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MINISTRY OF AGRICULTURE AND ANIMAL RESOURCES

Rural Sector Support Project (RSSP)

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PEST MANANAGEMENT PLAN (PMP)
FOR TARGET CROPS IN RSSP-3

FINAL REPORT

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EXECUTIVE SUMMARY

Rwanda Government gives priority to agriculture for economic growth. Due to high population and small plot per household, increase in crop production is expected to be achieved through increased productivity rather than expansion of area. Crop productivity is a function of productivity enhancing agricultural technologies and pest management to reduce crop losses in store and fields. In order to achieve this objective, farmers decision making and pest management should target using appropriate and timely pest and disease management tools. The farmers should have a clear understanding of requirements conditions and techniques for producing health plant, pests and diseases status, their survival mechanisms and management methods that are available to make a timely and informed decision.

The development objective of the Rural Sector Support Project III (RSSP-3) is to strengthen the participation of women and men beneficiaries in market-based value chains and increase the agricultural productivity of organized farmers in the marshlands and hillsides of sub-watersheds targeted for development in an environmentally sustainable manner; and . In order to achieve the latter, the Government of Rwanda and the World Bank agreed during the preparation of RSSP-3, to apply the World Bank's *Operational Policy on Pest Management* (OP 4.09), which is an environmental safeguard policy for promoting safe pesticide use and the use of integrated pest management (IPM) to reduce crop losses due to pest damage. This policy requires putting in place a Pest Management Plan (PMP) and structure for adoption of IPM and safe use of pesticides.

The PMP under RSSP-3 will focus on intensification of 13 target crops including five crops of RSSP-2 namely, rice, maize, potato, cassava, and tomato and 8 more namely bananas, wheat, cabbage, carrots, green beans, onions, pineapple and mushroom. These are important crops produced by small scale farmers or cooperatives. Main pest problems on these crops include diseases, insect pests and vectors. The application of PMP will promote the use of IPM in insect pests and diseases management and where necessary the safe use of pesticides as a component of IPM approach.

Currently, the use of pesticides in Rwanda is very limited and is primarily used with some cash crops, particularly coffee, potato and tomato. A limited quantity is also used for the protection of the stored food products. In general, pesticide use in Rwanda target mainly plant diseases management and nearly 75 % are fungicides, while the remaining 25% is composed of different insecticides and a few herbicides. Among the fungicides imported, more than 90% of the products are Mancozeb and Ridomil which are applied to potato and tomato against the late blight (*Phytophtora Infestans*).

Among the target crops of RSSP-3, pesticides, and particularly fungicides, are expected to be used as a part of IPM mainly in disease management; especially for late blight (*Phytophthora infestans*) of potato and tomato, and in rice against rice blast (*Pericularia orizae*). While insecticides will be used in cabbage production against diamond back moth, however, it will require close monitoring and training of farmers on safe pesticide use and IPM strategies. When feasible, research on biological of diamondback moth (DBM) will be initiated and collaboration with ICIPE in Nairobi, Kenya establish for natural enemy of DBM release and monitoring establishment. Management of pests and diseases in other target crops as well as other insect pests in general will use a variety of IPM approaches with less or no pesticides.

The PMP will address the weaknesses of safe pesticide use through training of various stakeholders along the supply and use chain since the knowledge of different pesticides and awareness of the negative impacts is low among sellers, users and extension agents of pesticides.

The PMP implementation monitoring will include monthly meetings and reporting of achievements and constraints. The pest management capacity of RSSP-3 will be supported and strengthened by recruiting expert consultants. The tentative program for the first project year provides the structure of the PMP, and will provide a view of the implementation of the PMP at the end of year. The tentative budget for first project year (excluding salaries) is 962,248USD.

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LIST OF ACRONYMS

ACMV : Africa Cassava Mosaic Disease

ASARECA : Association for Strengthening Research in East and Central Africa

CGIAR : Consultative Group on International Agricultural Research

CIP : International Potato Center /Centro Internacional de la papa

CMD : Cassava Mosaic Disease

CIMMYT **:** Centro International de Mejoramiento de Maiz y Trigo

CBO : Community Based Organization

EACMV-UgV: East Africa Cassava Mosaic Virus-Uganda Variant

EDPRS : Economic Development and Poverty Reduction Strategy

FAO : Food and Agriculture Organization

GOR **:** Government of Rwanda

ICIPE : International Centre for Insect Physiology and Ecology

IITA : International Institute of Tropical Agriculture

IPM : Integrated Pest Management

IRRI : International Rice Research Institute

ISAR : Institut des Sciences Agronomiques du Rwanda

MINICOM : Ministry of Commerce, Industry, Tourism and Cooperative

MINITERE : Ministry of Land, Forestry, Environment, Water and Natural Resources

NAP National Agriculture Policy

NAEB **:** National Agricultural Export Board

NGO : Non Government Organization

PMP : Pest Management Plan

PY1 : Project Year 1 (First year of project)

QDS **:** Quality Declared Seed

RAB : Rwanda Agriculture Board

RADA **:** Rwanda Agriculture Development Authority

RBS **:** Rwanda Bureau of Standards

REMA : Rwanda Environmental Management Authority

RSSP-2 : Rural Sector Support Project -2 (Phase 2)

RSSP-3 : Rural Sector Support Project -3 (Phase 3)

