PII-PSU-1 WORKPLAN  
Improving Bean Production in Drought-Prone, Low Fertility Soils of Africa and Latin America – An Integrated Approach

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Project Problem Statement and Justification  
This proposal is premised on four well-established facts:

1) Drought and low soil fertility are principal constraints to bean production in Latin America and Africa.

2) Most bean producers in poor countries cannot afford irrigation and intensive fertilization.

3) Bean genotypes vary substantially for root traits that determine their tolerance to drought and low soil fertility, making it feasible to increase yields in low-input systems through genetic improvement.

4) To exploit the potential of this approach, we need intelligent deployment of root traits in bean breeding programs, and better understanding of the socioeconomic and agro ecological factors determining the adoption and impact of stress tolerant crops and cropping systems.

Drought and low soil fertility are primary constraints to bean production throughout the developing world. Phosphorus limitation is the most important nutrient constraint to bean production. What is needed is integrated nutrient management, consisting of judicious use of fertility inputs as available, management practices to conserve and enhance soil fertility, and adapted germplasm capable of superior yield in low fertility soil.

We have shown substantial variation in bean P efficiency that is stable across soil environments. P-efficient genotypes possess root traits that enhance P acquisition. Genetic variation for these traits is associated with large variation in growth and P uptake among related genotypes in field studies. Several of these traits can be evaluated in rapid screens with young plants, greatly facilitating breeding and selection.

Drought is a primary yield constraint to bean production throughout Latin America and Eastern and Southern Africa. Beans vary substantially in drought tolerance, due primarily to variation in root depth and thereby access to soil water, earliness (drought escape), and secondarily to seed filling capacity. Drought tolerance has been identified in several races
of common bean, but is complex and associated with local adaptation. Utilization of specific traits in drought breeding, through direct phenotypic evaluation or genetic markers (eg QTL) would be useful.

We need a better understanding of how stress tolerant genotypes affect the sustainability of their cropping systems. One concern is that P-efficient genotypes will ‘mine the soil’, although we have recently reported that P-efficient genotypes actually protect soil fertility by reducing erosion. Another concern is that more vigorous bean root systems may affect the performance of maize or other intercrops.

Genotypes that are more responsive to inputs may promote the use of locally available inputs such as sparingly soluble rock P. Similarly, bean genotypes with deeper root systems may be synergistic with soil management techniques to conserve residual moisture.

We need a better understanding of socioeconomic factors determining adoption of stress tolerant bean germplasm and the likely effects such adoption may have on household income and nutrition. Our team has observed that factors such as family structure may play a large role in determining whether the introduction of more productive germplasm is likely to have positive or even negative effects on household income and nutrition.

Drought and poor soil fertility are primary constraints to pulse production in developing countries. Recent developments in our understanding of root biology make it possible to breed crops with greater nutrient efficiency and drought tolerance. Such crops will improve productivity, enhance economic returns to fertility inputs, and may enhance overall soil fertility and system sustainability, without requiring additional inputs. The overall goal of this project is to realize the promise of this opportunity to substantially improve bean production in Africa and Latin America.

**Planned Project Activities**

**Objectives**

Objective 1: Develop bean genotypes with improved tolerance to drought and low P.

Objective 2: Develop integrated crop management systems for stress tolerant bean genotypes.

Objective 3: Understand constraints to adoption of new bean technologies, income and nutrition potential, and intra-household effects and impacts.

Objective 4: Capacity building.

**Objective 1:** Breeding

**Collaborators**

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Approaches and Methods

Honduras The activities in Central America (mainly Honduras and Nicaragua) will include continuation of objective 1 as in the previous two years including the testing of a set of small red inbred backcross (IB) lines (Amadeus 77 background) in farmer’s fields, to study the value of specific root traits under low fertility and drought conditions. This set will include 10-12 IB lines which have similar shoot growth habit, days to flowering and maturity, and seed type, but differ on their root characteristics and response to diverse levels of drought and low fertility stress. The results of these field trials will be used to determine if multilines will provide better yield stability than single lines under a varying drought/low fertility conditions encountered by small farmers in Central America.

This set of IB lines will be also tested for BNF in a low fertility soil at Zamorano. The BNF trial will include two *Rhizobium* inoculated treatments with strains CIAT 899 (*R. tropici*) and CIAT 632 (*R. etli*), and an uninoculated treatment, and five replicates. This research will help to determine if there is a relationship of specific root traits with greater nodulation and nitrogen fixation under stressed field conditions.

During FY11, advanced lines developed from crosses between drought and low fertility tolerant parents (previously identified by the project in collaboration with CIAT and the DGPC-UPR/Beaver breeding project) with disease resistant cultivars, will be distributed for testing to at least five countries members of the Central America and the Caribbean (CA/C) Bean Research Network. In addition, promising tolerant lines identified in previous years, will be validated and considered for release in Honduras and at least one additional country.

A set of advanced lines and cultivars, mainly small reds and blacks and red mottled from the DGPC-UPR/Beaver project, will be sent to IIA researchers for field testing and root phenotyping. The set of IB small red lines with Amadeus type developed for Central America, will be sent to IIAM researchers during this year for testing of the multiline approach on FY12, whilst a set of IB lines is developed using a Mozambique commercial cultivar as the recurrent parent, to determine if the approach is proven to be useful under representative farmer conditions.

EAP will assist IIAM to develop breeding populations to improve commercial cultivars using disease resistance, stress tolerant Mesoamerican lines. At IIAM development of IB populations will continue, as will evaluation of single lines and multilines from genotypes identified as promising in phase one at multiple locations in northern Mozambique. PVS approaches will be initiated in Mozambique, with guidance from JCR at EAP.

Since the EAP is part of the UPR/Beaver DGPC breeding project team and its collaboration with CIAT bean breeder (S. Beebe) and physiologist (I. Rao) has been increased significantly during the last five years, interaction with these breeding groups will continue to be emphasized under this project. EAP, UPR and CIAT are involved in the distribution and exchange of improved germplasm thru the CA/C Bean Research Network under EAP leadership. More specifically, partnership with CIAT during recent
years includes the bean biofortification project supported by CIDA in Latin America (2005-10) and the drought/low fertility breeding project supported by Red SICTA/IICA/SDC (2007-09) in Honduras and Nicaragua. Recently EAP and CIAT, in collaboration with CIMMYT and the national research programs, have prepared and submitted a proposal to IDRC for conducting a collaborative regional research project.

