AN INTEGRATED PROGRAM TO ACCELERATE BREEDING OF RESILIENT, MORE PRODUCTIVE BEANS FOR SMALLHOLDER FARMERS

EXECUTIVE SUMMARY

Common bean (*Phaseolus vulgaris*) provides essential nutrients and ecosystem services to developing regions of Latin America, the Caribbean, and Eastern and Southern Africa. Bean yields in these regions are severely reduced by abiotic stress, especially drought, heat, and low soil fertility. These constraints are intensifying over time because of soil degradation, population pressure and climate change. Past breeding for stress-tolerant beans has relied primarily on yield trials, which are imprecise, costly, and sample a limited range of environments and management options. Recent developments in crop physiology, phenomics, genomics, and technology dissemination present opportunities to accelerate breeding progress by targeting specific traits and integrating them into breeding programs via marker-assisted breeding, trait phenotyping, and trait-based selection, and provide adapted varieties to rural communities using new dissemination technologies. This project seeks to integrate these new tools to develop new bean lines with greater tolerance to drought and heat stress in Eastern and Southern Africa, Central America, and the Caribbean. The project integrates several mutually supportive efforts to accelerate bean breeding:

Breeding: A coordinated network of Bean Abiotic Stress Evaluation (BASE) trials will be initiated in the USA, Mozambique, Colombia and Honduras to screen germplasm. The breeding strategy will focus on specific traits that improve yield under heat and drought stress. Heat and drought tolerance derived from Tepary bean (*Phaseolus acutifolius*) will be used to improve common bean through interspecific crosses. Supportive traits including root rot resistance, tolerance to low soil P, high N fixation, and high seed Fe content will be combined with heat and drought tolerance in the breeding program. We will:

1) Initiate BASE trials for selection of promising germplasm with abiotic stress tolerance.

2) Select parents for breeding through genotypic and phenotypic evaluation of elite abiotic stress tolerant germplasm.

3) Implement two breeding strategies, incorporating novel phenomic and genomic tools, which focus on incorporation of stress tolerance traits in local seed types.

4) Develop and release stress-tolerant Andean and Mesoamerican germplasm, using these novel breeding strategies and validating farmer acceptability through participatory selection, by project completion.

Phenomics: Novel field phenotyping platforms will be used to characterize bean germplasm for useful traits, identify new sources of tolerance, and guide selection programs. For drought tolerance, we will focus on root traits that improve water uptake from drying soil, more efficient grain filling under stress, and optimized phenology for drought avoidance. For heat tolerance, we will focus on improving pollen function and grain filling. We will:

1) Profile bean germplasm for traits known to enhance drought and heat tolerance using association mapping panels and RIL populations that will enable marker development and gene discovery for traits of interest.

2) Evaluate new traits for improved stress tolerance.

3) Develop robust high-throughput phenotyping platforms to support gene discovery and breeding pipelines.

Genomics: Next-generation genomics tools will be deployed to identify loci conferring greater drought and heat tolerance. These tools include the recently completed sequence of the bean genome, genotype-by-sequencing methods, mature association mapping techniques, and broadly available database resources. We will:

1) Collect genotype-by-sequence data for 2000 common bean genotypes.

2) Perform association mapping analysis.

3) Identify genetic factors associated with key phenotype traits.

4) Design medium-high throughput assays for key breeding traits.

Social Sciences*:* Social network analysis will be used to develop new approaches to seed dissemination, and to improve understanding of the impacts of new bean lines on women and children. We will elicit women's preferences for traits and pilot educational materials targeted specifically to women, to increase household resilience under climate change. We will:

1) Analyze bean production and consumption trait preferences among women and families, conduct Participatory Varietal Selection with new bean lines at village sites, analyze constraints to adoption by women.

2) Using social network analysis, simulate outcomes of network-based approaches to innovation diffusion, and design, implement and test an Agroecological Innovation Campaign targeting beans. Assess impacts of new beans on household income and nutrition.

3) Develop and pilot educational materials to increase women's knowledge of common bean varieties and legume-based farming system options that they themselves can employ to increase family/household resilience under climate change.

Overarching themes of our strategy

1) Integration of genomics, phenomics, and social sciences to accelerate the breeding pipeline

We will integrate genomics, phenomics, and social sciences in the breeding pipeline to develop and disseminate bean lines with greater yield under stressful conditions and greater acceptance by women farmers. These efforts will be interdependent and synergistic.

2) Novelty

Each of the modules of this project will deploy novel tools and resources, many of which have been pioneered by team members. The project as a whole will be novel in applying modern tools and approaches to accelerate the breeding pipeline for abiotic stress, and in focusing on specific tolerance traits in a scientific breeding program rather than relying on yield under stress.

3) Focus

Our focus is to improve bean production for smallholder farmers in stressful environments. To achieve this goal we propose to address drought as well as heat tolerance, Africa as well as Central America and the Caribbean, and to incorporate complementary traits such as root rot resistance in our breeding pipeline. The breadth of this approach is necessary to achieve impact. Drought and heat are often present together in key production environments, and many of the traits of interest are important for tolerance to both stresses. The coordinated development of stress-tolerant germplasm from breeding programs across three continents will enable substantial synergies, especially in the application of tools, results, and lines across regions and stresses. Integrating multiple traits and stresses across regions will broaden breeding impact and will be more effective than a more narrow approach in producing cultivars with broad utility, acceptance, and impact. This project will sustain this comprehensive effort despite relatively limited funding by substantial synergies with the expertise, resources, and ongoing projects of team members.

Project outputs

This project will result in more targeted, efficient and effective breeding programs, and new climate-resilient bean germplasm and released lines with greater productivity for smallholder farmers, by creating critical tools, knowledge, products, and capabilities. Collaborative research, education and training with NARS partners will enhance their capabilities to carry this work forward in the future. The phenomics team will identify novel traits for heat and drought tolerance, develop high-throughput phenotyping platforms for new and existing tolerance traits, and use them to identify sources of tolerance traits in bean germplasm. The genomics team will use phenotypic data to identify markers and candidate genes controlling useful traits, and characterize their genetic architecture and distribution. The social science team will identify opportunities and constraints to the adoption and dissemination of new bean varieties, and develop educational materials to promote them. The breeding team will use this information to locate, pyramid, and deploy specific traits in ongoing breeding programs to accelerate the development of germplasm and released varieties with greater heat and drought tolerance, greater resilience to climate change, greater nutritional value, greater acceptance by women farmers, and greater benefits for rural communities.

Our team has an extensive history of successful collaboration, and includes leaders in bean breeding, bean genomics, bean phenomics, and the adoption and impact of bean lines. We are confident we can achieve our goals.