Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize–Bean Production Systems (SO2.1)

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I. Abstract of Research and Capacity Strengthening Achievements

To understand limiting soil nutrients, we analyzed physical and chemical properties of three predominant soil types for growing common beans (*Phaseolus vulgaris* L.) in study communities in Uganda's Masaka and Rakai districts and in Mozambique's Gurué district. Results guided greenhouse nutrient omission studies using soils from farmers' fields, revealing effects of specific macronutrients and micronutrients on bean plant growth and development. Complementary lime requirement studies will demonstrate soil-specific pH amelioration requirements for bean root growth. Preliminary results from initial researcher-managed field trials in Uganda indicate strong relationships for soil pH, nodulation, foliar disease, and bean yield. When initial field trials start in Mozambique in early 2015, follow-up study in Uganda is planned. Trials will demonstrate soil-specific nutrient and crop management practices necessary to increase bean productivity in farmer fields. Baseline household survey results depict smallholder farmers' practices of field selection and preparation, crop and variety selection, planting methods and spacing, input use, intercropping and rotation patterns, gender-based division of labor, problem identification and management practices, market sales and storage. Farmer research groups are being formed and supported for field experiments to test and demonstrate the impact of variations in improved management practices and technologies for bean production. Training of three M.S. students at Iowa State University and three M.S. students at Makerere University is progressing.

II. Project Problem Statement and Justification

Poor soil fertility is a major factor in low bean yields in Uganda and Mozambique (Folmer *et al.* 1998), important Feed the Future focus countries. Average bean yields in Uganda are 0.6–0.8 MT ha^1, although yields of 1.5 MT ha^{-1} can be realized with improved varieties (Sibiko 2012). Both countries have weak extension systems and rural social and economic institutions (Anonymous 2013; Tomo *et al*. 2013), limiting widespread access to information and materials that could enable smallholder bean farmers to improve crop management practices and technologies—and achieve better yields (Athanase *et al.* 2013). This research project is based on two premises: (1) sustainable intensification of agriculture production requires improved soil fertility management in which legumes are an integral part of cropping systems (Bezner-Kerr *et al.* 2007; Kumwenda *et al.* 1996; Snapp *et al.* 2010); and (2) effectively addressing soil-related constraints will be based on enhancing smallholder farmers' capabilities in diagnosing and finding solutions to important yield constraints (Bursch *et al.* 1996), as well as helping to remove barriers to increased access to various types of soil amendments (Miruka *et al.* 2012). Analysis of soil physical and chemical properties, combined with field trials, can reveal soil-specific effects of macro- and micronutrients on bean plant growth and development. Documentation and analysis of cropping systems, practices and technologies utilized by farmers—and the problems they encounter, is essential for identification of strategies to address key constraints.

Working with farmer-led learning groups can effectively engage producers in field experiments that test and demonstrate the impact of variations in farmer- and scientist-recommended management practices and technologies for bean production, and help researchers learn about critical social, economic, and cultural factors and contexts that impact crop management decisions. This research approach can generate practical results, collectively transform farmers' beliefs and knowledge, encourage one another to make changes, strengthen social cohesion, and stimulate interest among others in learning from trials and demonstrations (Bartlett 2008; Critchley 2002; McCown 2005; Morton 2008, 2011; Sseguya *et al.* 2009, 2013).

This project is developing appropriate aids (methods and procedures) that will enable smallholder farmers with varying levels of education to better diagnose soil-related production constraints, and to make improved site-specific crop system management decisions which contribute to higher productivity of beans and associated crops and, over time, to improved soil fertility. It will assess the effectiveness of innovative communication approaches and technologies to engage farmers with diverse characteristics and other key stakeholders in widespread dissemination and adoption of diagnostic and decision support aids (Bello-Bravo and Pittendrigh 2012; Martin and Abbott 2011; Sseguya *et al.* 2012; Tenywa 2013).

III. Technical Research Progress

<u>Objective 1:</u> Characterize Smallholder Farmers' Practices, Problem Diagnoses and Solutions

The research team conducted Participatory Rural Appraisals (PRAs) in Uganda in January 2014, involving two communities in Masaka district and one community in Rakai district. Similar research activities were conducted in Mozambique's Gurué district in June 2014 (Photo 1). In each study area, focus group discussions (FGD) were held with local bean farmers who helped the research team to identify farmers recognized as innovative with whom individual in-depth interviews were later conducted (17 in Uganda and 25 in Mozambique). Semistructured interviews with key informants in Uganda included the District Production Coordinator, advisory service providers from Kabonera and Mukungwe subcounties in Masaka, and extension (National Agricultural Advisory Services) coordinator in Lwankoni subcounty in Rakai. The District Agricultural Officer in Masaka is a very enthusiastic supporter and facilitator for our community and field research. In Gurué, we met with local government officials and extension agents.

A significant range of soil types often exists within a given community, often on specific farms—providing both challenges and opportunities. Results from the team's discussions and interviews with productive and innovative farmers and our soil surveys revealed that smallholder farmers recognize the role and impact of a variety of soil-related characteristics on bean yield in their production systems: soil color (black soils are generally considered more suitable for bean production than red soils), particle size, soil texture, friability, topsoil depth, rocks, slope, water holding capacity, plant vigor, previous yield results, weeds, etc. In community focus group discussions, farmers identified and ranked the relative importance of each factor, with soil type consistently the primary criterion for planting beans. Farmers identified fields with predominant soils characteristics for extraction of samples for analysis, and for participation in development and testing of diagnostic aids. In Masaka and Rakai, these are referred to as black soils (*Liddugavu*) are preferred for bean production, while black, gravelley soils (*Luyinjayinja*) and reddish (*Limyufumyufu*) are known by farmers to be of poorer quality for bean production. Sandy soils (*Lusenyusenyu*) are more susceptible to water stress compared to clayey soils (*Lubumbabumba*). In northern Mozambique, they are *Tirokwe* (black), *Ekochokwe* (red), *Nicante* (paddy), and *Ehava* (sandy).

Application of nutrients by farmers typically appears to be greater to the Liddugavu soils than to the red Limyufumyufu soils. Farmers have little understanding of specific nutrient requirements for bean production, and rarely mentioned the need for any specific nutrient necessary for bean production. Soil pH *per se*, or the many well-known ramifications of low pH and soluble aluminum on bean growth, development, water use, nitrogen fixation, and yield were never mentioned. Additionally, although the concept of host plant resistance to insect pests and diseases may be understood by some farmers, utilization of varieties with improved levels of resistance to commonly occurring foliar diseases appears limited. In Masaka, farmers are aware well that bean production typically will be poor on red or gravelley soils, but due to lack of available farmland with better producing black soil, some farmers continue to plant beans on these soils. Many farmers also clearly understand the need to plant beans early to attain greater yields, and they also face the great difficulties drying seed for sale or storage when rainy seasons extend beyond typical length. Ugandan farmers have several months between two rainy seasons, while in Mozambique cultivation of beans and other crops in the dry season almost immediately follows harvest of crops grown during the rainy season.

Competition between weeds and beans is understood by many farmers, with some initiating weeding shortly after crop emergence. However, few farmers weed beans more than two times, due to labor constraints and greater importance put on production of higher value cash crops. Farmers also use indicator plants/weeds to identify good soils from poor ones. In Uganda, *Katabuteme, Sekoteka, Kafumbe* and *Lusenke* are indicative of fertile soils while black jack, Couch grass, *Kakuuku, Etteete* and *Muwugula omunene* grow on poor soils. Similarly, certain perennial crops (e.g., banana) do well on good soils while a few (e.g., mango) can tolerate poor soils. Many farmers are convinced that sticker-spreader adjuvants should be applied to bean to improve yield, despite these not having any yield enhancing value in many replicated studies published in refereed journals in developed countries.

Another important factor in crop production is choice of variety. Our biweekly crop monitoring in Uganda showed that nearly all farmers surveyed planted a single variety, one that was released nearly 20 years ago and has poor levels of host plant resistance to commonly encountered foliar diseases. Farmers plant this variety because it is preferred for consumption; however, at this time we have no data on preference for any of the newer released varieties that have higher levels of resistance to these foliar diseases.

Recently revised fertilizer recommendations for beans (Kaizzi *et al*. 2012) give optimal fertilizer requirements for beans as 15 kg N and 15 kg P per ha, but consider only inorganic fertilizer sources, ignoring organic sources which are more available and affordable for smallholder farmers. There is inadequate information on fertilizer requirements for beans involving combined application of organic and inorganic fertilizers at farm level. In a maize–bean intercrop, for example, farmers in Masaka indicated that they apply fertilizer to maize rather than beans (Tenywa *et al*. 2014), and even in pure stand, most farmers rarely apply fertilizer on beans. Since farmers grow beans on various soil types, site specific soil management advice is needed (Mansour 1975). By linking scientific and indigenous knowledge (e.g., local indicators used to predict the onset of rain), we can better advise farmers on crop and soil management. Farmers are also developing adaptation measures to address emerging challenges (e.g., early planting and weeding).

Farmers receive some support from government institutions and programs, such as formal extension at district and local levels, and NGOs that operate in the project's focal districts. These agencies provide technical information about improved agronomic practices through advisory services and training, establish on-farm demonstration sites, provide planting materials (including improved bean varieties) that may be directly repaid or distributed to other farmers after harvest, and other inputs, and sometimes purchase farmers' produce. The support system for cash crops differs significantly between Uganda and Mozambique, as well as among communities. Support involves training, provision of seed and other inputs, and marketing; overall, such support is more directly available in Mozambique, provided by private sector foreign investors, NGOs and international research organizations. In Mozambique, an array of cash crops have been introduced or efforts intensified in the past decade; soybean, pigeon pea, sunflower, pineapple, cotton, tobacco; in contrast, common bean production and sales appear to be almost exclusively driven by domestic market actors. If/when support is reduced or eliminated, or market prices for those crops decline significantly, common bean production is viewed in more lucrative terms. In Uganda, the two major cash crops are currently affected by disease—banana bacterial wilt and coffee rust; pineapple production is also widespread. Storage after harvest is rare in both countries because of income needs at (or before) harvest time and farmers' inability to store bean grain and seed safely; in

Uganda, farmers try to avoid bruchid damage by using strong chemicals (unsafe for human consumption), while most farmers in Mozambique use nothing.

