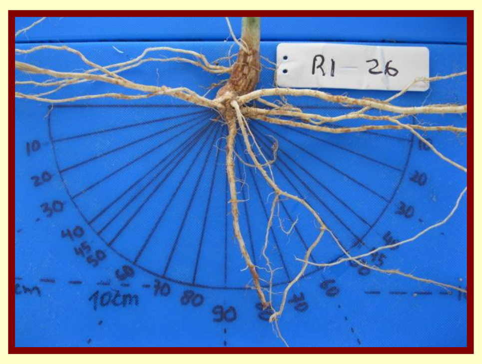


Fig 1: Grain yield of common bean genotypes differing in root shallowness monoculture and associated with maize under low and high phosphorus (P) conditions in Pennsylvania.



RESULTS AND DISCUSSION

For bean-maize polyculture:

- Bean and maize root phenotypes were not altered by the presence of the companion crop compared with monocultures.
- Under high P, the bean monoculture yielded approximately 3.8 ton ha^{-1} regardless of root phenotype, but under low P the shallow-rooted and deep-rooted bean categories had yield reductions of 55.3 and 75.5%, respectively
- When intercropped with maize, under low P, the shallow-rooted bean yield was 1.04 ton ha^{-1} which was 43.3% greater than the yield of the deep-rooted phenotypes. The average maize yield in monoculture was 10.78 ton ha^{-1}, it was reduced to 63.7% by association with shallow-rooted bean, but not reduced by the association with deep-rooted bean phenotypes

Regarding the effect of root shallowness on symbiotic N2 fixation

- Under low P, inoculation increased the nodule number of P-efficient genotypes by 34 to 71%. For P-inefficient genotypes, inoculation increased nodule number by between 20 to 46%. Nodule activity of P-efficient genotypes were consistent in both years and were between 50.6% and 92.5%, a rate at least 30% greater than for P-inefficient genotypes. For the P-inefficient genotypes the nodule activity varied between 27.5 and 33.4%.
- Under low P inoculated treatment the genotype L88-57 fixed the equivalent of 39 kg of urea ha^{-1} followed by G19833 and L88-14 fixing N equivalent to 32 kg of urea ha^{-1}, and the smallest amount was fixed by the genotype DOR 364 with the equivalent of 1.6 Kg of urea (46%) ha^{-1}

For the study on impacts on erosion we observed that:

- Shallow-rooted genotypes had 81.2% more roots in the surface 15 cm soil than deep-rooted genotypes. Shallow-rooted genotypes had consistently less runoff water volume, sediment and dissolved P than deep-rooted genotypes. The shallow-rooted genotypes had 46% more shoot biomass, 15 to 28% more canopy cover, and 26 to 34.6% less runoff sediment than deep-rooted genotypes. Compared to bare soil, the runoff reduction was 27 to 39% for shallow-rooted genotypes and approximately 14.5% for deep-rooted genotypes. Root length density in the top 15 cm was well correlated with canopy cover (R^2=0.98), runoff (R^2=0.85), and shoot biomass (R^2=0.89), and the volume of runoff was correlated with sediment suspended in water (R^2=0.80).

