Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans for Resistance to Biotic and Abiotic stresses

**Principle Investigators**
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**Collaborating Scientists**
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**Abstract of Research Achievement and Impacts**
Certified seed was produced of three new bean varieties, Zorro black, Santa Fe pinto and Fuji Otebo released in Michigan in 2008; a new vine cranberry bean is under consideration for release; high-yielding black, navy, red, pinto and kidney lines with resistance to common bacterial blight and anthracnose were identified; and bean lines were screened for tolerance to drought as part of a doctoral study at MSU. In NY, root rot screening of new germplasm from MSU and Puerto Rico was conducted in the field and selections were made and returned to the research programs for use in breeding; greenhouse screening of lines from Ecuador against Rhizoctonia was also conducted. In Ecuador three varieties INIAP 429 Paragachi Andino, INIAP 430 Portilla and INIAP 480 Rocha were released to the public at field days during May 2009. Farmers from six CIAIs in the Choto and Mira Valleys grew six varieties and four advanced lines, and produced 5 T of high quality seed. A small seed storage and cleaning plant was established to handle this seed production. In Rwanda climbing beans: MAC 9, MAC 49, MAC 44 (adapted to low altitude zone); RWV 2070, Gasirida, RWV 2373, RWV 2269, RWV 1368, RWV 1892 (for mid to high altitude zones); and bush lines: RWR 2245, RWR 1668, and RWR 1180, UBR (96) 26, RWR 2091, RWR 3042, RWR 2240, RWR 2340 were planted, characterized and descriptors developed in readiness for their official release in the 2010A season. Research activities conducted by a doctoral student in Rwanda included the identification of collaborative partners for implementation of on-farm participatory field trials, survey of potential on-farm field sites, a survey of past and current agro-ecology research efforts, development and completion of farmer focus groups in three regions, and identification of challenges and areas for improvement in the ISAR participatory bean breeding program.

**Project Problem Statement and Justification**
Common bean (*Phaseolus vulgaris* L.) is the most important grain legume (pulse) consumed in Ecuador, and the most important protein source in Rwandan diets. Around 120,000 hectares of beans are cultivated annually in Ecuador, and common bean is the most widely grown pulse in Rwanda on 300,000 hectares. Both bush and climbing beans constitute an important economic income for farmers, and staple food for thousands of Ecuadorian families, and the vast majority of small scale farmers in Rwanda. Improvement of bean genotypes for Ecuador environments has a potentially significant spinoff in terms of the high potential for adaptation to Rwanda upland farming systems, which is one of the most bean-dominated production areas in the world. Smallholder farmers, many of them widows supporting families, are keenly interested in rebuilding their bean genetic stocks and expanding into new market opportunities as stability has returned to their country. Building on international bean germplasm, but particularly on the Ecuador experience and germplasm, a tremendous opportunity is present to develop and deploy improved bean varieties in Rwanda, using the latest molecular and client-oriented plant improvement techniques. An improved understanding of plant traits and genotypes with resistance to multiple stresses from abiotic (e.g. drought) and biotic (root rot and foliar pathogens) sources will provide unique materials for small-scale farmers, while providing insights into plant tolerance mechanisms for enhanced plant breeding.
methods. Results of this project would contribute to improved yield, farm profitability and human resources in the host countries and indirect benefit to participating U.S. Institutions and bean producers.

**Planned Project Activities for April 1, 2008 - September 30, 2009**

**Objective 1:** Develop through traditional breeding and marker-assisted selection (MAS) a range of large-seeded Andean bean germplasm with differing combinations of resistance to major foliar diseases in contrasting bean growth habits for distribution and testing in the highlands of Ecuador, Rwanda and the Midwestern U.S.

**Approaches and Methods:**
1. Breeding research activities, past and present was reviewed in Ecuador and Rwanda.
2. Assemble a nursery of 72 bush types that includes collection of advanced lines in March four seed types from
3. Seed was increased in Ecuador for shipping to Rwanda prior to main planting season in September planting main cropping season. The nursery included Andean types from both the U.S and Ecuador.
4. Select parental breeding materials for crossing in Ecuador, Rwanda and U.S.
5. Identify select group of lines from Rwandan breeding for crossing with new introduced lines from Ecuador
6. Cross Rwandan sources of resistance for Fusarium wilt and Pythium and major foliar pathogens into large seeded lines with contrasting colors
7. Utilize markers in early-generation selection for major disease resistant traits in Ecuador
8. Initiate marker-assisted selection in Rwanda
9. Yield evaluation of advanced lines in range of seed types in Ecuador, Rwanda and U.S. Exchange of most promising materials among the three breeding programs
10. Initiate seed increase of most promising lines
11. On farm trials with advanced lines in Rwanda and Ecuador
12. Release of three bean varieties in three commercial classes for production in Michigan