In Uganda, organizations operating in the project districts include CEDO (Community Enterprises Development Organization), which focuses on replication of improved seed for beans and other crops; CIDI (Community Initiated Development Initiatives); CARITAS–MADDO (Masaka Diocesan Development Organization); BUCADEF (Buganda Cultural and Development Foundation); and Grameen Foundation, which assesses farm production and provides useful production and market information through smartphones. Farmers also rely on the private sector (e.g., traders, stockists, processors) to access agricultural inputs (seeds, farm tools and implements), purchase, add value and process farm produce. In Uganda, we have held discussions with district officials, extension service providers, private sector input dealers, and NGOs. As we foster the development of a bean sector innovation platform, we view the private sector in a central role for effectiveness and sustainability. In Gurué, an array of agricultural organizations operate: Government agriculture organizations (IIAM–Zonal Research Center, Direcção Distrital de Actividades Económicas [SDAE]), NGOs (TecnoServe, CLUSA/PROMAC), private companies (Quifel, AgroMoz, Murrimo Macadamia, Alif Quimica, and Rei do Agro, Inovagro), and international research (IITA, CIP).

To date, we have learned that the existence and strength of farmers' groups varies significantly in both countries. In Uganda, some farmer groups formed for projects often don't persist after project support ends (e.g., government extension); others have consolidated and grown into cooperatives. In Mozambique, farmers groups (associations) are relatively common, being the principal mechanism to access training and other support. A forum is comprised of several associations, and several forums constitute the apex organization, a federation; some associations are able to effectively engage in collective marketing, while others are not. This has significant implications for farmers' decisions to prioritize cultivation of specific crops, including beans, as they take into account the potential for earning needed income.

Farmers in Uganda and Mozambique currently use a variety of management practices and technologies (MPT) to maintain or increase bean productivity, with significant variation by location regarding type and extent of use—reflecting awareness, availability, access and affordability. Current MPT that farmers highlighted include:

- Purchase of good quality seeds, where and when available
- Changing the location for planting specific bean varieties, sometimes from season to season
- Minimum tillage—with and without use of herbicides to manage weeds
- Timing of planting—ranging from early to late, depending on rains, pests, market opportunities
- Planting patterns and spacing—some in rows, others broadcast
- Intercropping, with an array of different partner crops and precise timing of bean planting
- High plant density (makes weeding difficult and high risk of rapid pest or disease propagation)

- Crop Rotation—various patterns
- Chemical Fertilizers (relatively uncommon, constrained by availability but also price)
- Foliar sprays (purported to be fertilizers, often lacking nutrient value)
- Pesticides (commonly used in Masaka, rarely available and used in Gurué)
- Weeding, from one to three times per season
- Incorporating (burying) crop residues in soil, rather than burning
- Mounding ridges where beans and other crops are planted
- Farmyard manure (very rare, given low density of livestock)
- Mulching—various materials and methods
- Fallowing (very rare, given perceived shortage of land)

We met with key staff of a nongovernmental development organization that focuses on production of certified bean seed. In Uganda's Rakai district, adjacent to Masaka district, Community Enterprises Development Organization (CEDO) works with 80 farmers groups in five adjacent districts, including Masaka. CEDO has been active in Lwankoni subcounty in Rakai since 2005, and almost all farmers interviewed reported getting their bean seed through CEDO. CEDO may be an important source of high quality bean seed for project farmers as our research, demonstrations and dissemination progress.

<u>Objective 2:</u> Develop and Refine Models about Smallholder Bean Farmers' Decision Making

In each country, we conducted in-depth interviews with a representative cross-section of 300 farming households in the study communities to provide insights and to establish a baseline for monitoring changes associated with project activities. Topics covered land ownership, field selection and preparation, crop and variety selection, planting methods and spacing, input use, intercropping and rotation patterns, gender-based division of labor, problem identification and management practices, market sales, storage practices, food consumption patterns, and uses of income earned through farming and other activities, connections in social and economic networks, diet and food security.

Preliminary analysis of the Uganda baseline household survey data in Masaka and Rakai districts provides valuable perspectives on farming conditions, practices, challenges, and strategies; analysis of the Mozambican baseline household survey data will begin once data cleaning is completed. The average landholding is 4.9 acres (median 3.0), with a few larger than 50 acres. The average amount cultivated is 3.3 acres (median 2.0), with some seasonal variation. Nearly half do not cultivate all their available land, holding some land in fallow, but also due to insufficient labor or money for inputs and hire labor. One-fourth (25%) expressed concerns about security of land ownership or use rights for bean and other crop production.

Beans are an integral part all households' complex farming systems for both food security and income. The most widely grown food security crops are cassava (85%), beans (81%), maize (69%), sweet potatoes (53%), and *matooke* [cooking banana] (41%). The crops grown to earn income are beans (72%), maize (64%), coffee (42%), cassava (26%), and groundnuts (22%). They intercrop beans with maize (87%), maize and cassava together (39%), cassava (8%), and coffee (2%). The average amount of land devoted to beans is 0.85 acres (median = 0.50). Approximately 1.75 acres (median) is devoted to other crops. The most widely grown bean variety is K132 [mottled, dark red/white] (53%), with 12 other varieties cited. More than half (62%) of farmers grown just one variety of beans in a given season; 26 percent grow two varieties, and 12 percent grow three bean varieties. More than half of the seeds planted are traditional, farmer-saved (59%), followed by purchased certified (27%), and purchased quality declared (13%); some borrow or exchange bean seeds with other farmers. Major bean seed problems cited were high cost (35%) and fake seed on the market (31%); in addition, purchased seed often contains mixed varieties that they must sort by hand prior to planting. Some (31%) purchase bean seeds treated with fungicide for planting; very few use Rhizobium (three percent).

Bean production constraints cited covered an array of issues: pests (57%), heavy rains (57%), low soil fertility (43%), inadequate labor (33%), diseases (22%), and lack of improved seed (19%). More than half (53%) had changed bean varieties over the last three years to improve yields, generally using improved varieties. Some have stopped growing a specific bean variety due to lack of good market (33%), low yields (30%), and low tolerance to rain (18%). Primary constraints for producing other crops cited by farmers were similar—pests (63%), low soil fertility (51%), diseases (46%), and inadequate labor (35%). Overall, just under half (45%) of the farmers interviewed hired labor to assist in their farming. The majority (66%) indicated at least small losses of their beans to storage pests, but nine percent lost nearly half.

Farmers are engaged in a variety of actions to maintain soil fertility. Nearly all (90%) practice crop rotation in fields where beans are grown, mainly with maize (31%), groundnuts (25%), sweet potato (14%), and cassava (13%). Half reported making specific changes in the last three years to improve soil fertility, with manure the most common amendment, followed by inorganic fertilizers and compost. They commonly cited the need for more manure and fertilizers, and capital or credit to improve further. They carry out soil fertility related experiments, most compare yields between seasons, but some also compare experimental and control (untreated) plots in the same season. When their experiments indicate success, they put the results into practice, and some demonstrate their methods to other farmers. Soil erosion problems were also widely cited (70%), and efforts made to address this involve making or digging trenches, making terraces, and/or mulching.

Given the challenges of farming anywhere, especially under these conditions, it is noteworthy that more than half of farmers discussed how they have prepared themselves for any disaster that might result in crop losses or failure. Their strategies involve crop diversification (54%), intercropping (22%), livestock rearing (12%), and nonagricultural income earning activities (9%). Most (93%) raise livestock —the principal types are chickens (83%), pigs (62%), goats (42%), cattle (33%), and ducks (13%).

In social terms and information, the farmers interviewed seem to be relatively well connected. Half are members of a farmer or development group. Nearly all own a radio (88%) or cell phone (89%). More than half reported gaining information about agricultural practices in the preceding year. The principal sources were workshop trainings and on-farm demonstrations by extensionists from the government (28%) and NGOs (16%), their own experience (21%), fellow farmers (14%), parents or elders (12%); only seven percent cited public media (radio, television, or newspaper—e.g., weekly "Harvest Money" series in the *New Vision* daily newspaper) and only two percent cited group or cooperative.

The most frequent topics about which they gained information were line planting and spacing (47%), application of fertilizers (57%) and manure (46%), pest management (51%), and drying on tarpaulin (40%). Other topics included grain-seed storage and preservation; collective marketing (34%); field preparation (33%); disease management (33%); timing of weeding (31%); cleaning, sorting, grading (28%); and airtight storage (8%). Farmers also generate useful information through their own experience; most important are early field preparation and timely planting; the timing of weeding; cleaning, sorting, and grading; collective marketing; and grain-seed storage and preservation. They share information on beans with a few other farmers, close neighbors, and group members. They expressed interest in obtaining more information about fertilizers (65%), quality seeds (48%), pesticides and herbicides (39%) (adulterated agricultural chemicals are common problems), farm tools—especially pump sprayers (27%), and manure (20%). Opportunities for farmer-to-farmer information sharing through exchange visits are widely appreciated.

Despite learning about and trying to obtain more information about collective marketing, nearly all (97%) reported selling beans as individuals rather than as a group. Most cited problems of low market prices (82%) and faulty weighing scales (52%), and a few noted price fluctuations and the lack of collective marketing. They obtain most of their market price information from traders (75%); a few get this from fellow farmers (19%) or the radio (14%). Prices of beans in local markets are being monitored on a periodic basis. We expect that prices are very low just after harvest when most farmers sell, and much higher later. We did note that in Gurué beans produced during the dry season—in low land or with irrigation—are generally of higher quality and obtain higher prices.

Farming is the main income source for most, followed by livestock sales. Nearly half earn income from various types of employment, primarily petty trade, casual wage employment, handicrafts, and small businesses (e.g., retail shops, hair dressing). Income earned from bean and other crop sales is used to pay for domestic needs (85%), school fees (74%), health care (23%), and investments in agriculture (16%). Half of the households owned a bicycle and one-fourth owned a motorcycle.

Most households are involved in a variety of financial transactions involving money or items with monetary value. Most (73%) reported giving or sending money, food, or goods in the past year, and 63 percent reported receiving such from outside the household. Just over half were credit and savings group members, and two thirds had cash savings. Nearly half borrowed in past year, primarily from a savings group, but also from friends and a few from a commercial bank. Purposes of loans were for school expenses, to invest in farming, and to have capital to start or expand a business. Most (75%) indicated that they could get credit or a loan if needed.

