Common Bean: The Nearly Perfect Food

The Importance of Common Bean

For more than 300 million of the world's people, an inexpensive bowl of common beans (*Phaseolus vulgaris*) is the centerpiece of the daily diet. This staple is the world's most important food legume, far outdistancing chickpeas, faba beans, lentils, and cowpeas. The global bean harvest of 18 million tons annually has an estimated value of US$11 billion.

Nutritionists characterize the common bean as a nearly perfect food because of its high protein content and generous amounts of fiber, complex carbohydrates, and other dietary necessities. A single serving (1 cup) of beans provides at least half the US Department of Agriculture's recommended daily allowance of folic acid—a B vitamin that is especially important for pregnant women. It also supplies 25 to 30 percent of the recommended levels of iron and meets 25 percent of the daily requirement of magnesium and copper as well as 15 percent of the potassium and zinc.

The common bean was domesticated more than 7,000 years ago in two centers of origin—Mesoamerica (Mexico and Central America) and the Andean region. Scientists believe dry beans, along with maize, squash, and amaranth, probably began as weeds in fields planted to cassava and sweet potatoes in Central America. Over the millennia, farmers grew complex mixtures of bean types as a hedge against drought, disease, and pest attacks. This process has produced an almost limitless genetic array of beans with a wide variety of colors, textures, and sizes to meet the growing conditions and taste preferences of many different regions.

Beans are grown from sea level to more than 3,000 meters chiefly by small farmers with average land holdings of less than 1 hectare, without irrigation, and using little or no fertilizers or pesticides. Much of the bean production in Latin America and sub-Saharan Africa, where three-quarters of the crop is grown, takes place on steep, erosion-prone slopes with low soil fertility.

In recent years the common bean has found an important market niche in burgeoning Latin America cities, where millions of rural poor have migrated, seeking jobs to support their families. With about 70 percent of Latin America's population now concentrated in urban centers, bean farmers are finding new sources of cash income.

Latin America is the most important bean producing region, its 8 million hectares accounting for nearly half of global output. Beans are the fourth most important source of protein in tropical America and surpass two popular regional root crops—potato and cassava—as a source of calories. Throughout the region the common bean is known as the "poor man's meat." Because there is no cheaper source of protein, per capita consumption of beans is high in very poor countries, such as Nicaragua (with

22.5 kilograms per capita per year), and in poorer regions of higher income countries, such as Northeast Brazil (with 18.5 kilograms per year).

Dry beans were introduced in sub-Saharan Africa several centuries ago by Portuguese traders. Today, the crop is a vital staple on this continent, providing the main source of dietary protein for more than 70 million people. Dry beans are raised mostly by women for subsistence and the market on more than 3.5 million hectares, accounting for a quarter of global output. Production is concentrated in densely populated eastern Africa, the lakes region, and highlands of southern Africa.

Research for Development

Challenge

Given current trends in population growth and bean consumption, demand for this crop in Latin America and sub-Saharan Africa can be expected to grow at unprecedented levels well into the 21st century. How can countries in those regions meet the demand, and how can the low-income farmers who grow most of the bean crop benefit in the process? These are the main questions that our agenda of bean research and development must address.

In most bean-growing environments, land and labor scarcity severely limits the possibilities for increasing production by expanding the area planted. Moreover, most of this expansion would take place in ecologically fragile areas, incurring high environmental costs. It is thus vital that farmers gain the means to raise bean yields per hectare on the land already cultivated. And they must be able to do so without necessarily using heavy doses of purchased inputs, since most bean growers cannot afford these.

Against difficult odds Latin America has achieved notable progress in raising bean productivity over the last decade or so. With the aid of new technology, many rural communities have managed to intensify production, thus strengthening local food security and raising incomes through bean sales to local and urban markets. But to secure and expand those gains, bean research and development must persist in confronting a formidable array of constraints—including depressed yields, shifting disease and pest problems, and the stubborn physical constraints of infertile soils and drought.

Such research is a matter of particular urgency in sub-Saharan Africa, where bean yields have increased only modestly in recent years, while the area under production has actually declined. Rates of increase in bean production on this continent still lag behind population growth (which at 2.8 percent a year is among the highest in the world), with the result that growers are unable to keep pace with market demand. Because of the importance of beans in the African diet, the nutritional consequences of this gap are truly alarming.

