Research Proposal

Topic: Development and Promotion of Biological Control Program in the Management of Agricultural Insect Pests in Serra Leone

1. Executive Summary

Agricultural production is constrained by many variables, prominent among which is biotic pressure of insect pests which is observed to significantly undermine productivity of crops, unquestionably having a negative impact on achieving food security. The management of insect pests has been traditionally dominated by the use of synthetic chemical pesticides though having immediate effects of reducing the pest population below the economic injury level their applications are however associated with myriad of problems: environmental degradation, pest resurgence, secondary pest outbreak, development of resistant genes in insects as well as health hazards to farmers. These obvious challenges have dictated a paradigm shift to seek more viable and innovative option that harmonizes the management of pests with the environment with a focus on the use of natural enemies technically defined as biological control. Fortunately, natural enemies are in close association with pests in in diverse agro-ecosystems inflicting mortality on the pest population. This association provides unique opportunity for their exploitation and utilization as a sustainable pest management option. This project generally aimed at developing a biological control program constituting an established research unit with an enterprise facility in order to develop and promote the utilization of biological control agents (predators, parasitoids and entomo-pathogens) against insect pests . This ambition will be achieved through a survey of diverse agro-ecologies to identify, quantify the most common key agricultural pests and associated natural enemies, study their biology with a focus on population dynamics underscoring lifetable parameters of key pests and functional and numerical response of the natural enemies as attributes of ideal biocontrol agents. The project will further delve on the exploitation of virulent fungi species for their utilization as bio-pesticides for the management of insect pests. The fungal strains will be isolated through tissue culture techniques, the active ingredients will be extracted and characterized for virulence features and then exploited for development of bio-pesticides. The achievement of the project objectives will provide a platform for the establishment of a biological control facility with a characteristic features of national and international collaboration bringing on board private and public sectors for a greater interest of management of insect pests to boost agricultural productivity , capacity building of pest management personnel through short term trainings, provides unique opportunity for specialization in biological control at advance studies and a trajectory for development of bio-pesticides (myco-insectides), publication of project results for scientific audience and policy formulation and implementation with an arching impact of enhancing productivity and food security.

Keywords: biological control, pest management, agricultural pests, natural enemies, bio-pesticides, food security

2. PROJECT BACKGROUND AND RATIONALE

Agricultural is the main backbone of the economy in Sierra Leone with an estimated population of over 50% observed to engage in the cultivation of a wide range of agricultural crops notably cash crops, cereals, tubers, fruit tree crops, vegetables etc. Some of these crops like rice, potato, yams are cultivated at subsistence level for household consumptions while some are marketed to generate local income. The main cash crops like coffee, cocoa, oil palm cashew referred to as commercial crops are cultivated, processed and exported to generate foreign revenue. Vegetable farming is also quite common, a source of generating local income for a significant number of the women folks serving as major actors from production to marketing along the value chain.

Yield gap analysis of agricultural crops has significantly underscored insect pests as major constraint to production of agricultural crops at both vegetative and reproduction stages of plant growth. Damage can vary from light infestation where there is reduction in crop yield to severe infestation leading to total collapse of entire agricultural fields. Notably, insect infestations are aggravated when the insect pests are observed to serve as vectors to some deleterious viral, bacteria and fungi diseases that remain residual on crops and in the environment.

Synthetic chemical pesticides are habitually used to manage insect pests both in field and in storage. Despite their features to drasticly reduce pest population below the economic injury and threshold levels which are immediately realized after their applications, pesticides usage is however associated with myriad of environmental, social and health challenges. These challenges include but not limited to environmental degradation and pollution, killing of non-target organisms including natural enemies and pollinators, pest resurgence, secondary pest outbreak , development of resistant genes in the target insects, health hazards to the users among others.

These highlighted challenges dictate a paradigm shift to the use of natural enemies technically referred to as biological control as a viable option which is considered environmentally friendly and sustainable. Fortunately, the environment is endowed with natural enemies defined as predators, parasitoids and entomo-pathgens which are in close association with counterpart insect pests thriving under the same environmental conditions inflicting mortality on the insects under natural conditions. This endowment provides unique opportunity for their exploitation from their natural settings for subsequent domestication,

mass rearing and release into agro-ecosystems. Unequivocally, this management strategy of agricultural pests is considered an illustrious innovation as a viable pest management option which can be sustained periodically and at all time without hindrance to its sustainability.

