Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

PROJECT TECHNICAL DESCRIPTION

COVER PAGE

Code and Title of Legume Innovation Lab Project: SO1.B1 IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests of cowpea in Africa

Name, institutional affiliation and contact information of Lead U.S. Principal Investigator and University:
Dr. Barry Robert Pittendrigh, University of Illinois at Urbana-Champaign
Room 518 — Morrill Hall, Department of Entomology, 505 South Goodwin Avenue Urbana, Illinois 61801 USA

Office:	(217) 244-0567	Lab:	(217) 333-6538
Fax:	(217) 244-3499	Cell/Illinois:	(217) 417-8930
E-mail:	pittendr@illinois.edu	Skype:	barrypittendrigh

Name(s) and institutional affiliation of all Host Country (HC) and U.S. Co-PIs:
Dr. Manuele Tamò, IITA-Benin
Dr. Ibrahim Baoua, INRAN-Niger
Dr. Haruna Braimah, CRI- Ghana
Dr. Leonard Hinnou, INRAB-Benin
Dr. Clémentine Dabiré-Binso, INERA-Burkina Fa
Dr. Stephen Asante, SARI, Ghana
Dr. Julia Bello-Bravo, UIUC Co-PI

Project Period:	**Total Funding for 4.5 year Project**	**Total non-federal cost share commitment by U.S. institution(s)**
April 1, 2013 – September 29, 2017	$2,000,000	$114,340.95

HCs where project activities will be implemented:	**HC institutions to be sub-contracted (abbreviated names):**	**Percent of total project funding budgeted for each HC institution to be subcontracted**
Ghana, Niger, Burkina Faso, Benin	IITA, INRAB, INERA, INRAN, SARI, CRI	51.97% of direct spendable

Authorized Lead U.S. University Representative:
Name-
Title-
Mailing Address-
Email Address-
Phone Number-

Signature:____ **Date:**________________________________

SUMMARY PAGE (must print on one page)

Code and Title of Legume Innovation Lab Project: SO1.B1 IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests of cowpea in Africa	
Name and Institutional Affiliation of the U.S. Lead Principal Investigator: Dr. Barry Robert Pittendrigh, University of Illinois at Urbana-Champaign	
Abstract (Limit: 1800 characters including spaces—about 200-250 words): Cowpea is an important protein source for tens of millions of West Africans living under $2 a day. The major biotic constraint on cowpea crops in West Africa is an insect pest complex. Pesticides and/or transgenics will not provide the long-term solutions needed to bring these pest populations below economic thresholds needed by cowpea farmers – the only remaining logical strategy all of these Integrated Pest Management involving a pipeline of diverse pest control solutions. Our program is focused on the development and deployment of scalable pest control solutions involving a combination of traditional pest control and deployment strategies and cutting-edge technologies, including genomics and GIS to help direct the most effective deployment of these approaches, as well as testing and deploying cutting-edge ICT tools as part of the scaling of these solutions. Our program, termed IPM-omics, involves defining the pest problems, bringing forward appropriate solutions through a biocontrol/biopesticide pipeline, and scaling of solutions through multipronged strategies that will include farmer field flora, ICT approaches, women's cooperatives and partnerships with small-scale industries. We have and will continue to develop online interfaces that make our outcomes easily available to other groups who can benefit from the materials and we will continue develop approaches where we can share solutions with outsides groups that can help in the scaling and sustainability of these solutions. We will develop, deploy, and test training/technology packages/programs that will be passed-off to groups (e.g., NGOs, national/international agencies) and we will determine the potential for impact with this approach.	
Summary Checklist ***(select as many as appropriate)***	
	Project involves the use of proprietary transgenes or the generation of genetically modified organisms (GMOs)
X	Project involves human subjects and requires approval
	Project involves animal use and requires approval
X	Project involves the use of agricultural pesticides and requires a Pesticide Evaluation and Safe Use Action Plan
X	Project involves M.S. or Ph.D. degree training of HC personnel at a U.S. university (How many?) _To be determined_

A. Technical Approach (maximum of twelve pages, excluding the budget and budget narrative)

1. Problem Statement and Justification

Insect pests of cowpeas dramatically reduce yields for cowpea farmers in West Africa, many of who live on less than $2 per day. Arguably, the greatest biotic constraints on cowpea (*Vigna uguiculata* [L.] Walp.) production are insect pests. The major pests of cowpea in the field in northern Nigeria, Niger, and Burkina Faso include: (i) the legume pod borer, *Maruca vitrata* Fabricius; (ii-iii) the coreid pod-bugs, *Clavigralla tomentosicollis* Stal and *Anoplocnemis curvipes* (F.); (iv) the groundnut aphid, *Aphis craccivora* Koch; and, (v-vi) thrips, *Megalurothrips sjostedti* Trybom. Foundational work has been initiated to understand these insect pests in the areas were we propose to work to develop and deploy solutions. This foundational work, has positioned us well to have a better understanding of pest biology and population structure (due to molecular tools) – which will help direct current and future pest control strategies. Up until our last phase of this project, there were few alternatives to pesticide sprays for many of these pest species. Our program, over the past several years, has developed multiple promising IPM solutions for the pests of cowpeas. Additionally, for *M. vitrata*, there exists a potential biotechnology-based pest control solution. Transgenic cowpea expressing the *Bt*-protein Cry1Ab, effective against *M. vitrata* already exists, but has not been released, and may be a component of integrated pest management (IPM) in the next phase of this project. However, before transgenic Bt-cowpea can be released there will be a need for an insect resistance management (IRM) plan and our program has already set the stage for just such a plan (Onstad et al., 2012). Bt-cowpea, even if/when it becomes available to farmers, will only control one of many pests that attack cowpea. Thus, for more immediately tangible control strategies, we have other pest control solutions at hand for *M. vitrata*. Additionally, host plant resistant traits are being brought forward Dr. Phillip Roberts at California at Riverside (UC-R), some of which is being done in collaboration with our collaborators at INERA. We will continue our work with the aforementioned investigators, to bring forward for such host plant resistance traits. However, over the past phase of this project we have developed multiple IPM pest control options for cowpea systems, many of which will require the next phase of research to bring them forward to larger-scale release and testing of impact.

Although biocontrol agents, transgenic plants, and traditional plant breeding for insect resistant varieties are all potentially effective methods for controlling pests of cowpeas, a continued refinement of our understanding of pest populations is needed in order to integrate these, and other, pest control options into an overall integrative pest management (IPM) plan to maximize cowpea production in the field. IPM refers to a pest control strategy where a variety of complementary approaches are used to minimize the negative effects of pests on a given crop or cropping system. As we develop, refine and deploy IPM strategies, we must understand the important life-history parameters of these pest insects in relationship to their environment. In the past phase of CRSP we developed a more in depth understanding *M. vitrata* populations and have recently determined that *M. vitrata* living on cowpea and a great diversity of alternative host plants are common populations (unpublished) – this insight (due to the use of genomics tools) is extremely important as it means all alternative host plants, for *M. vitrata*, can likely act as a refuge for Bt-cowpea and when releasing biocontrol agents onto alternative host plants, programs can choose the host plants that are most useful and cost effective. The IITA group has demonstrated that release of biocontrol agents, for *M. virata* control, on different alternative host plants can be done with varying levels of cost-effectiveness. In other words, release on some host plants can be done in a much more cost-effective manner; thus, population genomics data will allow us to make better and more cost effective IPM decisions. Thus, as we move forward over the next four years we will determine the population genetic structure of the other pests of cowpea. We have developed molecular tools to accomplish such a task (Agunbiade et al., Accepted). Additionally, as cowpea is now being grown in Burkina Faso in times and areas not previously being used, new pests are starting to impact cowpea in the field, including whiteflies and Spodoptera species. We will also investigate the presence of these insects on cowpea and the population structure of these species, as well, if they prove to be pests causing significant economic losses.