CIAT scientists are convinced that new bean cultivars with higher yields, multiple disease resistance, and greater tolerance to drought and low soil fertility will enable farmers to increase bean productivity and achieve greater yield stability. New production technology, together with the bean crop's wide adaptability, will help it remain an attractive option for small-farmer cropping systems.

Genetic resources

One potent source of solutions to problems in bean production is the vast array of genetic diversity available for research and development in the world *Phaseolus* collection maintained at CIAT headquarters in trust for the Food and Agriculture Organization (FAO). The collection includes over 36,000 entries, of which 26,500 are cultivated *Phaseolus vulgaris*, About 1,300 are wild types of common beans, and the rest distant relatives of the common bean. Safeguarding, studying, and sharing this germplasm are fundamental responsibilities implied by CIAT's global mandate for bean research within the Consultative Group on International Agricultural Research (CGIAR).

Because the huge number of accessions greatly complicates detailed evaluation of the germplasm for useful traits, CIAT scientists have created more manageable core collections. These are small but thoroughly representative subsets of the gene bank's entire *Phaseolus* holdings. The core collection of domesticated common bean contains about 1,400 accessions, while the collection of wild common bean consists of about 100 accessions.

In recent years bean researchers at CIAT and in national programs of Latin America and sub-Saharan Africa have been evaluating the core collection for a wide range of traits, such as insect and disease resistance and tolerance to low phosphorous. Useful materials have been identified and incorporated into breeding programs at CIAT and elsewhere.

Crop improvement

Bean improvement research at CIAT concentrates on two main tasks: 1) developing germplasm that offers farmers distinct advantages with or without purchased inputs and 2) designing strategies for managing diseases and pests in bean-based cropping systems.

In this first line of research, a key activity involves the identification and development of germplasm that is tolerant to drought and low soil fertility. In conjunction with this work, we seek to identify the plant features or mechanisms that account for traits such as efficient use of phosphorus in beans. These insights better enable breeders at CIAT and elsewhere to select for stress tolerance and combine it with other desirable traits, such as higher yield and preferred grain types. Tolerance to physical stresses must also be combined with multiple resistance to diseases as well as with resistance to major pests. Toward this end our bean scientists continually screen and select the germplasm for disease and insect resistance and then "pyramid" resistance genes in agronomically desirable materials. These experimental materials are distributed to national programs for local evaluation through a series of germplasm nurseries.

Our research on disease and pest management in bean aims to speed the development of component technologies, principally disease and pest resistant germplasm but also biological and cultural controls. This work involves ongoing efforts to characterize and monitor major diseases and pests. Better understanding pathogen and pest diversity and severity across environments is vital for combating these stresses. We also characterize genes for disease and pest resistance, with a view to combining them more effectively through bean improvement.

While focusing mainly on dry beans, CIAT scientists are also working to improve snap beans. Demand for fresh snap beans for domestic consumption or export is growing in Africa, Asia, and Latin America, and sales are an excellent source of cash income for small farmers. Much of the Center's strategic research on dry beans, especially that dealing with diseases and pests, is readily applicable to snap beans.

Biotechnology

Classical breeding within the primary gene pool of common bean has given excellent results in the last two decades, with tangible benefits for farmers. To speed progress in this work and to harness valuable genes from wild *Phaseolus* and species distantly related to beans, we began in the late 1980s to integrate various biotechnology techniques into problem-solving research on the crop. Here are two recent highlights of that work:

- In studies that apply molecular marker techniques to the common bean core collection, CIAT scientists have achieved a better understanding of the genetic makeup and diversity of the crop. Similar studies are being carried out with a core collection of wild *Phaseolus*. This research is essential for using the available genetic resources more effectively in crop improvement.
- Through improved embyro rescue methods and a backcrossing strategy, CIAT scientists have succeeded in hybridizing common bean with the distantly related species *P. acutifolius*, or tepary bean, which possesses genes for resistance to common bacterial blight (CBB), leafhoppers, and drought. The resulting breeding lines have shown high levels of resistance to CBB. They have been distributed to national bean programs for evaluation of other traits, including tolerance to drought, and low soil fertility and resistance to leafhopper.
- CIAT researchers have developed a molecular marker-assisted approach to improving beans for resistance to bean golden mosaic virus (BGMV) that has cut breeding time and effort by about 60 percent. BGMV is a major production constraint of the crop in Central America and Mexico. One major source of BGMV resistance is the recessive gene known as *bgm*-1, which comes from a Mexican landrace. In 1996 the US Department of Agriculture (USDA) identified a molecular marker associated with the gene—in this instance a RAPD. CIAT scientists then converted this to a more useful type of marker called a SCAR. These have the advantage of highly stable expression and are thus more efficient than RAPDs in marker-assisted plant breeding. The results of recent molecular marking and selection work are highly encouraging, demonstrating not only the effectiveness of the SCAR-based strategy for selecting BGMV-resistant beans but also its efficiency.