Though biological control is not new globally, there is however no national recognized biological control facility in Sierra Leone that focuses on the utilization of natural enemies namely predators, parasitoids, entomo-pathogens more specifically myco-insecticides (bio-pesticides) as natural substitutes to synthetic pesticides on commercial basis. For these natural enemies to become more efficient in the management of insect pests they require scientific investigation and manipulation to enhance their potential as efficient control agents. The general goal of this project therefore is to establish a biological control facility with an enhanced scientific and commercial features for their utilization in the management of wide range of agricultural insect pests. It is expected that the establishment of this facility will create a platform for sustainable management of agricultural pests to boost production of agricultural crops which are under constant threats from insect pests. Equally importantly, this facility will serve as centre of excellence for capacity building and research on pest management efforts attracting both private and public sectors for collaboration with a pillar of commercialization in the development of bio-pesticides and natural enemies for biological control of insect pests.

3. PROJECT GOAL AND SPECIFIC OBJECTIVES

Project Goal:

The ambition of this project is to establish a biological control facility with an enhanced scientific features for utilization of natural enemies namely predators, parasitoids and myco-insecticides for management of wide range of agricultural insect pests. This facility will further operate as centre of excellence with a strong research component and commercial services integrating private and public sectors in a concerted efforts to achieve the ambition of short term trainings in biological control and pest management leading to enhanced productivity , food and nutrient security respectively.

Specific Objectives

1: *To identify and screen the most common natural enemies (predators, parasitoids, entomo-pathogenic fungi) and key agricultural pests in five major agro-ecosystems: rice, corn, cassava, vegetable, and orchard/cash crop agro-ecosystem respectively*.

This objective will critically look into the ecological distributions of the key pests and natural enemies in diverse ecological settings underscoring their co-existence under natural conditions which provides unique opportunity for their exploitation as natural control agents. Collection and identification of entomo-

pathogens and species identification will require the service of a consultant to assist in the description of fungal infected insect cadavars.

Objective 2: *To determine the biological attributes (development and reproduction) and population dynamics of selected key pests and natural enemies.*

Biological characterization exercise will critically look into the population dynamics and life table parameters of selected key pests and the most common predators and parasitoids identified above under simulated laboratory conditions. Characterization of the predators and parasitoids will significantly contribute to information leading to the efficacy of the biological attributes of natural enemies as ideal candidates for biological control. The functional and numerical responses which are biological features depicting the efficacy of natural enemies will be evaluated against the target pests. The selected predators and parasitoids will be evaluated under greenhouse conditions depicting semi-field conditions where climatic or natural conditions are partially manipulated. Field trials will be conducted on farmers plots and experimental plots under natural settings.

Objective 3 *To identify and screen virulent fungi isolates for characterization and development of myco-insecticides as organic pesticides for the management of agricultural pests*

This is the preliminary stage of developing organic pesticide sector will be initiated with collaboration from the private sectors, Ministry of Agriculture and Environmental Protection Agency (EPA), Food and Agricultural Organization (FAO) and other related agencies. The fungal strains will be screened isolated from host sources and then characterized for virulence against selected target pests by determining the toxicity parameters like Lethal Time (LT_{50}) and Lethal Concentration (LC_{50}) to depict the efficacy of fungal isolates. This preliminary action will lay a foundation as initial trajectory for bio-pesticides development.

Objective 4: To *establish a biological control unit with research and enterprising facilities.*

The establishment for biological control facility with equipped laboratory facilities will provide both research and commercial activities in collaboration with private and public sector respectively. Students will be capacitated to specialize in biological control, biological control agents reared will be commercialized as biocontrol agents, the facility will provide capacity building of smallholder farmers and collaboration with relevant stakeholders in developing policies for effective pest management strategies.

4. METHODOLOGY /APPROACH

Objective 1: To identify and quantify the most common natural enemies (predators, parasitoids, entomo-pathogenic fungi) and key agricultural pests in five major agro-ecosystems: rice, corn, cassava, vegetable, and orchard/cash crop agro-ecosystem respectively.

ACTIVITY 1: Identification and classification of key agricultural pests is the initial frontline exercise in crop protection. This is achieved by carrying out sweeping net collection of pests and associated natural enemies in farmers fields and experimental crop sites. This activity will be carried out both in the low and upland of four distinct agricultural ecosystems namely i) rice, corn ii) cassava, yam, potatoes iii) vegetable iv) orchard/cash crop ecosystem respectively. These agro-ecological systems comprised of the most cultivated crops and important commodity crops in food security and generation of income for smallholder farmers. The collected insects and associated natural enemies are immediately placed in 70% alcohol to immobilize and preserve them for identification in the laboratory. The identification is carried out in the laboratory in consultation with a taxonomist.