Mozambique
1) Seed increase
The objective of this activity is to increase seed of several genotypes identified in phase 1 and material that we will have received from our collaborators to be available for on-station and on-farm trials. We also do seed increase to maintain existing germplasm. Seed of P efficient and drought tolerant bean genotypes that were selected in phase 1 will be increased for future evaluations.

2) Testing and selection of bean genotypes
Several bean genotypes identified in Phase 1 will continue to be tested in on-station and on-farm to select genotypes tolerant to drought and low P conditions and adapted to Mozambique. During phase I of this project and the Mcknight project we identified bean genotypes with root traits suitable for low P conditions, and other genotypes with root traits adapted to drought tolerance. These genotypes will be evaluated in Sussundenga, Lichinga, Gurue under Phosphorus stress and in Chokwe under drought stress for yield performance. Promising genotypes will be selected for advanced trials. In parallel, we will be evaluating small red and black beans from Central America that will be received from in Honduras with sources of disease resistance and tolerance to drought and low P.

We will evaluate the performance and adaptability of red mottled bean lines with bc3 that performed well in Angola and Rwanda. Other bean lines to be evaluated in different sites in Mozambique include black bean lines that were screened for low N environment. These genotypes will be provided through collaboration with other DGP projects from Angola/Puerto Rico and Ecuador. The PVS approach will be used in on-farm evaluations so that the farmers can have the opportunity of selecting the varieties they prefer starting from the vegetative stage.

3) Phenotyping and screening bean genotypes for Low P and drought tolerance
Several bean genotypes will be screened in the greenhouse/field to identify genotypes with root traits suitable for drought and low P conditions. The root traits to be evaluated include root whorl number, basal root angle, adventitious and basal root number and length, and primary root length. Root branching is also another trait that will be evaluated. Genotypes with superior root traits will be selected for testing yield performance in Sussundenga, Lichinga and Chokwe. The other potential bean growing site for evaluations is Gurue. During the screening we will also be identifying sources of drought and low P tolerance that can be used as parents.

4) Testing F5 families developed previously
F5 families developed in previous project will be tested for adaptability and yield performance in different bean growing sites and superior lines will be selected for advanced yield trials. Currently we have more than 600 F4 lines and seed of F3 generations from different crosses that were developed using parents contrasting in root
hair traits. These lines are being evaluated for root traits in the laboratory and lines with superior root traits will be identified. Seed of these lines will be increased for advanced trials for identification of superior lines adapted to Mozambique. These lines will be candidates to be released and new varieties after testing in farmer’s conditions. The evaluations of the genotypes in farmer’s conditions will be in collaboration with extension services and NGOs working in the selected sites (Sussundenga, Lichinga, Gurue, Angonia, Chokwe). We will focus more on working with farmer that are organized in groups or associations. Some of NGOs collaborators include World Vision, Save the Children and CLUSA.

5) Development of bean genotypes and introgression of root traits suitable for low P and drought conditions

Crosses involving introgression of basal root whorl number and total number of basal root using genotypes identified from local germplasm and other root traits will be conducted. From our previous screening we have identified bean genotypes with high number of whorl and total basal roots that will be used as parents to develop bean genotypes adapted to low P soils. In addition, deeper-rooted genotypes were also identified previously that confer tolerance to drought. These genotypes will be used as parents to develop drought tolerant beans. Several early maturity genotypes and genotypes developed for drought conditions at CIAT were also preliminarily evaluated for adaptability in Mozambique. Promising genotypes will be submitted to advanced trials.

**Objective 2:** Integrated Crop Management

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**Approaches and Methods:** Activities will extend and expand on approaches employed in phase one, gaining greater reliability from evaluation at multiple locations and seasons, and with new lines as identified in objective one. Activities will continue to focus on agro ecological impacts and management synergies of new genetic materials, including effects on erosion, intercropped maize, and synergism with local sources of phosphate rock. In 2010 IIAM will obtain and prepare rock phosphate (RP) and lime; conduct in Chókwe a drought screening experiment to determine moisture deficit effects on yield of P-efficient, P-inefficient and selected lines; and conduct in Chókwe an experiment to determine moisture conservation techniques (mulch, no-till, microbasins) effects on growth and yield of P-efficient genotypes. In 2011 and 2012 activities from 2010 will continue, in addition, IIAM will establish, in Sussundega, Gurue and Lichinga, on-farm demonstration plots of drought tolerant, and P efficient common bean genotypes with moisture conservation techniques; establish, in Sussundega, Gurue and Lichinga, on farm demonstration plots of drought tolerant and P efficient common bean genotypes with moisture conservation techniques; conduct, in Chókwe and Sussundenga or Lichinga, a multiple-season pot experiment to determine available P release from rock P and liming effects on this, and incubation time effects on beans growth and yield; and in Gurue,
Lichinga or Sussundenga, conduct experiments to determine the effect of rock P and lime application on growth and yield of P-efficient genotypes.

The specific activities are detailed below:

2.1 Obtain in Nampula, and grind local rock phosphate (RP) and lime to use for the project activities. This activity is consists of manual grinding of RP, which has low productivity but is necessary to acquire enough material for the pot and field trials. Some areas of Mozambique have huge RP unexploited shallow reserves, which would make the mining profitable as cheaper P fertilizer. Although RP usually has no immediate impact in increase of yield as compared to commercial inorganic fertilizer, it has been reported to increase yields in the 2nd and 3rd years after application, especially in acid soils which are common in bean growing areas of Mozambique. Commercial inorganic fertilizer is both too expensive and also unavailable in remote areas of Mozambique mainly due to poor infrastructure. The outcome of our research on use of RP may become a driving force for private sector investment on small scale mining of RP which would make this fertilizer available to small scale farmers.