Partnerships

From the earliest days of CIAT, bean researchers debated the best way to transfer the results of their research to the poor small farm family. In 1978 the center pioneered the development of a regional bean research network for Central America and the Caribbean, known as PROFRIJOL. A similar network, PROFRIZA, was established for the Andean zone in 1988. Both Latin American networks have been supported by the Swiss Agency for Development and Cooperation (SDC).

Based on this model, the Center helped establish other networks in sub-Saharan Africa's eastern, central, and southern regions in the mid-1980s. Currently, two networks—the Eastern and Central Africa Bean Research Network (ECABRN) and the Southern Africa Bean Research Network (SABRN)—operate within the framework of the Pan-African Bean Research Alliance (PABRA). Network activities in Africa are financed principally by the Canadian International Development Agency (CIDA), SDC, and the US Agency for International Development (USAID). The networks are also backed by two key subregional organizations, the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) and the Southern Africa Centre for Cooperation in Agricultural Research and Training (SACCAR).

The bean networks are voluntary associations of national research institutions as well as universities and NGOs. Their purpose is to strengthen local problem-solving capacity and speed the development and transfer of improved technology through regional cooperation. CIAT contributes improved germplasm, training, and technical assistance. Through democratic governance the networks set regional priorities, make resources available for research, manage adaptive research projects, and share results.

While feeding into the regional networks, bean research at CIAT also draws heavily on partnerships with universities in developing countries (such as the Escuela Agrícola Panamericana in Honduras) as well as in industrialized countries (e.g., Cornell University and the Universities of California and Wisconsin in the USA and the University of Ghent in Belgium). These ties are especially valuable in our efforts to integrate biotechnology techniques into problem-solving research.

Impact

Since CIAT's establishment in 1967, national agricultural research programs in 39 countries have released 362 bean varieties—including 238 in Latin America and 111 in Africa—based on germplasm provided by the Center. These varieties are planted on a total area of nearly 2.4 million hectares and have generated cumulative benefits of almost $1.3 billion in 1990 US dollars. In Latin America Brazil and Guatemala have captured a particularly large share of these benefits, while in Africa Rwanda has been the single largest beneficiary of bean improvement at CIAT.

The multiple disease resistance of new bean varieties has helped farm families by reducing crop losses and lowering production costs. Higher productivity has benefited consumers by permitting a steadier supply of beans at lower, more stable prices. Improved varieties have had environmental impacts as well. By decreasing the need for pesticides, the new beans have helped diminish contamination of water and soil. And by permitting more intensive production on land already in production, they have reduced pressure on fragile environments, such as hillsides and forest margins. In the sections that follow, we present some highlights of germplasm impact.

Latin America

Over the last decade or so, total bean production in Latin America has risen 25 percent—to 5.3 million tons in 1993-95 from 4.2 million tons in 1983-85. At the same time, total area has risen by only 2 percent—to 8.1 million hectares from 7.9 million—and the annual rate of growth in area has actually declined to -0.5 percent.

Increased production has thus resulted mainly from higher yields. The annual growth rate in yield is now at about 2.7 percent (compared to 1.9 percent a decade ago), and this is well above Latin America's average rate of growth in population (1.9 percent). With beans more readily available in the marketplace, per capita consumption has started to rise as well.

In some parts of Latin America, the changes have been more pronounced than in the region as a whole. For example, in the Andean zone (Bolivia, Colombia, Ecuador, and Peru), bean production was essentially stagnant until the early 1990s. Rates of growth in yield and production lagged well behind population growth. But by 1995 bean production in these countries as a whole had risen sharply, apparently as a result of higher yields.