Such scalable IPM solutions are going to be highly necessary in order increase yields, which are dramatically affected by pest populations. From our last cycle of our CRSP program we observed that logical set of combined IPM strategies can increase yield of cowpeas by over 100% (e.g., neem plus *M. vitrata*-specific virus spray controls). We also have developed and released biocontrol agents that can be released and establish themselves in the field to suppress insect populations over the longterm – this is highly cost-effective, sustainable and farm-size as well as being gender neutral. Additionally, we need to investigate if the use of IPM strategies can decrease farmer input costs and reduce pesticide-related health hazards.

Over the next four years we will research, develop, implement and determine the impacts of an IPM-omics program for cowpea in West Africa. We will research and develop scalable solutions, with the potential for larger-scale impact with donor community buy-in.

We define IPM-omics in the following "equation":

IPM-omics = ***define the pest problems*** + ***appropriate solutions*** + ***scaling of solutions***

In order to define "IPM-omics" we will (1) define IPM, "omics," and how these dovetail together, and (2) the operational approaches we will take over the next 4-years towards our goals. **IPM** was first defined in 1967, by Smith and Van Dan Bosch, as a concurrent application of multiple control measures to reduce damage caused by insects to crop plants. In practical terms, this involves understanding pest systems in detail to define when and where they are a problem, defining ecologically and economically viable solutions, suppression of pest populations below an economic threshold level for increased yields and sustainable solutions. **Omics** is a term used in molecular biology to describe biological processes in large scale or high throughput. We use it to describe large-scale approaches now available to us in IPM. Thus, we define **IPM-omics** as the use of scalable technologies to understand, develop and deliver pest control solutions. IPM-omics is both a paradigm shift in how we need to think about best control in the present and in the future based on the use of cutting edge technologies available to us right now (Agunbiade et al., 2013).

In our IPM-omics "equation" we must first ***define the pest problems***. First, we must ask what are the paradigms and technologies are in our "toolbox" and how can we use them? At the current moment we have the follows "tools" to work with: (1) scouting, field experiments, light traps; (2) genomic markers to define pest and biocontrol agent populations – movement patterns and sources of the outbreaks; (3) computational modeling; and, (4) GIS systems – understanding pests in the background of their ecology and life history. These aforementioned combined tools will be focused on a regional understanding of pest problems on cowpea across West Africa.

In our IPM-omics "equation" the second step is ***appropriate solutions***. We have developed a Biocontrol/Biopesticide pipeline, in order to develop a series of environmentally and economically appropriate pest control solutions. This is not a pipeline of "magic bullets", but instead a diversity of technologies to provide farmers with a variety of solutions to suppress pest populations.

The final step in the IPM-omics "equation" will be the ***scaling of solutions***. When solutions have been developed we need mechanisms to effectively deploy them in a cost effective and sustainable manner. Discovering and testing such scaling pathways will be critical to determine which approaches will be most successful for scaling. Solutions, for scaling, fall into three categories: (1) direct release into the environment and natural establishment; (2) educational solutions; and (3) private sector and NGO involvement. **Direct release into the**

environment and natural establishment has and will involve the release of bio-control agents that ultimately become endemic in the environment and suppress the insect populations. The most effective places to deploy these bio-control agents is directly influenced by the knowledge we gain from our studies of "Defining the pest problems" and such agents come directly from our bio-control pipeline. **Educational solutions** are and will be pest control strategies that will require primarily educational interventions. Our past program has taken two educational approaches: (1) farmer field flora (FFF) (labor intensive, but scalable through partner organizations) and (2) cell phone animations (potentially highly scalable) voice overlaid in many West African languages and can be distributed by a variety of electronic mechanisms. We will study models of deployment and scaling of solutions through these approaches (Bello-Bravo et al., 2013). Two major questions arise around these. First, for the cell phone approaches we need to determine (experimentally) what people learn, what they retain, and what are their changes in behavior and what are the benefits for the farmers and their communities. Additionally, we need to test experimentally the most efficient pathways for deployment of such educational content. How do we make it accessible and who will use it with the greatest impact, something that we are well positioned to test experimentally. Second, for FFF how can we make this approach scalable through educational programs and technology packages for NGOs and other extensions groups, and can we demonstrate that these groups have had positive impacts in their target communities (e.g., increased production or reduced labor/input costs). Finally, solutions requiring **private sector involvement** (e.g., where a "product" needs to be produced and distributed) will be explored and implemented through co-operatives and other business models that empower women and unemployed youth. Finally, we will refine our online interfaces and create Apps that allow for the use of our "solutions" well beyond our own team – thereby allowing for greater impact. However, it is important to note that we are currently interacting with the Bill and Melinda Gates Foundation on a planning grant that, if funded, would involve an interactive IPM-omics system for identifying pest insect populations, making of management decisions and pushing back of solutions to farmers. If funded, this separate online system would complement our work in this project, however, it would be separate and beyond the scope of what we proposed to do in this project.

However, it is important to note that multiple aspects of the IPM-omics equation are researchable questions that we expect will allow us to develop efficient pathways from IPM innovations to scaling of these solutions. We will also test the impact of IPM approaches on farmer incomes, through studies with Dr. Mywish Maredia at MSU. As part of the development of our scaling pathways, we will work with multiple local and transnational programs such as AATF and CORAF.

We will continue our ongoing work in Burkina Faso, Niger, and Benin, however, we will also be adding the Feed the Future county Ghana to our program, as they have ongoing expertise in cowpea IPM and ongoing interactions with IITA on the development and deployment of IPM solutions. In the past phase of the CRSP we also worked with the FTF country Mali, but we were unable to continue these efforts due to the political situation in that country. If circumstances change in the next 4 years, we would hope to bring back the NARS program from Mali (IER) into our program.

2. <u>Objectives</u>

Our four (4) objectives lie under each component of the IPM-omics equation (*IPM-omics = define the pest problems + appropriate solutions + scaling of solutions*) with the addition of capacity building.

Thus, our four objectives are -

Objective #1 - Define the pest problems – we will use a mixture of field studies and molecular tools to define the pest population on cowpea across multiple ecological zones in Ghana, Burkina Faso, Niger, and Benin.

Objective #2 – Discover, document, and set the stage for scaling of appropriate solutions. This will involved the continued development of appropriates solutions, through host plant resistance traits, a biocontrol/biopesticide pipeline, and other solutions that can involve local educational programs.

Objective #3 – Scaling of solutions – We will both research and deploy tangible outputs for scaling of our IPM solutions, the details of which are outlined in the approaches and methods.

Objective #4 – Capacity building – We will continue to capacity build through a diversity of educational programs that range from graduate student and technician training to ICT technologies that will help local institutions increase their impact.

