Genetic Improvement of Middle-American Climbing Beans in Guatemala (SO1.A1)

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Abstract
With approximately 11 million habitants, Guatemala is mostly a rural country, with 60 percent of the population living on farms and 50 percent of the population indigenous. Maize and beans are the main staple food in most households, with a per capita consumption of 9.4 kg per year. Since few other sources of protein are available, this amount is not sufficient to ensure an acceptable nutritional quality, especially within poor households.

The highlands of Guatemala are a unique bean producing region where intercropping (locally known as *milpa*) is still the main production system, mostly with a maize–bean association. The system uses climbing beans that grow around the corn stalks either concurrently or in a relay system. Unfortunately, on-farm productivity of these climbing beans is approximately one-third of their genetic yield potential, mostly due to the lack of improved cultivars able to withstand biotic and abiotic stresses. This low productivity significantly impacts food security and nutritional quality in the region, especially among women and children. Historically, climbing beans have received less attention and breeding efforts in comparison with the bush-type beans commonly grown in the lowlands, as shown by the significant yield gap between regions. The Legume Innovation Lab is starting a new project focused in the highlands of Guatemala with the goal of developing improved varieties of climbing beans that would increase productivity in the region. In addition, the Guatemalan climbing beans are a unique group of germplasm that has not been studied extensively and could offer new genetic variation for traits of economic importance.

Problem Statement and Justification
Dietary recommendations from the Guatemalan government suggest a 75:25 percent daily ratio of maize:bean for a good nutritional balance between carbohydrates and protein intake; however, collected information suggests that the actual daily maize:bean ratio in rural households is approximately 97:3 percent. As expected, the resultant lack of protein intake has reduced the nutritional quality in many households, significantly affecting children. Severe malnutrition cases and even deaths are reported in rural areas, mostly in the highlands.

Beans are grown on 31 percent of the agricultural land and mostly in the low- to mid-altitude regions (0–1500 masl [meters above sea level]) in a monoculture system. In contrast, intercropping (*milpa*) is the main production system in the highlands, where maize–bean is the most common crop association. The main bean producers are small landowners, largely in the highlands. These farmers plant 66 percent of the total area planted to beans in the country, yet the production is only 53 percent of the total national bean

production. In contrast, large landowners (greater than 45 ha) in lowland areas produce 28 percent of the beans on only 18 percent of the area planted to beans.

On-farm productivity of these climbing beans is approximately one-third their genetic yield potential, mostly due to the lack of improved cultivars able to withstand biotic and abiotic stresses. Fungal and bacterial diseases and insect pests are the main cause for yield reductions. In addition, production is made with almost no inputs of fertilizers or other chemicals. Historically, climbing beans worldwide have received less attention and breeding efforts in comparison with the bush-type beans commonly grown in the lowlands, as shown by the significant yield gap between regions. There is an existing collection of approximately 600 accessions of climbing beans collected across all bean production regions in Guatemala. This collection is kept by ICTA and has been characterized morphologically and with few molecular markers (6 SSR primers). In addition, this is a group of germplasm that has not been intensively studied and, therefore, may be an untapped source for new genes for resistance/tolerance to biotic and abiotic stresses that could be useful for the entire breeding community.

Objectives

1. Development of germplasm with improved disease resistance and agronomic performance.
2. Characterization of the genetic diversity of this unique set of germplasm.
3. A better understanding of the current socioeconomic status and needs of bean production within the context of intercropping systems in the region.
4. Capacity building: training the next generation of plant breeders for Guatemala and establishing a long-term breeding plan to increase the productivity of climbing beans in the region.

Approaches and Methods

The bean breeding program at ICTA has selected a group of ten accessions from the germplasm collection that offer agronomic traits of interest, such as plant growth type, seed yield, disease resistance, earliness, and seed quality, among others. We will start field testing these ten accessions across ten to twenty locations. At the same time, genetic purification of selected lines will be done. After the first year of field testing, the best two lines will be selected for field testing in growers' fields at three locations. Seed from promising lines will be multiplied and released to the public as a first generation of improved climbing beans while a more formal breeding program is being established. Given the uniqueness of this group of germplasm, it is necessary to ensure we are collecting all the genetic variability within this collection so it can be used in the future in breeding programs. To better understand the organization of the genetic diversity of this group, we will screen the core 300 accessions with the 6k BeanCAP chip and conduct a genetic diversity study of possible genetic relationships among the accessions. In addition, an assessment of variation within the ten selected lines will be made to account for the heterogeneity not only among but also within accessions and, possibly, to extrapolate that information to the rest of accessions. The collection will be also evaluated in the U.S. (greenhouse) for reaction to bean rust, anthracnose, Ascochyta leaf blight, bean common mosaic virus, and Mexican weevil. This core 300 collection could be used as a diversity panel that could be used for Genome Wide Association Studies (GWAS).

In addition, this project plans to do a small-scale socioeconomic study that will try to answer some of these questions. The results will help design future strategies to improve bean productivity and consumption in the region. A grower survey will be deployed in the main regions where climbing beans are produced. Results of this survey will be shared not only within the project but with other projects currently working in Guatemala (e.g., Másfrijol) and government agencies. A second phase of this study will evaluate the acceptability of new varieties by growers and in the last two years of the project, an assessment of adoption, dissemination, and impact will be made.

Anticipated Achievements and Outputs

- The development and release of improved climbing beans with better agronomic performance (four years).
- A better understanding of the organization of the genetic diversity within this unique set of germplasm (two years).
- Identification of genomic regions associated with traits of agronomic/economic importance (four years).
- An information database of the current market situation and production needs of climbing beans in the highlands of Guatemala (two years).
- Training of the next generation of plant breeders (four years).
- Establishment of a long-term breeding approach (four years).

Projected Developmental Outcomes

Improved germplasm/varieties of climbing beans are expected to be released after this four-year effort. Disease and pest resistance and greater tolerance to abiotic stress of improved cultivars should increase or produce more stable bean yields in the Guatemalan highlands. Collaboration with other projects will allow the dissemination of this genetic material to other regions, further increasing this project's impact. This project will also produce a new information database of the current market situation and production needs of climbing beans in the highlands of Guatemala

Capacity Building of Partner Host Country Institutions

Two individuals from Guatemala will come to do graduate studies at NDSU (Plant Sciences), with the goal that those individuals will be incorporated into agricultural research back into Guatemala. We foresee research projects focused on the analyses of genetic diversity, genetic resistance to diseases, and production systems, among others. The graduate students will be provided a broad range of training in conventional and molecular plant breeding techniques so that they can assume roles of leadership in bean research programs in the target countries. In addition, an informal workshop will be made at NDSU for some members of the bean breeding program at ICTA during the third year. The goal of this training workshop will be to show the ICTA group how bean production is conducted in North Dakota (the largest bean producing state in the United States) and to provide training on molecular markers and other genomic tools that could help in the breeding process.