RSSP-LO : RSSP- Liaison Officer

RSSP-SPIU : RSSP- Support Project Implementation Unit

SNS : Service National de semence

SOPYRWA: Société de Pyrèthre du Rwanda

SPAT II: Strategic Plan for Agricultural Transformation II

ToMV /TYLCV / : Tomato Mosaic Virus/ Tomato yellow Curl Virus

TOT **:** Training of Trainers

UN : United Nations

WARDA : West Africa Rice Development Association

WB-CAS **:** World Bank Country Assistance Strategy

WHO : World Health Organization

1. INTRODUCTION

1.1 Background and Context

The agriculture has been identified in vision 2020 and EDPRS as engine of economy and means to attain MDG and poverty reduction, as a result the National agricultural policy (NAP) and Strategic Plan of Agricultural Transformation (SPAT II) has identified crop intensification as mechanism to attain the above objectives. The crop intensification would include the use of high yielding varieties, inorganic chemical fertilizer and pesticides. Agriculture has a combined dominance in employment and food security, and being also main activity in rural areas, the productivity growth in the sector is clearly pro-poor. For these reasons, the Government's national and sectoral strategies emphasize the importance of achieving higher productivity for agriculture. In order for crop intensification to be sustainable, it needs to establish sustainable pest management plan to ensure food safety, human and animal safety, and environmental protection. This can only be achieved through development and adoption of participatory integrated pest management system for all major crops. Likewise, agriculture has been identified by the World Bank's Country Assistance Strategy (WB-CAS, FY09-FY12) as one of the key sectors for both growth and poverty reduction. The agricultural sector accounts for about 36% of GDP, 80 % of employment, about 45% of foreign exchange earnings and provides 90% of the country's food needs. In terms of the country's growth, the improved performance in GDP growth of 8.5%% in 2008 was largely credited to strong agriculture growth of 14.8% in the same year. Since then agriculture has been steadily increasing with continued positive performance. Government of Rwanda (GoR) expenditure in agriculture reflects this priority, and RSSP is one of the Government effort to improve agriculture.

Moreover, Rwandan economy is agriculture based with more than 90% of its population deriving their livelihoods from agriculture. The National agricultural policy and Strategic Plan for Agricultural Transformation (SPAT) have identified crop intensification as a mechanism to attain the above objectives. The SPATII is aligned around ***four strategic axes (programs):*** (i) Physical resources and food production: intensification and development of sustainable production systems; (ii) Producer organization and extension: support to the professionalization of producers; (iii) Entrepreneurship and market linkages: promotion of commodity chains and the development of agribusiness; and (iv) Institutional development: strengthening the public sector and regulatory framework for agriculture. The most effective way of achieving agricultural growth is raising productivity and expanding employment resources that rural poor own or depend-on for their livelihoods. Increase in agricultural production in Rwanda can be achieved by increasing productivity rather than expansion of production area which is already over-stretched. In order to achieve this, the use of modern agricultural production technologies and reduction of yield losses in the field and store is vital. The reduction in crop losses requires farmers to take appropriate and timely pest management actions. This needs clear understanding of requirements and techniques related to plant growth, pest problem, causal agents and survival mechanism, and methods of control.

The preparation of RSSP-3 has triggered the World Bank's *Operational Policy on Pest Management* (OP 4.09) which is an environmental safeguard policy for promoting safe pesticide use and the use of integrated pest management (IPM). This policy requires that a Pest Management Plan (PMP) be prepared to structure the adoption of IPM and safe pesticide use during RSSP-3 implementation.

The RSSP-3 has identified a wider range of target crops to focus on its support and promotion, compared to RSSP-2. In all target crops, insect pests and diseases are known to cause serious damage leading to reduced yield and income for farmers.

Based on the above information, capacity building for farmers and extension staff, pesticides dealers in IPM practices will be an important component of technology transfer for crop intensification during RSSP-3. This will require good coordination and support among extension staff, farmer cooperatives, and the stakeholders. The research institutes and universities will play a key role in adaptive research of IPM technologies to develop site specific technologies with farmers.

The RSSP-3 has three components: (1) marshlands and hillsides rehabilitation and development, (2) strengthening commodity chains, and (3) the project coordination and support. Among these three components, the risks related to pest management are anticipated in component 2.

1.2 Objective of the assignment

The objective of the consultancy is to prepare the PMP for RSSP-3 in accordance with the World Bank's Operational Policy on Pest Management, based on the wide range of materials on IPM and pesticide use that were referenced and prepared under RSSP-2.

13 Methodology

Preparation of PMP for RSSP-3 involved a review on the existing baseline information and literature material. Detailed review and analysis of the national relevant legislations and policies as well as World Bank Safeguards Policies and other relevant documents were done.

Field visits to some potential subproject areas were arranged to collect information on IPM experience from RSSP 2 and identify issues and possible impacts of IPM adoption for the future subproject activities.