Food security is often considered as the most fundamental bottom line indicator of well-being. Half reported that all of their bean harvest from previous season (second season of 2013) had been consumed before the next season's harvest. We inquired about how long their bean harvest from the 2014 first season would provide food; their responses (in months) varied significantly—one (22%), two (18%), three (19%), four (15%), five (10%), six (7%). One-third of the households indicated that there were times in the past year when their family did not have enough food to meet their needs; 13 percent reported that there was no food to eat in the past four weeks.

From this profile, some important aspects emerge. The quantity and quality of land available for farming beans and other crops varies among households and communities. In their diverse cropping systems, beans are an important crop for both food security and income. Their practices that contribute to maintaining soil fertility include crop rotation, intercropping, and application of manure and fertilizer. Some are actively engaged in conducting their own experiments. Principal problems are pests, rainfall, soil fertility and erosion, and labor requirements. They also try to engage in additional activities that produce income. They belong to farmer and development groups, yet few sell collectively. While they have radios and cell phones, most depend on traders to learn market prices. With one-third experiencing inadequate food supply during the previous year and that for more than one-half their harvest lasts no more than three months, there is food insecurity problem in the area. Interventions that could help farmers increase food production will make a great contribution to community well-being.

Objective 3: Develop and Validate Appropriate Diagnostic and Decision Support Aids

The purpose of assessing nutrient contents of soils of the selected communities is to determine if current levels of nutrients are adequate for optimal plant growth, or if growth limiting factors typical of soils of the tropics such as Al and possibly Mn toxicity were present and are limiting bean yields. Our working hypothesis has been that all soils may have some nutrient limitations.

We collected and analyzed representative soil samples from selected farmers' fields in Uganda and Mozambique (Photo 2). Soil samples were collected at two depths (0–15 and 15–30 cm) from 32 bean fields managed by 17 community-selected innovative farmers in Masaka and Rakai districts, Uganda, in January 2014. In-depth interviews were conducted with all of these farmers. In addition, we have also been collecting biweekly data on farmers' agronomic practices and problems, including bean variety, planting date, weeding, and type of fertilizer or other amendments. In Mozambique's Gurué district, 46 soil samples were collected in June from the fields of 25 community-selected innovative farmers. GPS coordinates for soil types and sites were captured for development of site specific soil maps.

Soils were prepared and sent to Crop Nutrition Laboratory (soil and plant tissue) Services (CropNuts) in Nairobi, Kenya for analysis. This laboratory was selected so that analyses of soils between the two project sites, Masaka and Rakai districts in Uganda and Gurué district in Mozambique, will have used the same laboratory and same methods of analysis. The specific methods and procedures used by CropNuts have been developed for soils of the tropics, for example the measurement of P and K using the Mehlich-3 procedure for acid soils of low activity clays. The calculation of effective cation exchange capacity is required in soils of variable charge since the classic cation exchange capacity (CEC) is determined at pH 7 which is well above the usual pH of weathered soils.

An array of 19 chemical and physical parameters was determined for the samples at CropNuts, with some determinations of the Uganda samples completed at Makerere University. Data were analyzed by combinations of ANOVA, correlation, and regression. Analysis of these samples revealed the presence of low pH and consequent high levels of available aluminum in many fields (Table 1). Concentrations of K and P were low in Limyufumyufu and Luyinjayinja soils (Table 2). Additionally, concentrations of Ca and Mg also were lower than generally recommended in other locations for bean production. Nutrient levels in black soil (Liddugavu) appear adequate for bean production in a number of sampled fields. Results from the nutrient omission study conducted at Makerere University documented reduced bean growth in Limyufumyufu and Luyinjayinja soil when P, K, limestone, or N was not added. Nodulation of bean plants was nonexistent in treatments that had limestone omitted from these soils (Table 3).

In Gurué, four communities (*postos administrativos*) were selected for project work: Lioma, Ruace, Tetete, and Mepuagiua. The physical properties of soils of all four communities are coarse, with sand contents mostly above 45 percent. Silt contents ranged from about 25 to 40 percent whereas clay was usually less than 15 percent. Specific textures included clay loams, sandy loams, and sandy clay loams. None of the soils was grouped in the soil texture grouping of clay. These quantities of silt suggest the soils are capable of holding substantial amounts of plant available water.

Regarding soil chemical properties, nutrient levels varied greatly among the project communities suggesting that a range of bean production conditions are represented by the selected project sites (Figure 1). Mepuagiua, for instance, is characterized by lower levels of nutrients than the other three. Soil pH tends to be lower in that village and other measures such as the ECEC (Figure 2) also point to more highly weathered soil conditions. Given the generally higher levels of clay in soils of farmers, these soils are of the low activity group and thus should be managed with those limitations in mind. Of the nutrients studied, phosphorus (P) varies the most among the communities (see Figure 1). That there is such a high variability (represented by the standard error bars) suggests the need for diagnostic tools to discern which of the fields have sufficient quantities of P. The overall levels of P are surprisingly high, with averages exceeding 90 mg kg^{-1} in three of the four communities. Typical critical levels for this nutrient with Mehlich-3 range from 10 to 30 depending on the crop and soil conditions. Among the nutrient cations of K, Ca, and Mg all are present in surprisingly high levels, generally at or above critical levels recognized by IIAM Mozambique. The community of Mepuaguia, as in the case with nutrient P, is also characterized by the lowest levels of these nutrients. While the levels of these cations are medium to high they also are highly variable. With the relatively low levels of these nutrients and the highly variability, it is likely that there are some fields where the acidity is limiting or would be limiting to bean production. Here again, it is clear that there is a need for diagnostic methods to identify fields that may be responsive to additional nutrients and other soil amendments.

Several tentative conclusions can be drawn from this initial sampling of soils in Gurué. The high levels of nutrients in fields need to be confirmed. It is possible that farmers selected some of their best fields to show to the project team. Subsequent samples should be carefully selected to ensure representativeness. As indicated above, there is substantial variability in soil nutrient levels among the selected communities and techniques of diagnosing nutrient status in the field will be quite useful.

A nutrient omission experiment to diagnose nutrient deficiencies in selected soils for bean production (Deenik and Yost 2006) was conducted in a greenhouse at Makerere University Agricultural Research Institute (MUARIK) with 11 treatments (see Table 4) using a Completely Randomized Design. Each nutrient treatment was randomly assigned to three different soils (Liddugavu, Limyufumyufu, and Luyinjayinja) and replicated three times (total of 99 experimental units). Experimental factors were three soil types and 11 nutrient treatments. Four seeds were sown in each pot at planting and later thinned to two uniform plants per pot five days after emergence. Pots were watered with distilled water to keep moisture at field capacity (Photo 3). From 11 days onwards, regular observations were made to detect visual nutrient deficiency symptoms on foliar parts of plants. Stem height (cm) of plants and above ground biomass production (grams) were measured. Stem height was measured from plant base to apex, and used as growth parameter to measure plant size. Weights of plants were recorded after oven drying at 70^{o}C. Composite samples of aboveground biomass per treatment per soil were ground and analyzed for macro and micro nutrients. Yield of plants growing in a soil to which all nutrients had been added was the reference point for comparison to those in a series of treatments in which each of the nutrient elements had been omitted. Differences in growth between plants grown on a deficient and a complete treatment were assumed to be caused by deficiency of the omitted nutrient.

Above ground biomass mean dry weight for the three soils are summarized in Figure 3. Preliminary greenhouse results from the nutrient omission study showed that the most limiting nutrient in *Liddugavu* (black) soil was Ca followed by P. Mean bean dry matter yield was 1.5 g and 1.9 g for soil without Ca and P, respectively, compared to the control treatment where the dry matter yield was 1.6 g (Prossy Kyomuhendo, unpublished results, 2014). Omission of K triggered the highest aboveground biomass followed by omission of micronutrients treatments. The most limiting nutrients in *Limyufumyufu* (red) soil were P followed by N. Mean bean dry matter yield was 0.8 g and 1.0 g for soil without P and N, respectively, compared to the control treatment where the dry matter yield was 0.8 g. Omission of Ca triggered the highest above ground biomass followed by omission of Mg. The most limiting nutrients in *Luyinjayinja* (gravelly) soil were P and N. Mean bean dry matter yield was 0.8 g and 1.2 g for soil without P and N, respectively, compared to control treatment where dry matter yield was 0.6 g. Omission of K and S triggered the highest aboveground biomass in this soil type. These results require further field verification. Complementing the nutrient omission study and on-farm field experiments, we plan to conduct lime requirement studies (Manjula *et al*. 2005). In Uganda, this will involve collecting two soil types from four farmers based on their low soil pH and Ca levels. 300 g of soil will be amended with reagent grade $CaCO_3$ and eight levels of lime will be used. The 32 treatments will be replicated three times.

Analysis of soils from Gurué indicates that some soils fall in strongly acidic or acidic categories. These soils are likely to have aluminum toxicity problem or low base saturation. To assess the problem, liming curves will be developed for predicting the amount of soil amendment needed to raise soil pH up to adequate levels for bean and maize growth. This experiment will be followed with field testing of estimated liming requirement using both incubation study and the concentration of available Al in soils.

Identifying and understanding important interactions of soil chemical and physical parameters with bean production is a necessary component for developing improved management solutions for bean farmers. Bean growth, development, and yield were monitored every two weeks on 15 farms during the March–June 2014 rainy season in Masaka and Rakai. Several potentially highly important relationships previously not identified in Uganda include interactions among soil pH, bean nodulation, foliar disease level, plant density, weed density, and bean seed yield. Significant correlations were observed: red nodule number per plant with plant disease ($r = -0.620$). Further analysis of this relationship provided the regression, red nodule number/plant, $Y = 31.8–0.186x$, $r^2 = 0.385$, $P=0.0137$, where x is the percentage of leaf area diseased. The leaf area with foliar disease, often present as Angular leaf spot and anthracnose diseases, explains nearly 40 percent of the variation in effective nodule number on bean. Nodule number on a per plant basis explains nearly 40 percent of the variation in bean yield (bean yield, kg ha^{-1}, $Y = -1803 +41.5x$, $r^2 = 0.397$, $P=0.0209$ where x is the nodule number per plant). Another important relationship determined from soil analysis and biweekly bean monitoring was for weed density and soil pH at the 15–30 cm depth. Forty-five percent of variation in average weed density was explained by soil pH (total weed density, # m^2, $Y = -99 + 21.4x$, $r^2 = 0.450$; $P=0.0121$, where x is pH at 15–30 cm depth. This relationship allows us to determine that at higher soil pH values within our set of bean fields, the influence of weed management likely is more important to bean production than in soils with low, or very low, subsoil pH. Edaphic constraints are more important in some soil types than others.