2.2 Conduct, in Chókwe, an experiment to determine potential synergy between moisture conservation techniques (mulch, no-till, microbasins) and drought tolerant bean genotypes. This research is a follow-up of identification of P-efficient common beans which are more susceptible to drought because of having shallow roots. To minimize susceptibility to drought some ‘best bet’ technologies for moisture conservation are good options for adoption by farmers in order to reduce yield losses in years of lower rainfall. In this study we hypothesize that moisture conservation techniques will significantly reduce yield loss of P-efficient and/or drought tolerant genotypes under water deficit taking full advantage of better growth in low fertility soils. The genotypes to be used are selected from drought screening trials conducted under the breeding activities of this project. The moisture conservation techniques are ‘best bet’ technologies that have been promoted for adoption by farmers in other projects. Therefore, we anticipate that they will be easily scaled up for use by bean producing farmers.

2.3 Establish, in Sussundega, Gurue and Lichinga, on farm demonstration plots of drought tolerant, and P efficient common bean genotypes with moisture conservation techniques. Drought tolerant genotypes that are outstanding in the drought screening trials conducted at Chokwe Research Station will be used in these sites. The priority will be to install the demo plots at farmers associations’ fields to maximize the exposure of moisture conservation techniques, and the drought tolerant as well as P-efficient new genotypes. Other important strategies to maximize the exposure and adoption of moisture conservation techniques and the new genotypes are the links with NGO’s and local public extension who will be our collaborators and, as more genotypes are selected by farmers, can help to multiply them and extend these technologies beyond the area and time frame of our project.

2.4 Conduct, in Chókwe or Sussundenga, a multiple-season pot experiment to determine available P release, from rock P and lime effects, and incubation time effects on beans growth and yield. It is well known that the RP effects on crop growth and yield is not immediate. It is a result of P mining which gradually make the P more available for uptake by plants. Therefore, the research on use of RP involves multiple season trials. Although the P-efficient genotypes can grow better and attain higher grain yield under
low P, some very poor soils impair the growth of beans due to limited minimal P substrate. The RP appears to be a local P source that can be alternative for P amendment to improve yields. However, we are not aware of previous research ion the utility of RP for bean fertilization in African soils, hence the need for this study. The results of our work may create business opportunities for rock P mining and marketing since refined fertilizers are not available in remote areas due to poor infrastructure.

2.5 Write and submit reports.

Objective 3: Socioeconomics

Collaborators
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Bayou Demeke, CIMMYT-Nairobi
Maria da Luz Quinhentos, IIAM. Mozambique

Approaches and Methods: Phase II project activities will build on phase I survey research to understand constraints to adoption, income and nutrition potential for households, and intra-household impacts. Activities will include 1) engagement of farm households in PVS at our research sites, 2) on-farm testing followed by a farm household survey to determine critical constraints hindering adoption or reducing the diffusion of improved seed, including access to seed systems, 3) inclusion of survey questions specifically focused on disposition of newly-adopted beans (sales in alternative markets across supply chains, household consumption) by households, and 4) inclusion of both male and female perspectives in the survey to estimate intra-household impacts. The economic network approach used in phase I will be used to estimate the village-wide impacts of stress tolerant germplasm. The use of this approach in phase II allows for a short run ex ante/ex post comparison, focusing on adoption constraints and impacts.

Participatory Variety Selection (PVS) activities will be carried out at research sites in Gurue, Angonia, Lichinga, and Sussundenga in years 1 and 2 of phase II. Local farmers (male and female) will be included in the PVS, to understand farmer acceptance/resistance to selected characteristics of the beans. This activity will be used -- in concert with phase I survey results focused on stated preferences for particular bean characteristics -- to inform the larger research project on preferred characteristics and to identify most promising stress tolerant beans. At least 10 PVS participants will be included at each research site in both years 1 and 2, and gender balance will be maintained. We will assess differences, if any, in preferences across the 4 regions.

On-farm testing of the most promising stress tolerant beans will be conducted. In addition, a farm household survey will be conducted among farms participating in on-farm testing at the research sites. The survey protocol will be developed in year 1 of phase II, be translated into Portuguese, undergo Penn State Human Subjects clearance, be pretested locally among farmers, and be conducted across the research sites at Gurue, Angonia, Lichinga, and Sussundenga. The survey will include sections on constraints (agro-ecological, economic, social) to adoption and greater diffusion; assessment of yield and input cost impacts; impacts on household income versus household nutrition
attributable to beans; and intra-household impacts. If possible, we will include questions on the survey focusing on rock phosphate.

IIAM staff at the sites will conduct the household survey, in collaboration with interviewers/translators, after being trained by PSU collaborators. Training will take place in Sussundenga Fall 2010. Statistical analyses of the data will be conducted and adoption/diffusion models estimated. Simulations based on the *ex ante* and *ex post* data will conducted to estimate the overall impact of the new technology on the bean-growing regions of Mozambique, under different market scenarios.

Finally, we will collaborate closely with the Michigan State CRSP team in Mozambique to assure that both teams benefit from the other’s activities. Since both teams work collaboratively with IIAM, a PSU/MSU collaboration will provide an even greater benefit to our in-country hosts.

3.1 Train IIAM staff in PVS.

3.2 Conduct PVS among selected farm households at the research sites. Identify positive and negative characteristics, based on male and female preferences. Compare to stated preferences from *ex ante* surveys.

3.3 Develop farm household survey, translate into Portuguese, obtain Human Subjects clearance, pretest survey instrument. Train IIAM staff to conduct survey; IIAM staff will train additional interviewers.

**Objective 4: Capacity Building**

**Collaborators**
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Jonathan Lynch, PSU, USA
Magalhaes Miguel, IIAM, Mozambique
Juan Carlos Rosas, EAP, Honduras
Soares Almeida Xerinda, IIAM, Mozambique

**Approaches and Methods**

**Training IIAM (Mozambique) researchers at Penn State**

In this phase of the project we plan to train two IIAM researchers at Penn State. Samuel Camillo will receive formal graduate training in plant biology. We will request from IIAM that Venancio Salagua receive nondegree training in socioeconomics. EAP will provide training in PVS and MAS for African and/or Central American trainees.