2. CURRENT STATUS OF IPM AND USE OF PESTICIDE

2.1 Current and anticipated pest problems in Rwanda that are relevant to RSSP-3

RSSP3 is designed to promote increased use of IPM practices in the irrigated marshlands and surrounding hillsides being targeted by the Project. This requires a plan for the development and promotion of IPM for targeted crops. While PMP for RSSP-2 emphasized rice, Irish potato, tomato, cassava and maize crops; the PMP for RSSP-3 will consolidate information from the previous version of the document, covering RSSP-2 and add specific information on the new crops: banana, wheat, onion, green beans, carrot, cabbage and mushroom. However, the PMP for RSSP-3 covers all 13 crops, which are grouped into four categories as follows: (a) cereal crop (rice, maize and wheat), (b) root and tuber (cassava and potatoes), (c) Fruits (banana and pineapple), and (d) Vegetables (cabbages, carrots, green beans, onions, tomatoes and mushroom).

The 13 target crops are important crops produced by small scale farmers in their small plots or under cooperatives or under crop intensification programme (CIP) in leased marshlands and hillside. Major pest problems under Rwandan condition include mainly diseases, insect pests and vectors. While major diseases of potato, tomato, cabbage and rice need fungicides for their control, the major diseases of cassava, banana, wheat, maize, onion, green beans, carrot and mushroom do need pesticides, they can be controlled by IPM strategies successfully. In particular a combination of cultural practices, resistant varieties and minimum pesticides may control most of pest problems.

The yield loss for each pest in all the 13 target crops has not yet been established under Rwandan agro-ecological conditions. However, it is expected that the paired comparison of learning plots under Farmer Field School (the farmer practices against FFS demonstration plots) will give some estimates on the yield loss. Furthermore, diseases like late blight (*Phytophthora infestans*) cause 100% yield loss in both tomato and potato when no prevention spray done. Similarly the quantities of pesticides used are not yet known because the market is not well organized; and since pesticides used are not widely distributed, pest resistance to pesticides is not yet reported.

2.2 Current and anticipated pest problems in cereal crops

2.2.1 Maize

2.2.1.1 Major pests and diseases of maize

Maize is an important staple crop in Rwanda both as a food and source of income. The crop has a list of pests and diseases which are generally considered to be major constraint in production, however, their economic importance varies according to environmental conditions and cultural practices applied by farmers. These include maize stalk borers such as *Busseola fusca*, maize streak virus, leaf blight, striga weeds and storage pests. The diseases like maize streak, leaf blight are currently controlled using resistant or tolerant varieties such as tamira, katumani, isega, and magumba and cultural practices such as crop rotation with legumes for at least three months and flooding along Akanyaru river marshlands commonly practiced by many farmers.

The storage pests like grain weevils (*Sitophilus* spp.) and tropical warehouse moth (*Ephestia cautella*.) are not yet a threat, because of low production which does not need storage of cereals. The surplus production which needs storage can be handled by hermetic.

In addition, there is also striga weed (*Striga asiatica* or *Striga hermonthecas)* which is expanding in the Eastern province where it is reported to cause up to 100 % yield loss, and is renamed as Kulisuka (meaning zero yield). This will be controlled by using "push-pull" technology as an IPM tool. The couchgrass (*Digitaria scularum*) is widely distributed in the country while it is one of noxious weed of the world, specifically found in eastern African region. It causes a large loss if not controlled. Farmers use deep cultivation, but the later reduces area cultivated per person/day, hence use of system herbicide such as glasphosate (round up) is a best option recommended. However, it will require training and demonstration to farmers and extension staff.

Nevertheless, maize insect pests and diseases are manageable using cultural practices, resistant varieties and reduced pesticides as components of IPM tools. The current maize production systems such as crop rotation with legumes or potatoes, application of organic manure, flooding in marshlands like "Akanyaru" where large quantities are produced reduce pests and diseases. In addition, the current hermetic grain storage (known as "cocoons") promoted by Rwanda's Ministry of Agriculture and Animal Resources helps to reduce storage losses from pests through suffocation, which is a good IPM tool.

2.2.1.2 Current pest and diseases management practices of maize in Rwanda

Maize crop is an important staple crop and source of income in many parts of the country. However, many farmers lack the basic knowledge in good crop husbandry which gives high productivity, and pest and disease management techniques. Therefore, the Rwandan farmer interested in investing in maize production should learn improved maize production technologies and their role in pest and diseases management.

Maize crop is produced on hill side and in marshlands. In the Southern province, it is mainly produced in the marshlands along Akanyaru river and its tributaries during the dry season. It is followed by a rotational crop or flooding during the rain season. For example farmers association in Ngenda Sector (IZMGM) produces maize followed in rotation with bean and soya bean in the marshland of Murago, a tributary of Akanyaru river, and then followed by a flood from the river. This cropping system has an implication on the stem borer and other pest management.

In the Northern and Eastern provinces, maize is produced on the upland and as rain feed crop and in rotation with other crops like potatoes. Maize stalks are also used to feed livestock in the Northern Province. This is a good practice which is useful in the management of stem borer and other maize pests. The management of major maize pests and diseases are indicated in the following section.

The maize crop has a list of pests which are generally considered to be major pests. However, their economic importance varies according to environmental conditions and cultural practices applied by farmers. Nevertheless, maize stalk borers, striga weeds, maize streak virus, leaf blight and storage pests are among the major pests. Diseases like maize streak and leaf blight are reliably controlled using resistant varieties.

Currently, some of these pests are not a threat because the current maize production system which include crop rotation with other crops such as beans, soya beans or potatoes, and in some places flooding as seen in along Akanyaru river marshlands and tributaries. All these practices and their implications on IPM approach will be further elaborated in the sections below.