3. Approaches and Methods

Objective #1 - Define the pest problems

For this aim we will continue to use field studies coupled with cutting edge genomics [large-scale sequencing to continue to discover potential molecular markers, as well as single nucleotide polymorphisms (SNP) and microsatellite analyses] tools to assess pest populations in terms of their movement and host-plant use patterns (in collaboration with Dr. Brad Coates at Iowa State University). The technologies and analysis tools that we have used for *M. vitrata* will be used with the other pest species that attack cowpea crops in the field. All the technologies and approaches that we will use we have published on over the past phase of the CRSP. The in field studies will involve scouting on a weekly or monthly basis for these pests on cowpeas and wild alternative host plants. Timing and location (through GPS) will be kept track of and the insect samples will be sent back to UIUC for molecular marker analysis. Timing and location of the pests will also be entered into the online site to present out data in a manner that will help with the development of pest management strategies in a more real time manner. Our team is familiar with all the technologies needed to do all the aforementioned activities.

Thus, we will use two interlinked approaches to define pest problems in the field: field studies and genomics tools. In Niger and Burkina Faso we have over 4-5 years of baseline studies on the aforementioned pests, coupled with considerable molecular data on *M. virata*, however, what remains to be done is detailed studies on the wild alternative host plants of the other pest insects on cowpea coupled with molecular marker data analysis of these pest populations (like what we have done with *M. vitrata*). We will scout wild alternative host plants for these other cowpea pest species both during the cowpea growing season and during the off season. The timing, host plant and location (GPS location) will be recorded and entered into an online system we will create to keep track of (and provide a easy to follow interface for users to see these datasets against GIS data). Also, insects will be sent back to UIUC for molecular marker analysis. We will use, where appropriate SNP or microsatellite markers to determine (1) local and large-scale movement patterns and (2) population structure (i.e., which host plants provide are the base population that in turn impacts the cowpea crops). However, in Niger and Burkina Faso we will also assess and determine new pests that are thought to be emerging problems (e.g., whitefly or Spodoptera species). Where these pests appear to be significant, we will perform detailed pest distribution and molecular studies to understand these populations. In Ghana, SARI and CRI will need to do the baseline pest population experiments on all pests of cowpea. These will involve field-station experiments to monitor when and what impacts the various local and improved cowpea varieties. Such experiments will be almost exactly the same that were used in Burkina Faso and Niger over the past phase of the CRSP.

In terms of the **impact pathway** we expect the following:

Steps 4.1-4.3 – FY14-17 - First year field collections and molecular analyses of pest populations.

Steps 4.5 – FY14-17 - Development of IPM recommendations.

Budgetary Considerations

We expect the following total expenditures during the entire length of the project. In terms of the IITA budget $20,000 of salaries will be used for this effort and $2,000 in benefits, along with $24,000 in travel and $8,000 in supplies and costs. In terms of both INERA and INRAN budgets $20,000 of salaries will be used for this effort and $2,000 in benefits, along with $4000 in travel and $4000 in supplies and costs. Both at SARI and CRI the following budget will be used for these activities: (1) $4,000 in salaries, (2) $400 in benefits, (3) $2,000 in travel; and $3,200 in supplies. Our primary focus will be on the pests beyond *M. vitrata*. The samples will be sent to UIUC for SNP and microsatellite analyses (the $265,988 in salaries and in $118,820 benefits along with $52,025 supplies will benefit this section and the development of the interface to make the outputs available to the rest of the community).

<u>Objective #2</u> – Discover, document, and set the stage for scaling of appropriate solutions

We will implement a 'biocontrol pipeline' approach for reducing cowpea pest populations at the landscape level, i.e. from the wild vegetation down to the cowpea field. This approach is nothing else than a continuous pipeline of promising biocontrol candidates, from discovery, through initial screening for efficiency and suitability (including bio-security issues), to deployment in the cowpea field and through wide-scale release if appropriate. As opposed to chemical control, our strategy here is to continue developing sustainable, ecologically sound and socially affordable pest control options, which can be efficiently combined with host plant resistance in the field for synergistic impact on cowpea pest populations.

We have already successfully developed new simple rearing techniques for major host insect serving as substrate for the production of natural enemies. The best example is the rearing of the pod borer *M. vitrata*, using germinating cowpea grains, and this cheap and locally available rearing method is currently been successfully applied for mass production of hymenopteran parasitoids and a specific, highly efficient *Maruca*-specific *Mavi*MNPV virus. At the same time, on the downstream side, we have made good progress developing nursery plot release systems for thrips and pod borer parasitoids, which can be scaled out in the participating countries.

Also, during the previous phase of the DGP-CRSP, we have obtained promising results demonstrating the potential of mixing both neem oil and oil of *Jatropha curcas* with the *Mavi*MNPV virus. During two consecutive seasons, the combination of virus and botanicals produced cowpea grain yields statistically equivalent or superior to the standard chemical control.

During this phase we propose (1) to test novel natural enemies of the pod borer, including novel parasitoids from South East Asia, which are currently in the process of being introduced to the IITA cultures in Benin. They will first be tested in contained lab experiments, followed by host searching studies in the screenhouse, and finally experimental field releases and mass production. For flower thrips (2), we will continue to scale up the rearing and releases of parasitoids in all countries, and conduct regional monitoring surveys to assess their establishment and impact in FY17. A further study (3) will investigate sex and aggregation pheromones in pod sucking bugs for developing rearing-cum-release devices for egg parasitoids, which can be tested for deployment earlier in the cropping season to naturally augment the parasitoid population. A new approach (4) of applying fungal biopesticides is to use of endophytic strains, applied to the seed at planting, and we will follow this approach from the lab to the field, in collaboration with private sector. At the same time, (5) we will elucidate technical aspects of cost effective, income-generating production (by vulnerable groups such as rural women and unemployed youth) of bio-pesticide products such as emulsifiable neem oil, and *Mavi*MNPV, for integration with other compatible control methods. The same groups will also be trained in the production of egg parasitoids and their deployment devices.

In collaboration with the UCR-led Legume Innovation Lab project on genetic improvement of cowpea, we will be screening tolerant/resistant varieties, particularly against aphids, thrips and pod sucking bugs. These varieties will be integrated in our efforts to control cowpea pests in the field, e.g. together with the application of bio-pesticides. We would plant to test pod sucking bug resistance/tolerance in the field in FY16 and FY17 and flower thrip and aphid resistance/tolerance in FY15-onwards.

In terms of the **impact pathway** we expect the following:

Steps 4.1 in FY 14 - a) Novel *Maruca* parasitoids available for screening; b) thrips parasitoid available for scaling up ; c) new knowledge about sex and aggregation pheromones for pod sucking bugs; d) PCR techniques for detecting endophytic strains of *Beauveria bassiana available*; e) feasibility of storing *Maruca* virus both as liquid and solid substrate investigated (IITA); f) investigate host plant resistance traits (in collaboratiion with UCR); and g) continue to develop neem plus virus control strategies.

Step 4.2 in FY 15 - a) New knowledge about novel *Maruca* parasitoids; b) thrips parasitoid available for releases c) new knowledge about sex and aggregation pheromones of pod bugs; d) endophytic strains of Beauveria bassiana available for testing; e) liquid and/or solid *Maruca* virus substrate available for farmer participatory trials.

Step 4.3 in FY 16 - a) Novel *Maruca* parasitoids available for inoculative releases; b) new information available to better target thrips parasitoid releases; c) prototype deployment devices for pod bugs egg parasitoids available for validation with farming communities; d) endophytic strains of *Beauveria bassiana* available for testing in all countries; e) Maruca virus available for integration into IPM packages at FFF sites.

