Dry Grain Pulses CRSP Proposal
COVER PAGE (must print on one page)

Title of Proposal: Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans for Resistance to Biotic and Abiotic Stresses
Name(s), institutional affiliation and contact information of Lead U.S. Principal Investigator(s) submitting this proposal: **James D. Kelly** **Professor of Crop and Soil Sciences** **370 Plant and Soil Science Building** **Michigan State University** **East Lansing, MI 48824** **(517)355-0271 extension 1181** **(517)-353-3955 fax** **kellyj@msu.edu** **http://www.css.msu.edu/bean/**
Name(s) and institutional affiliation of all Host Country (HC) and U.S. Co-PIs **Sieglinda Snapp, soil biologist, MSU, farmer participatory research in Africa, snapp@msu.edu** **George Abawi, pathologist, root diseases, Cornell Univ. gsa1@nysaes.cornell.edu** **Eduardo Peralta, Instituto Nacional de Investigaciones Agropecuarias-(INIAP)** **Head of Legume Program- PRONALEG, at INIAP, Quito, Ecuador, legumin@pi.pro.ec** **PRONALEG team in Ecuador, includes two breeders, pathologist, biotech, pathologist, agronomist, participatory plant breeding, legumin@pi.pro.ec** **Mark Cyubahiro Bagabe, Director General, Institut des Sciences Agronomiques du Rwanda (ISAR), Rwanda, markbagabe@yahoo.co.uk** **ISAR team includes: Augustine Musoni (breeder) and Felicite Nsanzabera** **Gerardine Mukeshimana, bean breeder, National Univ. Rwanda NUR g_mukeshimana@yahoo.fr** **Joel Kajuga, Pathologist - ISAR; Vicky Ruganzu, Soil Scientist - ISAR; Joseph Mutware Socio-economist – ISAR**

Proposed Project Period: (30 months maximum, between April 1, 2008 – September 30, 2010)	**Total federal funds requested**	**Total non-federal cost share commitment by U.S. institution(s)**
	$449,893.00	**$45,625**

Proposed HCs where project activities will be implemented:	**Proposed HC institutions to be sub-contracted (abbreviated name):**	**Proposed budget for a sub-contract to a HC institution**	**Are you requesting the ME (MSU) to manage the Fixed-Price sub-contract for this HC Institution? (Yes/No)**
Ecuador **Rwanda**	**INIAP,** **ISAR, NUR**	**$136,000**	**YES**

Authorized lead U.S. institutional representative **(type name, phone number and e-mail):**<u>**Evonne Pedawi, 517-355-5040, pedawi@cga.msu.edu**</u> **Signature:** [signature] **Date:** 12-3-07 jp

Dry Grain Pulses CRSP Proposal

SUMMARY PAGE (must print on one page)

Title of Proposal: Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans for Resistance to Biotic and Abiotic Stresses
Name and Institutional Affiliation of the U.S. Principal Investigator: James D. Kelly, Crop and Soil Sciences, Michigan State University, East Lansing, MI 48824
Abstract (Limit: 1800 characters including spaces—about 200-250 words):
Pulse Crop of Focus ***(select at least one between beans and cowpeas)*** **Beans** ☒ **Cowpeas** ☐ **Other (specify):** ☐
Topical Areas to be Addressed By this Project ***Select one or more under Global Themes A-C:***
A. To reduce bean and cowpea production costs and risks for enhanced profitability and competitiveness. ☒ 1. Genetic Improvement ☐ 2. Integrated Crop Management ☒ 3. Mitigating Effects of Low Soil Fertility/Drought ☐ 4. Grain Quality ☐ 5. Sustainable Seed Systems
B. To increase the utilization of bean and cowpea grain, food products and ingredients so as to expand market opportunities and improve community health and nutrition. ☐ 1. Health and Nutritional Attributes ☐ 2. Consumer Attitudes and Preferences ☐ 3. Influencing Decision Makers ☐ 4. Urban Consumer Access to Value-added Pulse Foods
C. To improve the performance and sustainability of bean and cowpea value-chains, especially for the benefit of women. ☐ 1. Understanding constraints to smallholder pulse farmer participation in markets and trade ☐ 2. Identifying "weak links"/constraints in the functionality of dry grain pulse value-chains ☐ 3. Identifying strategic public sector interventions to alleviate constraints or market failures.
Select at least one from Global Theme D; If none selected from A-C, then select at least two:
D. To increase the capacity, effectiveness and sustainability of agriculture research institutions ☐ 1. Building and promoting partnerships with key stakeholders ☐ 2. Strengthening regional dry grain pulse commodity research networks ☒ 3. Training young scientists in the use of modern tools for research, management and outreach

Summary Checklist ***(select as many as appropriate)***
☒ Project addresses IEHA objectives (give anticipated level of effort as % of total budget requested):30 % ☐ Project devotes at least 30% of project funds on HC capacity building activities (Global Theme D) (give total % ☐ Project involves research on biotechnology as defined in the RFP (give % effort on biotechnology)20% ☐ Project involves the use or generation of genetically modified organisms (GMOs) ☐ Project involves human subject approval ☐ Project involves animal use approval ☒ Project involves M.S. or Ph.D. degree training of HC personnel (how many?)3

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

Technical Approach – 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. 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.

Priorities for Bean Improvement in Rwanda:

Beans are the second most important staple after maize in East and Central Africa. They are eaten as cooked dry or fresh grain (green shell), green pods or leaves by nearly all people in Rwanda, where they constitute 84% of the pulses grown and 65% of total plant and animal sources of protein diets (Sperling *et al*, 1992; FAOSTAT, 2007). Beans also contribute substantial amounts of energy (32%); micronutrients: iron, zinc and vitamins A and B that promote normal body and cognitive growth and development. Beans are particularly crucial in diets of the rural resource-poor that represent about 91% of the country's population. Due to their diversified nutritional value and dietary importance, beans are regarded as a *near-perfect* food in a pulse/cereal diet (CIAT, 1995), and as the *meat* for the poor (MINIPLAN, 1988). Beans have been grown in Rwanda since they were introduced into Africa in the 1600s (Debouck *et al.*, 1988) and Rwanda is considered an important secondary center of bean diversity (Allen *et al.*, 1990; Sperling, 2001). There are 12 agro-ecological zones in Rwanda and eight of the 12 zones in the southern, central, northern and north-eastern regions are particularly important for the cultivation of beans. Elevation ranges from 800 to 2300 masl; cool to warm temperatures of 18 C and 24 C; annual rainfall of 800 to 2000 mm and soils differ in type, reaction and fertility.

Bean are intensively cultivated on 320,000 ha, or about 30% of the arable land in Rwanda. Between 2000 and 2006, maximum annual production was over 300,000 tons and averaged about 232,000 tons of dry beans. On-farm productivity is about 800 kg ha^{-1}, about 2- 5 times less than the yield potential realized on research stations for bush and climbing beans, respectively. Though per capita productivity of bean seed is one of the highest in eastern and central Africa, Rwanda imports about 60,000 tons of additional grain annually from neighboring countries to offset the internal consumer market demand of 150,000 tons (Ferris *et al.,* 2002). This is partly caused by elevated per capita consumption of 50 - 60 kg, one of the highest in the world (about 3 times higher than Africa's average). Ferris *et al* (2002) have projected the deficit in bean demand to increase to over 300,000 tons by the year 2020 if the current trends of production and population increase (about 3%) continue.

Both determinate bush and indeterminate climbing beans are grown in Rwanda. Until recently, improved climbing beans were confined to the higher altitude zones, above 1800 masl, but they are rapidly expanding to lower altitude zones. Climbing beans occupied about one-third of the total bean acreage in the country and their adoption rate has steadily increased to 60% since they were introduced about 2 decades ago (Mugabo *et al.,* 2005; Musoni *et al*., 2001). The bush types are cultivated mostly in low and mid altitude zones, where their early maturity make them better adapted to the more drought prone zones in Rwanda. They are less labor intensive as they don't require staking. The indeterminate morphology is positively associated with the high yield potential of 3 to 5 t ha^{-1}. This represents three-fold increase of the yield of bush beans. Their extended growth pattern leads to sequential harvesting of leaves, pods and grain and ensures diversified nutrition and improved household food security for most of the growing season. The vigorous plant growth and above ground canopy creates unfavorable microclimates for disease and weed development that makes climbing beans more tolerant to biotic stresses than the bush beans (Sperling *et al*., 1992). The higher productivity of climbing beans has induced farmers to intensify production and to invest into planting fast growing and regenerating N-fixing trees like *Leucaena, Calliandra, Sesbania* and some grass species like *Pennisetum* on terraces to obtain stakes, and at the same time protect the soil against erosion. The residues from these species improve soil fertility, supplement animal feeds and cooking energy.

Prior research on beans in Rwanda was conducted by CIAT who were very active in the 1980s, especially with research directed toward climbing beans and seed/farming systems. Since the creation of networks under the Association for Strengthening Agricultural Research in East and Central Africa, and the relocation of CIAT to Kampala, Uganda, support has been channeled through ECABREN. This has involved germplasm exchange for specific constraints nurseries, e.g. drought and tolerance to low soil fertility, climbing beans etc. and some of the germplasm is bred at CIAT HQ. CIAT personnel have also backstopped beans research, especially during the lag period in the 1990s, after the war. They have been helpful in organizing (personnel, resources and facilities) training of ISAR staff, mostly short courses unlike that offered by MSU through the PEARL project. But funding has dwindled over time and currently there is only one project (BMZ) for participatory evaluation of drought tolerance materials introduced from CIAT, Colombia. The project supports a PhD and B.S. student. There is some work on biofortfication (beans), also under ASARECA/ECABREN, which is nearing completion with focus on seed production and dissemination. The only other project is to enhance competitiveness of snap beans for domestic and export markets but funding from the EU through ASARECA has been suspended as have all other EU proposals. Another project that was supported by ASARECA and just ended was: Application of Marker Assisted Selection (MAS) for the improvement of bean common mosaic necrotic virus resistance in common bean (*Phaseolus vulgaris*). Many of the markers used in this work were developed at MSU and some by a former Rwandan student.