**Results, Achievements and Outputs of Research:**
- The MSU breeding program is considering the release of new upright vine cranberry bean variety. The plant type is less decumbent than the current vine varieties, and produces a large (55g) round seed with excellent canning quality. This would be the first vine cranberry bean to be released by the breeding program at MSU. The seed type would have commercial appeal in both Ecuador and Rwanda.
- Certified seed of three new varieties Zorro Black, Santa Fe Pinto and Fuji Tebo bean was produced in 2009 and will be available in sufficient quantity to meet needs of commercial growers in the U.S. in 2010. Over 3500 yield trial plots were harvested and 3800 single plant selections were made as part of the MSU breeding program activities in 2009.
- Research continues to develop a stable transformation system for common bean. The effect of different factors including media formulation, genotypes, and explants that influence both regeneration and transformation of common bean were studied. Six basal media formulations were evaluated for their capacity to induce direct regeneration and different hormone combinations were also assayed. Four bean genotypes, (Redhawk, Matterhorn, Merlot and Zorro) were tested to evaluate their capacity for regeneration and transformation. Merlot seems to be the best cultivar for regeneration in media formulations tested. Different types of explants, leaves, stem, cotyledonary node, and mature embryos were assayed. To date mature embryos were the only explants that have been able to regenerate. This work and the next two studies were conducted by doctoral candidate, Ms. Mukeshimana.
- In Rwanda more than 500 double cross and single cross F₁ seed derived from new or previous single
crosses for multiple resistances to major diseases were harvested in July 2009. The selected F₁ seed of the different populations were planted in the field along side the parental materials for seed increase and individual plant selection during the current season. The populations were created using some of the differential materials for angular leaf spot (MEX 54), anthracnose (G2333) and BCMV (USCR-7, USCR-9) that were acquired through this project crossed with adapted Andean lines from Rwanda. The full set of differential materials for angular leaf spot, anthracnose, bean rust and BCMV that were received from Ecuador, USA and Puerto Rico were maintained and are being used to create new F₁ Andean recombinant populations for advance in 2010 since greenhouse space is now available at Rubona.

- The variety selection process continued as different promising lines were selected from previous trials in 2008 after evaluation in the stepwise preliminary, intermediate, advanced and multi-location trials in Rwanda. These include bush and climbing beans in the low, mid and high altitude stations and on-farm test sites. Farmer participatory approaches were used to select for high yield, tolerance to diseases, general adaptability as well as for farmer and market preferences criteria among the advanced lines. New varieties SER 12, SER 14, SER 16, SER 30 were among the new bush types with good adaptation to the semi-arid conditions of Umutara and Bugesera zones of eastern Rwanda that were selected through the participatory approaches. Their potential yields range from 2.5 to 3 T per ha. They have small red seed types associated with good taste and red broth color, important in mixed diets with tubers and cereals.

- During the previous season, a field day was planned as an occasion to release new bush and climbing varieties to farmers. The following new varieties were planted, characterized and descriptors developed in readiness for official release in the 2010A season. The climbing beans are: MAC 9, MAC 49, MAC 44 (for low altitude zone); RWV 2070, Gasirida, RWV 2373, RWV 2269, RWV 1368, RWV 1892 (for mid or high altitude zones); while the bush lines are: RWR 2245, RWR 1668, and RWR 1180, UBR (96) 26, RWR 2091, RWR 3042, RWR 2240, RWR 2340 (for low, mid or high altitude zones). Nearly all the new varieties represent a diversity of seed color and are of Andean gene pool. The varieties will be released for yield, tolerance to diseases or drought and potential market attributes. The bush beans yield up to 2.5 T per ha, while the climbers have a potential yield of between 3 T to 5 T per ha and a complete description of the lines is available in attached table.

- Three promising red mottled lines TP6, ARME2BC2 S143 and, ARME II and two black lines G21212 y L88-63 were increased by the CIALs in the Choto Valley in Ecuador. The L88-63 is a drought tolerant line developed by former CRSP Project in Central America and Mexico (Frahm et al., 2004). Lines were also identified for use in the local canning industry. Seed increases of the promising lines for testing in canning trials were made and seed of I-402 and the two black lines G21212 and L88-63 were sent to SNOB-CIPIA Company in Quito for canning trials.

- During the Oct-Dec 2008 growing season, a group of 740 bush bean accessions from the germplasm bank in Ecuador were grown out to renew the seed and collect data on agronomic and phenological traits, disease reaction and seed traits. 94 accessions were identified with resistance to rust. Disease reactions in the selections were verified in 2009 season and resistant accessions will be used as parents in crossing program to improve resistance and broaden genetic diversity of materials in the breeding program. A collection of 152 local materials recently collected in six localities from north and south of Quito were evaluated in field at Tumbaco and agronomic and phenological characteristics noted prior to submission to seed bank in INIAP. Materials included 36 climbers, 3 were P. coccineus. Among the remaining bush types 78 were evaluated for drought tolerance under a rain shelter in an attempt to identify new sources of drought tolerance in local germplasm.