1) Current pest management practices of maize stalk borers

Stem borers are the most destructive pests of maize crops. Its immature stage (larvae) causes damage either by 'Windowing' of the unfolding leaves as an early symptom or death of the central shoot of maize called "dead heart". Sometimes the early stage larvae mine into leaves causing yellow streaks in addition to the 'windowing.

The yield loss from stalk-borers varies from 23 to 53 % of the crop. Control of stem borers by insecticides is not economically justifiable and feasible because it is expensive for poor resource farmers. Moreover, it needs timing of application before boring into stem; otherwise pesticides do not reach the stem borers once inside the stem. There are three species of stem borers: *Chilo partelus*, *Sesamia calamistis* and *Busseola fusca*. These differ in ecological condition preference. In Rwanda, there is a possibility that *Busseola fusca* is more abundant and may be causing more damage to maize crop. *Busseola fusca* is indigenous to Africa and present in high and mid-altitude (areas above 1077 m asl). It is therefore expected to be the most common in Rwanda. The following crop management practices can reduce the damage of stem borers to a low and uneconomic level. However, there is a need for nationwide testing and promotion.

a) **Cultural practices**: The management of stem borer is more effective when life cycle is well understood in a particular area. The following cultural practices control borers and reduce the population below economical damage level. These include manipulation to reduce population below the damage threshold such as (1) Simultaneous early planted maize over a large area at the onset of rain to complete its vulnerable stages before the population of borers has time to build up, (2) destruction of thick-stemmed grass weeds which would act as an alternative host, (3) Uproot young plants which have been killed, (4). crop residues burning, deep burying or feeding to cattle to kill pupae left in old stems and tall stubble, (5) destroy damaged cobs and stems which might harbour diapausing larvae, since they will increase infestation in the next crop, (6) watch out for young plants with signs of 'windowing', and apply control early in the season for two reasons: (i) if the first generation is allowed to go unchecked, there will be greater damage to the cobs by the second generation; (ii) the caterpillars are most vulnerable to insecticides when they are in the funnel of the plant, and before they begin boring in the stem; and (7) closed season of at least two months to prevent population continuity, the objective here is to have as long period as possible when there are few hosts for it to feed on. If maize were planted only in the long rains, when it grows best, it would mean an eight month period from harvesting one crop to the young plants of the next, during which the maize stalk borer would find it difficult to survive. Most of them are commonly applied in Rwanda, especially in the marshlands and Virunga areas.

b) **Push pull strategy**: This is a technology developed by ICIPE and her partners as an effective, low-cost and environmentally friendly technology for the control of stem borers and suppression of striga weeds. It is a simple cropping strategy, whereby farmers use Napier grass and Desmodium legume (Silverleaf and Greenleaf Desmodium) as intercrops. Desmodium planted between the rows of maize produces a smell odour that stem borer moths dislike. The odour of Desmodium 'pushes' away the stem borer moths from the maize crop, while Napier grass *(Pennisetum purpureum)* which is planted around the maize plot attracts the adult moth and pulls to lay their eggs on it. Since the Napier grass does not allow stem borer larvae to complete development on it; the eggs hatch and the small larvae bore into Napier grass stems, the plant produces a sticky substance like glue which traps them, and majority of them die, and very few survive. As result the maize crop is saved from damage. In addition, Desmodium fixes nitrogen in the soil and enriches the soil. Details are provided in the maize IPM tool kit.

2) Management of other maize pests and diseases

The maize diseases are important and are serious threats causing heavy losses up to 100 % if not well controlled. The major diseases of maize include: (1) maize streak virus disease, (2) southern and northern leaf blight, (3) leaf rust and (4) grey leaf spot (not yet in Rwanda). However, during the visits, disease incidence and severity were very low in many fields.

This may vary from season to season, for example season "A" may have low incidence because of the long dry season preceding it, but in season "B" the incidence and severity might be higher because of continuous availability of host plants in the field in absence of closed season, and then in season C, it might be much higher. The researchers may have to monitor this problem.

Management of maize streak disease

Maize streak virus disease is transmitted by leafhopper of the genus" Cicadulina". The diseased plants show a marked streaky chlorosis of the leaves. The chlorotic streaks are individually narrow, often discontinuous, but evenly arranged in parallel across the leaf. The streaks occur uniformly over the infected parts of the plant that has grown after infection. The leaves produced before infections are free from streaks. The severity varies according to resistance of the host and virulence of the virus strain. The yield loss is proportional to the time of infection. The seedling infection results in 100% yield loss.

Disease management include the following practices: (1) Use of resistant varieties is the best management option, (2) maize crop planted early escapes build up of vector population and gets low infection, (3) close season by destroying source of infection from crop grown during dry season and also avoid to plant near the crop that was produced during the dry season using irrigation, and (4) rogue out all diseased plant as soon observed in the field.

Management of southern leaf blight (*Helminthosporum maydis*)

This disease is common in areas with warm damp climate. The dry weather is unfavourable for disease development. The primary source of inoculum is frequently plant debris from previous season. The disease develops very fast and can appear on young crops from infection of neighbouring fields. The fungus is also seed born and can spread by untreated seed, and seed should be dressed using fungicide & insecticide mixture.