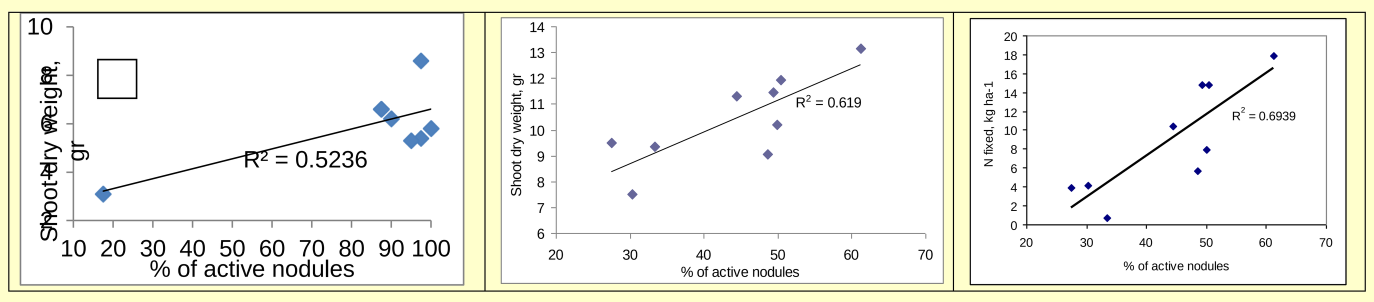


Fig 2: Correlation between % of active nodules and dry shoot weight of common bean under low P soils in Lichinga-Mozambique (A) in 2008, and at Ukulima-RSA (B) in 2010, and between active nodules and symbiotic nitrogen fixation (C). Bars with the same letters on top are not significantly different.

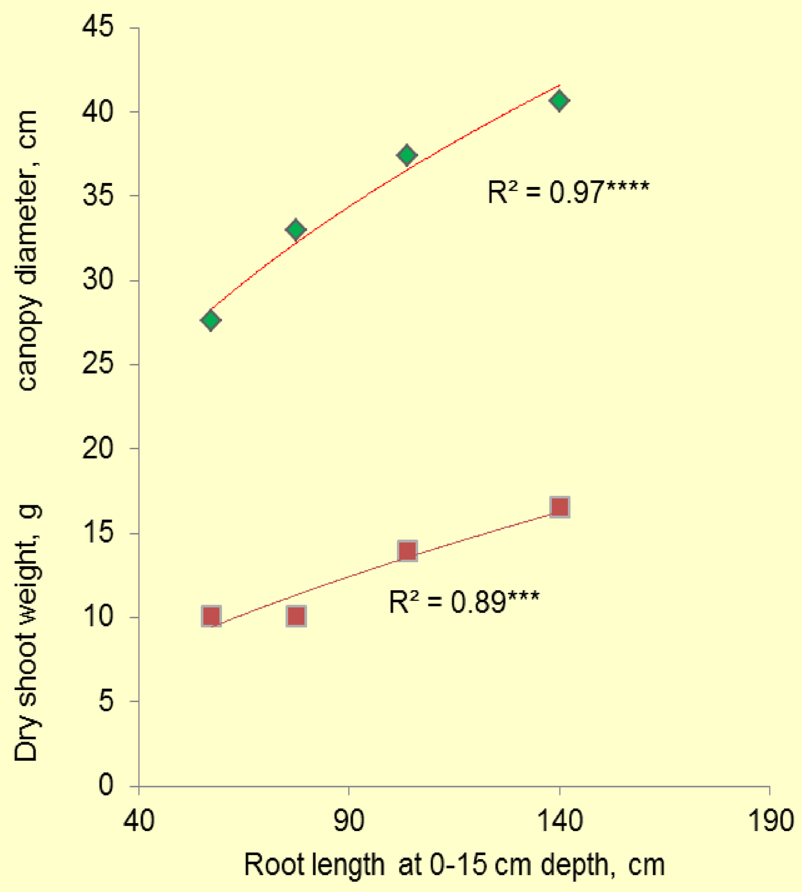


Fig 3: Canopy cover and dry shoot weight were directly correlated with root length at top 15 cm.

CONCLUSIONS

- The improved bean productivity of shallow-rooted genotypes intercropped under low P, demonstrates the high potential benefit for low-input systems from breeding for varieties with superior phosphorus acquisition efficiency, and the need for selection of appropriate matches of root systems for intercropped species in low-input agro-ecosystems
- The introduction of P-efficient genotypes may greatly contribute to increased productivity and sustainability of low-input systems since a considerable amount of N is fixed by the symbiotic nitrogen fixation process with P-efficient lines and its cost is lower than the use of inorganic fertilizer by poor farmers.
- The genotypes with root traits permitting greater P acquisition attain better shoot growth, better canopy cover, and reduced soil P lost to water erosion in low P tropical soils. Introduction of genotypes with enhanced phosphorus acquisition may therefore help conserve soil fertility by reducing soil erosion

References

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