- The breeding program in Ecuador identified five large seeded advanced lines in 2008 with favorable agronomic comportment, resistance to anthracnose, rust, yield and seed quality were reconfirmed in 2009 season. A second group of elite lines selected from among 63 selections derived from crosses with BelDaMI RMR-16 were selected for rust resistance and represent new source of rust resistance in adapted red mottled bush lines. A third group 109 F4 lines derived from triple crosses were
screened and 26 F5 lines were selected for combination of anthracnose and rust resistance. An elite group of 6 lines with superior seed quality were selected from among these lines. A group of 258 F5 lines with multiple disease resistance (rust, anthracnose, angular leaf spot) were identified and will be further screened for yield, local adaptation and seed quality.

Objective 2: Develop inbred backcross lines in a range of commercial seed types for testing under drought and root rot pressure in Ecuador, Rwanda and the U.S.

Approaches and Methods:
1. Four inbred backcross line (IBL) populations will be evaluated in growers field under conditions of drought in Ecuador
2. Identify specific populations for in depth study in Rwanda
3. Advance other IBL populations with specific drought and root rot resistance traits are being developed
4. Evaluate 120 drought tolerant lines in a range of seed types from CIAT in Ecuador; a sub-set of the best lines will be tested in Rwanda
5. Complete characterization of 80 new local traditional lines collected from growers in Ecuador to determine level of drought tolerance
6. Trials will be conducted for root rot resistance sources in Ecuador each season
7. In Rwanda two screening locations have been identified for drought based on lower rainfall levels – no irrigation available; identify field site for root rot evaluation
8. Characterize germplasm for individual root pathogens at Cornell

Results, Achievements and Outputs of Research:
- The mapping population to identify QTL for drought resistance in photoperiod sensitive Andean population (CONCEPCIÓN * 2/RAB651) is being advanced in tropical environment by Drs. Beaver and Porch in Puerto Rico. The population will be evaluated under moisture stress in Rwanda in 2010. Meanwhile, genotyping of the parental lines with SSR markers has been initiated. To date, 200 SSR primers were run on the parents RAB561 and Concepcion and over one-quarter (56) showed polymorphisms between the two parents.
- Two preliminary greenhouse experiments at MSU were conducted to identify bean lines with high levels of drought tolerance. Seven cultivars Blackhawk, Jaguar, Phantom, Zorro, TARS-SR05, L88-63, and B98311 were tested in the study. The first experiment was conducted in 9-cm square plastic pots where moisture is withheld. The root is constrained in this system to investigate shoot mechanisms underlying drought resistance in bean seedlings. The second experiment was conducted in 10-liter black plastic pots where moisture was withheld. Various variables including maintenance of stem greenness, unifoliate abscission, wilting, trifoliate senescence, recovery after rewatering, and dry matter were recorded. Data are still being analyzed but it appears that the capacity of the bean plant to maintain a green stem might be associated with the recovery after prolonged moisture stress.
- At Geneva, NY a total of 19 bean lines mostly from the bean program of collaborators in Ecuador (also 3 pintos from Mexico and several checks including Pink Panther, CLRK and Red Kanner) were evaluated under greenhouse conditions in soil artificially infested with a highly pathogenic isolate of Rhizoctonia solani. Three trials were conducted during April-May, 2009, the first 2 to determine the appropriate inoculum density (disease pressure) for the evaluation and the third test/trial for evaluating the materials on hand. I-424 Concepcion, I-425 Fanesquero/Blanco, and Negro San Luis appeared the most promising as they had the highest number of surviving plants in the third test.
- During the June-September, 2009 growing season, a replicated root rot evaluation trial was conducted at the experimental root rot field at the Vegetable Research Farm, NYSAES in Geneva, NY. A total of 43 advanced bean lines and varieties were evaluated for their reaction to root rot pathogens. Symptoms of Fusarium, Pythium and Thielaviopsis infections were observed on infected plants, but
unfortunately no symptoms of Rhizoctonia infections were observed. In addition, severe and uniform infections (epidemics) of Common Bacterial Blight (CBB) and Viruses (symptoms observed suggested the presence of Clover Yellow Vein Virus, Bean Yellow Mosaic Virus, and/or Cucumber Mosaic Virus) occurred at this site in 2009. Thirty three of the entries included in this trial were provided by Dr. Tim Porch (USDA/PR), six from MSU and 2 form the NY bean program. All the susceptible checks included in the evaluation (DRK, Pink Panther, Hystyle and Goldmine) were highly susceptible to all the pathogens observed. However, the advanced breeding bean lines differed greatly in their reaction to root rot, CBB and/or viruses. Twelve advanced lines were selected for advancement in the breeding programs as well as to conduct a follow-up test in the greenhouse on their reaction to individual pathogens over the next few months as well as for possible re-evaluation in the field next season. Also, leaves have been collected from one of the susceptible checks (exhibiting 100% virus infections) and also from the 4 highly virus-tolerant lines to identify the virus(s) present in each line by Dr. Marc Fuchs in Plant Pathology department at Geneva.