**Strengthening research infrastructure at IIAM**

Many IIAM researchers are posted in regional research centers, which encourages interaction with farmers in production zones, but limits research possibilities, since the zonal centers do not have effective internet access or lab facilities. In our current Penn
State-IIAM project funded by the McKnight Foundation we have invested in strengthening research infrastructure at the Sussundenga research center, which is the base of Magalhaes Miguel and is located near a main bean production zone. We installed a satellite dish for direct internet access and constructed a lab for soil and plant analysis. Internet access has been critical in maintaining communication between Mozambique and the USA, and in the ability of IIAM scientists to access research literature and other internet resources. The soil and plant analysis lab will be an important resource for the entire central region of Mozambique. Our proposed Pulse CRSP project would expand this effort by providing internet access for the Chokwe research station, the base of Celestina Jochua and Soares Xerinda, and adding additional capacity to the analytical lab at Sussundenga. During the phase I of the DGP CRSP project, we were able to purchase several lab equipment crucial for tissue analysis at Sussundenga research station. In the next phase, we plan to acquire several lab equipment and supplies, still in need for full operation of the Lab. We also need to物理 expand the facilities housing the lab to accommodate more equipment. Funds from phase II would help us to improve the working space of the Lab.

**Strengthening research and training capacity of Zamorano**
Zamorano serves undergraduate students from most Latin American countries. Dr. Rosas offers courses in Genetics, Plant Breeding and Crop Production, and guides thesis research projects utilizing field plots, greenhouse and laboratory facilities of the Bean Research Program. Traditionally, some Zamorano graduates become research assistants in the Bean Program; this experience has helped more than 20 graduates go to graduate school in the USA and abroad. The Bean Program at Zamorano has trained many researchers from the national bean programs of Central America, the Caribbean and Ecuador, as part of the previous Bean/Cowpea CRSP. Training in the Bean Program is offered in areas such as breeding and selection, field plot management, techniques for managing bean pathogens in the field and laboratory, marker assisted selection, and Rhizobium and mycorrhiza production technologies. Also, several graduate students from U.S. universities involved in CRSP collaborations with Zamorano have conducted their M.S. and doctoral field research in Honduras. Recently, the program has developed capability for root phenotyping to characterize and select genotypes with superior root traits associated with tolerance to drought and low soil fertility. Capabilities in this area will be upgraded as part of this project. In the proposed project, Bean Program facilities and expertise at Zamorano will be used in formal training of undergraduate students; in-service training of technical personnel from Central America, Caribbean and African; graduate research of doctoral and master science candidates from collaborating countries and the U.S.; and to organize and conduct short courses, workshops and project related events. In addition, the project would have access for conducting on site studies and research trials with CIAL and other farmer organizations which are involved in participatory plant breeding and seed production.

**Multilingual web-based delivery of research methods for root traits**
We have established a web site that describes research methods for root traits in English, Spanish, French, and Portuguese (http://roots.psu.edu). This site has been widely used, having received an average of 600 visitors, 3600 pages downloaded, and 8400 files downloaded per day over the first three months of 2010. Continued support for this web
site in the proposed project will be a resource for agricultural researchers throughout Africa and Latin America.

**Contribution of Project to Target USAID Performance Indicators**

Research capacity of host country institutions will be enhanced by training and infrastructure development. The development of new bean genotypes with enhanced yield in stressful environments will enhance rural livelihoods and improve food availability in urban and rural areas. Socioeconomic research will permit improvement of technology targeting and dissemination strategies.

**Target Outputs**

**Breeding:**

*Honduras:* A set of IB lines with Amadeus plant and seed type will be available for testing the multiline approach in farmer fields in Honduras and elsewhere.

At least 10 drought /low fertility tolerant advanced lines developed for the project in collaboration with UPR/Beaver and CIAT, will be included in the regional VIDAC and ECAR trials and distributed to Central American and Caribbean national programs and research organizations.

At least 40 promising lines and germplasm from EAP, PSU, UPR/Beaver and CIAT, will be sent to researchers of IIAM for testing in Mozambique.

*Mozambique:* Seed of several bean genotypes will be multiplied and made available for evaluations.

At least 20 lines with root traits adapted to low P conditions will be selected from F6 generations for advanced evaluations.

At least 100 bean genotypes or lines will be evaluated for root traits, and at least 20 genotypes will be selected. Parents with good root traits for drought and low P adaptability will be identified.

Seed of F1 generations from different crossed of parents contrasting in root traits will be increased.

**Integrated Crop Management:** At least two moisture conservation technologies to reduce drought susceptibility of P-efficient (shallow rooted) genotypes will be identified. In the following growing season will be exposed to farmers, through demonstration plots conducted with our partners (farmers associations, public extension and NGO’s).

From rock P trials will be identified minimal and optimal application PR application rates. These results will be used for field trials in the subsequent growing season. The field trial results will be shared with the socioeconomic unit of IIAM to integrate feasibility studies of RP use.
Socioeconomics:
PVS conducted across research sites.
*Ex post* survey developed.
Penn State Human Subjects clearance of *ex post* survey.
Field testing of survey instrument complete.

Capacity Building:
Degree training of an IIAM researcher in Plant Biology at Penn State.
Nondegree training of an IIAM researcher in socioeconomics at Penn State.

Engagement of USAID Field Mission(s)
When project staff are in Maputo we will attempt to meet with AID staff to brief them of our activities and progress, annually if their availability and interest permits.

Networking Activities with Stakeholders
Outreach/Impact in Honduras: The project will work in collaboration with at least 20 CIAL (farmer local agricultural research committees)) which are currently active in Honduras. These CIALs are composed of men and women interested in the introduction and testing of technological alternatives to improve the productivity and sustainability of the cropping systems in their communities. Although most CIAL members are male, it is quite common to find CIALs led by women and others composed only of women; also, many young farmers are members of several CIALs. Zamorano is currently collaborating with CIALs in four regions of Honduras, as part of participatory plant breeding activities started in 2000, to improve local landraces of beans and maize with specific agro-ecological adaptation and consumer preferences. So far, 11 bean (including three IB lines developed by the project from crosses of landrace x improved cultivars) and four maize cultivars have been released through these partnerships for conducting participatory plant breeding (PPB) activities with CIALs of Honduras. Several other breeding lines are under validation in communities of the regions of Yorito, Vallecillo, Yojoa Lake and the Yeguare river basin, and some will be released as cultivars by 2011.