CIAT, ECABREN and SABRN (South Africa bean research network) are united under the PAN Africa Bean Research Alliance, PABRA. They have the same sources of funding, but the funding of individual member countries is far from adequate. Currently ISAR is having problems financing activities. Because of this, PABRA and National programs are encouraged to develop bilateral proposals to meet research budgets and interests of individual member countries. Rwanda /ISAR is an active member within the PABRA framework and, despite the apparently lower capacity in terms of training and numbers, and infrastructure, many of the countries in the region have actually received and released a large number of bean varieties bred or selected and released in Rwanda, especially the climbing beans, since ISAR still has a comparative advantage. Since ISAR is active in ECABREN, they share germplasm, regional work plans and results etc. between countries. However, since funding by CIAT through PABRA has been reduced significantly, they have become more a partner (backstopping shortfalls) than a major funder. ASARECA has also undergone restructuring by combining and bracketing many existing networks into single (fewer) programs and the ECABREN may no longer exist or operate as has been the case in the past. As ISAR matures as an institution and continue to build capacities, they have to maintain the collaboration with all networks including PABRA, but they need to diversify research interests and partners/collaborators, so they are very interested in partnering with Pulse CRSP. ISAR has decentralized research into regional niches/zones at 10 research stations, and each zone has its own peculiarities in terms of biotic and abiotic socioeconomic constraints. They wish to tailor research proposals according to these zones and their specific conditions so as to avoid any overlap and activities would be more complementary. The PIs are looking forward with enthusiasm to the meeting in Barcelona, so that we can discuss and organize program details face to face with the host country PI and CIAT staff to ensure that all proposed activities are complementary and will not duplicate efforts of other programs or networks.

Bean production constraints in Rwanda:

The most important diseases of beans in Rwanda are angular leaf spot (*Phaeoisariopsis griseola*), root rot caused by complex of soil pathogens, particularly *Pythium, Fusarium and Rhizoctonia species* (Buruchara *et al.,* 1996), bean common mosaic virus (BCMV), and anthracnose (*Colletotrichum lindemuthianum)*. Ascochyta blight (*Ascochyta phaseolorum*) and halo blight (*Pseudomonas syringae pv. phaseoli*) are important diseases at higher and cooler altitudes (over 1700 m above sea level), while common bacterial blight and bean rust are more destructive in the warmer lower altitudes zones (1000 – 1400 masl). Angular leaf spot, anthracnose and root-rots alone cause annual loss of 761,900 tons in the eastern Africa region (including Rwanda). This accounts for 52% and 43% of the total grain yield loss attributed to all the biotic and abiotic stresses respectively (Wortmann, *et al*., 1999). These fungal diseases are responsible for yield losses of 220,000 tons per year, equivalent to $89 million in Rwanda (Trutmann *et al.,* 1993). The major insect pests include bean stem maggots (*Ophiomyia spp*) and aphids *(Aphis spp*), the vectors of the BCMV. Bruchids (*Acanthoscelides* spp and *Zabrotes* spp) are the important post-harvest storage pests. Due to population pressure (about 340 persons km^{-2}) and shrinking household land of less than 1 ha, cultural crop husbandry practices like fallow and rotations are not being applied in farmers fields. This exacerbates the cumulative effects and pressure of the diseases and pests on the bean crop.

The land scarcity also leads to intensive cultivation that depletes soil nutrients with little opportunity for replenishment (the rate of fertilizer application is estimated at 1.3-3% of the recommendation - Kelly *et al*., 2002; Gahakwa, 2005). Low soil fertility (low N, P) and acidity are therefore among the most important abiotic constraints and cause an estimated yield loss of 300,000 tons per year in eastern Africa (Wortmann *et al*., 1999). While annual rainfall (800 – 2000 mm) is adequate for crop production, its erratic nature is associated with spells of drought that limits yield in the low altitude zones, and contributes significantly to unstable and fluctuating national bean seed production. Poor adoption of improved bean varieties leads to low productivity in Rwanda. This in turn is linked with the lack of appropriate varieties and/or weak linkages within the seed value chain. Seeds of the common bean have different colors, shapes and sizes (market classes or seed-types) that impart mixed appeals among farmers, traders, processors and consumers. Small seeded beans are often preferred for better yield, especially in poor soils, while the large-seeded types are preferred for better culinary and market attributes. Similar to Ecuador, the large-seeded red-mottled, red, white and yellow market classes fetch premiums in urban markets in Rwanda (Ferris *et al*., 2002). The use of certified seed (and other inputs) among farmers is estimated at only 3% of the planted seed due to the weak seed and agro-input value chain system. Uncertified seed from informal sector serves as the predominant source of planting materials in Rwanda (Musoni *et al.,* 2006). Participatory plant breeding has been shown to be an effective means to develop and disseminate cultivars adapted to low yield environments, and to enhance adoption among smallholder clients who have not been served by conventional breeding programs (Atlin *et al*., 2001).

Priorities for Bean Improvement in Ecuador:

Climbing beans play a vital role in the farming system and livelihood of small producers in Ecuador, second only to corn in importance. The traditional intercropping system with maize predominates in Ecuador where 90% of the beans are grown in the highlands on landholdings that vary in size from 0.2 to 50 ha. Climbing beans are cultivated along the length of the inter-Andean mountain chain mainly in association with maize and part under trellis systems. The area cultivated with climbing beans has fluctuated annually, but is currently estimated at 97,000 ha. It is estimated that 90% of the area is planted with landrace or local varieties and the majority are susceptible to diseases, so a good part of the area lost is assumed to be due to presence of diseases such as rust (*Uromyces appendiculatus*), anthracnose, bacteria (*Xanthomonas, Pseudomonas* spp), viruses (BCMV) and insect pests (*Diabrotica* spp). In the system associated with maize, it is practically impossible to apply pesticides after cultivation as the rows close with the growth of the crop which is good from the health and environmental viewpoint, but not for the control of diseases and overall productivity. The bush types are planted in monoculture on some 24,000 ha. Bush bean production is one of the principle economic activities being conducted in the Valleys of the provinces of Carchi, Imbabura, Azuay and Loja and also in the foothills of the mountain range in Northwest Pichincha, Intag (Imbabura), Pallatanga (Chimborazo) and Chillanes (Bolivar). In these zones growers apply 3 to 4 applications of pesticides to control diseases and insect pests each growing cycle of 3 to 4 months. Beans are cultivated in two cycles per year in the valleys and one cycle in the foothills. Chemicals are used to control insects and diseases such as rust, anthracnose, angular leaf spot, bacteria, web blight, and root rots, in both improved and landrace varieties and inappropriate applications are made based on tradition, or on a calendar schedule or preventive - 'just in case'. The traditional control of diseases of beans in Ecuador is based on the exclusive and excessive use of fungicides which have produced levels of intoxication in growers and increased environmental contamination, production costs and the development of more aggressive and resistant insect pests and diseases. The recommended alternative to this problem consists of combining chemical control with genetic resistance. Finally, to reduce the use of fungicides and lower production costs, environmental contamination and risk to the farmers, the PRONALEG-GA program of INIAP is generating improved varieties with genetic resistance to diseases such as rust, anthracnose, and mosaic virus. These improved varieties contribute to a more sustainable production management system for the bean crop.

Drought is also responsible for the large disparity between potential bean yields and attainable yields in Ecuador and many other bean production areas in the world. In Ecuador, bean production is concentrated principally in highlands and valleys where limited precipitation and the lack of irrigation systems reduce the overall productivity of this staple crop. The principal bush bean production areas in the Chota and Mira valleys in Northern Ecuador are located in a dry ecological area "*Monte espinozo Pre-montano*" at 1,500-1,600 masl and receive an average annual precipitation of less than 400 mm. Since beans require a minimum of 400 mm of water to adequately complete the growing cycle, small-scale farmers who double crop beans face a deficit of natural precipitation. Confounding the problem are restrictive crop rotations that promote root pathogens and negatively effect overall root health. In order to optimize yields under these conditions, the most effective approach is the development of bean cultivars that possess resistance to root rots combined with root systems better adapted to the drought conditions of the region.

The importance of beans increased after the last change in the Government Food Policy and also due to changes in eating habits of Ecuadorians. The Government announced as part of the food program that grain legumes especially beans, produced locally, should be included in the diet of some 2 million Ecuadorian children. Additionally, the increased demand for processed foods for easy preparation has forced the private sector to increase the production of canned beans and the government has actually approached INIAP to develop varieties suitable for canning. Finally fast food chains have developed a series of meals that include beans as the demand for nutritious food grows. As a consequence the demand for beans has significantly increased and high stable bean prices to growers were maintained in the last two years (2006-2007).

Despite recent efforts to train additional scientists, there is shortage of qualified plant breeders, and other agricultural scientists and technicians in both countries. This shortage is felt more acutely in crop breeding as it embraces biotechnology for more precise and rapid selection of traits. Infrastructure in terms of modern laboratories (equipment and supplies), screen houses and transportation (vehicles) is also inadequate. This tends to limit effectiveness of on-stations and on-farm multi-location research. To lessen the deficit of bean production in Ecuador and Rwanda, it is imperative that research and development address prevailing diseases and pests (biotic), abiotic and socio-economic factors that constrain increased productivity, adoption and commercialization of beans in both countries. Research should be centered on several but integrated themes, with a general aim of developing and delivering adapted and farmer acceptable high yielding climbing and bush bean cultivars that are resistant and tolerant to the major constraints, along with packaged integrated management options to reduce the constraints.

Graduate training of scientists (PhD, MS) and targeted short courses for scientists and technicians, as well as the support of research infrastructure will be essential to improve the output, management and quality of research.

Objectives:

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.
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.
3. Characterize pathogenic and genetic variability of collected isolates of root and foliar pathogens in Ecuador and Rwanda.
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

Objective 1: The aim of the breeding programs in Michigan, Ecuador and Rwanda is to enhance bean productivity, minimize crop losses due to pathogens, pests and abiotic stresses and reduce production costs by eliminating the need to use pesticides as well as enhancing the acceptance and marketability of the new bean cultivars. The particular focus will vary by location but a common goal between Rwanda and Ecuador is to develop Andean bush and climbing bean lines that combine high yield with resistance against anthracnose, angular leaf spot, root rots (regionally specific) and BCMV in large-seeded solid red, red mottled, white and yellow colored market classes. A major goal of the breeding program in Ecuador is to develop bean populations with combined resistance to two or three important diseases such as rust, anthracnose, and angular leaf spot. Populations will be developed in different large-seeded Andean commercial bean classes using cyclic intermating systems followed by pedigree and single seed descent breeding methods to fix different resistance genes in single genotypes. The genes selected will be those identified as the most efficient to control the different races of the pathogen in Ecuador and Rwanda, based on pathogen surveys. The management, evaluation, and sequential selection in F2 to F5 generations will be conducted directly in the field and greenhouse. When appropriate, indirect selection using markers will be employed in earlier generations to detect desirable gene combinations to avoid gene interactions that occur with direct inoculation.