Step 4.4 in FY 16-17 - a) novel *Maruca* parasitoids available for inoculative releases in all countries; b) new knowledge about establishment and impact of thrips parasitoids available; c) releasing device for pod bug egg parasitoids available for integration with tolerant/resistant varieties; d) new knowledge about seed applications of endophytic strains of *Beauveria bassiana* available; e) new knowledge about impact of *Maruca* virus mixtures generated.

Step 4.5 – FY17 - a) Novel *Maruca* parasitoids available for releases in all countries; b) new knowledge about impact of thrips parasitoids at regional level generated; c) deployment devices for pod bugs egg parasitoids available for testing in farmer participatory trials; d) seed-based application of endophytic strains of *Beauveria bassiana* available for testing in partnership with private sector; and, e) *Maruca* virus bio-pesticide mixtures available on the local market

Budgetary Considerations

The total expenditures over the entire project duration will be as follows. The following aspect of the IITA budget will be used for both these above steps and for the testing of these approaches in the field: (1) Salaries of $40,000, (2) benefits of $4,000, (3) $16,000 in travel costs, and (4) $64,580 in S&E costs. For the steps above that INERA will be involved in, the following funds will be used: (1) $20,000 in salaries, (2) $2,000 in benefits, (3) $4,000 in travel, and (4) $4,000 in supplies. Both at SARI and CRI the following budget will be used for these activities (in FY14): (1) $4,000 in salaries, (2) $400 in benefits, (3) $1,000 in travel; and $2,500 in supplies. At both of these institutions, in the following years, their S&E and non-degree training budgets will be increased. These increases will facilitate increased testing and deployment activities.

<u>Objective #3</u> – Scaling of solutions

We fully recognize that a major constraint of many R4D projects is how can they be scaled and sustainable beyond the scope of any one given proejct. Our approach will be both to develop approaches for scaling and address researchable questions around scaling. Thus, we will take a multi-pronged approach for scaling: (1) release and establishment biocontrol agents, (2) educational solutions, and (3) enabling market opportunities. Again, ccaling will be both be a series of researchable questions and a mechanism to have impact.

It is important to note that we are currently writing an invited one-year planning grant proposal for the Bill and Melinda Gates Foundation to investigate the feasibility of scaling of neem/virus production in the marketplace, highly efficient spraying approaches (a low cost Electrodyne sprayer – which will be able to deliver neem to the whole plant in ultra-low volumes), scaling out of several bio-control agents, along with the development of an IPM-omics interface for capturing infield pest problems on a large-scale, through cell-phone technologies. We will also do a larger-scale marker assessment of *M. vitrata* populations to populate this database. These represent “pass-off” technologies, which require greater levels of resources to develop impact on a larger-scale. These are complimentary tor our work proposed here, but do not over-lap with out proposed Legumes Innovation activities.

First, we will study potential pathways for impact, in collaboration with Dr. K. Maredia of MSU, Dr. Michelle Shumate of Northwestern University, and our NARS IITA collaborators. Studying such pathways will include baseline studies on (1) interactions between potential deployment groups to determine which group (e.g., NGO, government agency, etc) might be most effective in using and sharing solutions more broadly that our program has developed (UIUC, Shumate at Northwestern University and INERA), (2) farming household income levels before and after the deployment of a biocontrol technology into a given region (Maredia at MSU, UIUC and INERA), and (3) potential private sector partners that are well-positioned (or what do they need to be well-positioned) to commercialize given products (e.g., a women’s group may need lessons in how to collectively save and invest in a small-scale neem extraction business) (Maredia MSU, UIUC, IITA and INRAB). On this third point, we need to understand the barriers for women’s groups to develop IPM products and, where opportunities exist, develop approaches (e.g., marketplace literacy) to reduce the barriers for them to enter and succeed in the marketplace. Where there are needs and opportunities for marketplace opportunities (based on the assessments from INRAB), we will work with groups at UIUC (who work in this area) to create content and we can test the impact of this content at several layers: (1) do women learn from the content, (2) do they learn useful skill sets to help them start businesses, (3) do they start such businesses (around IPM tools) or do they use this knowledge for other businesses, and (4) do these businesses succeed? We fully recognize that this represents an important constraint in our program as researchable questions to try to reduce these constraints.

Second, IITA, with other host country partners, will continue to refine the most cost-effective in laboratory rearing and, in field, deployment strategies for biocontrol agents. These will provide for the most cost-effective approaches for release of biocontrol agents, thereby increasing the potential for impact. Against the pod borer *Maruca vitrata*, we are targeting the parasitoids *Nemorilla maculosa, Therophilus javanus* and *Phanerotoma philippinensis* Against the pod sucking bugs *Clavigralla tomentosicollis*, we will work with the egg parasitoids *Gryon fulviventre*, while against flower thrips we will continue to work with the parasitoid *Ceranisus femoratus*.hey will also monitor for the levels of pest populations pre- and post-release. In the case of INERA, a baseline study has been done (in collaboration with MSU) to determine farmer income. We will do the post-biocontrol release study in this same region by year #4 (FY17) in the current program to determine impacts of farmer incomes.

Third, our two sets of educational solutions represent excellent researchable questions towards the goal of scaling for larger-scale impact. First, with the use of animations, there are simply a long list of questions that need to be addressed: (1) what do people learn (pre- and post-knowledge levels associated with an animation intervention), (2) how many times do they watch them if they are left behind on their phones, (3) what do people retain a month or a year after initial exposure, (4) in terms of Blooms Taxonomy what occurs next with this knowledge (does it stimulate discussion, local innovations, etc), (5) what behavioral changes occur (expected and unexpected), (6) what are logical pathways for people to gain access to these videos, (7) what are the digital divides in the countries we are working in and how does this impact who can access and deploy the knowledge (the first study has been completed in Burkina Faso on this digital divide – in collaboration with Dr. Michelle Shumate from Northwestern University) (manuscript in progress). Finally, in collaboration with Dr. Michelle Shumate, we have performed survey, which led to a nodal analysis of how development agencies in Burkina Faso interact with each other (who are the ones that have the most connections with cowpea farmers). This nodal analysis suggested certain groups would be highly likely to have impacts and others are less likely to have impact. We can now test this hypothesis by the release of videos (same video each labeled slightly differently – in a way we can document, but will not be noticed by the user) to these different groups and perform a study to determine which videos made it onto the phones the greatest number of people in a given region. Certainly, there are other potential measures of impact, however, these represent hypothesis driven approaches to test for the potential for impact.

In the past phase of this project we worked with Peace Corps volunteers and NGOs to perform initial tests to determine the potential for scaling FFF through their organizations. Our initial efforts were positive – however, it was highly apparent that we need to develop standardized educational packages for those that will run the FFF to make sure they are performed in a consistent manner that allows us to assess their impact. These organizations actively held FFF over multiple years and the trends were that they would educate farmers on IPM strategies and there is a general trend for increases in yield with these technologies. However, we are now well-positioned to take the next step. First, we need to determine yield levels, and input/time costs of cowpea, pre-FFF (FY14). Then, we will deploy FFF through NGOs and other collaborative organizations, including experimental design to statistical determine which IPM approaches in the FFF have positive outcomes (FY15). Finally, in the year post-FFF we will survey what technologies are in use and what are the impacts in that given community (FY16). If we can demonstrate impact, we will develop educational/technology packages that the NARs programs can teach and deliver to other organizations to scale this approach for impact (FY16-FY17).

