Bean Roots — A Plant Breeder's Perspective.

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Roots are an essential component of successful plant growth, development and productivity. In breeding for yield, however, plant roots are generally ignored during selection unless root health is a selection criterion. Root health is a trait for which plant breeders can and have made progress, despite confronting problems with confounding factors of environment, soil types, crop rotations, and the interaction of root pathogen complexes. However, limited knowledge on differential root morphology (architecture) within crops and the role and function of different root types (basal, lateral, or shoot derived) are not understood. Compounding these problems is the major difficulty of viewing and studying roots *in situ*.

In common bean (*Phaseolus vulgaris* L.), four major growth habits are clearly recognized (Singh, 1982). The stability in expression of these growth habits across environments (tropical and temperate) is quite remarkable as is the general agreement on the four categories by bean scientists worldwide. I would like to suggest that bean breeders could make use of above ground plant architecture to assist in selection for below ground root morphology.

Type I: Determinate type I growth habit exhibited by kidney bean cultivars (race Nueva Granada), has a characteristically shallow root system restricted genetically by the same determinacy gene(s) expressed in the shoot. When determinate types are planted in compacted soils or in fine-textured soils with high clay content, root growth and the corresponding shoot growth is severely restricted as is seed yield. Production in coarse-textured soils, coupled with careful soil management to reduce compaction, supplemental irrigation all contribute to improving productivity not only by producing a more vigorous plant but by producing a more extensive root system on which the larger plant can be sustained. Opportunities to improve the depth (vigor) of root systems within determinate cultivars will continue to be limited by the expression of the *fin* gene.

Type II: The plant structure of indeterminate type II growth habit, exhibited by black bean cultivars (race Mesoamerica), is typified by a dominant main stem with limited branching. Having hand pulled these types for over two decades, I can attest to the presence of a dominant deep tap (basal) root system with few lateral roots. Above ground architecture is genetically coordinated with a similar root morphology below ground. This root architecture permits the exploitation of soil moisture and mineral resources in a vertical plane, rather than in a horizontal plane due to the limited number of lateral roots. These root systems can sustain a plant for short periods of moisture stress (10-14 days, depending on temperature, growth stage and soil type) without significant loss in yield potential since they mine soil moisture content to greater depths. Such plant types are best suited to high density planting systems using narrow row widths, under relatively high natural rainfall conditions. They are least suited to shallow soils, low density dryland farming systems where high plant populations cannot be exploited due to overall limited precipitation.

Type III: The indeterminate prostrate vine plant structure of type III growth habit is exhibited by traditional pinto cultivars (race Durango) grown in the inter-mountain regions. Branching is less organized and more opportunistic (profuse) than that of either types I or II. The highly branched root system has a larger number of lateral branches and as a result is more superficial in profile, spreading

in a horizontal plane. Lower planting densities under dryland farming exploit the potential of this type to spread laterally rather than vertically. This superficial system is best suited to utilize soil moisture from sporadic heavy rainfall where there is less competition between plants, and where moisture is limited to the upper soil profile due to rapid run-off. The root system of type III plants demonstrates a high degree of flexibility and ability to adjust to available soil moisture and plant competition. In semi-arid regions, restricting irrigation during the vegetative phase of growth is common, since it forces the plants to root deeper and reduces interplant competition for moisture when moisture is applied later, during the critical reproductive period. Type III plant and root systems are best suited to semi-arid planting systems due to the flexibility exhibited by both the root and shoot morphology responsive to irrigation, sporadic rainfall and variable planting densities.

Type IV: Climbing type IV growth habit, exemplified by pole bean cultivars (race Jalisco), are long season genotypes which continue to sustain root growth long after flower initiation in contrast to type I genotypes which restrict translocation to the root when flowering occurs. Not having worked with climbing beans, my knowledge of root systems associated with type IV is limited. The potential of root systems associated with type IV genotypes is reported in the literature (Miller et al., 1997), but the problem of how to exploit that potential in other growth habits may be formidable.

What are the prospects to effectively improve efficiency of bean roots or root systems through empirical selection based on above ground morphology? I would like to illustrate some limitations with a few examples of growth habit changes in commercial bean classes which have resulted in similar changes in root architecture. Type II pinto bean cultivars such as Sierra possess the same root architectural characteristics associated with the type II growth habit of black beans, not the root architectural characteristics associated with the typical type III pinto such as Othello. The navy bean cultivar UI-237 exhibits type III growth habit typical of western bred pinto cultivars and lacks the dominant tap root system typical of other type II navy bean cultivars such as Mayflower. In the MSU breeding program, kidney bean breeding lines developed to possess a type II growth habit also possess the characteristic dominant tap root atypical of the determinate commercial cultivars. Without the opportunity to directly select for root architecture, bean breeders will indirectly select root architecture associated with the shoot architecture selected directly.

As breeders, we seek to identify and exploit unique genetic recombinants and some do exist. The prolific rooting system of the snap bean breeding line FR266 contrasts dramatically to that of commercial cultivars. This genotype was selected for root health (Silbernagel, 1987) and this may be one approach to improve individual root systems. However, there may be a cost to the plant for this particular root system, since the genotype has a very low seed productivity potential. We must recognize that progress has and can be made, but the coordinated morphology inherent between roots and shoots in beans and other crops, will continue to limit the plant breeder interested in combining distinct root attributes with the shoot characteristics of a different bean growth habit.

References:

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