Genetic Improvement of Cowpea to Overcome Biotic Stress and Drought Constraints to Grain Productivity (SO1.A5)

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Abstract
Cowpea is a highly nutritious grain legume crop vitally important to food security in sub-Saharan Africa, especially for women and children, where it complements cereals in the diet. However, in the Sudano–Sahel region of West Africa, typical smallholder farmer cowpea yields are only 10 to 20 percent of known yield potential. Biotic stresses caused by insect pests and diseases caused by pathogens, parasitic plants and nematodes, and abiotic stresses from drought and low-fertility soils are primary constraints to cowpea grain production.

This project focuses on cowpea breeding with emphasis on insect tolerance and resistance traits, combined where feasible with drought tolerance and disease resistance traits. More specifically, tolerance or resistance to aphids, flower thrips, and pod-sucking bugs is being pursued through trait discovery and molecular-driven breeding selection to generate improved cowpea varieties. Field and lab-based phenotyping in Burkina Faso, Ghana, and Senegal will be matched with SNP marker high-throughput genotyping to identify and select for target QTL in the cowpea genome. Advanced breeding lines are being tested regionally across the host countries to broaden their release potential. In addition, several near-release advanced lines will be performance tested for full release decisions in Burkina Faso and Senegal, capitalizing on previous USAID CRSP investment. In California, cowpea dry grain novel market classes of breeding lines will be advanced together with leveraged funding in support of the U.S. dry bean industry. Primary capacity building in each of the host countries will be achieved by graduate degree training in cowpea breeding and genetics coupled with short-term annual training of NARS scientists in molecular breeding.

Problem Statement/Justification
In the Sudano–Sahel region of West Africa, typical smallholder farmer cowpea yields are only 10 to 20 percent of known yield potential. Biotic stresses caused by insect pests and diseases caused by pathogens, parasitic plants, and nematodes and abiotic stresses from drought and low-fertility soils are primary constraints to cowpea grain production. By targeting insect tolerance and combining, where feasible, with drought tolerance associated traits, we have a realistic opportunity to increase cowpea productivity. To be widely adopted, new cowpea varieties must have features desired by consumers as well as farmers, including grain appearance, cooking qualities, and processing characteristics. Breeding targets include large white grains with rough seed-coat, preferred throughout West Africa and amenable to direct dry milling; they can be marketed over a wide area, buffering supply and pricing in the region. Cowpea varieties with large white grain and resistance to pests would increase marketing opportunities in both

West Africa and the United States. Large rough brown seed type is also in high demand, especially in large urban centers in Nigeria. Current, premium rough-brown cultivars like *Ife Brown* are susceptible to pests and diseases and require genetic improvement. Our project targets West Africa cowpea production in FTF focus countries Ghana and Senegal, and also Burkina Faso, which offers regional importance from an agroecological perspective for cowpea yield gain.

The project aims to 1. discover insect tolerance and resistance QTL for cowpea breeding application; 2. increase the productivity of African and US cowpea producers through the development of improved varieties that possess resistance or tolerance to the major insect stresses combined with drought tolerance or disease resistance impacting cowpea production; 3. expand farmer marketing opportunities by breeding improved cowpea varieties with desirable grain characteristics; and 4. provide training and capacity building in modern cowpea breeding to African researchers.

The project employs genomics and modern breeding methods to improve cowpea for yield-limiting constraints, emphasizing insect tolerance and resistance. Significant gain can be made by targeting the major insect threats that occur at early (aphids), mid-flowering and pod-set (flower thrips), and later pod-filling (pod-sucking bugs) stages of the cowpea season. Some promising leads on resistance and tolerance donors and initial QTL identity have been made to provide good starting points in the project. High throughput SNP genotyping platforms, high density consensus cowpea genetic maps, plus numerous discovered QTL for important biotic stress resistance and abiotic drought and heat tolerance traits are now available. Several early generation populations carrying various target traits provide a valuable starting point for breeding advancement. We have been working closely with the CGIAR–GCP Integrated Breeding Platform program development using our cowpea data as a test user case; these technological advances are being applied to the project work.