The project will also collaborate with the main NGOs of Honduras, especially those organizations that have been collaborating with Zamorano for more than 10 years (FIPAH, PRR, etc.), as well as with the National Bean Research programs from Honduras, Nicaragua and other Central American and Caribbean countries members of the Bean Research Network. This regional bean research network will be the mechanism to be used for the testing, validation and dissemination of novel bean lines and multilines developed by our project. The regional bean network has been coordinated by Zamorano since 1996. The bean network has facilitated the testing of breeding lines and germplasm for nearly 20 years, and its members (the national bean programs) have been involved in the release of improved bean cultivars developed by Zamorano which are currently the main cultivars used by farmers in the region.

Foundation seed of released cultivars will be produced by Zamorano to assist certified and artisanal seed production and distribution projects supported by governmental and NGO organizations, such as the technological bonus in Honduras, which is reaching over 75,000 farmers every year with high quality seed of improved bean cultivars. Similar seed production and distribution projects have been implemented in Nicaragua and El
Salvador in recent years, to assist small farmers with seed and fertilizer, as part of a policy for food security in rural areas and urban low-income sectors. These seed production and distribution projects will be assisted with foundation seed of improved cultivars developed by the project through our collaborators from the national bean programs and NGOs who are also involved in these seed projects.

The Zamorano bean program has been involved in training courses and in-service training in several aspects of bean research and seed production. The program has the required field, greenhouse and laboratory facilities to train technical personnel of our Central American and Africa collaborators in germplasm evaluation, breeding and selection, field plot management, marker assisted selection, participatory plant breeding, seed production and BNF technologies. Also, in collaboration with CIALs and NGOs, we can train technical personnel and farmers in on-farm innovation, participatory plant breeding and artisan seed production, focusing it from the perspective and needs of the small farmers.

Outreach/Impact in Mozambique: In Mozambique we will be working with NGOs, namely World Vision International (WVI), Care International and the Cooperative League of the United States (CLUSA), with involvement of small scale farmers in several regions in Manica, Tete, Zambezia and Niassa provinces in central and northern Mozambique. The proposed project will continue our collaborative work with World Vision International, which has been conducting activities in agricultural extension, variety testing, human nutrition and on-job training, involving thousands of farmers in Gurue, and Milange districts in Zambezia province; Malema and Mutuali, in Nampula province.

To maximize impact, the project will be working with farmers that have been organized themselves in organizations formed by several farmers associations and work with them in plant variety testing and evaluation. Currently, in almost all village communities in Mozambique farmers are organized in associations and sometimes, a number of farmers associations in a community form a cooperative, ending up with an organization with a large number of farmers. This is being encouraged by the CLUSA in Lioma, Gurue, which enables them to empower the farmers for acquisition of more expensive farming facilities and equipment, such as animal traction, tractors, implements, warehouses, etc., and better market access for their produce. We will be working with CLUSA to ensure that innovative technologies generated by the project can reach a large number of farmers capable of selling their increased production.

A major focus of WVI is the training of extensionists and then of the farmers in a community. Currently, extensionists lack training materials and useful information to deliver. In this project, we will, in parallel with the research activities, conducting training of extensionists, both from the public sector and NGOs, in relevant subjects like diagnosis of nutritional disorders, soil water conservation and techniques in participatory technology testing and dissemination. Since the farming systems vary among the regions where the project is going to be implemented, we will be developing training materials appropriate to each of the sites. For example, in Angonia farmers use ridges during land preparation, while in Gurue, and Sussundenga, farmers use flat red soils and/or in
declined terrain susceptible to erosion, for planting, and as a result water and nutrient status of the soils in these locations vary. Our project will develop technologies (plant materials and soil management techniques) adequate to these specific crop systems across targeted research and technology delivery sites.

Under this project we will be working with the above mentioned NGOs, and farmers associations in Sussundenga, Manica province, Angonia, Tete province, Gurue, Lioma, Milange in Zambazia province, and Malela, Molocue and Mutuali, Nampula province, reaching several thousand small-scale farmers growing beans in the region. The planned activities can be summarized as: a) genotype evaluation and testing using participatory approach, b) technology dissemination for adoption, and c) training for extensionists in relevant subjects such as diagnosis for nutritional disorders and techniques for soil water use conservation.

**Leveraging of CRSP Resources**

This project is highly leveraged with other ongoing projects and investments, including:
- a project funded by the McKnight Foundation Collaborative Crop Research Program entitled *Increasing Bean Productivity and Household Food Security in Stressful Environments in Mozambique Through the Use of Phosphorus-efficient Seeds by Farm Households* for $435,175 for 4 years to IIAM, PSU, and EAP
- a project funded by the Generation Challenge Program entitled *Basal Root Architecture and Drought Tolerance in Common Bean* for $900,000 for 4 years to PSU and CIAT
- a project funded by the Howard G Buffett Foundation entitled *Roots of the second green revolution* for $1,426,000 plus ca. $500,000 in capital investments for 5 years to PSU, with support from IIAM and CIAT
- a project funded by the International Atomic Energy Agency entitled *Characterization of root traits contributing to enhanced phosphorus acquisition from low fertility soil* for $40,000 for 4 years to PSU
- a project funded by the Norwegian Development Fund entitled *Participatory Plant Breeding for Mesoamerica: Promoting the management, conservation and development of Agrobiodiversity* for $250,000 for 5 years to EAP
- a project funded by the International Science and Education Program of the U.S Department of Agriculture entitled *Ag 2 Africa: Development of an International-US Learning Laboratory* for $149,993 for 4 years to PSU.
- a project entitled *Investigating the Social Influences Underlying Agricultural and Malaria Practices in Mozambique in Order to Diffuse Innovations in Beans and Malaria Vector-control* funded by the Clinical and Translational Sciences Institute (CTSI) for one year for $50,000.
- a pilot project funded by the Social Science Research Institute (SSRI) to explore the potential for developing cell phone technologies for widespread dissemination of information on improved bean seed, legume pests, and new seed access to illiterate farmers in Mozambique and East Africa. Total pilot project funding is one year for $20,000.
TMAC EVALUATION AND RECOMMENDATIONS
PLUS PI RESPONSES