To confirm the importance of these relationships, a study currently is underway at two locations in Masaka District. Treatments are three bean management systems, each with four different varieties of bean. Management systems vary for level of edaphic or biologic constraints managed by specific input levels or management factors. The bean varieties include the old standard, *Nambale Omumpi*, with another older variety and two newly released varieties with greater levels of resistance to Angular leaf spot and anthracnose. Lance Goettsch is the graduate student leading this study.

Field studies to validate soil fertility management options for beans by testing combined or sole application of inorganic (N, P) fertilizers with organic (poultry manure) were initiated in Masaka district, Uganda (Photo 4). A parallel study to test the added benefit of adding micronutrients (in addition to N, P) to beans was included, building on preliminary results of the nutrient omission study. Collection of data on leaf area, leaf area index, nodulation, grain yield and soil chemical characteristics is ongoing.

Objective 4: Develop and Assess Effectiveness of Innovative Approaches for Dissemination of Information and Decision Support Aids, Training, and Follow-up Technical Support

To realize our goals, we will be working with existing institutions and organizations to identify and develop messages that can provide farmers with reliable information to make critical decisions about beans and soil fertility, and pathways that can provide relevant information in an effective, efficient, and sustainable manner. During focus group discussions and in-depth interviews, farmers characterized strengths and weaknesses of current information providers and existing agricultural information dissemination systems in Uganda and Mozambique.

Extension, radio and fellow/model farmers are highly valued information sources for Ugandan farmers. However, while radio is easily available, extension visits and training occur less frequently. While mobile phones have made it possible for farmers to contact extension directly, actual training and field visits by extension agents are not common for bean production. Mobile phones also are used to check market prices. Fellow farmers, on-farm demonstrations, and exchange visits are considered important and available information sources. Grameen's mobile phone community knowledge workers are an additional new source. In Rakai, the NGO CEDO, in cooperation with extension, is a trusted source for bean seed and technical assistance. Farm chemicals and information are now provided by the private sector, but many farmers do not trust private sector products/information.

Farmer associations (20–25 annual dues-paying members) are an important but not universal information source in Gurué. These associations tend to be linked to specific crops such as soybeans, but do provide technical support and sometimes access to markets. Extension is spread thinly in the area, and although it is a trusted source, a number of farmers have had no contact with extension. NGOs such as World Vision, CLUSA, IITA (for nutrition linked to soybeans) and TechnoServe have been working in selected villages, but for the most part not directly with common bean production. Community radio exists in the area, but some visited communities had poor or no reception of programs. Mobile phones are being adopted, and are used to check market prices and coordinate activities. The emphasis in some areas on soybean production through World Vision has provided full value-chain access for that crop, while reducing local emphasis on bean production.

The perceived accuracy and value of each type of sources varies among study communities. Some information received through training sessions seems to conflict with information previously disseminated; in addition, some information broadcast on the radio by private sector businesses is viewed as misleading or inaccurate. We have developed an initial list of available and potential information channels and associated organizations. Initial discussions with providers are enabling us to assess their capacity and willingness to develop and deliver messages concerning beans and soil fertility; this process will be continued and expanded.

To work with local information providers and dissemination systems, we are starting with existing training materials regarding anaerobic bean grain and seed storage using jerry cans and the triple bag system that were developed during the previous Pulses CRSP project in Uganda's Kamuli District. This will enable us to test the information system and providers so that subsequent messages regarding crop and soil management practices and technologies can be launched effectively and efficiently. The Masaka District Agricultural Officer recently used those materials to learn about and evaluate the effectiveness of these anaerobic storage methods during a three month period. He is very enthusiastic about the results of this effective chemical-free method: "Thank you so much and I strongly believe it is technology we need to recommend to our farming community." He has already recommended it to local stockists. A second trial will take place following the second season harvest in late 2014. This will involve participating farmers and local agricultural officials. Training materials will be refined, pretested and distributed for this trial on a controlled basis to a sample of farmers. Results will be evaluated in late March 2015. If successful, a full-scale trial will be scheduled following the first season of 2015 (June and July) including participating farmers plus all target farmers in the area. Target farmers produce enough beans and can save them for at least three months before marketing. Extensive publicity would be given to this trial, including radio, extension, and local NGOs plus farmer groups. Message targets are those who can store beans for at least three months to benefit from increases in market prices later. Assessments will track channel and message effectiveness, and guide other dissemination activities developed later after soil tests and on-farm trials have been completed.

In Mozambique, IIAM and SAWBO are working on animated videos for use in Gurué. During PRA activities in June, a short workshop was organized to show an animated video in Portuguese to more than 50 women and men farmers. It was well received and generated considerable discussion during the session. They are working on a composting animation that should be available in early FY15, and identifying other topics for which collaborative work may be initiated in the coming year. Local language audio will be a key feature in future work, and SAWBO and IIAM will begin translating the composting animation into local languages during late 2014 and early 2015.

Following soil nutrient and crop analysis and community communication assessment, we will work with project staff and extension to develop an initial message that can test the communication system with a small number of farmer groups/associations. Given the relatively high—but uneven—level of membership in farmers and other development groups, this strategy should be effective, especially since horizontal farmer-to-farmer learning is highly valued in many communities. We will then evaluate the effectiveness of the dissemination system and provide additional training and/or revise methods to prepare for subsequent participatory dissemination activities. Dissemination, training and support will target priority decision-making points for individuals and groups.

<u>Objective 5:</u> Enhance Institutional Research Capacity Relative to Grain Legumes

Our project team is making a significant effort graduate student education and through mentored research activities in partner countries. Specific research foci and affiliations follow:

- Naboth Bwambale — Ugandan M.S. student in Sustainable Agriculture and Sociology at Iowa State University. His research is focused on “Farmers’ Perceptions, Knowledge and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management.”
- Lance Goettsch — American M.S. student in Agronomy at Iowa State University. His research is focused on “Practical Methods to Alleviate Constraints Limiting Common Bean (*Phaseolus vulgaris* L.) Production in Masaka, Uganda.”
- Prossy Kyomuhendo — Ugandan M.S. student in Soil Science at Makerere University. Her research is focused on “Limiting Nutrients and Lime Requirements for Bean Production.”

- Stewart Kyebogola — Ugandan M.S. student in Soil Science at Makerere University. His research is focused on "Evaluation of Soil Fertility Management Options for Beans in Masaka."
- Jafali Matege — Ugandan M.S. student in Extension and Innovation Studies at Makerere University. His research is focused on "Gender Dimensions of Bean Farmers' Decision Making for Soil Fertility Management in Masaka and Rakai Districts, Uganda."
- Sostino Mocumbe — Mozambican M.S. student in Journalism and Mass Communication at Iowa State University. His research is focused on "Sociotechnical Approaches for Dissemination of Information and Decision Support Aids."
- António Rocha — Mozambican Ph.D. student in Soil Science at the University of Hawaii. His research will be focused on "Alternative Management Practices for Improving Bean Production."

IV. Major Achievements

1. Challenges and opportunities to bean production in all project districts have been identified, which is an important step for developing specific research hypotheses.
2. Lesson learned through the IIAM social scientist's visit to Uganda to work with the team there contributed to improved baseline household survey design and implementation in Mozambique.
3. Interdisciplinary researchers from U.S. universities are helping young IIAM social and soil scientists to gain experience in data collection (PRA, baseline survey, soil samples) and analyses.
4. We have documented considerable variation in soil types and cropping patterns, as well as in social capital and market patterns among communities. This variability underscores the need for and potential value to farmers of the types of decision support aids that we will be developing.
5. The bean value chain in Masaka and Rakai had an informal platform which collapsed. Our interactions with extension, NGOs and the private sector reveal that this project will contribute to rejuvenation of the platform, contributing to increased yields, food security and income.

V. Research Capacity Strengthening

The breadth of our team which spans soil and crop sciences, sociology, economics, extension and communications contributes significantly to conceptualizing our research objectives, methods, data collection, analysis and interpretation. In addition, members from various institutions and disciplines contribute significantly to mentoring the research of graduate students (described under Objective 5 and Degree Training). In addition, two Institutional Capacity Strengthening grants have been awarded. One involves close collaboration among Makerere University, Uganda's National Agricultural Research Laboratories, and the University of Hawaii. It will focus on combining indigenous and scientific knowledge of soils. The second, for the Institute of Agriculture Research of Mozambique, focuses on recording, analyzing, and interpreting GIS associated data with biophysical, economic, and social data. Work with the funds from both supplemental grants is scheduled to begin early in 2015.