- The effect of corn, wheat, oat, barely, buckwheat, rye, sudangrass grain crops grown as cover or rotational crops, on survival and infectivity of *Rhizoctonia solani* to beans. A former student Ms. Mana Ohkura completed her thesis showing that a number of strains of *R. solani* have become capable of infecting and surviving on corn, thus questioning our standard crop rotation recommendation for controlling this pathogens (Plant Disease 93:615-624; 2009). In June 2009, we established a replicated trial in field microplots to further investigate the impact of corn and other small grain on the survival of *R. solani* and its damage to the following bean crop. Soil of the microplots were infected with one of three strains of *R. solani* (AG 2-2, AG 4 and a Binucleate) and planted to the various grain crops. In late August, the crops were cut and incorporated into the soil. Two weeks after incorporation of the grain crops, the soils of the microplots were bioassayed for the infectivity of *R. solani* (on-going now). Next spring (May 2010), all the plots will be planted to beans (CELRK) and the incidence of *R. solani* infection severity will be recorded as well as marketable yield. Information collected will contribute to our ability to formulate a sound crop rotation recommendation against this important pathogen of beans in NY and elsewhere.

- Relating soil health status and management practices to root health and yield of beans and other crops. We are continuing our investigations on assessing the impact of soil health management practices individually and in combination on root health and yield of beans and other crops as well. Several growing cycles are generally needed before significant differences are usually observed. However, to-date we have found that snap and dry bean yield are increased in zone-tiled plots as compared to no-till or conventionally-tilled plots. Yield increases were observed in spite of only minor differences in root rot severity/root health scores were observed on the plants. However, a good contact of seeds and soil (firming of the planting zone/row) is critical for attaining good yield. Also, we have observed that yield of beans is reduced after a cover crop of grain rye than vetch or no-cover crop, probably due to nitrogen tie-up early in the season.

**Objective 3:** Collect and characterize pathogenic and genetic variability of isolates of root and foliar pathogens in Ecuador and Rwanda.

**Approaches and Methods:**
1. In Rwanda conduct surveys to diagnose major root diseases and collect isolates of root pathogens for characterization. Initial survey will be conducted in Northern highland production region
2. In Ecuador complete characterization of root rot isolates collected previously in both Northern and Southern production regions at Cornell and Ecuador
3. Access potential for germplasm/isolate interaction in greenhouse at Cornell
4. Collect isolates of anthracnose, angular leaf spot (ALS) in Rwanda for race typing
5. Continue race typing of rust and anthracnose isolates, and initiate characterization of ALS in Ecuador
Results, Achievements and Outputs of Research:

- Isolates of anthracnose collected in Ecuador and Rwanda were characterized on the differential series at MSU. In both countries Andean anthracnose races were identified. Race 1 and race 4 were identified in Santana and Caldera, Ecuador, respectively and in Rwanda race 27 was identified in Rwerere and race 55 in Ruhengeri. The later race is a very virulent Andean race capable of defeating all known Andean resistance genes. This underscores the strategy of using broadly resistant Mesoamerica genes such as the Co-4⁷ as the best resistance sources against these virulent Andean races present in both countries.

- Anthracnose was a problem in Michigan in 2009. Isolates were collected from growers’ fields and all typed out as race 73. Adequate levels of resistance to this MA race are present in current cultivars, but farmer continue to plant ‘bin-run’ seed of susceptible varieties with having it verified to be disease free. The problem is most obvious on white beans as the anthracnose lesions are quite noticeable but is less obvious on black beans where the problem continues to persist.

- Rust was collected again from bean fields in Michigan in 2009. The strain appears to be similar to that collected over the last two seasons. The new strain characterized as race 22-2 defeats many of the current resistance genes deployed in MI. A similar race 20-3 was recently detected in North Dakota. Race 22-2 has been found previously in the U.S. (Stavely, 1984; Plant Dis. 68:95-99) and coded as race 48, collected from N. Platte NE in 1982. Likewise 22-2 is the same as race 62 from PR, DR and FL (Stavely, Steadman, McMillan, 1989; Plant Dis 73:428-432). A race collected in Arenac county MI by Fred Saettler in 1975 (based on isolate code), characterized as race 40 has a very similar profile to race 48 or 22-2 (source Stavely, 1984) as it has the ability to defeat the Ur-3 gene. The fact that similar races have been detected in the past and not persisted may suggest that this race has a low fitness and this is borne out by the fact that infection occurs late in the season and is not very widespread. Resistance has been identified in elite MSU black and navy bean germplasm.