The disease management includes the following practices: (1) Use of resistant varieties is the best management option and the most important measure, (2) destruction of crop residue prevents early diseases development, (3) use of seed dressed with fungicide & insecticide mixture to delay early infection.

Management of maize leaf rust (*Puccinia polysora, P. sorghi*)

This is a host specific disease and it does not have an alternative host. The spores are air-borne and are carried long distances by wind. The infected plant can spread diseases over long distance. P. polysora favours high temperature and high humidity and it is common in low altitudes, while P. sorghi is common in cooler high elevations in the tropics. Maize leaf rust management include the following practices: (1) Use of resistant varieties which is the best management option and the most important measure, (2) use of resistant varieties screened against rust, and (3) destruction of source of infection at community level to delay early disease development.

Management of striga weeds (witchweed) (*Striga hermonthica, Striga. asiatica*)

The parasitic weed Striga 'witchweed' is an important pest of maize, especially in drier areas like the Eastern Province.

There are two species of Striga which are common ***(Striga hermonthica and Striga. Asiatica)***. The *Striga hemotheca* has large attractive pink flowers, while the *Striga Asiatica* is smaller species with purple flowers. A distinctive feature of both species is that each striga plant can produce up to 20,000—50,000 seeds, which lie dormant in the soil until a cereal crop is planted again.

This dormancy can last for over 15 years. As striga germinates, its roots grow towards the host crop because the host plant releases chemicals which break dormancy and stimulates striga seed germination. The roots of seedlings of striga penetrate the host crop's roots and start to draw nutrients from the host. The young striga plants tap the roots of the maize plant and draw water and nutrients in the underground part, reducing production from 30% to 100%, or complete loss of the crop. If maize plants are attacked by both stem borers and striga weed, the yield loss is often 100%. When a farm is infested with striga, the affected plants seldom grow more than one foot (30 cm) tall. The weed does not put roots into the soil so as to grow on its own, but grows by attaching itself onto the host (e.g. maize) plant.

Taking into account the peculiar nature of striga seeds, farmers are advised to control it before the weed emerges above the soil. Manual removal of the striga reduces re-infestation, but it is uneconomical since most damage is done even before the weed emerges. Any control strategy has to begin within the soil. Currently striga management is possible using "push-pull" technology. A ground cover of Desmodium (Desmodium uncinatum, or silverleaf), interplanted among the maize, reduces striga weed. Research at ICIPE has shown that chemicals produced by the roots of Desmodium are responsible for suppressing the striga weed. Therefore, striga does not grow where Desmodium is growing. Being a legume, Desmodium also fixes nitrogen in the soil and thus enriches the soil. Therefore, "push-pull" technology used on maize stalk borers manages also both stem borers and striga. The details of the approach can be tested with farmer groups from different association. This can be done during one season, and study tour can be organized to visit western Kenya where the technology is adopted by many farmers, where Striga Hermontheca is predominant. Striga is becoming a problem in the Eastern province.

2.2.2 Rice

2.2.2.1 Current and anticipated pest and disease problems

The rice plant is a staple crop which is gaining importance in many parts of the country where it is grown as both food crop and source of income. Its major pests and diseases observed in the field and reported by farmers include: (a) Rice blast *(Pyricularia oryzae*, (b) stalk-eyed borer (*Diopsis thoracica*), (c) birds, and (d) rats.

1. The rice blast is the most important disease of economic importance. It attacks all aerial parts, leaves, culms, branches of panicles and floral structures. Its main host is the rice plant (*Oryza* spp) and a few wide ranges of other graminaceous plants and is widely distributed in all rice growing areas in the country. The current management of rice blast is mainly by use of resistant varieties such as Kigori, Yun yun and Zongeng or moderately tolerant varieties such as "Intsinzi, Gakire, and Intsindagirabigega" combined with varietal rotation. The application of cultural practices such as.crop rotation, destruction of rice straws, by burning or burying them to ensure they have rotten. synchronized sowing, fertilizer management to avoid overdosing which favour disease infestationis also possible but it may not be sufficient to suppress the disease by itself and sometimes it is combined with fungicide use (e.g., Kitazine/IBP).

2.2.2.2 Current pest management of Rice in Rwanda

The pests and diseases attacking the rice crop are many; however, only few of them are of economical importance in Rwanda due to high altitude. Among the diseases, only the blast (*P. oryzae*) is a serious diseases that calls for attention. The other diseases are minor which can be managed with various strategies and monitored closely without significant effect on yield. Similarly, the insect pests attacking rice in Rwanda are minor pests which need much attention.

Nevertheless, the major pest and disease problems observed in the field and reported by farmers are : a) Rice blast *(Pyricularia oryzae,* b) Stalk-eyed borer **(***Diopsis thoracica*, Diopsidae), c) birds, and d) rats.

a) Management of Rice blast (*Pyricularia oryzae*)

The rice blast is the most important and serious disease of rice. It attacks all aerial parts such as leaves, culms, branches of panicles and floral structures. Its main host is the rice plant **(***Oryza* spp) and a wide range of other graminaceous hosts. It is widely distributed in all rice growing areas. Alternative grass hosts, crop debris, volunteers and seed borne inoculums are major sources of the disease. High levels of nitrogenous fertilisers also increase susceptibility whereas high silica content in the leaf decreases it. The rice blast affects more severely the upland rice than paddy rice because drier conditions predispose plants to infection, and it is distributed in all major rice growing areas. Because of the nature of the disease, phytosanitary practices have little effect but it is the only option applicable and affordable by majority of our farmers.

