IMPROVEMENT OF COMMON BEAN FOR MINERAL NUTRITIVE CONTENT AT CIAT

Beebe. S.
Bean Program, CIAT, Cali, Colombia

Keywords: Iron nutrition, legumes, plant breeding, tannins, zinc nutrition, inheritance

Contents

Summary

Studies of mineral concentration in the grain of common bean have confirmed that broad genetic variability exists for most minerals, including iron and zinc. Although mineral concentration is to some degree affected by the environment, the genetic component is sufficiently stable to permit the extrapolation of results from one site to another, especially in terms of the ranking of genotypes. Accessions with as high as 100 mg kg^{-1} iron have been observed, representing almost double the average concentration in bean. The potential for increasing zinc content is more modest, and could be in the range of 40% above the average. There could also be potential for modifying content of uptake promoters or anti-nutrients, but their relative importance in iron bioavailability is still not well understood, and thus it is difficult to prioritize these factors as breeding objectives. Preliminary results with both segregation patterns and with molecular markers suggest that the inheritance of mineral content is quantitative and multigenic.

1. Introduction

As the twenty-first century opens, more than one billion human beings in the world live in a state of abject poverty. The nutrient status of the world's population reflects this reality, as nutrient deficiencies continue to drain the health, stamina, intelligence and productive capacities of the poor. In spite of a tragic global scenario, most health parameters reflect a gradual tendency towards improvement in the last half-century, with the exception of micronutrient status. Curiously, frequency of micronutrient deficiencies, and especially iron deficiency, have actually increased over recent decades, even in developed countries, although as expected, the developing world continues to suffer the most acute problems.

Among the various possible solutions to nutrient deficiency, crop improvement has been discussed as one of an array of options. The argument for this approach has been discussed elsewhere and will not be repeated here. Suffice it to say that crop improvement does not displace other options, and is totally compatible and consistent with more conventional approaches. Only time will tell what is the optimal "mix" of approaches. Meanwhile, it seems evident that a total solution can only result from a multifaceted attack on the problem. Food-based solutions must play a predominant role, and within the gamut of such solutions, crop improvement is only one of these (see *The Economics of Plant Breeding as an Agricultural Strategy for Reducing Micronutrient Malnutrition*).

This paper examines the case of common bean, its importance as a source of nutrients, and the potential for genetic improvement. We will review the importance of legumes in diets in general, and the case of common bean in particular, within certain geographical areas and social strata. We will then refer to some of the biological features of the common bean that impinge on the potential for genetic improvement of its nutritional value. Finally, we will briefly consider the question of implementation of a breeding strategy in a broader context of crop improvement.

2. Consumption of Legumes

2.1. The Importance and Role of Legumes in Diets

Legumes for food are probably as old as agriculture and civilization itself. Lentils are mentioned in the Old Testament, and beans figure in designs on pre-Colombian pottery from New World archaeological sites. Remains of bean have been found in diggings as old as 8000 BP in the Guitarrero cave in Peru. In both the Old and the New Worlds, legume consumption has evolved in conjunction with cereals: lentils, chickpeas, pigeonpeas, grams and cowpeas with wheat, rice, millet and sorghum in the Old World; common beans and other *Phaseolus* species with maize in the New World. Thus, the dietary role of legumes should be considered in this light.

Generally speaking, cereals represent the bulk of diets composed of basic grains and supply the greater energy component, while legumes contribute relatively more of other dietary components per gram consumed. Beans, like other legumes, supply proteins, carbohydrates, vitamins and minerals. Legumes, of course, have higher protein content than cereals (about double). Legume protein is rich in lysine and cereals are relatively higher in the sulfur-containing amino acids, thus the amino acid content of legumes and cereals tend to complement each other (see *Plant Based Sources of Proteins and Amino Acids in Relation to Human Health*). In general, legumes are superior to cereals as sources of micronutrients in two respects. On the one hand, legumes have a higher initial concentration of minerals than some cereals, such as rice and maize. The concentration of minerals in beans is found in Table 1.

