Getting to the Roots of Agriculture

By Andy Hammermeister, Ph.D., P.Ag.

In a time when we seem to be looking toward technology and biological manipulation to solve our agricultural problems, we seem to have forgotten the technology ingrained in nature. At the recent annual conference of the American Societies of Agronomy, Soil Science and Crop Science, I was particularly struck by efforts to go underground...

A presentation, "The Roots of the Second Green Revolution" by *Jonathon Lynch, Pennsylvania State University (SSSA Howard M. Taylor Memorial Lectureship)* developed the following idea. Before the first green revolution, crop yield was in part limited by soil fertility, however, crops receiving higher inputs were limited in their response by their tall growth habit and susceptibility to lodging. In addition to increasing yields through the use of chemicals and fertilizers, the first green revolution strove to develop dwarf varieties of crops that could respond to high fertility. In many respects the first green revolution has been successful. In hungry countries, however, 1 of 7 children still die before the age of 5. The goal of the second green revolution will be to increase crop yield at low fertility levels. Much of the world relies heavily on bean production as a source of food, however, bean production is only achieving 15-20% of its yield potential primarily due to low soil fertility, particularly phosphorus. Fertilization has limited the potential for addressing this problem due to cost, accessibility, the binding of phosphorus to the soil and soil acidification. An alternate approach is to select crop genotypes that are well adapted to low soil phosphorus. Modern crop varieties are not effective because they have been selected to respond to high input levels, and they may not be tolerant of aluminum toxicity that is common in acid soils.

Unlike some other nutrients, phosphorus does not move in the soil, meaning that the plant has to find the phosphorus. The solution therefore lies in the roots. Researchers are beginning to demonstrate that crop yield can be increased significantly by selecting for specific rooting characteristics. Such characteristics include more lateral roots, larger denser root hairs and larger root diameter. Root angle, depth and distribution can be selected to match the phosphorus distribution in the soil. Differences in management, such as tillage practices, can have considerable influence on where phosphorus may be most available. This means that different root characteristics are needed under different management systems. Another strategy may be to grow genotypes with different rooting habits, to reduce competition between plants and make better use of phosphorus throughout the soil.

When a plant invests in producing more roots, it takes energy away from leaf and seed production, hence limiting yield. For example, a root with a larger surface area (i.e. circumference) will contact more soil area and therefore be able to access more phosphorus. Increasing the size of the root may require a much larger input of energy. Phosphorus efficient genotypes can grow more root biomass for the same energy cost, which allows more energy to be sent to the leaves and ultimately seeds. The solution may lie with the air pockets in roots called aerenchyma. By increasing the size of the aerenchyma, the root diameter can be increased without large energy costs. Large differences in genotypes that can be observed under low fertility conditions may not be observed under high fertility conditions; some genotypes can adapt to soil fertility levels.

There may be one problem with phosphorus efficient genotypes. If they become so effective at scavenging phosphorus from the soil, will they eventually deplete it i.e. “run the well dry”? This may especially be a problem for growing other crops that may not be as efficient in extracting phosphorus. In many hungry regions of the world, the steeply sloping landscape results in losses of 100 kg/ha per year of phosphorus due to soil erosion. On average, a good bean crop would remove 2-4 kg/ha per year. By having better cover on the soil, lower erosion losses will compensate for the phosphorus removal by cropping. (Alternatively, phosphorus removals need to be balanced by replacing with phosphorus from human and livestock waste.)

The key messages from this lecture are: low-tech, low-input solutions are needed to solve the world’s hunger problems and selecting for good rooting characteristics may be the solution to achieving higher yields under low fertility. Currently, it costs $1,000,000 and takes several years to develop a new variety of wheat. Breeding for rooting characteristics would be much more costly. How much are we willing to pay to stop hunger?

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