1.Use of resistant varieties (e.g., Kigori) is the best option, however, there are very few varieties adapted in the highlands. Therefore a combination of cultural methods and chemical options are necessary.

2. **Cultural practices**: The cultural methods include the synchronized early planting, fertilizer management to avoid over dosing which favor pests and diseases, crop rotation and destruction of residues by burning or burying them to ensure they have rotten.

3. ***Chemical control*** There is a wide range of fungicides with specific actions available such as Isoprothiolane which is a systemic fungicide active against rice blast, and is available as granules, dust, and emulsifiable concentrates (rated slightly hazardous by WHO) and IBP/Kitazin which is also systemic fungicide and controls ice blast and has also insecticide action (it is rated III under WHO).

b) Management of stalk-eyed borer (*Diopsis thoracica* West, Diopsidae)

The stalked-eye borer's main hosts are rice and sorghum. It attacks rice plants and the maggot feeds on the central shoot of the young rice plant causing a typical 'dead-heart'. The larva on emergence moves down inside the leaf sheath and feeds on the central shoot above the meristem. Later generations of larvae feed on the flower head before emerging. Although, it is a serious pest of rice, its economical importance is not well established because of compensation nature of rice. The yield loss occurs only when the damage exceeds 50%. There is no justification as to why farmers should spend money on insecticides on this pest. The birds and rats have not been reported a major pests in rice fields.

As for the birds, the serious birds in Eastern Africa Region are quelea quelea which are very destructive are feared, hence monitoring of them is recommended, and where spotted, the aerial spraying is advised. The rats may be a problem in specific location and recommendation may be developed depending on the site.

2.2.3 Wheat

2.2.3.1 Current and anticipated pest and disease problems in wheat

Wheat has extensive pest spectra, but with different economical importance according to region. In the tropical regions where wheat is increasingly being grown in semi temperate environment, ***there are remarkably few major pests***. However, as the acreage of wheat crop increases, the minor pest situation may become more serious due to continuous availability of nutritive food in isolated areas like island. The semi temperate regions in the tropics are found in the highlands, surrounded by wide area of the tropical hot climate.

Therefore, the few insects pest currently present may multiply because of continuous supply of food especially under continuous monocropping system without rotation.

Currently in Rwanda, there is no serious pest problem, except head smut reported in Burera district. This would require a continuous field monitoring and reporting as soon as possible any infestation observed on minor scale. Most of wheat pests and diseases can be managed by cultural methods with a combination of resistant varieties without need for pesticides use. The best and sustainable strategy for smallholder farmers is the use of resistant varieties. It is also important to note that the resistance to some pathogens, such as rust, is short-lived and cultivars may need to be changed at short intervals as pathogens adapt to overcome the resistance of locally grown cultivars. Seed dressing using fungicide is often effective against seed-borne or soil- borne pathogens.

The major diseases of wheat are mainly rusts and head smut leaf and glume botch, and root rot, seedling blight and spot blotch.

Wheat rust: There are three types of rust which include: i) Stem or black rust (*Puccinia graminis f.sp. tritici,*); ii) Stripe or yellow rust (*Puccinia striiformis*), and iii) Leaf or brown rust (*Puccinia recondita f.sp. tritici*). *P. recondita* is the most widely distributed and occurs together with *P. graminis* in all tropical wheat areas; while *P. striiformis* is most prevalent in cooler areas (temperate or semi-temperate highlands in the tropics)..

P. graminis can parasitize barley, rye, oats as alternate hosts; *P. sfriiformis* has a wide host range on barley, and many other grasses; however, there is no known alternate host or sexual phase (Uredospore) in the life history, and it can very damaging in areas over 2400 m asl. While the *P. recondita* can also occur on barley species; and it is less important and occur at low altitude. In general, alternate and alternative hosts are unimportant in disease epidemiology, because the spore are air borne and are carried over long distance.

Leaf and Glume blotch: The leaf and glum blotch is caused by *Septoria tritici (Mycosphaerella graminicola* — Ascomycete), *Septoria nodorum (Leptosphaeria nodorum* - Ascomycete); and *Septoria avenae* f.sp. *triticea (Leptosphaeria avenaria* f.sp. i*riticea* — Ascomycete). They also parasitize barley, rye and some grasses especially *Poa* and *Agrostis* spp. The lesions of leaf blotch appear first on lower leaves as necrotic flecks which later expand to irregular elongated blotches. They become necrotic and develop a yellow to reddish brown colour often with paler centres in which the pycnidia are embedded.

The lesions of *Septoria tritici* are dark, and are arranged in rows along lesion and can be seen with hand lens. While the lesions of *Septoria nodorum* often develop chlorotic haloes and may join together to kill the areas of leaves and cause premature senescence.

The fungi survive in crop debris and can be seed borne. The spore can remain viable for long period and the conidia can be dispersed by rain from debris in soil and between leaves. Later in season are dispersed by wind.