VI. Human Resource and Institution Capacity Development

Short-Term Training

Soil Classification

1. **Purpose of Training:** soil identification, characterization and classification
2. **Type of Training:** participatory and scientific methods
3. **Country Benefiting:** Uganda
4. **Location and Dates of Training:** Masaka and Rakai; January and June, 2014
5. **Number Receiving Training (by Gender):** 2 female, 2 male
6. **Home Institution(s):** Makerere University and National Agricultural Research Laboratory
7. **Institution Providing Training or Mechanism:** University of Hawaii, Makerere, NARL

Soil Testing

1. **Purpose of Training:** soil testing
2. **Type of Training:** field and laboratory
3. **Country Benefiting:** Mozambique
4. **Location and Dates of Training:** Maputo; September, 2014
5. **Number Receiving Training (by Gender):** 2 female, 3 male
6. **Home Institution(s) (if applicable):** Institute of Agricultural Research of Mozambique
7. **Institution Providing Training:** Institute of Agricultural Research of Mozambique

Innovation Platform

1. **Purpose of Training:** innovation platform formation
2. **Type of Training:** participatory methods
3. **Country Benefiting:** Uganda
4. **Location and Dates of Training:** Masaka; June, 2014
5. **Number Receiving Training (by Gender):** 3 male
6. **Home Institution(s):** Makerere University and Masaka District Agriculture Office
7. **Institution providing training or mechanism:** Makerere University

Baseline Survey

1. **Purpose of Training:** household baseline survey design and implementation
2. **Type of Training:** participatory methods
3. **Country Benefiting**: Mozambique
4. **Location and Dates of Training:** Masaka, Uganda; August, 2014

5. **Number Receiving Training (by Gender):** 1 male
6. **Home Institution(s) (if applicable):** Institute of Agricultural Research of Mozambique
7. **Institution Providing Training or Mechanism:** Makerere University

Degree Training

Trainee #1

1. **Name of Trainee:** Naboth Bwambale
2. **Country of Citizenship:** Uganda
3. **Gender:** Male
4. **Training Institution:** Iowa State University
5. **Supervising Legume Innovation Lab PI:** Robert Mazur
6. **Degree Program for Training:** M.S.
7. **Program Areas or Discipline:** Graduate Program in Sustainable Agriculture *and* Sociology
8. **If enrolled at a U.S. university, will Trainee be a Participant Trainee as defined by USAID?** Yes
9. **Host Country Institution to Benefit from Training:** Makerere University
10. **Thesis Title/Research Area:** Farmers' Perceptions, Knowledge and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management
11. **Start Date:** August 2013
12. **Projected Completion Date:** December 2015
13. **Training Status (active, completed, pending, discontinued or delayed):** Active
14. **Type of USG Support (Full, Partial or Indirect) for Training Activity:** Full

Trainee #2

1. **Name of Trainee:** Lance Goettsch
2. **Country of Citizenship:** United States
3. **Gender:** Male
4. **Training Institution:** Iowa State University
5. **Supervising Legume Innovation Lab PI:** Andrew Lenssen
6. **Degree Program for Training:** M.S.
7. **Program Areas or Discipline:** Agronomy
8. **Host Country Institution to Benefit from Training:** Makerere University
9. **If enrolled at a U.S. university, will Trainee be a Participant Trainee as defined by USAID?** No
10. **Thesis Title/Research Area:** Practical Methods to Alleviate Constraints Limiting Common Bean (*Phaseolus vulgaris* L.) Production in Masaka, Uganda
11. **Start Date:** August 2013
12. **Projected Completion Date:** August 2016
13. **Training Status (active, completed, pending, discontinued or delayed):** Active
14. **Type of USG Support (full, Partial or indirect):** Partial

Trainee #3

1. **Name of Trainee:** Prossy Kyomuhendo
2. **Country of Citizenship:** Uganda
3. **Gender:** Female
4. **Training Institution:** Makerere University
5. **Supervising Legume Innovation Lab PI:** Moses Tenywa
6. **Degree Program for Training:** M.S.
7. **Program Areas or Discipline:** Soil Science and Crop Production
8. If enrolled at a U.S. university, will Trainee be a Participant Trainee as defined by USAID?
9. **Host Country Institution to Benefit from Training:** Makerere University
10. **Thesis Title/Research Area:** Limiting Nutrients and Lime Requirements for Bean Production
11. **Start Date:** January 2014
12. **Projected Completion Date:** August 2016
13. **Training Status (active, completed, pending, discontinued or delayed):** Active
14. **Type of USG Support (Full, Partial or Indirect) for Training Activity:** Partial

Trainee #4

1. **Name of Trainee:** Jafali Matege
2. **Country of Citizenship:** Uganda
3. **Gender:** Male
4. **University to Provide Training:** Makerere University
5. **Supervising Legume Innovation Lab PI:** Haroon Sseguya
6. **Degree Program for Training:** M.S.
7. **Program Areas or Discipline:** Extension and Innovation Studies
8. **If enrolled at a U.S. university, will Trainee be a Participant Trainee as defined by USAID?**
9. **Host Country Institution to Benefit from Training:** Makerere University
10. **Thesis Title/Research Area:** Gender Dimensions of Bean Farmers’ Decision Making for Soil Fertility Management in Masaka and Rakai Districts, Uganda
11. **Start Date:** June 2014
12. **Projected Completion Date:** August 2016
13. **Training Status (active, completed, pending, discontinued or delayed):** Active
14. **Type of USG Support (full, Partial or indirect):** Partial

Trainee #5

1. Name of Trainee: Stewart Kyebogola
2. Country of Citizenship: Uganda
3. Gender: Male
4. Training Institution: Makerere University
5. Supervising Legume Innovation Lab PI: Onesimus Semalulu

6. Degree Program for Training: M.S.
7. Program Areas or Discipline: Soil Science and Crop Production
8. If enrolled at a U.S. university, will Trainee be a Participant Trainee as defined by USAID?
9. Host Country Institution to Benefit from Training: National Agricultural Research Laboratories
10. Thesis Title/Research Area: Evaluation of Soil Fertility Management Options for Beans in Masaka
11. Start Date: June 2014
12. Projected Completion Date: August 2017
13. Training Status (active, completed, pending, discontinued or delayed): Active
14. Type of USG Support (full, Partial or indirect): Partial

Trainee #6

1. **Name of Trainee:** Sostino Mocumbe
2. **Country of Citizenship:** Mozambique
3. **Gender:** Male
4. **Training Institution:** Iowa State University
5. **Supervising Legume Innovation Lab PI:** Eric Abbott
6. **Degree Program for Training:** M.S.
7. **Program Areas or Discipline:** Communications
8. **If enrolled at a U.S. university, will Trainee be a Participant Trainee as defined by USAID?** Yes
9. **Host Country Institution to Benefit from Training:** Institute of Agricultural Research of Mozambique (IIAM)
10. **Thesis Title/Research Area:** Sociotechnical Approaches for Dissemination of Information and Decision Support Aids
11. **Start Date:** August 2014
12. **Projected Completion Date:** December 2016
13. **Training Status (active, completed, pending, discontinued or delayed):** Delayed
14. **Type of USG Support (full, Partial or indirect):** Full

Trainee #7

1. **Name of Trainee:** António Rocha
2. **Country of Citizenship:** Mozambique
3. **Gender:** Male
4. **Training Institution:** University of Hawaii: Manoa
5. **Supervising Legume Innovation Lab PI:** Russell Yost
6. **Degree Program for Training:** Ph.D.
7. **Program Areas or Discipline:** Agronomy and Tropical Soils
8. **If enrolled at a U.S. university, will Trainee be a Participant Trainee as defined by USAID?** Yes

9. **Host Country Institution to Benefit from Training:** Institute of Agricultural Research of Mozambique (IIAM)
10. **Thesis Title/Research Area:** Alternative Management Practices for Improving Bean Production
11. **Start Date:** January 2015
12. **Projected Completion Date:** September 2017
13. **Training Status (active, completed, pending, discontinued or delayed):** Pending
14. **Type of USG Support (Full, Partial or Indirect) for Training Activity:** Full

VII. Achievement of Gender Equity Goals

The project team has actively sought input from women farmers during focus group discussions and in-depth individual interviews (approximately one-half), and the baseline household survey (approximately two-thirds). In the baseline survey, we explicitly inquire about women's roles in making decisions regarding 16 activities in bean production, storage, marketing, and income use. Four women have benefitted from short-term training and one woman is benefitting from long-term training.

VIII. Explanation for Changes

1. Nutrient Omission Study for soils from Gurué will soon be conducted following receipt of data from laboratory profiles of soil samples collected in late June. Adequate funds exist for this.
2. Information Practitioner Workshops . Our statistical analyses of these data from household baseline surveys in Uganda and Mozambique will help identify the content and participants for the information practitioner workshop, which is scheduled for mid-2015. Adequate funds exist for this.
3. We exceeded short-term training planned (five people) by an additional eight people (total 13).

IX. Self-Evaluation and Lessons Learned

We have made a significant investment in developing a collegial multidisciplinary multicountry team. This brings multiple perspectives to bear in understanding dimensions of the central problems and in determining methodological approaches—everyone's input is highly valued. We are responsive in multiway communications and collaborate well in discussing, planning and implementing all project activities. Considerable organizational and logistical effort and costs have been involved in bringing the team together for field research activities in Uganda and Mozambique. Researchers from all institutions are actively involved in mentoring all of our graduate students in their research. This generates high quality scientific data, engages diverse teams in analysis and making critical decisions, and following through. We continue to build on our diverse experiences and expertise to make wise decisions with limited resources and achieve meaningful outputs and impacts.

In both countries, we are operating within complex systems that directly and indirectly influence key elements of farming systems. In Mozambique, the creation of large-scale agricultural enterprises that emphasize certain crops (e.g., soybeans) affects bean growing and soil fertility efforts. In Uganda, government initiatives favoring larger commercial farmers over smallholder farmers have myriad impacts. Our project strategy and activities have to adapt to these dynamics to achieve our key goals.

X. Scholarly Accomplishments

Goettsch, L. & A. Lenssen. 2014. U.S. Borlaug Fellows in Global Food Security graduate research grant. "Practical methods to alleviate constraints to common bean (*Phaseolus vulgaris* L.) production in Masaka, Uganda." Funded $14,996.

Goettsch, L. 2013–2015. Louis Thompson Endowment Graduate Fellowship. Agronomy Department (its premier fellowship). Iowa State University.

Goettsch, L. 2014. Global Programs Travel Grant. Iowa State University. $2,000 support for travel to Uganda for M.S. research.

Five M.S. student research proposals at Makerere University and Iowa State University.

Farmer Decision Making Project Team. 2014. *Farmer Focus Group Discussions—Masaka and Rakai Districts, Uganda.* January (unpublished report).

Farmer Decision Making Project Team. 2014. *Farmer Interviews — Masaka and Rakai Districts, Uganda.* January (Unpublished report).

Farmer Decision Making Project Team. 2014. *Farmer Focus Group Discussions — Gurué District, Mozambique.* June (Unpublished report).

Farmer Decision Making Project Team. 2014. *Farmer Interviews — Gurué District, Mozambique.* June (Unpublished report).