On the other hand, many cereals are polished before eating, as in the production of white rice or wheat flour for white bread. A significant proportion of the minerals are found in the bran, and are thus discarded during processing. Many legumes, and this certainly includes common beans, are consumed whole, thus conserving the mineral content.

	Wild			**Cultivated**		
	Mean	**SD**	**High**	**Mean**	**SD**	**High**
B	18	5.9	58	10	1.8	18
Ca	3207	1327	6450	1466	412	3152
Cu	6	2.0	12	9	1.8	14
Fe	60	10.2	96	55	8.3	89
K	16271	1629	20055	14782	2481	21255
Mg	2151	231	2705	1874	207	2510
Mn	23	9.0	74	15	4.4	29
Na	16	7.1	38	12	4.0	50
P	6044	705	7782	3684	696	7095
S	2354	314	3073	2120	259	3078
Zn	29	4.5	43	35	5.0	54

Table 1. Mineral concentration (mg kg^{-1}) of wild and cultivated common bean.

In the course of the Green Revolution, yield increases of legumes have lagged far behind those of cereals such as rice, wheat and maize. For reasons that are not wholly understood, the genetic improvement of legumes for yield capacity is especially difficult and remains a great challenge for plant breeders. On the other hand, legumes are often more profitable to farmers than other basic grains, in part due to their scarcity and higher prices, and are thus attractive economically.

An example from India illustrates all of the above points. The Indian subcontinent has traditionally been the region of the world where the greatest tonnage of grain legumes is consumed. However, while the Green Revolution resulted in increased wheat and rice yields and kept pace with population growth, legume yields have scarcely changed and total production has only remained stable. As a result, per capita consumption has dropped. A lower proportion of legumes in the diet was cited as a cause for higher rates of anemia in the 1980s. This both illustrates the importance of the legume component of the diet, and serves as a warning for other regions where per capita legume consumption is in danger of falling off. Although this paper focuses on the improvement of nutritional value, it should be evident that yield improvement of legumes is still an important component of any strategy to maintain or optimize the contribution of legumes to human nutrition. Thus, addressing the need for more legumes, and more nutritious legumes, is an important agricultural issue in the third world, especially in Asia, Sub-Saharan Africa and Latin America.

2.2. Bean Consumption and Global Micronutrient Needs

Common beans are native to the American continent and formed part of the traditional diet of Native Americans throughout much of Middle and South America long before Europeans arrived in America. Indeed, beans were among the crops that the Spaniards and Portuguese soon transported to Europe, from which they spread through temperate Asia: Turkey, Iran and as far as China. Portuguese traders likewise are thought to have carried the common bean to the African continent some 300 years ago, where it is now a traditional crop, especially in the highlands that stretch from Ethiopia through Kenya, the Great Lakes region, and south to Malawi and South Africa. Production occurs over a remarkably wide geographic and ecological range, from 50^oN latitude to 40^oS latitude and on every continent except Antarctica.

Common bean is by far the most important food grain legume on a worldwide basis, representing more than twice the tonnage of the next most important grain legume, chickpea. More than 12 million metric tons are produced annually, of which eight million tons are found in tropical countries of the third world. In relation to consumption, common bean makes a particularly important contribution to the diet in Sub-Saharan Africa and in Latin America.

Within eastern and southern Africa, per capita bean consumption is reported to be as high as 50 kg per year, reaching 66 kg in the Kisii region of Kenya. In Kenya and in southern Africa, maize is consumed in large quantities and serves to balance the diet. But in Rwanda and Burundi there is no cereal that represents a significant contribution to the diet, nor is there any other dietary component with a significant protein content. Meat is consumed in very small quantities and for most of the poor, does not represent a significant source of minerals.