Ecuadorian germplasm could have additional value in Rwanda as it possesses desirable large seed size, in a range of colors and growth habit types. Previous work in Ecuador indicated that common strains of the most pathogens are Andean in origin so breeders deploy major Mesoamerican resistance genes. A similar strategy should be effective in Rwanda, based on work by Guzman *et al*., (1995), who showed that isolates of angular leaf spot in Malawi were strongly Andean. These data and personal discussions suggest that a similar type of virulence probably exists among bean pathogens in Rwanda. For example it is known that the Mesoamerican Umubano/G2333 genotype released in Rwanda has been a successful variety, and the anthracnose resistance has been durable and effective. A number of different large-seeded types from Ecuador now carry the same resistance gene(s) from G2333 and would be valuable germplasm to evaluate in Rwanda. Other potential sources of valuable germplasm for testing in Rwanda are Andean lines developed as part of B/C CRSP for Malawi which carry combinations of the *Co-4*^{2} and *bc-3* genes for resistance to anthracnose and BCMV, respectively. These were developed by Dr. Miklas using MAS and anthracnose resistance was confirmed by direct inoculation in Michigan.

To further broaden the genetic base of the Andean germplasm, the program will collaborate with Dr. Beaver at the University of Puerto Rico to access improved germplasm developed for the Caribbean basin. Germplasm from this region is recognized as a secondary center of diversity for Andean beans (Duran *et al.*, 2005) and would be a valuable source of new germplasm for testing in Ecuador and Rwanda. Large-seeded Andean germplasm for the Caribbean region bred to carry the *bc-3* gene are also available for testing. Since coevolution has been demonstrated in angular leaf spot, the Mesoamerican resistance sources being used by Dr. Rosas in Honduras will be valuable to test in both Ecuador and Rwanda. Collaboration will also be established with colleagues in CIAT and Brazil with expertise with this pathogen. In order to effectively test germplasm enhanced for different disease resistance traits a number of nurseries would be established with entries that possess enhanced levels of resistance to an array of different pathogens for regional testing in both countries across a range of environmental conditions. All advanced lines with multiple disease resistance, commercial seed quality and good yield potential coming from the two breeding programs will finally be evaluated using participatory approaches with groups of farmers in CIALs located in different locations (environments) in the principal bean production areas in both countries. The goal of the project is to release one or two lines as improved varieties for the different production regions.

The bean breeding and variety development program in Rwanda follows conventional methods, with minimal use from molecular tools, particularly the use of MAS. The current strategy is to complement conventional variety selection using MAS to shorten the conventional selection cycle, and improve precision by avoiding confounding effects of escapes and epistatic interactions between major resistance genes. Donor parents will include MEX 54 and G2333 as sources of genes that offer broad resistance against angular leaf spot (*Phg-2*) and anthracnose (*Co-4*^{2} & *Co-5*), respectively. SCAR markers, *SAS13, SH18, SBB14* and *SAB3* linked to anthracnose resistance, and *SN02* linked to *Phg-2* gene, shown to be effective in MAS (Kelly *et al.*, 2003; Young *et al.*, 1988; Miklas *et al.*, 2006), will be deployed as part of the breeding programs. A new SCAR marker linked to genes conditioning resistance to *Pythium* root rot, the other intransigent and major root disease of beans, is also in use after its identification from another Rwandan variety, RWR 719, which is routinely used as source of resistance of the disease in Rwanda (Buruchara *et al.*, 2007). MAS can be transferred to Rwanda based on the successful application of the technology in Michigan and Ecuador as scientists acquire more skill through training and as molecular laboratory facilities are further modernized at ISAR and NUR. The existing collaboration with regional partners that have the molecular lab facilities and expertise, particularly with CIAT in Uganda and with Dr. Gepts at the University of California, Davis will be strengthened. Experience from the breeding program in Ecuador where MAS is routinely being used to fix specific resistance genes can be applied in Rwanda. Plans to expand the repertoire of markers linked to a broader array of resistance genes will be pursued in Ecuador and Michigan. In addition, studies to characterize the rust resistance in large-seeded red-mottled genotype JeMa and the anthracnose resistance in Yunguilla will be concluded and markers linked to the unique resistance will be developed using bulked segregant analysis.

Progress to improve the overall productivity of Andean beans such as kidney and cranberry types in the U.S. have been limited when compared to other market classes in the Middle American gene pool (Beaver and Kelly, 1994). The overall lack of genetic variability in these classes is a contributing factor. Traits that need to be improved include yield, and resistance to root rots and bacterial diseases such as common and halo blights. Germplasm being enhanced for these traits would represent a valuable resource for testing and introgression into more temperate genotypes. Access to improved large-seeded Andean germplasm from Ecuador and Rwanda would offer some unique opportunities to expand the genetic base of US Andean beans and could contribute to future improvement in these classes. Consumer interest in Andean beans may be stimulated by recent reports that these types were more effective in reducing certain types of cancer when compared to Mesoamerican seed types (Thompson *et al*., 2007).

Objective 2: Drought, due to insufficient or unpredictable rainfall, has been identified worldwide as a bean production problem that is exceeded in magnitude only by bean diseases. Drought, whether intermittent or terminal in expression, can be intensified by high temperatures, or aggravated by shallow infertile soils, and root rotting pathogens. Recognizing that drought stress varies throughout the LAC region and East Africa, the nature of drought stress is critical to identify the genotype best suited to the particular stress. Drought tolerant germplasm identified in prior work in Mexico and Central America (Frahm *et al*., 2004) cannot be used directly to improve Andean germplasm but requires cyclic breeding methods to introduce the quantitative trait into the large-seeded types. Inbred backcross line (IBL) populations are under development using the inbred backcross method to develop population for testing for drought tolerance in genetic backgrounds that possesses the desirable agronomic and quality characteristics of the Andean beans. Sources of drought resistance being introgressed into large-seeded red-mottled and yellow seed types include L88-63, NSL, RAB 651, and RAB 655. Since there is a substantial time lag in developing these types of populations, in the short term we propose to collect and characterize bean landraces cultivated in semi-arid regions in Ecuador and/or Rwanda for their reaction to drought stress using a known differential set of international breeding lines for comparative purposes.

In Rwanda bush beans are nearly exclusively grown in the low altitude zones with low rainfall (800 – 1000 mm), as they escape drought due to short duration compared to climbers. Though the bush beans are less productive than the climbers, they are more plastic in adaptability to stress. In addition bush types are less labor intensive and easier to plant as they do not require any staking. The project will target the selection of early maturing and drought resistant bush and climbing bean varieties for drier production zones in the east of Rwanda. As part of the overall effort to study reaction to drought, a study of root architecture among selected genotypes which exhibited superior performance under limited water availability will be conducted to determine if specific root traits contribute to drought tolerance. The second phase of the project would involve a QTL analysis of the drought response of the IBL populations under contrasting environments of stress and non stress. The advantage of the IBL populations is that sufficient seed would available for extensive testing for traits that appear to play a role in determining response to drought. Identifying QTL associated with these traits and determining the role of specific root traits to biotic/abiotic stresses such as drought and root rot would provide breeders with additional tools to more efficiently select future stress tolerant varieties.

An essential part of drought tolerance in beans is overall root health. Initial work will be conducted to search for new sources of resistance to root pathogens with emphasize on evaluations of bean landraces collected in Ecuador and Rwanda. Field screening for root rots in both countries needs to be conducted to identify the types of pathogens and potential sources of resistance. Promising breeding materials and characterized bean collections from other programs will also be included in these evaluations. Initial evaluations will be conducted in established root disease nurseries in Ecuador, Rwanda, and NY. Bean germplasm lines that exhibit field resistance to root diseases pathogens, adapted to local conditions, and/or possess other desirable traits will then be evaluated in greenhouse tests for resistance to target single pathogens. It would be important to validate methods to evaluate resistance in poor soils with high disease pressure following inoculation with specific root pathogens and isolates in the greenhouse. In a final analysis it would be important to quantify the co-occurrence of superior yield performance under stress and root rot in drought prone shallow soils with high pressure of root rotting pathogens. The outcome of this work would be the development of marketable high-yielding drought tolerant bush and climbing beans lines released for the low altitude agro-ecological zones of Rwanda and the highland valleys of Northern Ecuador.

Objective 3: It is well established that most plant pathogens exhibit considerable variability in morphological traits, virulence, and genetic fingerprinting. Thus, it is critical to assess the genetic and pathogenic variability of the target pathogens of beans identified as a high priority in this investigation. The success of the breeding programs in developing durable and adapted resistant bean cultivars will requires the adequate representation of the genetic and pathogenic diversity of the pathogen(s) involved.

Isolates of the target pathogens will be collected from naturally infected bean tissues throughout the major production regions in Rwanda and Ecuador. The recovered isolates of the pathogens will be subcultured on appropriate agar media and, where possible, single spore cultures are then established and their identity confirmed. Standard microbiological and pathological procedures will be used to determine the virulence of the target pathogen on local commercial varieties and differential bean cultivars, available for rust anthracnose and angular leaf spot. Results of the latter tests will contribute to identifying the existence of races or biotypes among the collected populations of the target pathogen as well as the existence of cultivar/germplasm x pathogen isolate interactions. In addition, molecular techniques based on polymerase chain reaction will be used to further study the genetic variability and relationships among the isolates of the target pathogens. The identity of the genetic fingerprinting of the isolates will also be helpful in clarifying the difference observed in the reactions of bean cultivar to infection by various isolates of a pathogen and might also explains the factors involved in unusual disease outbreaks and yield losses.