XI. Progress in Implementing Impact Pathway Action Plan

The project team is making measured progress in implementing the action plan:

1. Project activities are on track to enable the team to develop and refine appropriate models of farmer decision making strategies that reflect influences of social, cultural, economic, institutional and contextual factors;
2. We are beginning to consider materials that will be useful for development of diagnostic aids using observable characteristics that enable farmers to make site-specific management decisions; and
3. We are beginning to understand the appropriateness of existing methods and media for information dissemination to intermediate and end users.

XII. Annexes

Annex 1. Tables, Figures, and Photos Cited in the Report

Tables

Table 1. Soil pH, available phosphorus, potassium, and aluminum, silt, sand, and clay concentration, and bean stand, height, seed yield, and root nodules for three soil types, Masaka District, Uganda.

Parameter	pH	P	K	Al	Silt	Clay	Sand	Stand	Ht	Yield	Nodules	Red nodules	Leaf diseases	Weeds
Soil		mg kg^{-1}			g kg^{-1}			no. m^{-2}	cm	kg ha^{-1}	no. $plant^{-1}$		% of leaf area	no. m^{-2}
Liddugavu	6.4 a†	49 a	177 a	0.02	132	292	584 a	9.7	38 b	426 a	54 a	31 a	9 c	28.1
Limyufumyufu	5.4 b	4 b	67 b	0.52	106	390	504 b	10.2	27 c	177 b	48 b	24 c	36 a	21.1
Luyinjayinja	5.7 b	38 a	194 a	0.50	136	292	583 a	10.7	54 a	36 c	48 b	28 b	14 b	14.3
Depth (cm)														
0-15	5.9	32	175	0.32	130	309	562							
15-30	5.8	28	117	0.38	120	340	552							
Significance								<u>*P* value</u>						
Soil	***	***	***	**	ns	***	**	ns	***	*	**	***	***	ns
Depth	ns‡	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-	-
Soil × Depth	ns	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-	-

*Significant at P= 0.05; **Significant at P=0.01; ***Significant at P=0.001. †Means followed by different lowercase letter within a column and parameter are significantly different at P≤0.05; ‡Not significant.

Significant correlations and regression functions:

Yield vs nodules/plant=.630, 0.0006; Yield = -1803 +41.5x, r2 = 0.397, P=0.0209

Plant height vs %leaf disease=-0.52977; Height = 42 – 0.378x, r2 = 0.281, P=0.0626 (not very good, NS, but only n=13 points) NOT PRESENTED

ABOVE

Red nodules number/plant vs %leaf disease= -.6201; Red nodules/plant = 31.8 – 0.186x, r2 = 0.385, P = 0.0137

<u>0-15 cm depth follow:</u>

Total weeds (#/m2) vs pH, 0-15 cm depth = 0.622; Total weed density = -97 + 20.7x, r2 = 0.387, P = 0.0176

<u>15-30 cm depth</u>:

Total weeds (#/m2) vs pH, 15-30 cm depth = 0.617; Total weed density = -99 + 21.4x, r2 = 0.450; P = 0.012

Table 2. Mean (SE) Mehlich 3 - Available Phosphorus, Potassium and pH – Farmers Fields, Uganda

Soil	Depth	pH	P	K
Liddugavu (n=13)	0-15	6.4 (0.1)	53 (16)	192 (36)
	15-30	6.3 (0.1)	44 (14)	162 (28)
Limyufumyufu (n=4)	0-15	5.5 (0.2)	5 (1)	79 (18)
	15-30	5.3 (0.2)	3 (1)	55 (19)
Luyinjayinja (n=6)	0-15	5.9 (0.2)	38 (19)	253 (87)
	15-30	5.6 (0.2)	37 (22)	134 (20)

Table 3a - Mean (SD)* Results for 11 Treatments in a Nutrient Omission Study, Run 1, Liddugavu Soil - Uganda

Parameter	Treatment	FW	DW	DM	Total nodules	Red nodules	Height	Leaf
		g plant^{-1}		g kg^{-1}	no.	%	cm	no. plant^{-1}
No additions	1	12.1 (0.90)	1.6 (0.18)	132 (5)	30.2 (24.7)	95 (8)	76 (14)	5.5 (1.0)
All nutrients added	2	16.5 (1.98)	2.1 (0.41)	126 (13)	2.5 (1.3)	31 (27)	81 (8)	7.0 (0.8)
All nutrients + Rhizobium	3	19.3 (2.31)	2.7 (0.19)	138 (8)	13.8 (13.5)	74 (44)	95 (11)	7.5 (1.3)
- N + Rhizobium	4	13.9 (2.02)	2.0 (0.41)	140 (9)	32.8 (5.1)	99 (1)	64 (14)	5.7 (1.0)
– N	5	15.2 (0.38)	2.1 (0.10)	141 (10)	25.8 (7.3)	82 (21)	77 (30)	7.2 (1.0)
– P	6	13.9 (5.56)	1.9 (0.80)	135 (19)	7.2 (12.0)	62 (54)	66 (22)	6.2 (1.5)
– K	7	19.0 (1.46)	2.8 (0.25)	150 (8)	17.2 (14.2)	90 (13)	67 (12)	7.7 (0.3)
– Mg	8	13.8 (2.94)	2.3 (0.91)	164 (7)	8.2 (7.3)	22 (20)	73 (22)	7.0 (1.3)
– S	9	15.2 (0.80)	2.2 (0.32)	147 (29)	11.3 (19.6)	23 (40)	71 (13)	7.2 (0.3)
– Ca	10	11.0 (3.56)	1.5 (1.21)	118 (83)	5.7 (6.0)	26 (22)	62 (47)	6.7 (1.0)
– micronutrients	11	16.8 (5.76)	2.7 (0.36)	173 (53)	20.3 (19.6)	90 (10)	88 (10)	7.2 (1.2)

Table 3b - Mean (SD)* Results for 11 Treatments in a Nutrient Omission Study, Run 1, Limyufumyufu Soil - Uganda

Parameter	Treatment	FW	DW	DM	Total nodules	Red nodules	Height	Leaf
		g $plant^{-1}$		g kg^{-1}	no.	%	cm	no. $plant^{-1}$
No additions	1	5.7 (0.28)	0.8 (0.02)	136 (9)	0.0	-	31 (9)	3.5 (0.5)
All nutrients added	2	13.8 (1.86)	1.7 (0.24)	127 (10)	0.0	-	73 (14)	5.8 (0.3)
All nutrients + Rhizobium	3	8.2 (3.99)	1.0 (0.01)	126 (7)	0.0	-	36 (18)	4.8 (1.0)
- N + Rhizobium	4	11.8 (1.06)	1.1 (0.98)	93 (8)	13.2 (18.9)	56 (48)	76 (22)	5.8 (0.3)
– N	5	12.2 (0.74)	1.7 (0.12)	135 (8)	0.7 (0.8)	56 (51)	61 (18)	6.2 (0.3)
– P	6	5.7 (0.54)	0.8 (0.05)	132 (18)	0.0	-	31 (7)	3.7 (0.3)
– K	7	12.8 (1.69)	1.7 (0.26)	134 (5)	0.0	-	78 (7)	6.3 (0.3)
– Mg	8	13.5 (1.33)	1.8 (0.27)	134 (11)	0.0	-	78 (6)	6.3 (0.3)
– S	9	13.1 (1.32)	1.6 (0.40)	124 (26)	0.0	-	71 (20)	6.2 (0.3)
– Ca	10	14.3 (2.30)	2.0 (0.51)	139 (16)	0.0	-	78 (17)	7.7 (0.8)
– micronutrients	11	13.0 (2.58)	1.7 (0.25)	135 (8)	0.2 (0.3)	0	78 (29)	6.0 (0.9)

*For all parameters; n=3 pots with 2 plants per pot

Table 3c - Mean (SD)* Results for 11 Treatments in a Nutrient Omission Study, Run 1, Luyinjayinja Soil - Uganda

Parameter	Treatment	FW	DW	DM	Total nodules	Red nodules	Height	Leaf
		g plant^{-1}		g kg^{-1}	no.	%	cm	no. plant^{-1}
No additions	1	3.7 (0.35)	0.6 (0.17)	147 (40)	3.2 (5.5)	26 (46)	39 (28)	4.0 (1.7)
All nutrients added	2	12.0 (2.01)	1.4 (0.31)	118 (10)	1.2 (2.0)	0	59 (31)	6.0 (1.0)
All nutrients + Rhizobium	3	10.6 (2.68)	1.4 (0.37)	132 (2)	1.0 (1.7)	22 (38)	55 (23)	5.0 (1.3)
- N + Rhizobium	4	8.5 (2.15)	1.2 (0.32)	145 (19)	4.8 (2.9)	83 (18)	41 (15)	4.2 (1.0)
– N	5	9.0 (0.27)	1.2 (0.13)	135 (10)	7.2 (7.5)	55 (47)	50 (20)	3.8 (0.3)
– P	6	5.6 (0.81)	0.8 (0.09)	141 (39)	0.0	-	32 (7)	3.5 (0.0)
– K	7	12.6 (0.43)	1.8 (0.10)	143 (9)	1.5 (1.3)	38 (38)	75 (34)	6.0 (0.0)
– Mg	8	11.6 (1.18)	1.6 (0.20)	142 (22)	1.2 (1.0)	11 (19)	71 (3)	6.0 (0.0)
– S	9	12.6 (1.14)	1.8 (0.09)	142 (11)	0.7 (0.8)	33 (58)	71 (4)	6.8 (0.8)
– Ca	10	12.9 (0.13)	1.7 (0.19)	135 (16)	2.3 (3.6)	8 (13)	72 (39)	5.0 (1.3)
– micronutrients	11	12.8 (1.46)	1.7 (0.23)	136 (22)	1.2 (0.6)	56 (51)	57 (51)	5.7 (0.7)