A growing body of evidence from field studies suggests that improved varieties have contributed importantly to yield increases. A literature database maintained on CIAT's Web site contains abstracts of about 40 such studies.

One of the earliest analyses was conducted in Costa Rica. This work cast doubt on the then conventional view that technical change generally bypasses small farmers in Latin America. The study documented widespread adoption of new bean varieties, together with a new and more profitable bean production system.

Central America as a whole has benefited from cooperative development in the 1980s of bean varieties resistant to Bean Golden Mosaic Virus. This virus had devastated bean crops throughout the region as well as in Mexico and the Caribbean. Within 4 years after release of the first resistant lines, they had been widely adopted in Guatemala and neighboring countries. At present about 40 percent of Central America's total bean area is planted to varieties of CIAT origin.

In Brazil a series of surveys conducted during the early 1990s by CIAT and several national organizations found that improved varieties were being planted on 75 percent of the total bean production area in four states (Espírito Santo, Goiás, Minas Gerais, and Rio de Janeiro). Their economic impact, through additional production, was estimated at US$85 million annually.

A 1990 survey carried out by CIAT economists in Peru's northern Cajamarca department documented the success of the variety Gloriabamba, released 3 years earlier by Peruvian bean researchers. Despite the harsh growing conditions of this remote semiarid region, 65 percent of small farmers were growing the variety on about 35 percent of the total bean area, with an average yield increase of 27 percent. The additional production made possible by Gloriabamba was estimated at 3,038 tons per year, worth $1.5 million.

In Bolivia's Eastern Plains, where bean production was not even a part of local agricultural tradition, the crop was introduced during the early 1980s for production in the winter season. Previously, a lack of options during that period had forced farmers to seek temporary work elsewhere. But now many of them stay home to produce beans for export, mainly to Brazil, Colombia, and Japan. To increase returns from the enterprise, small farmers belonging to a bean production cooperative added an export arm to their organization, and it now earns $3 million annually.

Sub-Saharan Africa

Improved bean germplasm is spreading in this region and beginning to have an impact according to field studies, but the effects are still not evident in national production figures. In fact, as mentioned previously, growth in the continent's bean output still lags well behind demand.

It is encouraging, though, that progress has made even under the most trying circumstances, as in Rwanda. The vast majority of the country's farmers grow common beans, and the crop accounts for a third of all calories and two-thirds of all protein consumed by Rwandans. Since the 1980s the national bean program, with CIAT support, has released about 20 new climbing beans of Mexican origin, which show marked advantages over bush beans and local climbing varieties, especially in terms of yield and root rot resistance. They are the ideal technology for a country where producing more food on less land is of the utmost urgency.

In 1993 a nationwide survey found that 43 percent of all Rwandan farm families were growing improved climbing beans on about 20 percent of the country's total bean growing area. The new beans raised production by 66,000 tons a year, generating extra income of about US$15 million.

In late 1995 a new survey was conducted to monitor the impact of seed aid following the genocide and civil war that shattered the country in 1994. Remarkably, the study found that, despite the violence and its aftermath, improved climbing beans were being grown by nearly half of the farmers surveyed and accounted for a third of the seed sown.

Since then the climbing bean varieties that appeal to Rwandan farmers have also been spread by means of the regional networks to Burundi, Congo (formerly Zaire), Ethiopia, Kenya, Tanzania, Uganda, and Zambia. A 1996 study conducted near Kakamega in western Kenya showed that 1,000 farmers had adopted one or more of five climbing varieties within four growing seasons after their introduction. A similar study carried out in central Kenya during 1998 found that 1,700 farmers were growing these varieties and selling the seed to neighbors at premium prices.

The impact of new bush bean varieties is evident in northern Tanzania and southeastern Uganda. The higher yields and disease resistance of the varieties have strengthened the food security of farm families and enabled them to produce a surplus for the market. For example, a survey conducted in Uganda's Mbale District showed that two new varieties had increased bean supplies during periods of food shortage, raised adopting farmers' cash income, and reduced the amount of labor women invest in gathering wild vegetables to stretch dwindling food supplies. A popular new variety in northern Tanzania has been shown to have environmental benefits as well. Because of its shorter cooking time, it reduces annual consumption of firewood in rural households by 10 percent.