To effectively screen germplasm for resistance to the predominant soilborne bean pathogens in New York, a root rot nursery (~ 1 ha) was established twelve years ago at the Vegetable Research Farm, NYSAES, Geneva, NY. The soil of this nursery is now heavily infested with *F. solani*. f. sp. *phaseoli*, *T. basicola*, *P. ultimum* and *R. solani*. Seedling emergence and stand establishment are recorded at 3 and 6 weeks after planting, respectively. The number of productive plants and seed weight are recorded at harvest. Root rot severity is assessed at the full-bloom stage (usually 6 weeks after planting) on 20 or more plants dug from one of the two rows. The washed roots are rated on a scale of 1 (normal root/healthy) to 9 (75% of root and stem tissues affected and decaying). Generally, germplasm lines with an average root rot severity ratings of 1-3, >3-6, and >6-9 are described as resistant, intermediate, and susceptible, respectively. Known susceptible and known or reported resistant germplasm (if available) are included for comparison and for determining fluctuations in root rot severity between growing seasons and monitoring which pathogen(s) are present.

The reaction of bean germplasm lines to a single pathogen, specific race/strain of a pathogen or combination of pathogens can be tested under greenhouse conditions. Seeds or seedlings of bean germplasm are planted in clay pots (≥10 cm in diameter) containing pasteurized soil (30 min at 60ºC). Depending on the target pathogen, the soil can be infested with the inoculum prior to planting, at planting time or at a specific seedling stage. However, several suggested methods for inocula preparation and inoculation techniques for the various root rot pathogens are available (Abawi and Pastor-Corrales, 1990). For example, soil-potato inoculum is effective for screening for resistance to *R. solani*. Bean seeds are planted in pasteurized soil mixed thoroughly with this inoculum preparation at a rate of 1-5% (vol. to vol.) or the infested soil is placed around the stem of emerging seedlings in a plastic or paper collar placed on top of the pots. Seed of grain crops or beet seed colonized by *R. solani* can also be used as an inoculum source and mixed with pasteurized soil or placed directly next to the seedling stems near the soil surface. For screening for resistance to the Fusarium wilt pathogen, it is best to first plant seeds in sterile sand or light soil. After one week, seedlings are removed; 1-cm segments are cut from the root tips, seedlings are dipped in a spore suspension of Fusarium and then transplanted into pots filled with pasteurized soil. Greenhouse evaluations have resulted in uniform, high infection rates and are generally simple, cost-effective and rapid. Greenhouse evaluations are ideal for characterization of resistance gene(s) to specific pathogens and assist in the development of molecular markers to such factors.

Objective 4: The approach proposed is to conduct participatory, client oriented-plant breeding to rapidly test and deploy new stress tolerant bean varieties with smallholder farmers in Rwanda and Ecuador. Advanced statistical and survey methods are improving the ability of researchers to work closely with expert bean producers (including many women farmers) and traders to identify and integrate bean seed quality traits within the plant breeding process. However, capacity building is required to provide support for integrating a client oriented approach across activities of Rwanda and Ecuador plant breeders, technical staff, and interdisciplinary scientists on the team (plant pathologists, agronomists and socio-economists).

Selection of populations and advanced lines will be done under participatory plant breeding approaches. The objective will be to document the criteria that the farmers and other end-users use to accept or reject the bred lines. Breeders with farmers will evaluate the bean lines across diverse environments. Breeders will solicit the positive and negative selection criteria from participants using open-ended and structured interactions. They will rate the “invisible” traits like actual diseases’ severity and productivity. Yield, market seed-types, plant architecture, vigor, maturity, tolerance to pests and poor soils, and perceived culinary traits will be among the traits to be assessed. Another strategy of the project will be to validate several options of good husbandry practices for water and soil fertility conservation (ridging, organic and inorganic soil amendments) and other integrated pests and diseases management, including cultural practices, soil amendments and bio-pesticides with farmers. This integrated approach is essential to improve bean performance, as it addresses the key agronomic constraints in conjunction with genetic improvement.

Participatory selection that is cognizant of seed quality traits and multiple uses of beans (for vegetable leaf and related products such as fresh beans) is particularly important for beans which are grown for home consumption, local and regional markets. Our approach will explicitly address this through the above described advanced on-farm trials, combined with expert farmer panels (including women and market traders) to identify preferred seed and vegetable quality along with cooking traits. Thus, the cultivars developed will have the quality traits essential for acceptance, in addition to improved pest resistance and stress tolerance. The trait information obtained that will be fed back into the breeding programs, to enhance selection criteria used at earlier stages.

Wide-scale dissemination of the promising cultivars identified through advanced breeding and participatory selection will be the goal of this integrated approach. A seed-to-market linked approach is key to deployment of cultivars by addressing simultaneously the need for: A) enhanced capacity for seed dissemination through building local seed supply and farmer access to improved seeds (e.g., farmer and informal private sector/trader seed enterprises); B) building capacity in seed quality production methods for the informal seed sector and C) link to socio-economists working in the target areas, for improved market access through market analysis and promotion. Use of quantitative methods (e.g., participatory research methods, surveys, etc) will be essential to train extension and agricultural scientists, so that systematic input from the demand side, from end-users regarding which seed traits (cultivar type and seed quality) are prioritized in scaling up efforts. The long-term goal is to improve capacity within Rwanda and Ecuador for an integrated demand-supply chain, for an effective bean seed sector that deploys improved bean cultivars rapidly to insure widespread access.

Training in participatory research methods, client oriented breeding and high quality seed production locally through informal as well as formal seed systems will be conducted. On-farm, participatory research trial design and statistical analysis methodology will be the focus this training. In Ecuador an advanced workshop will be held, building the skills of scientists and extension staff involved in on-going participatory plant breeding work. In Rwanda a two part initiative will be undertaken: A) a training workshop addressing the need for a general overview of methods will be held in conjunction with research activity planning so that workplans will incorporate the latest methodology in participatory, client-oriented breeding. B) A scientist involved in advanced graduate studies will be identified to be the point person for integrating participatory approaches through out the process of genetic improvement, and will help coordinate two advanced workshops – one focused on interdisciplinary, participatory approaches to improving bean health (including agronomy, genetics, root observations and pathology diagnosis on-farm) and the other workshop on improving seed system chains and participatory approaches to improve seed quality in informal seed production.

The project will provide training for national scientists and extension staff, to promote partnership with private sector and NGO's involved in informal seed sector. Our training in participatory seed quality methods (including testing quality at local venues, disseminating training materials widely to reduce dependence on a central lab). We will also enhance capacity in seed sector analysis to promote the non-conventional production of good quality seed of the improved varieties developed through the project, and the dissemination of new varieties in strategic areas identified by the project.

To promote improved bean health, this project will support the synthesis of information to develop and disseminate training materials on soil health issues, including participatory approaches working with extension on how to train farmers to diagnose and demonstrate the relationship of soil health to root health to plant health, thus improving yield and profitability (http://www.soilhealth.cornell.edu). This training exercise and participatory extension program will be conducted in both Ecuador and Rwanda, building on the advanced collection of visuals and experience at Cornell in above-ground symptoms and signs of root diseases on beans, below-ground specific symptoms and sign of infection of the various root rot pathogens, how to assess the extend of damage to stand establishment and roots, and the various practical and cost effective management options. The illustrated training materials will be made available in hard copies and also electronic files. The field trainings will emphasis and encourage do-it-yourself assessments of root disease incidence and severity throughout a planting with a simple design and careful sampling and examination of roots. Follow up on the impact of the root disease and soil health training will be conducted in collaboration of the extension educators in host countries through personal interview, simple and brief surveys and other appropriate means.

Benchmarks

The bean breeding team will focus on the development of large-seeded Andean race bean cultivars with greater disease resistance and tolerance to abiotic stress primarily drought. This should result in greater or more stable bean yields in the LAC, East Africa regions and the U.S. and less dependence on pesticides. Bean breeding lines and cultivars with significantly higher levels of anthracnose, rust, root rot and drought resistance will be developed. These new cultivars will permit growers to save disease-free seed for planting and increase bean production during the growing season when rainfall patterns are less favorable. Bean growers also will be less dependent on the use of fungicides to control rust. Drought tolerant beans will be valuable in the U.S. where production costs due to irrigation continue to increase resulting in lower economic returns to bean producers in certain regions of the U.S. Once molecular markers for specific genes for disease resistance have been identified and verified, they will be available to bean breeders to pyramid genes for resistance to create more durable disease resistance. The availability of robust molecular markers linked to disease resistance traits should accelerate the development of disease resistant bean lines for the U.S., LAC and East Africa. Most important multiple disease resistant bean cultivars are now a reality through the use of MAS. In the past, those bean breeders who were reluctant to work with specific pathogens now have the opportunity to indirectly select for multiple disease resistance in the absence of the pathogen. The incorporation of new genes for resistance into bean breeding lines will reduce genetic vulnerability to the emergence of new pathotypes of the angular leaf spot, rust or anthracnose pathogens, and help assure stability in bean production in targeted regions.

Specific outputs from this project are:

1. The development and release of locally adapted, acceptable and disease resistant bean cultivars for the major production regions in Rwanda and Ecuador.

2. Increased productivity and profitability of bean production due to increased yield and reduced inputs.

3. Improved grower income and stability of bean production will contribute to better nutrition and health of farm families.

4. 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.