DATA COLLECTION: The identified insects are then classified with description into order , family and species. In a similar way, natural enemies are sorted out and categorized into predators and parasitoids. These two categorized will be further subjected to full description for classification into various taxonomic orders, families and species. The service of a taxonomist will be consulted for accurate taxonomic description into the various taxonomic levels. New species will be taxonomically described as type specimens for detail studies.

DATA ANALYSIS: Taylor Power Law and Iwao regression analysis will be employed to determine distribution pattern as whether is randomly, sparsely and cluster (aggregated).Species richness and dominance of pests and natural enemies will be determined using Simpson and Shanno-Weiner Indices for each agro-ecosystem for the two seasons . The collected insects will be classified into taxonomic order, family and species to determine the most dominant order, family and species.

Objective : Determination of biology and population parameters of selected key pests

ACTIVITY : Five key pests are selected from the collection for detail studies on biological parameters . The selected key pests are reared in cages under laboratory conditions, and a cohort of 50 eggs selected for each key pest and the developmental stages (larva, pupa and adults) monitored for mortality. For fertility or fecundity of the female, a pair of male and female of the emerged adults are allowed to mate 24hr and then confined on selected host plants. For this activity a cohort of 10 mated female adults will be confined to a host plants and number of eggs laid are observed daily until the last female died.

DATA COLLECTION: The number of eggs hatched are counted and recorded, the number of individuals that survived at each stage counted and recorded . The number of eggs laid daily per female are recorded until the last female.

DATA ANALYSIS : The life and fertility tables will be calculated from the cohort of eggs according to Atwal (1974). The death and survival rates q_x and s_x for the immature stages (egg, larva and pupa) are computed . The probability of surviving from birth (cohort eggs) to age X (L_x) for each immature stage will be calculated. The intrinsic rate of population growth (r_m) will be calculated according to Atwal (1974). The following demographic parameters : R_o = Gross reproductive Rate ; Λ = Finite Growth Rate ; GT =Generation Time ; DT = Double Time will be computed.

Objective: Determination of biological attributes of natural enemies . For this objective, the natural enemies collected will be screened and three predators and three parasitoids selected for detail studies.

ACTIVITY: This activity will focus on the determination of the functional and numerical responses which are the two most important parameters that determine the efficacy of biological control agents which can be measured by undertaken the following activity: For functional response , the natural enemy under investigation will be exposed to five varying prey densities (10, 20,30, 40 and 50) for daily consumptions. For numerical response i.e. the ability of the natural enemy to increase in number, the number of eggs laid daily are monitored for each prey density.

DATA COLLECTION : The number of eggs or immatures consumed daily is counted and recorded for each prey density and the number of offsprings produced by the natural enemy are recorded to determine the reproductive capability.

DATA ANALYSIS : The functional response model will be employed to calculate two biological parameters: the handling time (i.e. the time required to attack, consume and digest the prey) and attack rate or searching efficiency. This model describes the way the predator responds to changing density of its prey. The data on functional response will be analyzed in two steps : the first step is using logistic regression of the proportion of prey consumed (Na/Nt) as a function of prey density (Nt) where Nt is the initial prey density , Na is the number of prey eaten , and Na/Nt is the probability of being eaten. The second step is to determine the searching efficiency (a) and the handling time (Th), the amount of time the predator or parasitoid handles its prey. The Holling Disc Model will be employed to describe the type of functional response that predicts the suitability of natural enemies that display potential features for an ideal biological

control agent . The three types of functional response models will be tested to determine the most suitable one that best describes the behavior of natural enemy to manage the insect pests.

Objective : Isolation, screening and characterization of fungal species

ACTIVITY : The agro-ecologies most preferably orchards and cash crop plantations will be scouted for fungal infected cadavers i.e. dead bodies of insects that have been killed as a result of fungal infection. These cadavers which are major fungal sources will be isolated through tissue culture technique following the single spore isolation protocols according to Hu et al (2012). The spores isolated will be cultured severally to purify the strains and then identified and then labelled serially with help of a mycologist. The identified fungal strains or isolates are characterized and then tested for virulence against selected target pests under laboratory conditions.