Phase II Project: PII PSU-1. Improving bean production in drought-prone low fertility soils of African and Latin America – an integrated approach

Lead U.S. PI- Dr. Jonathan Lynch, Pennsylvania State University

A. Comments Regarding Workplan for FY11
1. Many of the previous concerns raised by the TMAC when reviewing the Phase I project have been reasonably dealt with in the FY 11 workplan.
2. There still remain concerns about issues associated with student training.
3. The TMAC believes that enhancing bean productivity on low fertility soils should be a program priority. To best achieve gains in this area, it is important that there be collaboration and coordination of activities among three Pulse CRSP projects, PII-PSU-1, PIII-ISU-2 and PII-UPR-1.
4. The TMAC raised several concerns about the feasibility of using rock phosphate to enhance bean productivity in low P soils in Mozambique.
5. The TMAC questions the relevancy of research findings in Chokwe to the principle bean production areas in Mozambique? A priority of the CRSP is to generate research findings that can be transferred to other bean production areas in Eastern and Southern Africa and thus scaled up.
6. Transportation and mobility is a constraint in Mozambique. Is the group overstretching themselves by establishing field research on so many different sites?
7. Please work with the MO to deal with issues associated with indirect costs on the subcontracts.

B. TMAC Recommendations and PI Responses
The TMAC recommends the approval of the FY11 work plan and budget contingent upon the submission of satisfactory responses to the TMAC’s recommendations.

1. The TMAC recommends that the PIs involved in Pulse CRSP projects PII-PSU-1, PII-UPR-1 and PIII-ISU-2 establish tighter collaborative links in their research activities on improving productivity on low fertility soils and on BNF.

Response:
At the Quito meeting Jim Beaver discussed with our team the prospects for collaboration on BNF training between Angola and Mozambique. On July 16 Jim submitted a proposal to utilize DGP CRSP institutional capacity building funds to conduct a workshop dealing with biological nitrogen fixation research techniques on July 16. Bean researchers from Central America, Haiti, Angola and Mozambique would attend the workshop which will be held at Zamorano in November 2010. In the proposal two bean researchers from Mozambique sponsored by the PII-PSU-1 project would attend the workshop. I have also spoken with Mark Westgate and we have agreed to have a meeting to discuss tighter links between the PSU and ISU projects in the BNF
realm, specifically on inoculant production, which is a major need in Mozambique. Mark will take leadership of the workshop arrangements. Both of us will be at the ASA-CSSA-SSSA meetings in November- if Jim Beaver can also attend those, this would be a very cost effective way to meet. Mark tells me that he has discussed with you additional funding for a workshop- this is currently not planned in our PSU budget. Since the TMAC is aware of these efforts, I am not sure what additional information is being requested at this time.

2. The TMAC recommends that the PIs consider the following relative to the implementation of the rock phosphate research.

a. The team should conduct a feasibility study (cost-benefit analysis) to determine if the use of rock phosphate and lime is economically viable. Do the costs of mining, grinding and transport justify its use on bean fields? Will resource-poor farmers purchase and apply rock phosphate and lime if they don’t see an immediate yield response?

Response:
After the global PI Quito meeting, we established contacts with the socio-economic unit of IIAM (Mr. Feliciano Mazuze and Dr. Cynthia Donovan) to arrange the possibility of conducting an economic feasibility study even though we knew that we did not have funds for this activity. The IIAM Socio-economic Unit (CESE), contacted the representative of IFDC based in Maputo/Mozambique (Marcel van Denberg) to help in the process, who also got in touch with the IFDC principal scientist, Steven van Kauwenbergh, based in Muscle Shoals (Alabama) who provided a book on Fertilizer Raw Materials, as well as his expert opinion regarding exploration of rock P in Mozambique. The larger reserves of Rock P near the major bean production areas of Mozambique, which are research sites of our projects (DGP CRSP, McKnight, IIAM National Legume Program), are located in Tete with RP containing approximately 4,150,000 Tons of P2O5, and Nampula with RP containing approximately 155,413,000 tons of P2O5. The P2O5 is about 5.01% in Tete RP, and 14-18% P2O5 in Nampula. The ore is located about 150 m deep in Tete, and at the surface (less than 4 m deep) in Nampula (Monapo) where we have been collecting the RP for use by DGP CRSP project. Samples from Monapo were recently sent by IIAM to Brazil and South Africa for analysis, and were confirmed to have 18% of P2O5. The localization of the site is optimal because Nampula (Monapo) is closer to Niassa, Zambezia (Gurue, ~90 Km), and not too far from Angonia (Tete Province) which are 3 out of 5 research sites. The soils are acidic (pH<5) in 4 out of 5 research sites, and typically in 4 major bean growing areas of Mozambique under rainfed conditions in which we have research sites (Lichinga, Angonia, Gurue and Sussundenga), which is a condition for responsiveness of RP. The fifth site is good for developing drought tolerant materials since it is located in semi-arid climate zone. Grinding RP reduces the time of reaction. Though, RP application may not have desirable response before at least 6 months after application, implying that response is likely not significant in the first year since we have unimodal rainfall with one
good cropping season per year for annual crops like beans. Dr. Findeis expressed interest in participating in the study, but the current project has no budget provision for a socioeconomic study.

Costs of transportation- Current transportation infrastructure in Northern Mozambique, especially near Nampula, are in flux due to investments by China and other partners. The present status is not a good indication of the situation that likely will be obtained in the next 5 to 10 years. An economic analysis would have to consider this point. We note however that our objective is to assess the agronomic utility of RP with new P-efficient bean lines, which does not require an economic analysis, which is needed in order to conduct an economic analysis, is less costly than an economic analysis, and is within our budget and expertise, unlike an economic analysis of fertilizer costs in Mozambique. If the TMAC insists on this point we will simply drop this objective from our CRSP program, and continue the research with other funds.