*For all parameters; n=3 pots with 2 plants per pot

Table: 4 NOS Treatment levels

Nutrient treatment	Code	Nutrients added
Control	1	Natural condition of soil
Complete nutrient treatment	2	N,P, K, Mg, Ca, S, Micronutrients
Complete nutrient treatment + Rhizobia	3	N,P, K, Mg, Ca, S, Micronutrients & Rhizobia inoculation
N omitted + Rhizobia	4	P, K, Mg, Ca, S, Micronutrients& Rhizobia inoculation
N omitted	5	P, K, Mg, Ca, S and Micronutrients
P omitted	6	N, K, Mg, Ca, S, Micronutrients
K omitted	7	N, P, Mg, Ca, S, Micronutrients
Mg omitted	8	N, P, K, Ca, S, Micronutrients
S omitted	9	N, P, K, Mg, Ca, Micronutrients
Ca omitted	10	N, P, K, Mg, S, Micronutrients
Micronutrients omitted	11	N, P, K, Mg, Ca, S

Figures

Major Nutrients of Soils of Four Project Communities - Gurué, Mozambique

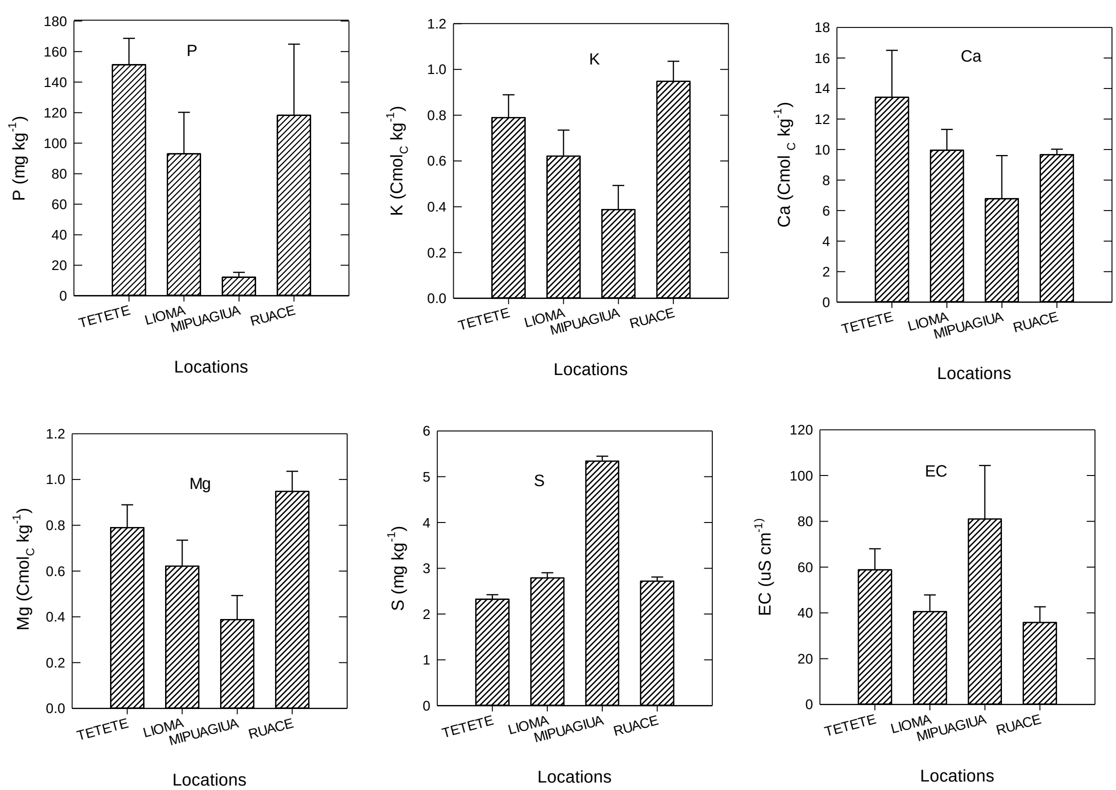


Figure 1. Soil Acidity, and Major Organic Constituents of Soils of Four Project Communities - Gurué, Mozambique

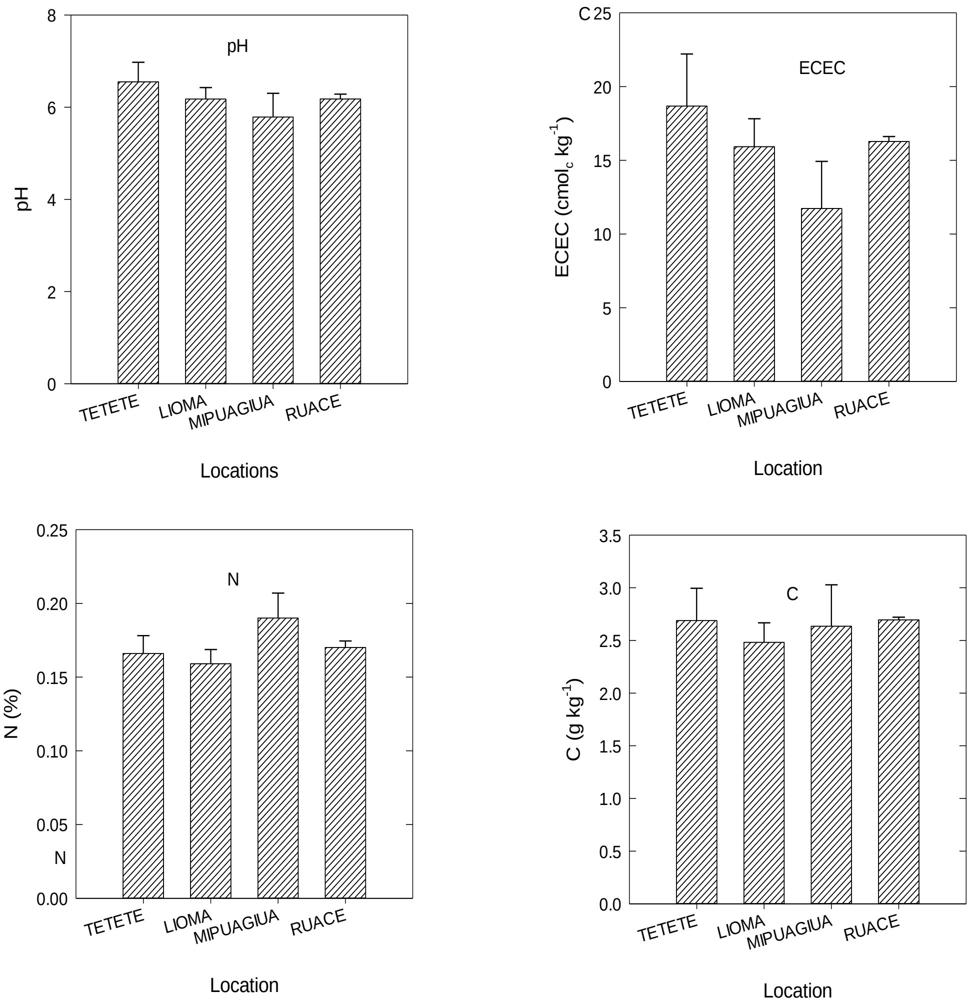
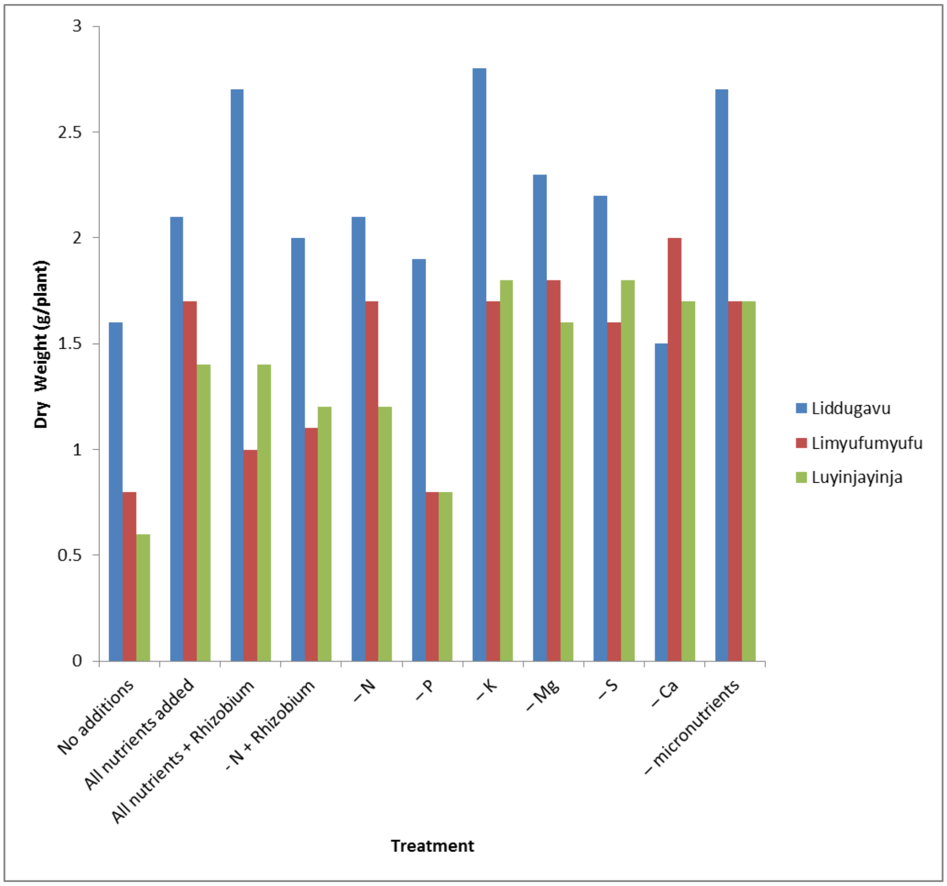


Figure 3. Nutrient Omission Study Dry Weight at Harvest in Three Soils, Uganda



XIII. Milestones

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Research, Training and Outreach Workplans
(April 1, 2013 -- September 30, 2014)

SEMI-ANNUAL MILESTONES OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

Project Title: ***SO2.1 - Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize-Bean Production Systems***

Provide abbreviated name of institutions in columns below. Start with the U.S. institution.