5. Identification of germplasm sources that are of benefit in the improvement of selected bean traits for the US market.

30-Month Research Time-Line

Year 1, Quarter 1

1) Planning workshops in Rwanda and Ecuador
2) Training workshop in Rwanda on participatory techniques
3) Review bean research in Rwanda, including a literature review (referred and gray literature of performance of genotypes, bean cultivars currently recommended and survey data available on farmer uptake of bean)
4) Two PhD students identified from Rwanda, one MS student from Ecuador

Year 1, Quarter 2

1) Training workshop in Ecuador on advanced participatory techniques
2) Write-up and disseminate review conducted in Rwanda on state of bean research
3) Plan and conduct a baseline survey in Rwanda as a foundation for participatory research
4) Assess in strategic, representative areas the current bean cultivars grown, farmer and other stakeholders (market traders local and regional) preferences for seed quality traits, and level of current seed system function
5) Two PhD students start at MSU, and one from Ecuador start at Cornell
6) Plant breeding activities at MSU and Ecuador
7) Review plant pathology materials at Cornell to identify training and extension information to be reviewed by Rwanda and Ecuador staff

Year 1, Quarter 3

1) Conduct plant breeding and screening activities in Ecuador, including on-farm trials to evaluate advanced selections
2) Analyze data from baseline survey in Rwanda
3) Develop on-farm screening sites in Rwanda
4) Students take courses at MSU and Cornell

Year 1, Quarter 4

1) Analyze data from plant breeding and screening activities in Ecuador and Rwanda, summarize for distribution and discussion with team members
2) Initiate and improve pathology screening sites in Rwanda and Ecuador, establish disease nurseries at research site, screen houses for disease and pest tolerance evaluations, and establish plots with different soil health status through specific management practices working with farmers for participatory research screening sites (geo-referenced)
3) Prepare report and disseminate information from baseline survey in Rwanda through the bean network for Eastern Africa
4) Students continue at MSU and Cornell

Year 2, Quarter 1

1) Workplan development meetings in Rwanda and Ecuador
2) Initiate screening, and participatory research activities at on-farm screening sites in Rwanda
3) Conduct training in participatory root health and pathology methods in Rwanda and Ecuador
4) Conduct research at on-farm screening sites in Ecuador, and laboratory pathology and plant improvement research
5) Students continue at MSU and Cornell

Year 2, Quarter 2

1) Initiate screening, and participatory research activities at research sites in Michigan, Rwanda and on-farm screening sites in Rwanda
2) Conduct research at on-farm screening sites in Ecuador, and laboratory pathology and plant improvement research
3) Analyze data

Year 2, Quarter 3

1) Advanced genetic improvement work at MSU, Cornell, Ecuador
2) Participatory research activities at on-farm screening sites in Rwanda and Ecuador
3) Analyze and summarize plant breeding data
4) Review seed system function in Rwanda and plan collaborative activities to improve seed quality in informal seed sector

Year 2, Quarter 4

1) Carry out plant breeding research, screening materials for root health, priority tolerance, and yield stability
2) Training workshop on seed quality and seed sector function
3) Third student identified for graduate studies at MSU

Year 3, Quarter 1

1) Carry out plant breeding research, screening materials for root health, priority tolerance, and yield stability
2) Extension materials developed to support training of trainers in Rwanda and Ecuador on disease assessment and improvements in seed quality. Third student starts graduate studies at MSU

Year 3, Quarter 2

1) Produce report on plant breeding results documenting improved genotype performance across sites, participatory assessment of seed quality and root health characteristics
2) Extension materials developed to promote promising bean cultivars, presented at Bean network for Eastern Africa
3) Conduct a web-based short course on advanced integrated and client-oriented research approaches to testing agronomic by genetic improvement under stressed, on-farm conditions

HC Institutional Capacity Building

This project will support the training of two PhD degree students from Rwanda at Michigan State University. The two areas where training is being proposed are in plant breeding and genetics and in farmer participatory/agroecology. In the case of the latter the development of adapted and farmer-preferred varieties requires understanding of gene by environment interactions, agronomic performance and farmer selection criteria. Rwanda researchers and scholars have requested training for a PhD student in these research areas, participatory research advanced methods and agroecology. Given the importance of beans in the diets of Rwandans, having a doctoral scientist conducting breeding/genetic research in country should have impact not only Rwanda but in the region. The only Rwandan student to receive MS training in plant breeding and genetics as part of PEARL project worked on beans which speaks to the need to continue to support training in this area. This students' research project will be developed in close collaboration with the bean breeding and variety development and dissemination efforts of this CRSP funded project. We would hope to bring one student from ISAR and one from NUR following in-depth discussions with the PIs involved.

An MS degree in plant pathology at Cornell University will be the goal for a scientist from Ecuador. Cost effective approaches to conduct this important, long-term graduate training will be pursued, including students spending part of their time conducting research in host countries. Graduate training in Rwanda was identified as a very high priority, as human resource capacity requires rebuilding in this country. Plant pathologists are in demand in Ecuador given the wide diversity of crops, broad ecological zones and the serious negative impact of diseases on crop production. The current pathologist of the INIAP Experimental Station headquartered in the Department of Vegetable Protection is working on other crops and other projects and has not shown any interest in supporting the work on bean being conducted by the PRONALEG-GA (bean) team. Based on the experience of the last five years more significant progresses could have been made if the program had hired a plant pathology from the outset. Assessing the pathogenic and genetic variability among the prevailing root pathogens of beans in Ecuador will contribute significantly to the breeding efforts and the development of locally adapted, lasting, and root rot resistant bean cultivars. Thus, it is important to train a young scientist in the traditional and molecular techniques and protocols needed for characterizing the populations of the prevailing bean pathogens and their use in determining the reaction of promising bean germplasm. We will select a young scientist with the interest and proper qualification for enrolling in a M.S. degree program at Cornell University to conduct his/her thesis research topic on this specific topic.

Short-term training will be pursued as part of an integrated approach to building capacity in Ecuador and Rwanda in areas identified as priorities, supporting project objectives. These include workshops on quantitative participatory research techniques (statistical analyses, advanced survey methods and on-farm trial design and evaluation techniques), expertise in applied plant pathology and seed quality techniques, and on-farm research methodology. Follow up training will include an internet-supported short course for advanced training of trainers, including host country extension, researchers, private advisors and students. Education materials will be made available to support Rwanda and Ecuador research and extension staff in conducting more extensive training of front line staff and farmers, building institutional training capacity. Short term training of Rwandan scientists in Ecuador might be highly beneficial to both programs as the program in Ecuador has developed skills in molecular breeding. At some point of the project, once we have structured activities in Rwanda we will attempt to provide support to Zambia initially by sharing specific nurseries with them.

Research facilities upgrading, including laboratory equipment, field screening sites and equipment and logistical support will be important institutional capacity building to support human resource capacity. Acquisition of logistical facilities and research equipment will be particularly important in Rwanda, as a foundation for an effective and multidisciplinary bean improvement team. Training on pathology and agronomic on-farm research approaches will be complemented by strategic purchase of applied equipment to set up farm-based research using the latest techniques, including geo-referenced baseline information for on-farm screening sites, to facilitate layering and archiving of data as it is collected. Computing facilities and software upgrades in Rwanda and Ecuador will provide essential support for statistical approaches that staff will be trained in through the workshops proposed by this project. A 4-wheel drive vehicle will need to be purchased to support field work and participatory breeding activities in Rwanda.

Contribution to USAID Objectives and Initiatives

Both host countries, Ecuador and Rwanda participating in this proposal are USAID-eligible countries. Increasing bean yields will contribute to economic growth and improve the lives of the small scale producers and their families who produce the crop in both countries. The project provides a unique opportunity to continue to foster the development of large-seeded beans as part of a more mature breeding program in Ecuador and share these materials to strengthen and expand breeding activities with scientists in another continent. The development of bean cultivars with enhanced levels of resistance to biotic and abiotic constraints for Rwanda contributes directly to the Presidential Initiative to End Hunger in Africa (IEHA - http://www.usaid.gov/locations/sub-saharan_africa/initiatives/ieha.html). A major focus of the proposal is to train scientists in Rwanda in areas of plant breeding and genetics, agroecology (including participatory approaches to crop science integrated with genetic improvement) and one scientist in plant pathology for Ecuador which will help sustain future research in the general area of bean improvement in both countries.

The proposed research addresses a number of the major foliar pathogens that limit bean production on both continents. Diseases such as anthracnose are most serious for small producers who save seed, since anthracnose is a seed borne pathogen. The problem is perpetuated through the planting of disease infected seed. Other disease problems such as angular leaf spot continue to expand in many countries as global climate change causes temperatures to increase. Root pathogens are a particular problem as farmers are forced to shorten rotation cycles for economic reasons. The interactive role of root diseases in antagonizing susceptibility to drought is particularly serious as rainfall patterns appear to be more erratic around the globe and is particularly problematic for small producers who do not have access to irrigation.

The most important output of the proposed research will be the development and release of bean varieties with enhanced levels of resistance to biotic and abiotic constraints such as disease resistance and drought. The establishment of regional nurseries to test improved germplasm will be valuable throughout both regions where large seeded beans are grown. Experiences gained with participatory plant breeding methods in Ecuador can be shared with farmers and scientists in Rwanda as the final outcome of the breeding research – seed of improved bean varieties needs to be evaluated, multiplied and adopted by local growers.

Leveraging additional resources and funds

In Rwanda, beans are a priority food crop, and one that is being promoted as an import substitution and potential regional and international export crop in the current Plan for Strategic Transformation of Agriculture in Rwanda (MINAGRI, 2004). The breeding program has a record of past achievements, particularly with climbing beans and is one of the most active in Africa (Musoni *et al*., 2001). Currently there is a team of scientists (4 MS training – breeding, pathology) and technicians working on the crop directly and collaborating scientists in agronomy (soil science) are available at ISAR and UNR. A number of Rwandan scientists received training and Masters Degrees in a range of disciplines at MSU including Ms. Mukeshimana who received MS in plant (bean) breeding and genetics. Basic laboratory and office facilities exist at both institutions but improvements are needed. ISAR (and UNR) have 10 research stations scattered across all ecological zones of the country. These stations have adequate land for experimental work that is ideal for the evaluation of the respective biotic and abiotic constraints. In addition, ISAR and UNR uses multidisciplinary and multiple partnership approaches in research and for scaling up and expanding research products at the national (extension, NGOs, Farmers and Community Based Organizations), regional networks like the East and Central Africa Bean Research Network under the sub-regional organization, the Association for Strengthening Research in East and Central Africa (ASARECA) and with Future Harvest Centers (e.g. CIAT). The national regulatory environment and policies in Rwanda (closely guided by the millennium development and global poverty reduction strategies) are conducive and favorable to scientific advances.

In Ecuador, there has been change in government food policy toward nutrition, human health and locally produced crops including beans. The Government announced that grain legumes especially beans, produced locally, should be included in the diet of some two million Ecuadorian children. Additionally, the increased demand for processed foods for easy preparation has forced the private sector to increase the production of canned beans and the government has actually approached INIAP to develop varieties suitable for canning. As a result, the bean program at INIAP was recently funded through Proyectos CEREPS: Cuenta Especial de Reactivación Productiva y Social, Desarrollo Científico Tecnológico y de la Estabilización Social – Special Account for Social and Production Revitalization, Scientific Development and Technology and Social Stabilization to advance new technology development to enhance bean production in Ecuador. Finally fast food chains have developed a series of meals that include beans as the demand for nutritious food increases. As a consequence the demand for beans has significantly increased over the last two years which has helped support high stable bean prices to local growers.