Will resource-poor farmers purchase and apply rock phosphate and lime if they don’t see an immediate yield response? It is our assessment that resource-poor farmers would be willing to purchase and apply rock phosphate and lime if our research (on-station and on-farm) and demo-plots are successful in showing the advantage of applying RP to increase bean yields. We anticipate greater impact in acid soils with soil test P values below 10 ppm. In a soil fertility survey, our team found that 52 out 60 farmers’ fields had P-test below 15 ppm, with including 39 fields with soil P-test below 10 ppm. In general, soil test P below 15 ppm is considered low and plants do not develop and attain economic yield at that soil fertility condition. Our P-efficient genotypes can grow and yield better from about 10 ppm. Therefore, it is very important to find cheap and locally accessible sources of fertilizer amendment to gradually improve the soil P condition. This can be done by liming to increase the pH and free some of P that is trapped and not available for plant uptake at low pH, or by applying rock P that will increase P availability especially in acid soil and its effect is improved when applying finer particles after grinding the RP.

b. The PIs are strongly encouraged to contact Bill Payne (Texas A & M) regarding his experiences and knowledge of the scientific literature regarding the use of rock phosphate on grain legumes in Africa.

Response:
We already contacted an RP expert of IFDC, who provided relevant information. The IFDC may become interested in exploration and marketing of RP in Mozambique, but at this point in time no one did studies to demonstrate the agronomic utility of RP for crop production in Mozambique. We are more likely to succeed since we are working with a high value crop (common bean) and our approach of using P-efficient genotypes does not demand large quantities of fertilizer. A starter P fertilizer from RP can improve P level from critical levels to levels that P-efficient beans will be responsive still at low P range. We will be contacting Bill Payne (Texas A & M) soon, but for now we have some relevant information provided by IFDC (Muscle Shoals, 83
Alabama). Has Bill worked with P-efficient bean varieties in volcanic and weathered soils of eastern Africa?

c. Clarify how the private sector is, or could be involved in the project as it deals with the use of rock phosphate. What is the possibility of involving the private sector in grinding and marketing of the rock phosphate? Why hasn’t the private sector taken an interest to date in mining and marketing of rock phosphate?

Response:
For now, it can be difficult to involve the private sector in exploration of RP since there is no demonstration of its profitability. That is why we need to do research plots in pots, on-station and finally on-farm, and extensive demo-plots will be necessary to convince farmers (potential buyers) and the private sector (sellers: producers and distributors/marketers) in that they can do profitable business with the rock phosphate. Some southern Africa countries like Uganda and Tanzania are already using rock P. The private sector generally does not invest in research, especially in countries like Mozambique.

The private sector has not taken an interest to date in mining and marketing of RP in Mozambique because no one has done research on the agronomic profitability of using RP in Mozambique and RP is not imported from other countries since large quantities would be necessary. In addition, our approach of using P-efficient beans is an innovative entry point since for conventional beans or other crops would be necessary greater quantities of RP to achieve profitability. Possibly, if we succeed the impact of promotion of use of RP will trigger higher demand of other fertilizers, considering that most farmers do not use any inorganic fertilizer at the moment in our target areas. Therefore, this would be better business environment for fertilizer marketing, and overall agriculture productivity.

3. The TMAC suggests that the PIs consider focusing field research activities in Mozambique on sites in important bean production areas so that farmers can benefit and observe plots. How relevant is the field research conducted at Chokwe to the soil and agro-ecological conditions for bean production in areas such as Lichinga? May want to focus research activities to fewer sites due to the costs of transportation and necessary technical staffing required.

Response:
The Chokwe Research Station is located in the semi-arid zone of Mozambique which makes it the best site to conduct drought studies. In this project we have (a) screening of genotypes for drought tolerance, and (b) moisture conservation techniques using P-efficient genotypes planned to be conducted in Chokwe. The other research sites of our project are not good due to higher probability of getting consecutive wet years.

Drought: In Southern Mozambique (including Chokwe) beans are produced during the dry season under irrigation. During the dry season we will conduct field trials and screening for drought under controlled irrigation in Chokwe. Then,
the genotypes we will select from drought screening will be evaluated in the field under phosphorus stress in Sussundenga and/or Lichinga. Genotypes selected from both stresses will be tested in other bean production regions (Angonia, Lichinga, Gurue) where both phosphorus and drought stress occur. We selected Chokwe as a site for drought screening because it is located in a semi-arid region and has an operational irrigation system for better management of the drought stresses directly in the field. In Central (Angonia, Gurue) and Northern (Lichinga) Mozambique beans are grown during the rainy season and we may not get good drought stress if regular precipitation occurs. So, in summary we plan to conduct drought screening in Chokwe and screening for low phosphorus adaptability in Sussundenga (on-station). Then, the material selected will be evaluated in on-farm conditions in the main bean production regions such as Lichinga, Angonia or Gurue. Genotypes and other research findings developed from these sites can be transferred to other bean production regions.

In addition, Chokwe Research Station is a site where we do most of the seed increase and germplasm maintenance under irrigation. In the past we lost several genotypes in Sussundenga due to drought during seed increase and the irrigation system was not operational. After that experience we considered the option of using Chokwe as a potential site for seed increase to guarantee seed for future trials and to our collaborators.

In the past it has been difficult to install on-farm trials in all sites in the same season. Whenever possible we always tried to use IIAM transportation if available and local IIAM technicians or extension services for field assistance to reduce the number of trips for field supervision. However, now we have support from McKnight and GCP vehicles, and technicians hired under McKnight in different sites for field assistance. This technical support will significantly reduce the number of trips of the researchers for field supervisions. We also plan to conduct field research (on-station and on-farm) in different sites in different seasons. For, instance, we first do the on-Station trials mainly in Chokwe, Sussundenga and/or Lichinga. The best genotypes or technology will then be tested in other sites in different seasons.