In Latin America, beans continue to play an important role in the diet. In Central America, Nicaragua is the country that reports the highest per capita consumption in the region with some 17 kg $person^{-1}yr^{-1}$. Brazil reports similar levels of consumption nationally, with some regions, such as the northeast and Rio de Janeiro, as high as 20 kg. In general, meat is more accessible to consumers in Latin America than in eastern Africa, and undoubtedly serves to ameliorate mineral deficiencies and anemia. However, within Latin America the lower economic strata enjoy limited access to meat, and beans make a relatively greater contribution to the diet of the poor. For example, even though Honduras is the second poorest country in Latin America, with a limited economic spread, bean consumption is systematically stratified. The poor consume about 40% more beans than the relatively rich.

When bean consumption patterns are compared to iron deficiency and frequency of anemia in women, Sub-Saharan Africa emerges as the region in which iron-rich beans could make a particularly important contribution. Within this region, more than 40% of women suffer from anemia, and the situation is worsening. Bean farmers are often women, and even in areas in which male family members cultivate beans commercially, such as Uganda, women grow their own plots of beans for home consumption. Thus women are in a position to receive and apply technology in the form of new, iron-rich bean varieties. Within Latin America, rates of anemia are highest in Middle America

(Mexico and Central America), where an estimated 28% of women are anemic. In this region, beans are still a crop for home consumption in rural areas, although Latin America is generally becoming more urbanized and much of the bean crop is marketed to cities and towns.

-
-
-

Bibliography

Schoonhoven A. van, Voysest O. (Eds) (1991) *Common Beans: Research For Crop Improvement*. C.A.B. International, Wallingford, U.K; Centro Internacional De Agricultura Tropical, Cali, Colombia. [This Is A Wide-Reaching Description Of Research On Common Beans, And Includes A Description Of Bean Origins And Domestication].

Tohme J., Jones P., Beebe S. And Iwanaga M. (1994). The Combined Use Of Agroecological And Characterization Data To Establish The CIAT *Phaseolus Vulgaris* Core Collection. In: Hodgkin T, Brown AHD, Van Hintum Th JL And Morales EAV (Eds). *Core Collections Of Plant Genetic Resources*. J. Wiley And Sons; Chichester, U.K. Pp 95-107. [This Describes The Philosophy And Selection Process Of The Common Bean Core Collection].

Welch, R.M., House, W.A., Beebe, S., And Cheng, Z. (2000). Genetic Selection For Enhanced Bioavailable Levels Of Iron In Bean (*Phaseolus Vulgaris* L.) Seeds. *J. Agric. Food Chem*. **48 (8)**, 3576-3580. [This Article Presents Evidence To The Effect That Variable Amounts Of Iron In The Seeds Of Different Bean Genotypes Result In Different Amounts Of Bioavailable Iron In The Diet Of rats].

Wortmann C.S., Kirkby, R., Eledu, C.A., and Allen, D.J. (1998). *Atlas of Common Bean (Phaseolus vulgaris L.) Production in Africa.* [This is a well-illustrated reference on distribution of bean production and its problems in the African continent].

Biographical Sketch

Stephen Beebe received his Bs. Degree in Horticulture from Iowa State University (1974) and his Ms. (1976) and Ph.D. (1978) degrees in Plant Breeding-Plant Genetics from the University of Wisconsin. He has worked with the common bean (*Phaseolus vulgaris* L.) at the International Center of Tropical Agriculture (CIAT) since graduating. He was been based at CIAT headquarters in Cali, Colombia for two years before being posted to Guatemala from 1981 to 1985, when he was transferred back to Cali. He has worked on the development of varieties resistant to diseases (especially bean golden mosaic virus, for which several cultivars have been released) and abiotic stress (low soil phosphorus availability and drought). From 1992 to 1998, he concentrated on the study of genetic resources of common bean, including laboratory characterization with molecular markers, gene tagging, and phenotypic evaluation for agronomic and nutritional traits. From 1998 to the present, he has continued his work on varietal development involving biotic and abiotic stress, incorporating marker assisted selection into the selection procedure, and has initiated efforts to introduce nutritional quality into the objectives of the breeding program.