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- M. S. Esteban Falconi, Bean breeder - INIAP
- Ing Nelson Mazón, Agronomist – INIAP
- Ing. Cristian Subia, Agronomist - INIAP
- Ing. Diego Rodriguez, Pathologist - INIAP
- Ing. Paula Estrella, Technician – INIAP
- Jose Pinzon, Technician - INIAP

BUDGET NARRATIVE:

Institutions: The financial arrangements of the project will only be established with CORPOINIAP in Ecuador and ISAR in Rwanda. We plan to involve a few scientists from the National University of Rwanda (NUR) as some of the current projects involve NUR scientists e.g. the phenotypic screening for drought and Al toxicity being conducted at the Karama/Nyagatare and Gikongoro sites. In the past, projects involving ISAR scientists have been administered through NUR without any problems.

Salaries & Fringe Benefits: A major portion of the grant goes to support the training of two Ph.D. graduate students from Rwanda, including travel to the US, and support to conduct research in their home country. The salary item in the budget is to provide research assistantships for the training of two graduate students from Rwanda. A third MS student from Ecuador will be trained at Cornell University. Part time support for lab technicians is included to conduct molecular marker development work at MSU.

Travel: The requested amount for travel is to cover the cost of travel during the 30 months of the project to visit with collaborators in Rwanda and Ecuador to assist in the planning of the proposed research, involvement in the diagnosis of disease problems and germplasm evaluation as well as to participate in the extensive outreach activities outlined in the proposal. Travel was estimated to cover costs of three researchers, Kelly, Snapp and Abawi to travel from the US to both Rwanda and Ecuador to set up the project and visit two countries annually to determine progress. In country travel is budgeted for scientists in the Host Countries and for students to travel to the US for training.

Equipment: A 4-wheel drive vehicle will be needed by the project in Rwanda as part of the field work being planned. The item could not be included in the initial budget because of higher start up and indirect costs in the first year and we needed to give priority to training in the first years. We will work with ISAR to find alternate sources of funding for the vehicle but we want to make clear that this is an item that will be needed should any additional supplemental funds become available through the CRSP.

Materials and Supplies: The amount requested will be used to cover the costs in establishing (land preparation and planting) and maintaining (fertilizer, herbicide, and insecticide products and applications, at the different proposed field evaluation trials for the bean root rot nursery in NY and for multiple sites in growers fields and research stations in both Ecuador and Rwanda. These funds will also be used to defray costs of conducting greenhouse trials as well as needed laboratory supplies including agar media and primers and other needs for molecular characterizations of the isolates of collected pathogens, and the molecular marker selection work planned as part of the breeding work.

Other: A workshop is planned for researchers in Rwanda for the third year of the project. Past experience has shown that it takes about $7,000 to conduct a workshop in Africa of about 3 days duration, mostly to cover the cost of accommodation at the venue plus per diems and travel for participants.

Indirect Costs: A total of $16,500 is requested to cover the IDC charged by Cornell (25%, which was kindly reduced specifically for this proposal by the Dean's Office of CALS). Indirect costs on first $25,000 is shown at 26% as the ME Pulse CRSP at MSU will manage the fixed-price subcontracts for the three locations, Rwanda, Ecuador and Cornell.

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Kelly, J.D., P. Gepts, P.N. Mikias and D.P. Coyne. 2003. Tagging and mapping of genes and QTL and molecular marker assisted selection for traits of economic importance in bean and cowpea. Field Crop Research 82: 135-154.

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Miklas, P.N., J.D. Kelly, S.E. Beebe, and M. W. Blair. 2006. Common bean breeding for resistance against biotic and abiotic stresses: From classical to MAS breeding. Euphytica 147:105-131.

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Musoni, A. and J. Mutware. 2006. From Research to Market: Assessment of Seed Systems Value Chain in Rwanda. Alliance for Green Revolution in African (AGRA). Bill & Melinda Gates/Rockefeller Foundation

Ohkura, M., and G. S. Abawi. 2007. Isolation and characterization of *Rhizoctonia solani* and related fungi causing diseases on vegetables in New York State. Phytopathology (Suppl.) 97: S86 (Abstr.).

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Sperling, L., O. Scheidegger, R. Buruchara, P. Nyabyenda, and S. Munyaneza. 1992. Intensifying Production among Smallholder Farmers: The Impact of Improved Climbing Beans. CIAT

Thompson, H.J., M.A. Brick and M.D. Thompson. 2007. Effects of *Phaseolus vulgaris* L. on the development of experimentally induced breast cancer**.** Presented at BIC 2007, Madison WI. http://www.css.msu.edu/bic/PDF/2007%20BIC%20Program%20&%20Abstracts.pdf

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Young, R.A. and J.D. Kelly. 1997. RAPD markers linked to three major anthracnose resistance genes in common bean. Crop Sci. 37:940-946.

Young, R.A., M. Melotto, R.O. Nodari, and J.D. Kelly. 1998. Marker assisted dissection of the oligogenic anthracnose resistance in common bean cultivar, G 2333. Theor. Appl. Genet. 96: 87- 94.

CURRICULUM VITAE

JAMES D. KELLY

Address: Department of Crop and Soil Sciences, Michigan State University
East Lansing, Michigan 48824

Phone: 517-355-0271 ext. 1181 FAX: 517-353-3955 EMAIL: kellyj@msu.edu

Appointment Date: June 1980 **Rank:** Professor

Specialty Area: Plant Breeding and Genetics **Current Appointment**: 85% R, 15% T

Education:

B.S.	Queens University of Belfast, N. Ireland, 1968, Botany
B. Agr. (Hons.)	Queens University of Belfast, N. Ireland, 1969, Agricultural Botany
M.S. 1971	University of Wisconsin, 1971, Plant Breeding & Genetics
Ph.D. 1974	University of Wisconsin, 1974, Plant Breeding & Genetics, Minor: Botany

Positions held (since terminal degree):

1994 - Present	Professor, Crop and Soil Sciences, Michigan State University, E. Lansing MI 48824
1985 - 1994	Associate Professor, Michigan State University
1989 - 1990	Visiting Professor, University of California, Davis
1980 - 1985	Assistant Professor, Michigan State University
1975 - 1980	Research Associate: Campbell Institute for Agricultural Research, Napoleon, Ohio

Professional Societies:
American Society of Agronomy
Crop Science Society of America
Bean Improvement Cooperative

Professional Activities:
President of the Bean Improvement Cooperative - BIC, 1998- present. http://www.css.msu.edu/bic/
Past president of W-150 Regional Project and Phaseolus Crop Advisory Committee

Professional Awards:
Distinguished Faculty Award of Michigan State University – MSU, 2007
Honorary Member of Michigan Crop Improvement Association – MCIA, 2003.
Meritorious Service Award from the Bean Improvement Cooperative - BIC, 1997.
Distinguished Achievement Award from the Bean Improvement Cooperative- BIC, 1989.

Profession Service:
Member of USDA-CSREES On-site Review team that evaluated the Plant Science Dept at North Dakota State University, Fargo ND, 6/23-26/1997.
Chair of the Center Commissioned External Review (CCER) panel that evaluated five projects in the area of plant breeding and genetics at the International Center, CIAT, Cali, Colombia. Projects included beans, cassava, rice and tropical legumes improvement programs throughout Latin America and Africa, 11/15-20/1998.
Member of Review Panel for USDA-ARS National Program 301: Genetic Improvement via Crop Breeding and Molecular Genetics, Beltsville MD, 1/28-29/2004.

Research Responsibilities:

Dry bean breeding and genetics with emphasis on the use of molecular markers to assist in selection for yield, plant architecture, processing quality, drought tolerance and disease resistance; participation in international agricultural activities related to genetic improvement in beans. http://www.css.msu.edu/bean/

Significant Outputs and/or Accomplishments:

Developed (with MSU colleagues) and released 34 dry bean varieties in 11 commercial classes. http://www.css.msu.edu/bean/Variety.cfm

Participated in development (with USDA-ARS colleagues) of 68 improved bean germplasm in seven commercial classes.

Participated in development (with International colleagues) of seven dry bean varieties for the semiarid highlands of Mexico and four varieties for highland Ecuador.

Identified 13 molecular markers linked to 10 different major genes that control resistance to distinct races of viral and fungal bean pathogens.

Identified QTL for resistance to white mold, root rot, drought tolerance and canning quality in beans.

International Activities:

Principal Investigator for project to improve drought tolerance in beans in the semiarid highlands of Mexico, Ecuador and Guatemala. Project is part of a LA/C regional effort funded by USAID and administered through the Bean/Cowpea CRSP. Kelly has successfully conducted annual winter nurseries in Puerto Rico since 1980.

Committees:

Year	**CSS Committees**
1981-88	Member of Bean Commodity Committee
1992- Present	Chair of Bean Commodity Committee
1981-99	Member of Commodity Policy Review Committee
2000- Present	Chair of Commodity Policy Review Committee
1985-86	Chair of Seminar Committee
1986	Chair of Social Committee
1988	Chair of Courtesy Committee
1988-91	Member of Agronomy Farm Committee
1988-89; 2002-03	Member of Graduate Programs Committee
1992-95; 1999-00	Member of Department Advisory Committee
2004-05	Secretary of Department Advisory Committee
2000-01; 2005-06	Chair Department Advisory Committee
2005-06	Chair Promotion and Tenure Committee
1999- Present	Faculty Coordinator of Saginaw Valley Research Farm
1999	Member of University Hearing Board and University Grievance Panel
2002- Present	Member of Michigan Agricultural Experiment Station PMERC Committee
1991- Present	Chair of mentoring committees for 3 Junior CSS faculty, member of 3 other committees

National	
1990- 2007	Principal Investigator of Bean/Cowpea CRSPproject in Mexico, Ecuador, Guatemala
1993-95	Member of Technical Committee of Bean/Cowpea CRSP
1987-88	Chair of National Dry Bean Research Task Force
1987-90	Secretary of Phaseolus Crop Advisory Committee
1991-93	Chair of Phaseolus Crop Advisory Committee
1997; 2000	Secretary of W-150 Regional Project (rewrite, 5-year renewal proposal)
1998	Chair of W-150 Regional Project

Refereed Publications (recent):

In print (120):

Miklas, P.N., K.M. Larsen, K.A. Terpstra, D.C. Hauf, K.F. Grafton, and J.D. **Kelly**. 2007. QTL analysis of ICA Bunsi-derived resistance to white mold in a pinto x navy bean cross. Crop Sci. 47:174-179.