P efficiency:

The other study planned for Chokwe and Sussundenga (or Lichinga) is the multiyear pot experiment with Rock phosphate (RP). In Chokwe we will use a very poor soil (less than 2 ppm of P) which allows us to consider options of lower RP application rates, increasing gradually to study full response curve of beans; as opposed to sites where the P-test may be above 5 ppm. To have a more representative study we have a replicate of the pot experiment planned to be conducted in Sussundenga (or Lichinga) Research Stations.

Highly weathered sandy and heavier textured, acid red Oxisols are common in the tropics and subtropics. Since our research sites have these soil types, results will be applicable to many Southern Africa Countries. Malawi, Zambia, Zimbabwe and Tanzania are neighbor countries that can adopt most technologies.
immediately after development and deployment. Sussundenga is near Zimbabwe, Angonia is near Malawi, and Lichinga is close to Tanzania, and the climate is similar. In general, the countries test the promising technologies (seed or agronomic practices) in their own research system before recommending their implementation in larger scale.

In addition to these technical issues, a practical issue is that Celestina Jochua and Soares Xerinda are based in Chokwe. Any activities that require them to be in Northern Mozambique are expensive and time consuming. Work that can be technically conducted at Chokwe therefore uses project resources more efficiently than conducting the same work in the North.

4. Has the student from Mozambique (Samuel Camilo) successfully passed the GRE and TOEFL exams and been admitted into a graduate program at Penn State for the Fall 2010 semester?

Response:
Samuel is at Penn State now enrolled in intensive English. We hope that he will be able to pass the TOEFL in December so that he can begin his MS studies in the Spring 2011 term. I attach here a description of the process to get Samuel to Penn State and the reasons for the delays, from Melanie Gilbert, staff in our international programs office who has been handling this.

“Hi Jonathan,

The timeline of events that resulted in Samuel’s delay in training can be traced as follows:

On 11/3/09, upon acknowledging that Herminio Abade was not going to be able to obtain a sufficient TOEFL score, Samuel Camilo was chosen as a new trainee. A notification of selection for program was sent from IIAM to Jonathan, which was forwarded to MSU.

I began to correspond with Samuel on 11/17/09 to request information that was required to obtain the visa via TraiNet. By 11/30, I had received all of this documentation from Samuel and had submitted the information to TraiNet and to the USAID Mission in Mozambique. Also on 11/30, a training/budget update proposal was submitted to Mywish from Jonathan. This was approved on 12/4.

Shortly after submission of info to TraiNet, I was notified by the USAID mission that Samuel should not be registering for English training in the US but should instead be taking English training in a third country (typically South Africa), which brought into question the TraiNet training category under which Samuel had been entered. Between 12/8-1/20, various communication took place both via email and phone between PSU, MSU, and USAID Washington, resulting in a final clarification that Samuel’s could be trained in the US and that his training category should be changed from non-degree training (for the English training) to Degree training, which would allow him to undertake the English training as well. It was clear at this time that Samuel would not be beginning his English
training in Spring 2010 and was recommended that he take the English training in Summer 2010 and begin his studies in Fall 2010.

Samuel applied to the Intensive English program in early February and is accepted to the program; however, the program coordinator was concerned that the summer program was not intensive enough for him to successfully complete the TOEFL given based on his preliminary English scores. Additionally, Samuel’s application to the Horticulture graduate program was not complete until May 6, which did not give us sufficient time to secure the visa before the beginning of the Summer 2010 English session. Samuel would have missed at least 2 weeks of that six week program, and given the coordinator’s earlier concerns about his ability to pass the TOEFL after the full 6 weeks, it was suggested (via email dated 5/6 to Irv) that he instead enroll in the Fall 2010 Intensive English program and begin his graduate studies in Spring 2011, one semester later than the original target (Fall 2010).

Due to some other administrative paperwork issues at the USAID Mozambique office, Samuel arrived at Penn State on September 11, missing the very beginning of his English program, but he began the English classes immediately and will continue to take them through the Fall 2010 semester.

I hope this is helpful! Please let me know if you need anything else.

Melanie”
Dry Grain Pulses CRSP FY 2011 Workplans

FY 2011 PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Improving Bean Production in Drought-Prone, Low Fertility Soils of Africa and Latin America – An Integrated Approach
Lead U.S. PI and University: JP Lynch, Penn State
Host Country(s): Mozambique, Honduras

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<td>Number of women</td>
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<tr>
<td>Number of men</td>
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<tr>
<td>Number of agricultural firms/entities benefiting</td>
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<tr>
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<td>Number of women organizations receiving technical assistance</td>
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<td>Developmental outcomes:</td>
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### Dry Grain Pulses CRSP Budget

**Project Title:** Improving Bean Production in drought-prone, low fertility soils of Africa and Latin America – An Integrated Approach

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<th>IIAM</th>
<th>HC or U.S. Institution (3)</th>
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**Total direct cost budgeted for U.S. institution(s):** $183,538.13  
**Total direct cost budgeted for H.C. institution(s):** $134,823.19

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**Attribution to Capacity Building**

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**U.S. Institute PI:** Jonathan P. Lynch

**Authorized Institutional Approval:**
## FY 2011 Semi-Annual Indicators of Progress by Institutions and Time Period

**Project Title:** P2-PSU-1

<table>
<thead>
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<td>4/1/11</td>
<td>9/30/11</td>
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### Objective 1: Breeding
- testing small red IIB lines: x
- BNF in small reds: x
- drought/low P advanced lines: x
- lines sent to IIA: x
- seed increase: x
- selection: x
- phenotyping: x
- testing F5 families: x
- introgression: x

### Objective 2: ICM
- prepare RP: x
- water conservation/genotype: x
- on farm demos: x
- RP pot study: x

### Objective 3: Socioeconomics
- train IIAM staff in PVS/survey: x
- develop PVS & HH surveys/translate: x
- Human Subjects clearance: x
- pretest HH survey in field: x
- interviewer training - HH survey: x
- conduct PVS/brief PVS survey: x x

### Objective 4: Capacity Building
- MS training of IIAM plant biologist: x x
- nondegree training of IIAM social scientist: x x

### Name of the PI responsible for reporting on benchmarks
- J.C. Rosas
- M. Miguel
- J. Lynch

### Signature/Initials
- JCR
- MM
- JL

### Date
- 

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90