

## Successes and Challenges in Improving Common Bean Productivity

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Grain legumes are an important component of agricultural and food systems throughout most of the world. They complement cereal crops in dietary terms, as sources of protein and minerals, showing two or more times the levels found in most cereals.

Agronomically, legumes serve as rotation crops with cereals, reducing soil pathogens and supplying nitrogen to the cereal. Finally, legumes receive better prices in the market and in some regions are more profitable. Among legumes that are used for direct human consumption, the common bean (*Phaseolus vulgaris* L.) is, by far, the most important, representing more than twice the total production of chickpea, which is the second most important.

Legume productivity has been relatively stagnant, however, compared to that of cereals, over the last 30 years, during which time cereal production has doubled. With a doubling of population, this has necessarily led to declining per capita consumption of legumes. With declining real prices of cereals and scarce legumes, poor consumers naturally gravitate toward the consumption of cereals, with important implications for human health.

While plant breeding has dramatically increased the yields of cereals, no such increase has been registered in legumes. Why has yield improvement in legumes proved so difficult, compared to cereals? There are many fundamental differences between cereals and legumes, some of which affect yield potential and the ease or difficulty of yield improvement. Legumes are physiologically more complex than cereals in terms of management and use of nitrogen (N) and its relation to photosynthesis. Nitrogen fixation in legumes implies a demand for energy that cereals do not confront. Legumes also face greater competition for N to form protein. As seed fills and protein is deposited, this results in remobilization of N from leaves and early stress on the rate of net photosynthesis. This is another likely cause of the lower yield potential of legumes.

Another possible cause of slow progress in legumes, and certainly in common beans, is the intensity of diseases. Many breeding programs have been dedicated primarily to resistance breeding, with relatively less emphasis on yield *per se*. Finally, in the case of common beans, demands for very specific commercial types (with different seed colors, shapes and especially sizes) have slowed progress significantly.

Successes in common bean breeding in the past have been registered primarily in the development of disease- and insect-resistant varieties. Breeding for biotic stress resistance is a defensive breeding strategy and does not necessarily raise yields dramatically. For example, even in Central America, where breeding for resistance to bean golden yellow mosaic virus (BGYMV) was very successful in producing resistant

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varieties from the mid-1970s to the late 1990s, regional yields increased only from 550 to 650 kg/ha, a modest absolute increase and still far from the potential yield of the crop. Diseases and pests are an ever-present threat to the crop and pose a significant risk, so resistant varieties are much appreciated by farmers. However, in a given year, disease intensity varies greatly from one field to the next, or even within a single field. If one calculates the area infected by disease and the likely yield loss, it is difficult to account for so wide a yield gap as is registered on a regional basis.

Drought does not affect most production regions year after year, but when it does strike, it can affect entire regions very dramatically and with great intensity. Instead of reducing yields sporadically across the landscape, as diseases usually do, drought can affect a majority of farms over large regions, but only in some years.

Soil problems, on the other hand, including low fertility and aluminum toxicity, are widespread across the landscape and occur with high frequency. They also occur every year, and with an intensity that reduces yields significantly. As an indicator of yield reduction due to soil fertility, one need only look at yield responses in fertilizer trials, or at the difference between on-station and on-farm trials, which differ largely in terms of soil fertility management. Soil fertility is the most important single factor explaining the large gap between yield potential and real yields across a continental landscape. If we are to meet the challenge of raising bean yields significantly, we must address the problem of low soil fertility, and to some degree drought.

To address abiotic stresses requires an integrated approach involving both genetic and agronomic solutions. Improved genetic potential alone will not maximize yields, and techniques for achieving optimal agronomic management are often not economically feasible for farmers. On the genetic side, CIAT has made significant progress in improvement of both drought tolerance and response to soil problems, including low soil fertility.

For example, as a result of CIAT collaboration with Embrapa, the breeding line A774 was released as BRS Marfil, a variety relatively tolerant to low soil fertility, which showed an advantage of 30% over local checks in national yield trials. However, more recent lines show more dramatic improvement in drought tolerance and have acceptable grain types in the small-seeded color classes. The new lines yield two to five times more than commercial checks, depending on the color class, under severe stress. Furthermore, preliminary indications suggest that selection under drought has also improved tolerance to low soil phosphorus availability. We believe there are common mechanisms of stress tolerance, which apply to different stresses, and that selection under drought stress reveals the genes for these mechanisms especially well. We hope to extend this breeding strategy to other grain classes, especially in the large-seeded types, which have higher value in Latin America and sub-Saharan Africa.

Aluminum toxicity is another abiotic stress for which there is hope of good progress in the development of tolerant bean germplasm. Vast regions of the tropics are subject to soil aluminum toxicity, and liming, where practiced, benefits only the upper 15-20 cm of

the soil profile. Very high levels of aluminum tolerance have been identified in a sister species of common bean, *Phaseolus coccineus* L., and are being transferred to common bean.