O Boyle, P. D., W. W. Kirk, and J. D. **Kelly**. 2007. Use of marker-assisted selection to breed for resistance to common bacterial blight in common bean. J. Amer. Soc. Hort. Sci. 132:381-386.

Vidigal Filho, P.S., M.C. Gonçalves-Vidigal, J.D. **Kelly**, and W.W. Kirk. 2007. Sources of resistance to anthracnose in traditional common bean cultivars from Paraná, Brazil. J. Phytopathology 155:108-113.

Gonçalves-Vidigal, M.C., and J.D. **Kelly**. 2006. Inheritance of anthracnose resistance in the common bean cultivar Widusa. Euphytica 151:411-419.

Kelly, J.D., G.L. Hosfield, G.V. Varner, M.A. Uebersax, and J. Taylor. 2006. Registration of Capri cranberry bean. Crop Sci 46: 2706-2707.

Kelly, J.D., G.L. Hosfield, G.V. Varner, M.A. Uebersax, and J. Taylor. 2006. Registration of Sedona pink bean. Crop Sci 46: 2707-2708.

Miklas, P.N. K.F. Grafton, D. Hauf, and J. D. **Kelly**. 2006. Registration of partial white mold resistant pinto bean germplasm line USPT-WM-1. Crop Sci. 46:2239.

Miklas, P.N., J.D. **Kelly**, S.E. Beebe, and M. W. Blair. 2006. Common bean breeding for resistance against biotic and abiotic stresses: From classical to MAS breeding. Euphytica 147:105-131.

Caixeta, E.T., A. Borém, and J.D. **Kelly**. 2005. Development of microsatellite markers based on BAC common bean clones. Crop Breeding and Applied Biotechnology, 5(2):125-133.

Ender, M., and J.D. **Kelly**. 2005. Identification of QTL associated with white mold resistance in common bean. Crop Sci. 45:2482-2490.

Ernest, E.G., M.J. Bassett, and J.D. **Kelly**. 2005. A spontaneous mutation at a seedcoat pattern locus in the dark red kidney bean 'Red Hawk,' which changes seed from self-colored to the partially colored virgarcus pattern. HortScience 40:57-59.

Ibarra-Pérez, F.J., J. A. Acosta-Gallegos, B. Cazares-Enriquez, R. Rosales-Serna, and J.D. **Kelly**. 2005. Registration of 'Flor de Mayo 2000' common bean. Crop Sci.45: 2657.

Kelly, J.D., G.L. Hosfield, E.G. Ernest, M. Uebersax, G.V. Varner, and J. Taylor. 2005. 'Redcoat' Soldier Bean. HortScience 40:263-264.

Kelly, J.D., G.L. Hosfield, G.V. Varner, M.A. Uebersax, and J. Taylor. 2005. Registration of 'Condor' black bean. Crop Sci. 45:795-796.

Mukeshimana, G., A. Pañeda, C. Rodriguez, J.J. Ferreira, R. Giraldez, and J.D. **Kelly**. 2005. Markers linked to the *bc-3* gene conditioning resistance to bean common mosaic potyviruses in common bean. Euphytica 144:291-299.

Román-Avilés, B., and J.D. **Kelly**. 2005. Identification of quantitative trait loci conditioning resistance to *Fusarium* root rot in common bean. Crop Sci. 45:1881-1890.

Acosta-Gallejos, J.A., F.J. Ibarra-Perez, B. Cazares-Enriqez, A. Castillo-Rosales, R. Rosales-Serna, J. D. **Kelly** and S.P. Singh. 2004. Registration of 'Negro Vizcaya' shiny black bean. Crop Sci. 44:1866-1867.

Frahm, M.A., J.C. Rosas, N. Mayek-Pérez, E. López-Salinas, J.A. Acosta-Gallegos, J.D. **Kelly**. 2004. Breeding Beans for Resistance to Terminal Drought in the Lowland Tropics. Euphytica 136: 223-232.

Hosfield, G.L., G.V. Varner, M.A. Uebersax, and J.D. **Kelly**. 2004. Registration of 'Merlot' small red bean. Crop Sci. 44: 351-352.

Kelly, J.D. 2004. Advances in Common Bean Improvement: Some Case Histories with Broader Applications. Acta Hort. (ISHS) 637:99-122.http://www.actahort.org/books/637/637_11.htm

Kelly, J.D. and V. A. Vallejo. 2004. A comprehensive review of the major genes conditioning resistance to anthracnose in common bean. HortScience 39(6):1196-1207.

Melotto, M., M.F. Coelho, A. Pedrosa-Harand, J.D. **Kelly**, and L.E.A. Camargo. 2004. The anthracnose resistance locus *Co-4* of common bean is located on chromosome 3 and contains putative disease resistance–related genes. Theor. Appl. Genet.109:690-699.

Curriculum Vitæ

Sieglinde S. Snapp

Department of Crop and Soil Sciences — email: snapp@msu.edu
W.K. Kellogg Biological Station — tel: 517-282-5644
Michigan State University — fax: 517-432-2242

Hickory Corners, MI 49060 — **http://www.kbs.msu.edu/faculty/snapp/**

Education

Ph.D., Plant Physiology (1992) Vegetable Crops, University of California, Davis 4.0 GPA
M.S., Plant Physiology (1985) Agronomy Dept., University of Minnesota, St. Paul 3.6 GPA
B.S., Agronomy (1983) Agronomy Dept., Washington State University, Pullman 4.0 GPA

Experience

Associate Professor, Soils and Cropping System Ecologist (1/06 – current)
50% Research/25% Extension/25%Teaching. *Kellogg Biological Research Station and the Department of Crop and Soil Sciences, Michigan State University.* Research interests include cropping system design and ecologically based management practices, including plant root architecture for resilient, sustainable farming. Elucidating processes involved in nutrient efficiency, utilization of biologically-mediated access to nutrients through legumes and cover crops for improved soil function and promotion of healthy crop roots. I have developed and extended novel participatory research methods and on-farm research trial designs, which have been adopted in 20 countries in Africa and Southeast Asia by plant breeders and agronomists. Agronomic Advisor to the NSF-funded Long-term Ecological Research Row Crop trial at *W.K. Kellogg Biological Research Station, MSU*; I teach: International Agricultural Systems CSS 430.

Assistant Professor (11/99-5/04); Associate Professor, Vegetable Integrated Crop Management (6/04 – 12/05) **50% Research/50% Extension** *Departments of Horticulture and Crop and Soil Sciences, Michigan State University, East Lansing, MI.* Co-taught **Plant Mineral Nutrition 853** Supervised 5 graduate students, 1 post doctoral associate and 2 technicians.

International Scientist, Soil Management and Cropping Systems (6/96 – 11/99) International Crops Research Institute for the Semi-Arid Tropics (**ICRISAT**), Southern and Eastern Africa Responsibilities, based in Lilongwe, Malawi and Bulawayo, Zimbabwe. Initiated, funded and supervised network research trials with collaborators in 3 countries. Published new inorganic and organic fertility and cropping system recommendations, and nutrient budgets. Developed novel on-farm trial design methodology, developed and taught Soil Ecology Graduate course. Supervised 2 graduate students, 1 post doctoral associate, 5 technicians and served on 2 graduate committees.

Soil Scientist and Agronomist Fellow, **The Rockefeller Foundation** (12/93 - 5/96) Lilongwe, Malawi. Conducted research on integrated nutrient management in Malawi and Zimbabwe. **Adjunct Assistant Professor, University of Malawi**, Taught graduate courses in soil biology and fertility and cropping system ecology, co-supervised 2 MS graduate students
Research Fellow (7/94 - 9/94) **International Center for Tropical Agriculture** Cali, Columbia.
Post Doctoral Researcher (1/92 - 11/93) Department of Horticulture, **The Pennsylvania State University**. Advisors: Dr. J. Lynch and Dr. R. Koide
Research Assistant (9/87 - 12/91) Vegetable Crops Dept., **Univ. of California, Davis**
NSF Fellow and **Research Assistant** (7/83-12/86) Agronomy Dept., **Univ. of Minnesota.**

Honors and Professional Accomplishments

2004-06 Secretary, and Chair, Soil Quality Regional Research Committee, NCR59
McKnight Foundation External Reviewer; Legume Biodiversity for Africa
2000 Member of External Review Panel, The Rockefeller Foundation

Books

S.S. **Snapp** and B. Pound (Eds.) 2008. Agricultural Systems: Agroecology and Rural Development. Academic Press, 460 pages.
Pound, B. S.S. **Snapp**, C. McDougal and A. Braun (Eds.) 2003. “Uniting Science and Participation: Managing natural resources for sustainable livelihoods” Earthscan, U.K. and IRDC, Canada

Total Grant Support Obtained 3.9 million – recent grants:

2006 – 2009 McKnight Foundation $420,000 ‘Legume Best Bets to Acquire Phosphorus and Nitrogen and Improve Family Nutrition’ PI G. Kanyama-Phiri (Co-PI S. Snapp).

2005 – 2008 CSREES – USDA $754,000 ‘Partnering to Cultivate Organic Agriculture in Michigan and the Midwest’ PI S. Snapp (Co-PIs D. Mutch, J. Bingen, J. Biernbaum, M. Ngouajio and M. Brewer).

2005 – 2008 NSF – Biocomplexity Program $240,000 Co-PI S. Snapp ‘Understanding linkages between human and biogeochemical processes in agricultural landscapes’ (Lead PI at Cornell University L. Drinkwater total grant $1,380,000)

46 Journal Publications - Recent Articles:

Brook, W.J. and S.S. **Snapp**. 2008. Winter Cover Crops for Local Ecosystems: Linking Plant Traits and Ecosystem Function. *Journal of the Science of Food and Agriculture, In press*

Cichy, K A., S.S. **Snapp** and W.Kirk. 2007. Root versus shoot genotype and root traits in common bean *Plant Soil In press*

Snapp, S.S., K. Date, W. Kirk, K. O’Neil, A. Kremen and G. Bird. 2007. Root and shoot tissues of *Brassica juncea* and *Cereal secale* promote a healthy potato rhizosphere. *Plant and Soil* 294:55-72

Nyiraneza, J. and S.S. **Snapp**. 2007. Integrated management of inorganic and organic sources in an Alfisol enhance nitrogen efficiency and productivity. *Soil Sci. Soc. Am. J.* 71:1508-1515

Bezner-Kerr, R., S.S. **Snapp**, M. Chirwa, L. Shumba and R. Msachi. 2007. Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility. *Experimental Agriculture*, In press.