Currently, we have considerable knowledge on pest problems and solutions that need to placed into easily accessible educational packages and at UIUC we have developed considerable expertise to work with these host country groups to turn this knowledge into accessible educational content across multiple formats. Thus, over the next 4 years, 30% of the direct

UIUC budget will be dedicated to the creation of such educational packages and the short-term training of people both in our NARs programs and beyond (e.g., NGOs, extension programs, university students and staff/faculty in host countries) for scaling. Through outside funding sources UIUC (SAWBO) has already developed initial ICT training packages that have been used for 1-day in country ICT training sessions (we will refine and deploy these packages over the FY14 and FY15). Thus, in order to help have much larger-scale impact the UIUC (through collaborations with IITA and the NARs program) training component will focus on creation and performance of training sessions with host country groups. Training packages for other groups to learn how to create and run FFF will be created, tested and deployed from FY14-FY17. Such training materials will be sustainable beyond this program, as such booklets and CDs/DVDs and online materials that can be easily copied, accessed, or downloaded by groups in the future.

Finally, INRAB (Benin) will take a leadership role (in collaboration with IITA and MSU or Northwestern University or both where applicable) to research opportunities to partner with private sector entities and determine what “gaps” need to be filled in order to increase the chances of organizations will enter the market (and be successful in the market) for production of IPM products. For example sake, what is needed for women’s cooperatives to be successful in neem production and sales? Are their knowledge limitations on busy the business marketing site or lack of knowledge of the technologies or barriers for the cost of entry into the market place or all of the above. We need to determine the limitations and then define what researchable questions, technology development or educational programs do we need to develop (or a combination of these) to reduce the barriers groups face for entry into the market. Of course, market assessments need to occur, at the beginning, to determine what markets may exists and what is the potential in the marketplace. Additionally, where we determine gaps, in marketplace literacy, that could facilitate women creating new businesses for IPM products, we will create, test and deploy educational packages to help fill those gaps. We fully recognize that many groups will face significant marketplace challenges, due to lack capital or in many cases marketplace literacy. To this end SAWBO is already working with a market place literacy program to create content around marketplace literacy. If and where need be, such materials may be useful to help to develop capacity for women’s groups to develop the necessary steps for business creation about IPM-based products – however, these are very researchable questions.

In terms of the <u>impact pathway</u> we expect the following:

> Step 4.1 in FY 13-14 - 1) Releases of biocontrol agents scaled out; 2) Educational solutions - ICT training materials, online and in-country ICT training sessions available for testing with current partners and potential new partners, FFF program available for testing of impact leading to educational packages for scaling, Potential pathways for deployment of educational videos explored, and begin testing of pathways to deploy videos; and, 3) Private sector/NGO involvement.
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> Step 4.2 in FY15 - 1) First wave of training packages available for deployment and testing, including creation of new language variants, already available training packages undergoing second year of FFF testing for impact. 2) online training sessions available for refinement and validation. 3) Biocontrol agents available for scaling out.

Step 4.3 in FY16 - ICT training packages and content made available through online and in country training, available packages undergoing third year of test of FFF for impact through collaborative organizations.

Step 4.3 in FY17 - 1) ICT training packages and content available for scaling through online and in country training, FFF packages available for delivery to outside groups. 2) Information on impact of biocontrol agents available (with MSU) in Burkina Faso.

Step 4.4 in FY17 - 1) ICT training packages and content available for scaling through online and in country training, FFF packages available for delivery to outside groups. 2) Information on impact of biocontrol agents available (with MSU) in Burkina Faso.

Step 4.5 in FY17 - 1) Educational solutions available for deployment. 2) Impact of biocontrol agents on cowpea yield demonstrated in Burkina Faso.

Budgetary Considerations

Over the total length of the grant, IITA will use $20,000 in salaries, $2,000 in benefits, $16,000 in travel and $12,000 in supplies to work with INRAB, UIUC, and MSU to investigate potential pathways for impact. For INERA the following funds will be used for scaling of solutions activities: (1) $40,000 in salaries, (2) $4,000 in benefits, (3) $4,000 in travel, and (4) $12,000 in supplies. For INRAN the following funds will be used for scaling of solutions activities: (1) $22,000 in salaries, (2) $2,200 in benefits, (3) $8,000 in travel, and (4) $6,000 in supplies. The full INRAB budget direct spendable of $28,559 ($9,000 salaries, $900 benefits, $4,300 travel and $2,700 supplies) will be used for assessment of scaling activities, including $11,659 for non-degree training which will be used in INRAB personnel time to cross-train with IITA staff of these assessment approaches. At UIUC our full non-degree training funds will be used for object #3 for ICT development and scaling activities.

<u>Objective #4</u> – Capacity building

Capacity building will occur at multiple levels.

First, we will continue graduate-level training at INERA, INRAN, IITA, and UIUC. At UIUC we will have a female West African PhD student continue on a Howard Hughes Medical Institute Pre-Doctoral grant. Additionally, during the four years of this grant, we expect to apply for additionally scholarship funding to support another West African student studying at UIUC. Additionally, where time and additional resources permit graduate students may also be included in the programs at SARI, CRI or INRAB. Continued efforts will be made to be inclusive of other Legume Innovation Lab programs.

Second, we will bring host country scientists to UIUC for several week information exchange and educational content development sessions. We will bring both scientists from within our program and other ICT specialists who are part of other Legume Innovation Lab programs. For example, Sostino Júnior Mocumbi from IIAM (in Mozambique – also part of the ISU project) has been extremely helpful in collaborations on ICT materials developed for cowpea farmers and has adapted some of these materials for Mozambique (e.g., non-pesticide based controls strategies). We welcome the opportunity to build links with other Legume Innovation Lab programs, such that they can potentially adapt and use our education content in their programs. We have set aside funding each year for such an exchange with people from within our program and potentially with host country scientists from other Legume Innovation Lab programs.

Third, we will continue our cross-training programs of technicians across host country programs. As new pest control approaches are developed the biopesticide/biocontrol pipeline, there will be a need to make sure technicians across IITA and NARS programs can exchange new findings, protocols and techniques for optimizing the impact of the release and deployed IPM strategies in their own countries.

Fourth, we will continue to develop and test educational packages for enabling farmers to learn about techniques for minimizing pest damage. First, we will continue to develop and voice overlay educational animations in local languages. We will test their effectiveness in educating people on given techniques and ideas, as well as test and develop detailed deployment and use pathways, such that our NARS collaborators will have educational content and well-defined pathways by which they can release such information as part of their educational programs. These will constitute readily available educational packages that their programs can use beyond the scope of the current grant (a sustainable approach). Finally, we will create and then test the effectiveness of FFF training packages for NGOs to implement FFF programs. We will develop packages where other programs are trained to hold FFF and deploy the technologies we have developed. We will then test how successful these training packages are documenting increases in yield, or reduced input costs or both. Then, these packages will be available through the NARS programs.