(Tick mark the time period for achieving identified milestones by institution)

	Iowa State University			University of Hawaii			University of Illinois			Makerere University			Nat'l Ag. Res. Lab - Ug.			Inst. Ag. Res. - Moz.		
Identify Milestones by Objectives	10/1/13	4/1/14	10/1/14	10/1/13	4/1/14	10/1/14	10/1/13	4/1/14	10/1/14	10/1/13	4/1/14	10/1/14	10/1/13	4/1/14	10/1/14	10/1/13	4/1/14	10/1/14
Objective 1: Characterize Smallholder Farmers' Motivations, Current Knowledge and Practices																		
1.1 Initiate reviews of lit. & practices	X			X						X			X			X		
1.2 Identify knowledge gaps		X			X						X			X			X	
1.3 Conduct PRA, select farmers Masaka		X			X			X			X			X				
1.4 HH Interviews conducted in Masaka		X			X			X			X			X				
1.5 Conduct PRA, select farmers Gurué			X			X			X									X
1.6 HH Interviews conducted in Gurué			X			X			X									X
1.7 Report on PRA in Masaka			X			X			X			X			X			
1.8 Report on PRA in Gurué			X			X			X									X
1.9 Report on interviews in Masaka			X			X			X			X			X			
Objective 2: Develop and Refine Models about Smallholder Bean Farmers' Decision Making																		
2.1 Interviews on land & investments		X									X						X	
2.2 Analyze resource access/constraints		X	X								X	X					X	X
2.3 Analyze livelihoods & goals		X	X								X	X					X	X
2.4 Description of extension services											X	X					X	X
2.5 Description of local organizations											X	X					X	X

Objective 3:	**Develop and Validate Diagnostic and Decision Support Aids**																	
3.1 Collect soil samples from Masaka											X			X				
3.2 Analyze soil samples from Masaka		X	X		X	X					X	X		X	X			
3.3 Conduct nutrient omission study UGA		X	X		X	X					X	X		X	X			
3.4 Conduct lime requirement study UGA		X	X		X	X					X	X		X	X			
3.5 Collect soil samples in Gurue																		X
3.6 Analyze soil samples from Gurue			X			X												X
3.7 Nutrient omission study Gurue			X			X												X
3.8 Determine farmer diagnost. criteria Ug		X			X						X			X				
3.9 Determine farmer diagnost. criteria Moz			X			X												X
3.10 Synthesis farmer ag. knowledge Ug			X			X						X			X			
3.11 Synthesis farmer ag. knowledge Moz			X			X												X
Objective 4:	**Develop and Assess Effectiveness of Innovative Approaches for Dissemination**																	
4.1 Conduct lit. rev. info dissem. systems	X						X			X						X		
4.2 Interview information providers		X						X			X						X	
4.3 Determine effectiveness info systems		X						X			X						X	
4.4 Determine importance info. systems			X						X			X						X
4.5 Conduct info. practitioner workshop			X						X			X						X
4.6 Develop and test messages			X						X			X						X
4.7 Design farmer feedback system			X						X			X						X
Objective 5:	**Enhance Institutional Research Capacity Relative to Grain Legumes**																	
5.1 Two students start graduate studies	X									X								
5.2 Three students start graduate studies		X			X						X							
5.3 Students continue graduate studies		X	X		X	X					X	X						
Name of the PI responsible for reporting on milestones	Robert Mazur			Russell Yost			Barry Pittendrigh			Moses Tenywa			Onesimus Semalulu			Ricardo Maria		
Signature/Initials:																		
Date:																		

XIV. Performance Indicators

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Project Name: **Farmer Decision Making Strategies for Improved Soil Fertility Management in in Maize-Bean Production Systems**

Summary of all institutions

Indic. numbe	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	FY 14 Target	FY 14 Revised	FY 14 Actual	FY 15 Target	FY 15 Revised	FY 15 Actual	FY 16 Target	FY 16 Revised	FY 16 Actual
		(only April 1, 2013 - September 30, 2013)			(October 1, 2013 - September 30, 2014)			(October 1, 2014 - September 30, 2015)			(October 1, 2015 - September 30, 2016)		
1	4.5.2(6) Degree Training: No. Individuals who have re	2	0	0	5	5	5	7	7	0	8	0	0
	Number of women	0	0	0	1	1	1	1	1	0	1	0	0
	Number of men	2	0	0	4	4	4	6	6	0	7	0	0
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	0	0	0	7	5	5	8	8	0	4	0	0
	Number of women	0	0	0	2	2	2	3	3	0	1	0	0
	Number of men	0	0	0	5	3	3	5	5	0	3	0	0
	Numbers by Type of individual				7	5	5	7	8	0	4	0	0
	Producers	0	0	0	0	0	0	0	0	0	0	0	0
	People in government	0	0	0	7	5	5	7	8	0	4	0	0
	People in private sector firms	0	0	0	0	0	0	0	0	0	0	0	0
	People in civil society	0	0	0	0	0	0	0	0	0	0	0	0
3	4.5.2(13) Beneficiaries: (numbers of households)												
	New/Continuing (total)	0	0	0	36	32	32	36	64	0	80	0	0
	New	0	0	0	36	32	32	0	32	0	16	0	0
	Continuing	0	0	0	0	0	0	36	32	0	64	0	0
	Gendered Household Type						32	36	64	0	80	0	0
	Adult Female no Adult Male (FNM)	0	0	0	4	2	2	4	4	0	5	0	0
	Adult Male no Adult Female (MNF)	0	0	0	2	1	1	2	2	0	2	0	0
	Male and Female Adults (M&F)	0	0	0	30	29	29	30	58	0	73	0	0
	Child No Adults (CNA)	0	0	0	0	0	0	0	0	0	0	0	0

Performance Indicators, continued

4	enterprises (for profit), producers organizations,												
	Type of organization												
	Private enterprises (for profit)	0	0	0	0	0	0	0	0	0	0	0	0
	Producers organizations	0	0	0	0	0	0	0	0	0	0	0	0
	Water users associations	0	0	0	0	0	0	0	0	0	0	0	0
	Women's groups	0	0	0	0	0	0	0	0	0	0	0	0
	Trade and business associations	0	0	0	0	0	0	0	0	0	0	0	0
	Community-based organizations (CBOs)	0	0	0	0	4	4	4	4	0	10	0	0
	New/Continuing (total)	0	0	0	0	4	4	0	4	0	6	0	0
	New	0	0	0	0	4	4	0	0	0	2	0	0
	Continuing	0	0	0	0	0	0	0	4	0	4	0	0
5	4.5.2(12) Number of public-private partnerships formed as a result of USG assistance												
	Number by type of partnership (total)	0	0	0	0	0	0	0	0	0	0	0	0
	Agricultural production	0	0	0	0	0	0	0	0	0	0	0	0
	Agricultural post harvest transformation	0	0	0	0	0	0	0	0	0	0	0	0
	Nutrition	0	0	0	0	0	0	0	0	0	0	0	0
	Multi-focus	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0
6	4.5.2(2) Developmental outcomes:												
	Number of additional hectares under improved technologies or management practices												
	Number under specific technology types (total)	0	0	0	18	1.56	1.56	18.48	3.43	0	4.75	0	0
	crop genetics	0	0	0	0	0.06	0.06	0.12	0	0	0	0	0
	animal genetics	0	0	0	0	0	0	0	0	0	0	0	0
	pest management	0	0	0	0	0.06	0.06	0.12	0	0	0	0	0
	disease management	0	0	0	0	0.06	0.06	0.12	0	0	0	0	0
	soil-related	0	0	0	9	0.72	0.72	9.12	1.71	0	2.37	0.00	0
	irrigation	0	0	0	0	0	0	0	0	0	0	0	0
	water management	0	0	0	0	0	0	0	0	0	0	0	0
	post-harvest handling and storage	0	0	0	0	0	0	0	0	0	0	0	0
	processing	0	0	0	0	0	0	0	0	0	0	0	0
	climate mitigation or adaptation	0	0	0	0	0	0	0	0	0	0	0	0
	fishing gear/technique	0	0	0	0	0	0	0	0	0	0	0	0
	other	0	0	0	0	0	0	0	0	0	0	0	0
	total w/ one or more improved technology	0	0	0	9	0.66	0.66	9	1.71	0	2.37	0.00	0
	New/Continuing hectares	0	0	0	9	0.66	0.66	9	1.7131	0	2.3731	0	0
	New	0	0	0	9	0.66	0.66	9	1.05	0	0.66	0.00	0
	Continuing	0	0	0	0	0	0	0	0.66	0	1.71	0	0
	Sex of person managing hectare			0	9	0.66	0.66	9	1.6656	0	2.3256	0	0
	Male	0	0	0	4	0.33	0.33	4	0.83	0	1.16	0.00	0
	Female	0	0	0	5	0.33	0.33	5	0.83	0	1.16	0.00	0
	Association-applied	0	0	0	0	0	0	0	0	0	0	0	0

Performance Indicators, continued

7	4.5.2(39) Number of new technologies or management practices in one of the following	0	0	0	2	1	1	2	2	0	2	0	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	0	0	0	2	1	1	2	2	0	1	0	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	0	0	0	0	0	0	0	0	0	1	0	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	0	0	0	0	0	0	0	0	0	0	0	0
8	4.5.1(24) Numbers of Policies/Regulations/Administrative Procedures in each of the following stages of development as a result of USG assistance in each case: (Stage 1/2/3/4/5)												
	Sector (total)	0	0	0	0	0	0	0	0	0	0	0	0
	Inputs	0	0	0	0	0	0	0	0	0	0	0	0
	Outputs	0	0	0	0	0	0	0	0	0	0	0	0
	Macroeconomic	0	0	0	0	0	0	0	0	0	0	0	0
	Agricultural sector-wide	0	0	0	0	0	0	0	0	0	0	0	0
	Research, extension, information, and other public service	0	0	0	0	0	0	0	0	0	0	0	0
	Food security/vulnerable	0	0	0	0	0	0	0	0	0	0	0	0
	Climate change adaptation or natural resource management (NRM) (ag-related)	0	0	0	0	0	0	0	0	0	0	0	0
	Stages of development												
	Stage 1 of 5: Number of policies / regulations / administrative procedures analyzed	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 2 of 5: Number of policies / regulations / administrative procedures drafted and presented for public/stakeholder consultation	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 3 of 5 : Number of policies / regulations / administrative procedures presented for legislation/decree	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 4 of 5 Number of policies / regulations / administrative procedures	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 5 of 5: Number of policies / regulations / administrative procedures passed for which implementation has begun	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID website http://feedthefuture.gov/sites/default/files/resource/files/ftf_handbookindicators_apr2012.pdf