Drinkwater, L.E. and S.S. **Snapp**. 2007. Nutrients in agroecosystems: Rethinking the management paradigm. *Advances in Agronomy*. 92: 163-186.

Harrigan, T.M., D.R. Mutch and S.S. **Snapp**. 2006. Manure slurry-enriched micro-site seeding of biosuppressive covers. *Applied Engineering in Agriculture* 22:827-834.

Kravchenko, A.N., G.P. Robertson, S.S. **Snapp**, and A.J.M. Smucker. 2006. Using information about spatial variability to improve estimates of total soil carbon. *Agron. J.* 98:823-829

Snapp, S.S. 2005. Early planting enhances root growth in fresh market tomatoes. *Journal of Vegetable Crop Production. 11:117-13*2.

Snapp, S.S., S.M. Swinton, R. Labarta, D.R. Mutch, J.R. Black, R. Leep, J. Nyiraneza and K. O’Neil. 2005. Evaluating benefits and costs of cover crops for cropping system niches. *Agronomy Journal 97:322-332*

Snapp, S.S. and H. Borden. 2005. Enhanced nitrogen mineralization in mowed or glyphosate treated cover crops compared to direct incorporation. *Plant and Soil 270:101-112.*

Long, C., **Snapp**, S.S., D. Douches and R. Chase. 2005. Tuber yield, storability and quality of Michigan cultivars in response to nitrogen fertility and seed-piece spacing *American Journal of Potato Research 81:347-357*

Snapp S.S. 2004. Innovations in extension: Examples from Malawi. *HortTechnology* 14:8-13

Roman, B., S.S. **Snapp** and J.D. Kelly. 2003. Assessing root traits associated with root rot resistance in common bean. *Field Crops Research 86:147-156.*

Snapp, S.S., M.J. Blackie, C. Donovan. 2003. Realigning research and extension services: experiences from southern Africa. *Food Policy 28:349-363*

Snapp, S.S., R.B. Jones, E.M. Minja, J. Rusike and S.N. Silim. 2003. Pigeon pea for Africa: A versatile vegetable - and more. *HortScience*. *38:1073-1078*

Snapp, S.S. W. Kirk, B. Roman and J.D. Kelly. 2003. Root traits play a role in integrated management of *Fusarium* root rot in snap beans. *HortScience*38:187-191.

Snapp, S.S., G. Kanyama-Phiri, B. Kamanga, R. Gilbert and K. Wellard. 2002. Farmer and researcher partnerships in Malawi: developing soil fertility technologies for the near-term and far-term *Experimental Agriculture* 38:411-431.

Snapp, S.S., D.D. Rohrbach, F. Simtowe and H.A. Freeman. 2002. Sustainable soil management options for Malawi: can smallholder farmers grow more legumes? *Agriculture Ecosystems and Environment* 91:159-174.

Snapp, S.S. and S.N. Silim. 2002. Farmer preferences and legume intensification for low nutrient environments. *Plant and Soil*. 245:181-192.

Recent Extension Bulletins and Website

I coordinate a website on soil ecological management **www.safs.msu.edu/soilecology/index.htm**

Snapp, S.S. D. Smucker, R. Chase, W. Kirk, G. Bird and D. Douches. 2007. Michigan potato systems. S. Deming et al. (Eds.) Ecologically Based Farming Systems. MSU Extension Bulletin. E2983

Snapp, S.S. K. Date, K. Cichy and K. ONeil. 2006. Mustards: A Brassica Cover Crop for Michigan. Michigan State University Extension Bulletin. E2956 (New)

Oneil, K. and S.S. Snapp. 2005 Time Travel and Soil Quality, Vegetable CATalert Newsletter.Snapp S.S. and K.U.Date. 2004.Strategies to suppress root rots in snap beans. Great Lakes Expo Proceedings, December, 2004.

Snapp S.S**. and K.U.Date.** 2004**.** Mustard, rye and cover crops for healthy potato roots. The Michigan Potato Industry Commission. MPIC Newsline, November.

Snapp, S.S. 2004. Evaluating nitrogen availability in organically managed fields. New Agriculture Web-based Newsletter http://www.ipm.msu.edu/new-ag.htm, MSU IPM.

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Geneva, New York
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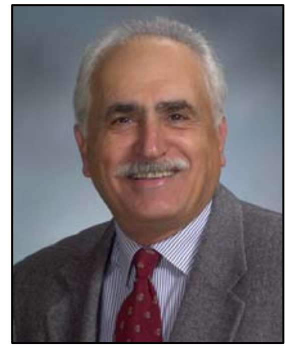
E-MAIL: gsa1@cornell.edu



EDUCATION

Year	**Degree**	**Institution**
1970	Ph.D. (Plant Pathology/Mycology)	Cornell University
1965	M.S. (Plant Pathology/Soil Micro)	Cornell University
1962	B.S. (Plant Science/Agriculture)	University of Baghdad

CURRENT RESPONSIBILITIES

Research (80%): Vegetable pathology, root diseases, biology and ecology of soilborne pathogens (fungi and plant-parasitic nematodes), integrated disease management (IPM), soil health and tropical plant pathology.

Extension (20%): Focus on developing and communicating sustainable and cost-effective disease management programs for vegetable diseases, especially root diseases caused by pathogenic fungi and nematodes. Special recent collaborations deal with a holistic approach to soil management for improving health and productivity.

PROFESSIONAL OVERVIEW

Major research responsibilities and interests deal with the ecology and biology of fungal and nematodal soilborne plant pathogens and the integrated management of their resultant root diseases. Commodity responsibility at Cornell is in vegetable crop pathology. Research projects conducted have been of a problem-solving nature and have included both applied and basic aspects of Plant Pathology and Nematology. All potential control measures such as seed and soil treatment with selected pesticides, cultural production practices, host resistance, and biological control have been investigated. Current projects are emphasizing microbial interactions, determination of damage threshold densities, biological control, identification and advancement of resistant germplasm sources, and the development of Soil-IPM programs for vegetable production systems. In addition, I have always been interested in international agriculture and have developed special interest in tropical diseases and their management. My future research objectives will be to continue the current thrust of the efforts leading to the wide implementation of sustainable Soil-IPM programs and also to emphasize collaborative research and training dealing with soil health as a component of the overall management and sustainability of soils and their productivity.

PROFESSIONAL EXPERIENCE

Professor: Dept. of Plant Pathology, Cornell Univ., NYSAES, Geneva, *1985-present*
Associate Professor: Dept. of Plant Pathology, Cornell Univ., NYSAES, Geneva, 1978-1985
Assist. Professor: Dept. of Plant Pathology, NYSAES, Cornell Univ., Geneva, 1972-78
Research Assoc.: Nematology program, Dept. of Plant Pathology, Cornell Univ., Ithaca, 1970-1972

Sabbaticals & leaves: Univ. of California–Davis, 1975-76; Univ. of Illinois-Urbana and North Carolina State Univ.-Raleigh (1978-1979); CIAT-Cali, Colombia (1985-1986).

HONORS AND AWARDS

1993	Elected Fellow, American Phytopathological Society
1977	Received the CIBA-Geigy Agricultural Recognition Award from APS

PROFESSIONAL SERVICE

2006-2009	Board member, Foundation, American Phytopathological Society (APS)
2005-2008	Board member, Office of Public Relations and Outreach (OPRO), APS
2006-2009	Member, Extension Committee of the Society of Nematologists (SON).
2001-2004	Director, Office of International Programs (OIP), APS
1998-2008	APS Representative to International Society of Pl. Path. (ISPP)
2003	Co-Chair, Local Arrangement Committee, SON Annual Meeting, Ithaca
1972-present	NYS Beans (snap and dry), Beets, Peas, Carrot and Onion Advisory Committee
2006-2008	Faculty Advisory Committee on Tenure Appointment (FACTA)
2004-2005	Member, CALS Faculty Environmental Task Force (2004 & 2005)
Various	Editor, Phytopath., Plant Dis., J. of Nematology, J. of Nematologia Mediterrana

PUBLICATIONS—RESEARCH AND EXTENSION (Selected few)

Gugino, B. K., J. E. Carroll, T. L. Widmer, P. J. Chen, and G. S. Abawi. 2007. An IPM program for managing fungal leaf blight diseases of carrot in New York. Plant Disease 91:59-65.

Gugino, B. K., J. W. Ludwig, and G. S. Abawi. 2006. Damage and management of Meloidogyne hapla using Oxamyl on carrots in New York. J. of Nematology 38: 483-490.

Yao, S., I. A. Merwin, G. W. Bird, G. S. Abawi, and J. E. Thies. 2005. Orchard floor management practices that maintain vegetative or biomass groundcover stimulate soil microbial activity and alter soil microbial community composition. Plant and Soil 271: 377-389.

Padgham, J. L., J. M. Duxbury, A. M. Mazid, G. S. Abawi, and M. Hossain. 2004. Yield loss caused by *Meloidogyne graminicola* on lowland rainfed rice in Bagrladesh. J. of Nematology 36:42-48.

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Cornell University
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November 29, 2007

Dr. James D. Kelly
Department of Crop and Soil Sciences
Michigan State University
East Lansing, MI 48824

Dear Jim:

This is to confirm my interest and willingness to collaborate on the proposal titled "Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans for Resistance to Biotic and Abiotic Stresses" that will be submitted for funding consideration under the new Dry Grain Pulses CRSP of USAID. As you know, I am especially interested in the diagnosis, biology, and management of root disease pathogens impacting bean production in Rwanda and Ecuador. Thus, I am hoping that I will be able to assist in the identification of resistance genes against root pathogens and their deployment into adapted bean cultivars, in the characterization of the genetic and pathogenic variability of major root pathogens involved and to the proposed participatory outreach dealing with root health and soil health issues.

I am truly looking forward to working with you and all the other collaborators in the US, Rwanda and Ecuador. Good luck and please let me know if you need any additional information at this time.

Sincerely,

George S. Abawi
Professor of Plant Pathology and International Agriculture