Root rot, seedling blight and spot blotch: Drechslera (Helminthosporium) sativa (Cochiiobolus saavus — Ascomycete) Drechslera (= Helminthosporium) tritici-repentis (Pyrenophora tritici-repentis — Ascomycete). It also occurs on a wide range of Gramineae. The root rot occurs sporadically as a restricted brown discolouration of roots. The plant may die if the secondary infection by *Fusarium spp*. occurs. The seedling blight kills the coleoptiles and young leaves. The light to dark brown necrotic blotches lesions spread along the leaf causing premature senescence. The fungi survives in crop debris and can persist in the soil as mycelia and conidia.

Loose/head Smut: *Ustilago nuda* **(***Ustilago tritici*): The fungus causing loose smut is internally seed borne and remains viable in stored seed for long time. They infect through the flower and establish in ovary. The fungus remains in dormant mycelium in the seed till when the seed germinates, the fungus also grows as seed concurrently keeping pace with growing point till inflorescence when the fungus forms smut spores. The entire inflorescence, except the rachis, is replaced by masses of smut spores (teliospores). These black teliospores often are blown away by the wind, leaving only the bare rachis and remnants of other floral structures. Yield losses depend on the number of spikes affected by the disease; incidence is usually less than one percent and rarely exceeds thirty percent of the spikes in any given location.

Flag Smut (*Urocystis agropyri):* Masses of black teliospores (masses of spores) are produced in narrow strips just beneath the epidermis of leaves, leaf sheaths and occasionally the culms. Diseased plants often are stunted, tiller profusely and the spikes may not emerge. A severe infection usually induces the leaves to roll, producing an onion-type leaf appearance. The epidermis of older diseased plants tends to shred, releasing the teliospores. Flag smut generally is not an economically important disease, but where present, yield losses can range from trace amounts to moderate levels when susceptible cultivars are grown.

2.2.3.2 Current pest management major pests of wheat

The management of major diseases of wheat are mainly rusts and head smut, leaf and glume botch, and root rot, seedling blight and spot blotch.

Wheat rust: There are three types of rust which include: i) Stem or black rust (*Puccinia graminis f.sp. tritici*,); ii) Stripe or yellow rust (*Puccinia striiformis*), and iii) Leaf or brown rust (*Puccinia recondita f.sp. tritici*). *P. recondita* is the most widely distributed and occurs together with P. graminis in all tropical wheat areas; while *P. striiformis* is most prevalent in cooler areas (temperate or semi-temperate highlands in the tropics)..

P. graminis can parasitize barley, rye, oats as alternate hosts; *P. sfriiformis* has a wide host range on barley, and many other grasses; however, there is no known alternate host or sexual phase (Uredospore) in the life history, and it can very damaging in areas over 2400 masl. While the *P. recondita* can also occur on barley species; and it is less important and occur at low altitude. In general, alternate and alternative hosts are unimportant in disease epidemiology, because the spore are air borne and are carried over long distance. This is minor disease which is managed by cultural practices.

Leaf and Glume Blotch: The leaf and glum blotch is caused by *Septoria tritici (Mycosphaerella graminicola* — Ascomycete), *Septoria nodorum (Leptosphaeria nodorum* - Ascomycete); and *Septoria avenae* f.sp. *triticea (Leptosphaeria avenaria* f.sp. *Iriticea* — Ascomycete). They also parasitize barley, rye and some grasses especially *Poa* and *Agrostis* spp. The leaf and glume blotch are controlled using phytosanitary measures such as stubble destruction, crop rotation with none host (eg legumes), use of clean seeds, avoid excessive nitrogenous fertilizer, and use of recommended spacing.

Root rot, seedling blight and spot blotch: *Drechslera* (Helminthosporium) *sativa* (*Cochliobolus sativus* — Ascomycete) *Drechslera* (= Helminthosporium) *tritici-repentis* (*Pyrenophora tritici-repentis* — Ascomycete). It also occurs on a wide range of Gramineae such barley, rye, grasses in particular Agrostis spp and Poa spp. The diseases can be controlled using crop rotation with none host like legumes which limits pathogen survive in the debris from season to season, use clean seeds, clean ultivation, avoid excessive nitrogen fertilizers, timely planting to avoid moisture stress

Loose/head Smut (*Ustilago tritici):* The entire inflorescence, except the rachis, is replaced by masses of smut spores. These black teliospores often are blown away by the wind, leaving only the bare rachis and remnants of other floral structures. Yield losses depend on the number of spikes affected by the disease; incidence is usually less than one percent and rarely exceeds thirty percent of the spikes in any given location.

Control of loose smut: The disease can be controlled by cultural practice such as use of clean seed from clean field. Where infestation is high,ensure that all diseased plants are removed and destroyed to reduce spread. In addition, the seeds may be clean before planting using hot water treatment as follows: soak the seeds in cold water for five hours followed by soaking in hot water at 54-56^{0}C for 10 minutes. The cold water helps to activate the mycelium and renders them more sensitive to heat. Since the loose smut is an internal infection, it can be killed only by hot water treatment of seed. However, care should be taken to ensure that temperature does not exceed 56^{0}C and harm the seed. The systemic fungicide like benomyl (0.2.-0.25 %) can also be used in seed treatment as it gives good results. The reliable control method is to use certified seed.