5. ANTICIPATED OUTPUTS AND OUTCOMES

Outputs	Outcomes
Key agricultural pests identified, screened and biology studied	▪ Help promote effective and efficient control measures of the pests. ▪ Publication of results for wider audience will be envisaged. ▪ Develop policy on management of the key agricultural pests ▪ Help design effective control systems in real time
Pest population dynamics and life table parameters determined	▪ Knowledge on possible pest outbreaks acquired and control measures design to avert potential outbreaks
Natural enemies (predators and parasitoids) identified, screened and biological parameters determined	▪ Biological control will be established and strengthen for management of agricultural pests. ▪ Pest management strategies will be harmonized with environment on sustainable basis. ▪ Public and private sectors will be motivated for collaboration for sustainable pest management ▪ Results will be published in scientific journals for wider audience ▪ Policies on the use of natural enemies will be advocated to protect the sanity of the environment

Identification, screened and characterization of virulent fungal isolates.	▪ Platform will be laid for development of organic or bio-pesticides ▪ Promotion of sound environmental pest management on a larger scale ▪ Potential for collaboration with private and public sectors on development of organic pesticides ▪ A trajectory for establishment of commercial enterprise on bio-pesticides ▪ Biological control program promoted at national level ▪ Natural enemies mass reared for commercial purposes
Biological control facility erected and biocontrol program developed.	▪ Farmers capacitated on the use of natural enemies ▪ Students capacitated and specialized in biological control ▪ Platform established for collaboration with private and public sectors on promotion of biological control ▪ Policy will be initiated and promoted on the use of natural enemies by relevant stakeholders ▪ Consultancy on biological control will be envisaged ▪ Research on biological control strengthen and publication of results in scientific journals to a wide audience. ▪ Agricultural pests controlled and agricultural productivity enhanced leading to increased food security .

6. KNOWLEDGE UTILIZATION AND DISSEMINATION PLAN

Information sharing and visibility of research and project results are critical for expanding the sphere of knowledge to beneficiaries and scientific communities, policy makers for societal development. Project results will be communicated to target beneficiaries through conferences, seminars, workshops radio discussion, short interviews, publication in scientific journals of high impact factors. Visibility of project activities will be effected through agricultural exhibitions, hand bills, leaflets will also constitute means of visibility and communication. Demonstration farm plots will be established at community level, local farmers will be trained in techniques to showcase the efficacy of natural enemies and their utilization in the management of agricultural pests.

7. PROJECT GOVERNANCE

The directorate of Project Planning , Research and Development (PDRD) an established office under the purview of Vice Chancellor & Principal of the University will serve as advisor to the implementation of the project to ensure that best practices for implement projects are well observed. The team for the project implementation are indicated below :

1. Dr. Peter D. Musa : PhD in Agricultural Entomology & Pest Control : Research Entomologist , Senior Lecturer & Head of Department, Horticulture Njala University . Project Lead & Coordinator for all project activities
2. Mrs Memuna Sawi , Acting Director , Institute of Food Science and Consumer Studies , Co-Principal Investigation
3. Dr. Jenneh Bebelay : PhD in Agronomy, Research Scientist in Agronomy & Gender – Sierra Leone Agricultural Research Institute (SLARI) , an expert in cereal cultivation , she will be responsible for conducting and collecting data on pests and natural enemies on rice and tuber agro-ecosystems
4. Ms Bridget Sheriff , MSc in Agro-Forestry , Lecturer, Forestry Department School of Natural Resources Management : She will assist in field collection of pests in orchards, cash crop plantation.
5. Madam Miatta Yongawo – Principal Field Technician, Kabala Horticultural Crops Research Centre, SLARI , assists in the collection of field data on vegetable crops.
6. Mr. Sahr Torto : MPhil Crop protection, Lecturer in Department of crop protection , School of Agriculture & Food sciences , assists in collection of data on insects and natural enemies and laboratory and greenhouse trials
7. Mr. Abu Bakarr Matthew : Field Coordinator , Sierra Agro Investment & Consultancy Company – will closely work with farmers at community level.
8. Ms Isata Sumah : Laboratory Technician, Mycoloy Lab., Department of Horticulture, Njala University will assist on tissue culture laboratory activities and spawning of fungal strains and their characterization

The university administration is well structured and highly recognized in handling project implementation efforts. The Finance Director of Njala University has statutory function of handling and overseeing all project funds under the purview of the university while procurement office recommends all procurement activities related to implementation of project at a particular threshold that requires bidding to ensure that such procurement efforts are in compliance with National Procurement Authority rules and regulation. The university also has an internal audit unit to audit, regulate and record all financial transactions including project implementation activities.