Fifth, we will develop an online website that will allow for inputs of research results and our understanding of the pest populations, what previous studies mean for IPM, and resources (both educational and tangible contacts to obtain materials useful in IPM programs – HPR lines, biocontrol agents, viruses, where to obtain neem oil or neem presses). This web system will be about "connecting the dots" and making all our output available to other groups in a highly transparent manner. We will also work with such organizations as AATF and CORAF to make sure the interface is useful to their organizations and is also connected to their websites, and inclusive of their content (where appropriate). Such a website involves a considerable amount of upfront costs in terms of people's time (both designing the system and programmer time), however, if structured properly, their continued maintenance has minimal costs (as we have experienced with both the SAWBO and SusDeViKI websites). The site(s) will be hosted on a UIUC or IITA server and adding data beyond the scope of this project will not require extra funding.

Sixth, as we are entering a new time interval where we expect to see major changes in ICT technologies (we found several people with iPads in the market place in Ghana this past summer – online with SIM cards in their iPads) there are renewed opportunities to develop approaches where we can make our educational content more accessible to educators who can then transfer the videos to the target audiences. Thus, we have already developed a SAWBO "App" for i-devices and we will create versions for Android devices (for those involved in deployment of educational materials). Currently, with SAWBO we now have hundreds of videos (between the various videos, different languages and the many different countries with their language and accent variants) and the App allows one to choose the (1) language, (2) the country or (3) the topic or any combination of the these groups to narrow down to the video that can be downloaded and used in an educational program. For example, if I wanted a video explaining biocontrol and I am in Ghana and I want the video in Ewe, I would click these three terms (biocontrol, Ghana and Ewe) and the correct video would be displayed. I could then download it into the memory of my device, play it anytime when I am away from WiFi (e.g., in a village), and then use Bluetooth to transfer it to other phones when I am in a village (thereby passing it to the farmers). The App will be created through other sources of funding, but we will develop code to keep track of the use and downloads of the videos from the Apps and we will also work towards distributing Android devices with these Apps on them for testing in the field. If successful, this App could serve as a system to distribute many different forms of educational videos and other types of presentations in local languages. We will test the potential use of such an App, on Android devices, to assist deployers' of knowledge access and use of appropriate content. Obviously, this has the potential for scaling. Additionally, SAWBO, through support from the Chancellor's office at UIUC have developed preliminary one-day ICT training workshops to bring in partner groups (e.g., extension agents, universities, and NGO) on how to download, use and create new language variants of our educational materials. These training sessions and packages have been tested in multiple African countries and have resulted in a system to bring in multiple deployment groups, such that they can incorporate this educational content into their own programs (Bello-Bravo et al., 2013). We plan to further develop and use these ICT training sessions and then follow-up with such outside organizations to determine their use of our materials in their educational programs.

In terms of the **impact pathway** we expect the following:

> Step 4.1 in FY 13-14 - 1) graduate training ongoing across all four HC and at UIUC, 2) initial ICT training tools in progress, 3) technician training in biocontrol initiated (training will primarily occur at IITA). Short course online ICT training will occur upwards of 3 times per year and an in country session will occur in Ghana
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> Step 4.2 in FY 15 - 1) Graduate education in progress, 2) initial ICT training tools available on the web, 3) technician training ongoing (training will primarily occur at IITA). Short course online ICT training will occur upwards of 3 times per year and an in-country session will occur in Benin.
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> Step 4.3 in FY 16 - 1) Graduate education in progress, 2) ICT tools available for teaching to over 200 outside individuals, 3) technician training ongoing (training will primarily occur at IITA). Short course online ICT training will occur upwards of 3 times per year and an in-country session will occur in Niger.
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> Step 4.4 in FY16 - 1) Graduate education in progress, 2) ICT tools available for teaching to over 200 outside individuals, 3) technician training ongoing (training will primarily occur at IITA). Short course online ICT training will occur upwards of 3 times per year and an in-country session will occur in Burkina Faso.
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> Step 4.4 in FY17 - 1) Graduate training close to be completed, 2) ICT tools available for teaching to over 1000 outside individuals and 3) technician training completed.

Budgetary Considerations

Over the total duration of the project, we expect the following graduate students: (1) one BS (e.g., for an honors project) or MS student will be partially supported at SARI in Ghana (entomology - $6,000), (2) one BS (e.g., for an honors project) or MS student will be partially supported at CRI in Ghana (entomology - $6,000), (2) one PhD graduate student will work with both INRAB and IITA (but will be funded through IITA) (in order to strengthen their partnership

– this student will work on assessment studies – degree program TBD - $20,000 for this partial support), (3) one PhD student will be partially supported at INERA (entomology - $20,000), (4) one honors or MS student will be partially or fully supported at INRAN in Niger (entomology $11,800), and (5) three more PhD or MS students will be partially/fully supported at IITA in Benin (entomology – partial support for each student at $20,000 per student). This brings a total of eight students. The HC student at UIUC will continue at least into FY14 under Howard Hughes fellowship and we expect her to complete her degree in 2014. This would in fact, bring our total to 9 students, however, the ninth student is completely supported by other funds and represents a student from a previous funding cycle. The UIUC program will be actively looking to find another MS or PhD student from one of the HC to attend UIUC, however, this will not occur in FY14, as it will not be possible to bring in a student (from an admissions prospective) until the fall of 2014.

In terms of non-degree training, IITA will use a total of $45,200 for training visiting scientists and technicians from the other host countries. Both INREA and INRAN will use each $20,000 for FFF in their respective country. As mentioned earlier, INRAB will use $11,659 for non-degree training which will be used in INRAB personnel time to cross-train with IITA staff of the assessment approaches in objective #3. Both CRI and SARI will use each $6,930 for training technicians in biocontrol approaches focusing on rearing and deployment of beneficials. UIUC will use $33,117 for travel and $7,117 for supplies for hosting HC scientists on short term attachments at UIUC.

4. Collaboration with Host Country Institutions

The UIUC, bringing in partners where necessary (such at Dr. Coates at ISU for genomics, Dr. Shumate at Northwestern University for defining educational pathway approaches, and Dr. Maredia for impact assessment) has worked in a highly effective manner with IITA, INERA, and INRAN over the past phase of this program. Additionally, IITA has had a very long-term working relationship with both aforementioned NARs programs as well as with all three new NARs programs (SARI, CRI, and INRAB). The UIUC team will continue to co-ordinate the overall program, develop online tools (in collaboration with IITA and all NARS programs), and perform the genomics assessment to feed into IPM decisions. IITA and NARS programs will all continue to perform the necessary field experiments and collections of insects that will feed into the genomic assessments performed by UIUC. IITA will be the group primarily responsible for the biocontrol/biopesticide pipeline and will co-ordinate the outputs and deployment of this with the NARS programs. INERA will continue to work with IITA on the deployment of IPM outputs and contribute heavily to bringing forward host plant resistance traits, continue to test and deploy animation and FFF approaches, and finally they will continue to deploy IPM approaches into a region where INERA/MSU/UIUC did a baseline assessment. In FY17, they will perform the post-assessment to determine impact on farmer income. INRAN will continue to develop and deploy IPM programs (e.g., biocontrol agents), as well as testing both animations and FFF for the potential for scaling. SARI and CRI will work together with IITA to characterize the pest populations in their regions, bring forward neem technologies (develop low-cost neem oil extraction equipment) and work with IITA on the deployment of biocontrol agents. INRAB's role will be to work with IITA to assess the market potential for sellable IPM products, determine potential groups that could develop business models and determine their limitations (and how these can possibly be circumvented) in entry into the marketplace.