- Isolates of bean rust, anthracnose, and angular leaf spot have been extensively collected in Nyagatare, Gatsibo and Kabarore districts by ISAR staff in collaboration with students of Umutara University. The isolates are being preserved for race typing both in the screenhouse on the differential cultivars (sent to Rwanda in 2008) and by molecular analysis in collaboration with Cornell University.

- The experimental farm at Tumbaco has become a useful site to screen for resistance to Fusarium wilt caused by *Fusarium oxysporum*. The continual cropping of beans had lead to a build up of the pathogen in the soil. A group of 18 lines previously selected for resistance to wilt were re evaluated in this site and they exhibited high levels of resistance and will be used as parents in future breeding for resistance to Fusarium wilt. The program recently acquired access to a greenhouse at Tumbaco (2400m) for use in screening for resistance to angular leaf spot (ALS). Attempts to work with the pathogen at the main farm (Santa Catalina 3000m) proved ineffective due to colder temperatures at the higher elevation. Mist chambers were constructed in the greenhouse in preparation for screening with ALS. Monosporic isolates of six isolates of ALS collected from Northern valleys and from Tumbaco will be characterized on the differential cultivars prior to screening to ensure that adequate pathogenic variability is present in these races to screen the local bean germplasm.

**Objective 4**: Employ participatory plant breeding to assist the breeding process in Ecuador and Rwanda to enhance productivity and marketability of beans under development.

**Approaches and Methods:**

1. Design and validate sustainable farming practices including integrated nutrient and pest management systems for small farmers in Rwanda
2. Compare and contrast advanced line selection practiced by breeders and farmers in different agroecological regions in Rwanda
3. Evaluation of 10 tests in 10 CIALs each growing cycle in Ecuador
4. Facilitate non conventional seed production in Ecuador
5. Release of two bean varieties using farmer participation in Ecuador
6. Organize visit of Rwandan scientists to Ecuador to participate to interchange experience between investigators, breeding population management, germplasm banks, screening, and crossing at different INIAP research stations; interchange of experience on participatory methods and seed production for local community use with small farmer members in CIALs in Choto and Mira, Ecuador- anticipated date November 2009.

Results, Achievements and Outputs of Research:

- The scarcity of staking materials remains a big challenge for the adoption and expansion of climbing beans to newer farmers, especially those that live in regions where agroforestry has not been established in Rwanda. Following the learning exchange visit by Louis Butare and the experience from Ecuador bean breeding project, validation and demonstration trials of six different options for staking climbing beans were conducted in seven different sites last season. Through participatory evaluation, the farmers from all the seven locations opted for the option that reduces staking wood from the recommended 50,000 to 16,700 stakes per ha that were reinforced with strings and cords (picture available). A lack of staking wood, less labor and costs as well as environmental issues were sited as reasons for the ranking of the staking innovations.

- Approximately 10 tons of breeder and pre-basic seed of the pre-released and released bush and climbing beans mentioned above were produced on research stations in Rwanda. Seed was sold and distributed to farmers and farmers cooperatives; NGOs such as ADRA and to RWASCO, IMBARAGA, DERN, COAMV and RADA partners for secondary seed multiplication and distribution to more farmers. During the National Agriculture Show in Kigali on July 4, 2009, posters displaying new bean technologies: New Marketable Varieties; Integrated Soil Fertility and Root Rot Diseases Management; Staking Options; Variety Selection Scheme; as well as brochures of descriptors of 10 new varieties were displayed to thousands of show goers. Partner seed multiplication agents displayed and sold tons of seed of new varieties at the same show.

- Three varieties INIAP 429 Paragachi Andino, INIAP 430 Portilla and INIAP 480 Rocha were released to the public at field days during May 2009 to help promote the distribution of new bean varieties in different CIALs in the Choto and Mira Valleys. In addition to the growers who attended the field days technicians from eight public institutions and different NGOs were in attendance. Release of Portilla was attended by 46 farmers in San Clemente; Paragachi Andino attended by 36 farmers in El Juncal and a larger field day was attended by 150 growers from 11 CIALs in San Vicente de Pusir in the Chota Valley to promote all three new varieties. Production of these varieties is directed to consumption of fresh green shell and dry seed for both the national market and exportation to Colombia. Seed increases of promising lines selected by members of individual CIALs in Choto and Mira Valleys were increased during the second season 2008. Eleven farmers from 6 CIALs grew 6 varieties and 4 advanced lines, planted 275kg basic seed and produced 4,724 kg of high quality seed. With assistance from Foundation PRODECI a small seed cleaning plant was established in the Choto valley with storage containers and electronic balances and silos with 4 T capacity.