8. SUITABILITY OF NJALA UNIVERSITY

Njala university is a tertiary public institution initially established in 1918 as an Agricultural Experimental station during the colonial era to undertake agricultural field activities in the cultivation of cereals, tubers, irrigation & water management pests and diseases management and other agricultural related activities. In 1948 the institution was transformed to agricultural training institute to capacitate field technicians to serve in agricultural government services across the nation. With expansion of agricultural activities resulting to high demand of technicians the institute was later upgraded to agricultural college named as Njala University College for training of agricultural instructors for both primary and secondary schools in 1964 through the support of USAID and University of Illinois. This transformation set a stage for modern agricultural innovation where activities where not only limited to training of agricultural instructors but recognized as institution for active research and community development related programs , where the institution was merged to Fourah Bay College as University of Sierra Leone in 1970 with activities expanded from agricultural education to biological and community development programs. In 2005, Njala gained autonomous university status through (University Act 2005) as Njala University with seven Faculties /Schools located in two campuses.

The Department of Horticulture, School of Natural Resources Management is well recognized as a Department for undertaken active research and existing programs for undergraduate, masters and research degrees (MPhil & PhD). More recently the department of horticulture completed a training program on mushroom value chain where 250 youths and other vulnerable populations were trained to acquire skills as part of youth empowerment to food security. Currently students are enrolled in research degree programs in nematode control in Tomato crops and plant nutrition and fertilization. The university has strong collaboration with Ministry of Agriculture and Sierra Leone Agricultural Research Institute (SLARI) , Sierra Agro Investment and Consultancy Company as collaborative partners.

9. CAPACITY BUILDING

Capacity building will be considered as an integral component of this project with the aim to build the human resource for continuity of knowledge in the field of pest control. As the department has existing research programs in line with the project objectives, scholarship will be provided to two MPhil candidates to pursue studies leading to specialization in bio-pesticides specifically myco-insectides which is a novel initiative of biological control in Sierra Leone. One lab technician will be supported to specialize in tissue culture and extraction of bioactive ingredients from fungi. Short term training will be organized for smallholder farmers to enhance their understanding in biological control. Demonstration plots will be

established that would be supervised by collaborating private sector to cascade agronomic and biological control skills in the management of insect pests.

10. MONITORING AND EVALUATION STRATEGY

The project time line will be strictly followed to make sure that the underscored project activities are implemented according to stipulated time line. The project specific objectives will be strictly followed, quantified and evaluated. Quarterly and yearly submission of project reports indicating achievement records, risks and challenges. Procured items from the project fund will be acknowledged, identified and labelled. Project implementation sites would indicate project visibility billboard displaying project topic, source of funding, implementation period and implementing partners.
Receipts, consultancy agreements /MoU and other relevant documents will be maintained for monitoring . Publications of results, short communications will be maintained for scrutiny .

11. GENDER, ETHICS AND SUSTAINABILITY

The project implementation team will comprise of 40% of female participants with defined responsibilities. The project will ensure women groups will be highly integrated in the implementation phase particularly at community levels. The enhancement and mass rearing of predators, parasitoids and bio-pesticides have commercial features that can be marketed to farmers and private sectors to generate revenue to sustain the activities after expiration of the project. With establishment of biological control facility which will be considered centre of excellence for short term training in pest management and biological control programs will attract crop growers, researchers, private and public sectors. Opportunities will also exist for specialization in biological control for higher degree candidates and platform for collaboration with private and public sectors and researchers will be strengthened.

12. Proposed Project Time Line

Project Activities	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

Collection and identification of insect and natural enemies	XXXXX							
Classification of insects and Natural Enemies at Taxonomic levels	XXXXX	XXXXX	XXXXXX					
Laboratory experiment on Pest Biology		XXXXX	XXXXX					
Laboratory Assessment of Natural Enemies		XXXXXX	XXXXXX	XXXXXC				
Fungal Collection and Isolation		XXX	XXXXX	XXXXX	XXXXXX			
Evaluation virulence of Fungal isolates on				XXXXXX	XXXXXX	XXXXX		
Mass Rearing of Natural Enemeis					XXXXXX	XXXXXX		

)Predators and Parasitoids and release								
Post field Evaluation							XXXXX	
Report writing and submission								XXXXX