5. Coordination with other International Grain Legume Research Programs/Projects

Our project has been structured in a manner that we have and will continue to build on existing national and international strengths across numerous organizations in a synergistic manner. We will be working with Dr. Brad Coates, a USDA-ARS, on the genomics component of our program; we have been working with him for the past 3 years of our program and we will continue to work with him in same capacity, where he will provide important input and guidance on the population genomics work. We have heavy connections with the CGIAR Grain Legume Program, as Dr. Tamo is the IITA focal point for this program. Dr. Pittendrigh has also already participated in a meeting with this CGIAR program. We will continue to collaborate individuals involved in the Tropical Legume program(s). We have and will continue to work with CORAF scientists and in this phase of the project we plan to deepen our connection with this organization, especially keeping them informed of our activities to find potential synergies and buy-ins. Our team will also make efforts to continue to interact with AATF in order to keep abreast of the developments of Bt cowpea, in order to determine where our efforts can be supportive of their activities, with the potential for syngeries and buy-ins. In the past phase of our program we played an important role in an expert panel for *Bt* cowpea and published multiple papers that will be critical for the development of an IRM plan for *Bt* cowpea. Additionally, Dr. Michelle Shumate, at Northwestern University and Dr. Mywish Maredia, represent two excellent collaborators bring an important social science and pathway assessment analyses that will be critical for our program. In the past phase of our project we established collaborations between Drs. Shumate/Maredia and our NARS programs. We expect that these interactions will be extremely important to address critical issues associated with deployment and scaling of impact in this phase of the program.

6. Outputs

In terms of technical outputs we will have (i) biocontrol agents and cost effective deployment strategies in the field and release of biocontrol agents in all four host countries, (ii) we expect to have tested in the field resistance/tolerance traits for one to several pests of cowpea available for field testing (in collaboration with UCR) (iii) we expect to have validated and scalable FFF approaches that will allow NARS programs to train other groups to scale these educational programs and have impact in their communities (increased yield or reduced input/labor costs or both), (iv) we expect to have validated and deployed educational animation approaches that can be scaled through our and outside partner groups, (vii) a highly defined set of IPM approaches across all four countries, IPM strategies appropriate for their regions, easily accessible educational package for deployment of these materials, and locations/people where they can obtain biological materials (seeds with insect resistance traits, or bio-control agents). We will have a more highly defined understanding of timing and location of pest populations (in the four countries we will be working in), coupled with detailed molecular studies to determine the movement patterns temporally, spatially and on/off wild alternative host plants. This understanding is absolutely critical for the development and guiding of IPM decisions. We also expect to have developed an understanding of pathways for scaling and the impact in the field for biocontrol agents and biopesticides.

7. Capacity Building of Partner Host Country Institutions

We will continue our past efforts to build institutional capacity through a series of approaches. However, in this phase of the project, we will include the Feed the Future country Ghana in this process. We will continue graduate level training, primarily in the HC programs and with IITA, as this is the most cost effective graduate training (with particular attention to gender balance). However, we will make efforts, where time and resources permit for some of these individuals to cross-train in different countries. We will continue to have technicians cross-train in IITA and NARS programs. We found, in the past phase of the project, that 2-week technician internship programs (e.g., INERA technicians going to IITA to learn how to rear parasitoids) to be an incredibly cost-effective approach to build institutional capacity. We will also make efforts to have Francophone NARS staff to exchange with the Ghanian institutes, in order to assist in scientific cross training (with the added bonus of informal language training in English – allowing the Francophone scientists to improve on their English skills). UIUC will continue to host a West African female PhD student, who is and will continue to be support for a Howard Hughes Graduate Fellowship. As we realized the concern with age demographics in two of our NARS countries, our planning meeting included a series of young scientists who will be able to be part of our program in the building of their careers. UIUC, in collaboration with IITA and our NARS programs, will continue to build ICT tools that will be useful for the HC programs for scaling of educational strategies. In this next phase of the program 30% of the UIUC direct spendable budget will be dedicated to creation of training content, holding ICT training session (both virtually and within countries) and testing of these training strategies. We feel it is critical for UIUC to use these training resources towards scalable short-term training strategies as this will be the best way for us to have the potential for large-scale impact in terms of training and capacity building.

B. Alignment with USAID Feed the Future Goals and Strategic Research Objectives

1. Alignment- Our project is in keeping with the FTF "overarching goal of sustainably reducing global poverty and hunger". We expect to both provide novel economic opportunities, in the development of locally based biopesticide production women's cooperatives, as well as increasing the yield of cowpea crops (with the potential to help reduce hunger) to address "increasing agricultural productivity". Although not specifically a direct goal, where women can develop profitable biopesticide production, there is a potential to increase their incomes ("increasing incomes so the poor can purchase food"). FTF also have the goal of "improving health" – the reduced use of pesticides by our approaches has considerable potential to have positive health benefits due to reduced exposure. Direct spraying of conventional pesticides on crops, and runoff, has resulted in malaria mosquitoes becoming resistant to these compounds, making malarira control programs far less effective. Reduced use of these compounds on crops may also reduce problems associated malaria control problems. Additionally, although rarely discussed, the used of pesticides in Africa has significant negative impacts on the environment, damage lake and river ecosystems due to runoff. This runoff can impact fish and snails in this system – two important commodities that people often sell or eat. Thus, we expect successful IPM strategies, which reduce the need and use for pesticides, to have positive impacts on value chains beyond cowpeas.

Our project will be focused on "Inclusive Agriculture Sector Growth" through developing economic opportunities for women in the production of biopesticide products and represents important "Private sector engagement". Obviously our program is also concentrated on "Research and Capacity Building" and it part of a "Climate-Smart development path" as it involves sustainable solutions that help to reduce "environmental degradation".

2. *Gender Equity*- Our program has several layers that deal with gender equity. First, and foremost, the release of biocontrol agents into an ecosystem, where they suppress pest populations, is gender and farm size neutral. Second, we have been focusing on the development of women's cooperatives to develop private sector IPM solutions (e.g., neem production and Maruca virus cottage industries) and we will continue to do so in the future. This has considerable potential to increase women's income and the standard of living for their families. Additionally, the reduction of pesticides has a significant potential to improve the health women in areas where women are the ones that tend the cowpea fields – due to reduced exposure to pesticides. During FFF and animation deployment we will make every effort to develop effective deployment strategies for women, such that they have access to improved strategies for growing cowpeas under insect pressure. In our short-term, technician, and degree training programs we will make every effort to maintain gender balance, as we did in the past phase of our project. In development and deployment of ICT and FFF training packages we will make efforts to maintain gender balance as well.

3. <u>USAID Mission Engagement</u>- Dr. Pittendrigh, with Dr. Larry Beach, has already met with the Ghana mission during our program planning meeting and Dr. Pittendrigh will be presenting (this will likely be past tense by time the review of this document occurs) on IPM-omics at the Innovation Lab Workshop to be held in Accra, Ghana, on July 8 and 9, 2013, a meeting involving USAID mission staff. Additionally, one of the Ghana mission's representatives has already begun to contact Drs. Tamo (at IITA) and Dabire (INERA) about the possibility of exploring intercropping of cowpea with crop(s) important for FTF value chains. They were interested in the IPM technologies we are working on and seek opportunities for connections with their focus. Thus, we have already begun this important process of engaging missions in West Africa in regards to our program. As our Ghanaian PI's and other host country PI's (and our UIUC team) travel to cities in West Africa with USAID Missions, we will make every effort to visit with and engage the Missions. Additionally, as tangible outputs emerge from our program (e.g., publications, educational content, and other documents activities) we will make the Missions aware of these (through e-mails vetted by the MO and USAID Washington) to determine potential for synergistic opportunities.