- A new CIAL was established in Pallatanga in 2008, with 49 people (35 men and 14 women) from different local communities and grower organizations in attendance. Preference was shown for new red mottled bush variety Portilla followed by Concepción, while red mottled varieties with short runners are still being evaluated. In canario seed types, preference for Guarandeño over Rocha was noted while in whites Blanco Belén was preferred over Fanesquero. Seed was evaluated in second season 2008 and based on seed quality the following varieties Yunguilla, Portilla, I-Libertador, Guarandeño, Rocha and Canario del Chota were chosen for planting at two locations in 2009.

Objective 4: Degree Training
Gerardine Mukeshimana, Citizenship: Rwandan – Major Professor – Kelly; Program started August 2008; Research focus will be on the development and study of drought tolerance in beans and part of the work will be conducted in Rwanda.(Research progress reported herein)
Krista Isaacs, U.S. - Major Professor – Snapp; Program started August 2008; Research focus is on agrodiversification of bean-based cropping systems and nutrition, and part of the research work will be conducted in Rwanda. (Research progress reported herein)

- Multiple research activities were carried out during a two-month visit to Rwanda in June and July 2009 by doctoral candidate Ms. Krista Isaacs. These research activities included the identification of collaborative partners for implementation of on-farm participatory field trials, survey of potential on-farm field sites, a survey of past and current agro-ecology research efforts, development and completion of farmer focus groups in three regions, and identification of challenges and areas for improvement in the ISAR participatory bean breeding program. These activities and findings were the first stage in ensuring the participatory bean breeding and cropping systems research focus in this project are appropriate to Rwandan scientists’ needs and farmer constraints. These activities and particularly the informal focus groups carried out with ~120 farmers have influenced the PhD research design and proposal of the graduate student Krista Isaacs, which will focus on developing sustainable bean cropping systems in collaboration with farmers.

- The national non-governmental organization Northern Rural Development based in Ruhengeri, Rwanda was identified as a collaborative partner for the implementation of on-farm research activities. Both ISAR and DERN have worked together on other projects and DERN has an extensive network of community extension providers and works in close association with farmer organizations. ISAR facilities will be used to conduct on-station trials in the cropping systems component of the project. Initial cropping systems trials will be carried out on-farm in northern Ruhengeri in three communities with farmers’ associations of 15 members each. Discussions with scientists from multiple organizations and a literature review of past and current agro-ecology research in Rwanda revealed emphasis on watershed management, new trials on spatial variations in intercrops for eastern Rwanda, and a focus on intensification of cropping systems. Farmer focus groups to gage farmer cropping system constraints and needs were conducted in twelve communities with an average of ten farmers present for each group interview. Results indicate that farmers have soil fertility constraints and some are willing to try green manures as an intervention. It was also found that farmers switched to monocultures of beans and maize due to a misinterpretation of government policy and reported higher yields. However, farmers almost always plant the intercrops with mixed (improved) varieties broadcast, whereas they plant monocultures in row with one improved variety. In addition, farmers that previously planted and ate beans, the staple crop and maize each season, now only harvest one of the crops per season. Farmers expressed interest in trying intercropping with improved varieties planted in rows. There was no indication that farmers used specific varieties of beans for different cropping systems. Challenges and areas for improvement in Participatory Variety Selection (PVS) were identified with ISAR scientists. These include the need to incorporate biological and ecological factors during site screening, training of stable staff that would enable the inclusion of PVS evaluations at earlier stages of bean development, training in the analysis of the data collection, modifications in group activities that encourage women to express their opinions, and additional planning and funding to support these various activities.

- Louis Butare from Rwanda visited the breeding program in Ecuador during November 2008 to study INIAP labs and field facilities and nurseries, visit different CIALs where cooperative work is underway to study participatory research approach and seed multiplication strategies currently working in Ecuador. Experience from that trip has been applied to bean staking studies in Rwanda.

**Explanation for Changes**

None

**Engagement of USAID Field Missions**

Kelly has visited the Agricultural Officer, Ryan Washburn in the USAID Mission in Kigali on two occasions to discuss the role and work of the PULSE CRSP in Rwanda and introduce HC partners Mr.
Musoni and Ms. Mukeshimana. The Mission in Quito is aware of CRSP activities in Ecuador and publications of project on variety releases and bean production practices prepared by INIAP were provided to the Mission Director during visit made by PI in 2006.