Objectives

1. Discover QTL for insect resistance and apply in molecular breeding for target regions in West Africa and the United States.
2. Complete release and validation of advanced cowpea lines developed under the Pulse CRSP in Burkina Faso, Senegal, and United States.
3. Increase capacity of NARS in Burkina Faso, Ghana, and Senegal to serve the cowpea sector.

Research Approach and Methods

We have developed the necessary tools to exploit molecular breeding for cowpea, including genetic SNP markers; high density SNP-based genetic maps, including consensus maps; a high-throughput SNP genotyping platform for cowpea; QTL for many major biotic and abiotic stress resistance and tolerance traits; and accompanying software programs. These tools enable selection of multiple traits simultaneously across the genome. Under three subobjectives on aphid, flower thrips, and pod-sucking bug resistance, the approach is to discover and validate QTL underlying the target insect tolerance/ resistance traits, and then apply the QTL knowledge to breeding population development and advancement. The KASP SNP platform has 1,022 mapped SNPs providing excellent coverage across the cowpea genome. Breeding parents and progenies (individuals or bulked families) will be phenotyped and genotyped for QTL discovery or trait selection. Genotyping data will be used for both foreground (trait) and background selection. Three backcrossing populations per partner will be developed to combine insect tolerance and drought plus other traits carried by the chosen parents. Intercrossing of advanced backcross line will provide further opportunity to combine additional traits. Molecular profiling of insect populations in the target countries will be made to index biotype variation.

We are capitalizing on the previous Pulse CRSP breeding effort by completing the release requirements of advanced lines now in the final stages of performance testing. In Senegal, three prerelease large white grain type cowpeas and in Burkina Faso, 20 prerelease CRSP advanced lines require final on-farm multilocation performance testing. They will also offer the opportunity for tracking along the impact pathway as new releases entering the seed multiplication and distribution process in each country. Gender considerations have been incorporated into the trait selection process regarding grain types preferred by women farmers, processors of value-added products, and consumers. A second component of this objective is to use our SNP marker genotyping capability to advance the backcrossing of the BT gene insertion for *Maruca*-resistance into preferred varieties using breeding populations in Burkina Faso and Ghana. The genome-wide SNP data will be used to measure the percent recovery of the recurrent parent background to expedite the backcrossing selection process.

Anticipated Achievements and Outputs

- Biotype definition of aphid populations in response to aphid resistance genes in cowpea will produce new knowledge important to insect resistance breeding. Similar approaches will be made for flower thrips and pod bug insect populations.
- QTL governing cowpea tolerance and resistance to aphids, flower thrips, and pod-sucking bugs will be discovered and validated, providing new breeder resources (mapped QTL tagged with SNP markers and new understanding for their successful application).
- Improved cowpea varieties and advanced breeding populations of consumer preferred market types with resistance to biotic stresses and drought tolerance will be produced by recurrent backcrossing to introgress specific traits into preferred varieties, and recurrent selection to develop next generation varieties.
- Variety releases will be made from existing CRSP-developed cowpea advanced lines in Burkina Faso and Senegal.

Projected Developmental Outcomes

Higher yielding cowpea varieties will increase the nutritional status of diets for women and children in sub-Saharan Africa. Higher yielding, market-preferred cowpea varieties will generate additional family income to support improved living conditions and child educational opportunities. New knowledge of insect tolerance and resistance traits in cowpea will benefit grain legume breeding programs beyond the project host countries. Short- and long-term training will increase the likelihood of next generation cowpea breeders applying modern breeding in sub-Saharan Africa.

Contributions to Institutional Capacity Building

A combination of short-term and long-term training activities is being conducted to develop capacity in modern cowpea breeding in the NARS of Burkina Faso (INERA), Ghana (SARI), and Senegal (ISRA). The QTL discovery and molecular breeding activities provide an excellent training framework for both new and senior breeders in cutting-edge molecular breeding approaches. Training includes both short-term visits by HC breeders to UC Riverside, breeding workshops coupled to LIL and related project annual meetings, and long-term degree training to develop a new generation of cowpea breeders. Graduate students (two already enrolled) are being trained directly at UC Riverside in cowpea genetics, pathology, and molecular breeding, and also by mentoring those working on cowpea breeding dissertation projects at WACCI, Ghana, and other African Universities.