C. Impact Pathway Plan

We have provide this pathway in an excel file. In summary, we expect to have high an excellent understanding of pest populations such that we can make IPM recommendations based of regions and timing. We expect to have biocontrol agents released and having impact (increased yields) by FY17 through a series of steps where ITTA works with HC partners for release. We expect to have educational solutions tested and scaled and delivered through partner groups through and beyond our HC groups (e.g., NGOs, and other outside agencies). This will occur through a series of steps testing these solutions and testing and deploying scaling approaches. Finally, we expect to have solutions that can potentially double the yields of cowpea farmers in the regions where are we working.

D. Project Budget

<u>Overall</u>

We are requesting a total of $2,000,000 over a 4.5 year time frame for this cost extension of our project formerly known as "UIUC-1: Biological Foundations for Management of Field Insect Pests of Cowpea in Africa", now called "SO1.B1 IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests of cowpea in Africa." The requested budget is split over the following fiscal years: (1) FY13 - $59,074; (2) FY14 - $485,926; (3) FY15 - $485,000; (4) FY16 - $485,000; and (5) FY17 - $485,000. Over the 4.5 years the HC will collectively receive over 50% of the direct spendable budget. Additionally, all aspects of our project will include 30% of a degree or non-degree training as per the conditions of the Legumes Innovation Laboratory. In FY13 the budget is/was to pay for a planning meeting which was held in Accra, Ghana in June of 2013. This activity has already been completed. The remaining FY14-FY17 will be focused on the development and deployment of IPM solutions through a multi-institutional collaboration between our ongoing partners (INERA, INRAN, and IITA) and with new partners (INRAB, SARI and CRI).

<u>Personnel Cost</u>

At UIUC the personnel costs will include one month of summer salary for Dr. Pittendrigh each year from FY14-FY17, as he will be traveling in West Africa for upwards of one-month each summer for this project. Salary is also requested for at PhD-level scientist who will (and has over the past four years) coordinated all of aspects of the details of the molecular biology aspects of this project. Additional funds are requested for the non-degree category to fund an individual (and pay for supply costs) in Dr. Pittendrigh's laboratory to coordinate all aspects of the online training, develop educational packages (ICT training packages, the final FFF documents and packages, animations, voice overlays, interface development and population of the databases for the educational solutions that can be shared with the world, design and printing of CR-ROMs/CD with content, wallet USB drives with SAWBO content on them, etc.) and work with Dr. Pittendrigh to prepare the necessary training packages he will be involved in when he will be traveling to Africa. At each host country we are requesting that 30% funds be spent on degree training for graduate students and on short-term training, which will include personnel costs for FFF, as well as participation in short-term ICT and cross-institutional technician training programs. Support for students and technicians will also go towards surveys that need to be performed as part of our on going collaborations with Dr. Maredia and Shumate on the social science aspect of our program. Personnel cost for IITA and HC will include additional lab and field staff for carrying out the planned activities associated with defining pest populations, exploring and demonstrating effectiveness of solutions and for scaling of solutions.

Travel

The UIUC budget includes travel costs for the PI (and/or where necessary co-PI) to travel to Africa for co-ordination of activities as well train HC groups in ICT training programs and to attend meetings and conferences that will enhance our ties with other Legume Innovation Lab programs (e.g., ISU and Sostino Júnior Mocumbi), with USAID Missions, with other organizations like the CGIAR-system's main office, CORAF and AATF. Funds will cover flights, hotel costs, per diem and VISA costs. For the NARS programs all travel budgets are primarily for within country travel and travel to nearby countries where our program has activities. Within country travel for INRAN/INERA/IITA/SARI/CRI will also involve insect sample collections (in country travel expenses). Also, funds for exchanges will also be for technician and graduate student cross-training. In the case of IITA some travel funds will also be made available for Dr. Tamo to visit Dr. Pittendrigh at UIUC.

Supplies

At UIUC the supplies costs will be as follows: (1) DHL costs for having insect samples shipped from HC partners (NARS programs and IITA) in RNAlater or ethanol; (2) sequencing costs if and when we need to generate any more potential polymorphisms in the pest species we are working with; and, (3) SNP and microsatellite analyses. Additionally, some of the supplies funds will be used for computer programs used in the development of educational materials and interfaces for deployment. For IITA, the supplies costs will be associated with both within laboratory rearing and in field deployment strategies of biocontrol agents, plus shipping costs of biocontrol agents from Taiwan where necessary. Supply costs will also be set aside for materials costs in survey work developed between IITA and INRAB associated with determining the market potential for biopesticides. SARI and CRI will also use part of their supplies funds to work with local entrepreneurs to make a low-cost prototype neem press. SARI and CRI will also document pest populations and collect insects to send back to UIUC for molecular testing, however, all packaging and shipping costs will be paid for by UIUC. As with the past phase of the CRSP program, the UIUC partner will cover for the publication costs of papers that emerge from collaborative publications across projects. In the past phase of our program, due to the high numbers of papers published, these costs exceeded $5000 for our program. We expect that costs will be at least this high in the upcoming phase of this program. Thus, the supplies costs will include these funds over the 4.5 years of our project.

Training

All aspects of program will include the 30% short term and degree training. Again, degree training will be for institutions in West Africa. Any degree training at UIUC will need to come from other funding sources, for us to use our resources in the most cost-effective manner. Instead UIUC will focus on the development and the deployment of educational packages that can be used both within out program, extended out to other groups that can scale these materials, and these materials will be available to the world beyond the scope of this program in a sustainable way (may will exist on websites or in the hands of NARS programs to use in their training programs).

Indirect Cost and Indirect cost on sub-contracts

UIUC will charge a 55% indirect rate on all funds spent at UIUC. For new partners, SARI, CRI, and INRAB, UIUC will charge overhead at a rate of 55% on the first $25,000 on each sub-contract (institutional direct and overhead). For existing partners IITA, INRAN, and INERA, sub-contracts exceeding $25,000 have already occurred. UIUC will not charge additional overhead on these sub-contracts.

Cost Share

UIUC will provide contributed effort for Dr. Pittendrigh's time on this award. A total of $108,784 is committed for the 4.5 years, representing a 15.2% cost-share of total U.S. direct costs.

Attribution to Capacity Building

For both our UIUC and in-country activities we estimate that half of all activities will ultimately contribute to HC and IITA capacity building. All of the data and outputs from our genomics studies will lead directly into decision management tools for IPM (when and where to deploy given strategies – we had such outcomes for *Maruca vitrata* in the past phase of this program) and all of our short-term training materials will be accessible and in the hands of all HC partner groups, such that they can use these materials both within this program and beyond the scope of this program. Each NARS program and IITA will dedicate 30% of their budgets to training which will ultimately build capacity. Additionally, at least 20% of their budgets will also lead to the development of new insights into pest problems and their solutions, giving each institution capacity for understanding, dealing with, and deploying IPM programs (for a total of a minimum of 50% of their budgets). Building of such institutional capacity will allow them to use knowledge and tools gained beyond the scope of our 4.5-year program.