Networking and Linkages with Stakeholders
ISAR and the bean program hosted the first AGRA Legume Breeders Network that was held in Kigali in October, 2008. The Director of the Dry Grain Pulses CRSP, Dr. Irvin Widders, and the project PI, Dr James Kelly attended. ISAR collaborates with: Government Extension, Farmers cooperatives and seed production agencies, and NGO in Rwanda; World Vision, CARE, ADRA, CARITIUS, and Catholic Relief Services. NGO in Ecuador; PRODECI, PRODER, CRUZ ROJA, Agricultural Organizations; COPCAVIC, 10 CIALs, Grupo de Evaluadores de Frijol de Bolivar, Assoc. de Productores de Frejol de INTAG. Government Organizations; MAGAP, INIAP, Univ. Tecnia del Norte, and Univ. Catolica de Ibarra.

Leveraged Funds
The bean program in Rwanda continues to strengthen its collaboration with national, regional and international partners. The program leader Mr. Augustine Musoni participated in the Strategy and Priority Setting meetings for the non-staple crop program (NSCP) that was organized by ASARECA in July, 2009. The snap bean breeding project that was among all the ASARECA projects that had been suspended by EU donors was renewed. Leveraged funding, notably by government, national partners such as DERN, PABRA and AGRA, provide support to the project. Two new double cabin pick-up trucks were bought for the bean breeding projects supported by the Alliance for a Green Revolution in Africa (AGRA) and PULSE CRSP from MSU. The bean team leader participated in the PABRA joint ECABREN and SABREN Steering Committee that was held in Kampala in September, 2009. In October, he participated in the first AGRA Program for the African Seed System (PASS) General Meeting that was held in Mali. He presented a paper on the new climbing bean varieties due for release in the drought-prone zones of Rwanda. In Ecuador, the national government approved the project entitled: “Investigation and development of edible grain legumes (bush and climbing bean, peas, broad beans and lentils) to aid in the food security and safety in Ecuador”. The project will strengthen research being conducted by INIAP for a four year period to increase and improve the activities in edible grain legumes as part of the strategy of food security and safety. The project started July 3, 2008 but due to the global recession, funding has been rescinded.

List of Scholarly Activities and Accomplishments


Extension publications on new varieties in Spanish in Ecuador.
**Contribution of Project to Target USAID Performance Indicators**

- The development and release of locally adapted, acceptable and disease resistant bean cultivars for the major production regions in Rwanda, Ecuador and Michigan.
- Increased sustainable productivity and profitability of bean production due to increased yield and reduced inputs.
- Improved grower income and stability of bean production will contribute to better nutrition and health of farm families.
- Increased awareness and knowledge of participatory breeding methods, root health and soil health issues will further improve bean productivity, long-term land management, environmental risk, thus contributing to sustainability of bean production and agricultural communities.
- Identification of germplasm sources that are of benefit in the improvement of selected bean traits for the U.S. market.
- Enhanced human resource development, gender equity and improved infrastructure capacity of participating institutions in Rwanda and Ecuador.

**Contribution to Gender Equity Goal**
Two women students currently in doctoral training at MSU

**Capacity Building Activities: P1-MSU-1**

**Degree Training:**

**Student #1**

First and Other Given Names: Gerardine
Last Name: Mukeshimana
Citizenship: Rwandan
Gender: Female
Degree: Ph.D.
Discipline: Plant Breeding and Genetics
Host Country Institution to Benefit from Training: ISAR and National University of Rwanda
Training Location: Michigan State University
Supervising CRSP PI: Kelly, James
Start Date: 08/08
Project Completion Date: 08/11
Training Status: Active
Type of CRSP Support (full, partial or indirect): Full (Category 1)
Student #2
First and Other Given Names: Krista
Last Name: Isaacs
Citizenship: US
Gender: Female
Degree: Ph.D.
Discipline: Ecology, agronomy, nutrition
Host Country Institution to Benefit from Training: US and Rwanda
Training Location: MSU
Supervising CRSP PI: Snapp, Sieglinda
Start Date: 08/08
Project Completion Date: 08/11
Training Status: Active
Type of CRSP Support (full, partial or indirect): Partial (Category 2b)

Short-term Training:
Type of Training: Participatory plant breeding
Description of training activity: Organize and conduct participatory plant breeding and root/soil health training workshop in Rwanda planned for third year in 2010 but may be offered earlier in 2009 if possible

Status of this activity:
Reason if training activity not completed as planned:
When did the activity occur?:
Location: Rubona, Rwanda
Who benefited from this activity?:
Number of Beneficiaries: 30
   Male: 
   Female: 
   Total: 
**Project Title:**

<table>
<thead>
<tr>
<th>Abbreviated name of institutions</th>
<th>MSU</th>
<th>Cornell</th>
<th>Ecuador</th>
<th>Rwanda</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target</td>
<td>Achieved</td>
<td>Target</td>
<td>Achieved</td>
</tr>
<tr>
<td><strong>Benchmarks by Objectives</strong></td>
<td>10/1/09</td>
<td>Y</td>
<td>N*</td>
<td>10/1/09</td>
</tr>
</tbody>
</table>

*(Tick mark the Yes or No column for identified benchmarks by institution)*

**Objective 1**

- Review breeding program
- Andean bean nursery - Increase
- Plant Andean nursery
- Selection parental lines
- **Selection elite lines**
- **Nursery evaluation**
- **crossing**
- Marker assisted selection
- **Advanced yield trials**
- On farm trials
- Variety Release

**Objective 2**

- Advanced Population development
- Test Populations in Rwanda
- Other population development
- Characterize CIAT resistance sources
- Increase, characterize local germplasm
- Characterize germplasm to root pathogens

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**Objective 3**

| Survey root pathogens in Rwanda | x | x | x | x |
| Characterize root rot isolates | x | x | x | x |
| Root Pathogen x germplasm interaction | x | x | x | x |
| Collect foliar pathogens in Rwanda | x | x | x | x |
| Race characterization | x | x | x | x |

**Objective 4**

| Visit of Rwandan scientists to Ecuador | x | x | x | x |
| Workshop Participatory in Rwanda | | | | |
| Evaluation of elite lines in CIALs | x | x | x | x |
| Variety releases in Ecuador | x | x | x | x |
| Farmer vs. Breeder Selection | x | x | x | x |
| Sustainable practices, nutrient mgt | x | x | x | x |

**Name of the PI reporting on benchmarks by institution**

| James D. Kelly | George Abawi | Eduardo Peralta | Augustine Musoni |

**Name of the U.S. Lead PI submitting this Report to the MO**

| James D. Kelly |

**Signature**

Oct. 1, 2009

*Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Ecuador

MSU and Cornell: Research not completed due to the unavailability of characterized root pathogens isolates/genetic variants from the target work areas. The collection, purification, and characterization of pathogen isolates require the direct involvement...
**PERFORMANCE INDICATORS/TARGETS**

for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

**Project Title:** Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans for Resistance to Biotic and Abiotic Stresses

**Lead U.S. PI and University:** MSU

**Host Country(s):** Ecuador and Rwanda

<table>
<thead>
<tr>
<th>Output Indicators</th>
<th>2008 Target</th>
<th>2008 Actual</th>
<th>2009 Target</th>
<th>2009 Actual</th>
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<tbody>
<tr>
<td><strong>Degree Training: Number of individuals who have received degree training</strong></td>
<td></td>
<td></td>
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<tr>
<td>Number of women</td>
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<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Number of men</td>
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<tr>
<td><strong>Short-term Training: Number of individuals who have received short-term training</strong></td>
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<tr>
<td>Number of men</td>
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<tr>
<td><strong>Technologies and Policies</strong></td>
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<td></td>
</tr>
<tr>
<td>Number of technologies and management practices under research</td>
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<td>4</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Number of technologies and management practices under field testing</td>
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<td>3</td>
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</tr>
<tr>
<td>Number of technologies and management practices made available for transfer</td>
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<td>2</td>
<td>8</td>
<td>12</td>
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<tr>
<td>Number of policy studies undertaken</td>
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<td></td>
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<tr>
<td><strong>Beneficiaries</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Number of rural households benefiting directly</td>
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<td>3100</td>
<td>8300</td>
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<tr>
<td>Number of agricultural firms/enterprises benefiting</td>
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<td>2</td>
<td>9</td>
<td>19</td>
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<tr>
<td>Number of producer and/or community-based organizations receiving technical assistance</td>
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<td>54</td>
<td>110</td>
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<tr>
<td>Number of women organizations receiving technical assistance</td>
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<td>15</td>
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<tr>
<td>Number of HC partner organizations/institutions benefiting</td>
<td>18</td>
<td>8</td>
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<tr>
<td><strong>Developmental outcomes:</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Number of additional hectares under improved technologies or management practices</td>
<td>5400</td>
<td>1200</td>
<td>7000</td>
<td>14000</td>
</tr>
</tbody>
</table>

"Number of public-private sector partnerships formed as a result of USAID assistance" 8

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Rwanda: More than 200 T of seed of improved varieties has gone to farmers through ISAR and main partners (RADA, NGOs, CBOs and Farmers)

Ecuador: Over 250 T of seed of improved varieties has gone to farmers through INIAP

MSU & Cornell: Established actively collaboration with USDA-ARS Mayaguez to evaluate root rot germplasm at Geneva NY