Flag Smut (*Urocystis agropyri):* Masses of black teliospores are produced in narrow strips just beneath the epidermis of leaves, leaf sheaths and occasionally the culms. Diseased plants often are stunted, tiller profusely and the spikes may not emerge. A severe infection usually induces the leaves to roll, producing an onion-type leaf appearance. The epidermis of older diseased plants tends to shred, releasing the teliospores. Flag smut generally is not an economically important disease, but where present, yield losses can range from trace amounts to moderate levels (when susceptible cultivars are grown). The cultural practices such as .clean cultivation, crop rotation, nutrient management, seed treatment, residue destruction and resistant varieties such as Mwamba distributed under crop intensification programme (CIP) is currently used to manage the disease in Burera district and revived the crop).

2.3. Current and anticipated pest and disease problems of target root and tuber crops

2.3.1 Irish potato

2.3.1.1 Current and anticipated pest and disease problems of potato

The experience from the field visit is that the major pest and disease problems of potatoes are (1) Late blight, (2) Bacterial wilt, (3) Potato tuber moths and (4) Aphids (serious during low rain season). The potato crop is one of the major crops in Rwanda and it is produced in rotation with maize in the Northern Province.

Among the major pests and diseases, the late blight is the most serious and is continuously controlled using fungicides (e.g., Dithane M45 or Ridomil) in combination with resistant varieties. Late blight (Phytopthora infestans) is a major disease which cause up to 100% yield loss when no control measures are applied. To date there is no record of resistance to fungicides. Moreover, resistance can occur mainly on systemic fungicides . The commonly available systemic fungicide is ridomil which is not used regularly, hence not easy to develop resistance. It is applied only when rainfall is continuous and heavy rains can wash out protective on leaves.

2.2.4.2 Pest Management of major pests and diseases of potato

The pest management in potatoes is complicated and difficult, as the potato is a vegetative propagated crop using tubers for seed. The seed can carry easily bacteria, viruses, fungi and insects. Additionally, and some pests and diseases are rapidly disseminated by cutting knives. Therefore, the source of relatively pest-free seed is essential for healthy potato production. This is complicated by the quantities needed as seed rate per unit area. The experience from the field visit under RSSP1 was that major pests and disease problems include: 1). Late blight (*Phytophthora infestans)*, 2) Bacterial wilt *Pseudomonas solanacearum* 3). Potato tuber moths and 4) aphids. Pest management tools include cultural practices, resistant varieties and fungicide application.

Increase in potato yield is a result of good cultural methods such as right fertilizer, weed, insect and disease management. There is a wide variety of cultural practices and agro-ecosystem manipulations used to control potato pests. Some of them may be integrated into pest management programs in Rwanda.

The best IPM tool is the use of healthy planting material since most of the major diseases of potato can be carried by 'seed tubers'. The production of healthy seed tubers requires the use of virus-free mother parts. These are often produced by micro-propagation techniques; and are grown under disease-free conditions, including the absence of virus vectors. Basic prerequisite for improved agricultural production is the availability of a reliable source of relatively disease free seed. Potato seed producers should obtain their seed from "foundation" seed produced in isolated areas either at ISAR or certified fields, where they are maintained extremely in high standards free from disease.

The general phytosanitary techniques such as crop rotation are also essential. Potato rotation with other crops is a component of both traditional and modern agriculture. Crop rotation is recommended as a means of disease control, and is especially important for the long-term control of diseases such as verticillium wilt, and fusarium wilt *(Fusarium* spp.) etc. It is important that crop rotation does not include plants that are also hosts of the potato pathogens, like tomatoes since that may make the problem more serious.

The cultural manipulations and sanitation procedures such as use of clean seed, destruction of source of inoculums, hilling up and killing of infected vine near harvesting are used to reduce losses due to disease organisms such late blight disease (*Phytophthora infestans),* as it is important to delay initial infection.

The potato farmers in the North Province are very conversant with both protective and curative fungicide against late blight.
They apply Dithane M45 (protective fungicide) when rainfall is not continuous, and Ridomil (systemic fungicide) when there is continuous rainfall which can wash out protective fungicide. This knowledge is good and their experience is an important tool in IPM because it is based on their observation.

It is recommended to apply fungicide (e.g. Mancozeb/Dithane M45), when growing both susceptible and resistant varieties as cash crop, especially when weather condition is favourable for spread of disease. A combination of fungicides and resistant varieties gives a relatively higher yield. The only risk with potato farmers is that they mix the insecticide with fungicide whenever they apply on weekly basis without any recommendation.

Management of potato late blight (*Phytophthora infestans*, Oomycete) : The late blight disease is caused by the fungus (*Phytophthora infestans, Oomycete)* and it is the most important limiting factor for high potato yields in the country. The epidemics are more severe in the North province of Rwanda. The first reason for the severity of blight epidemics is the absence of a prolonged dry period to check the disease; where it thrives throughout the year not only on potato crops, which are planted in many months of the year, but also on volunteer potato, tomato and alternative species. The second reason is that the climatic requirements of both the fungus and the crop are identical and are met in most months of the year. The management options include:

a) ***Resistant varieties****:* Although resistant cultivars are important tools in disease management, given the highly variable pathogenicity of the fungus, complementary fungicides have to be applied in order to get high yield. There are a number of resistant varieties in the country under national seed service including Kigega, Gikungu, Mizero, Ngunda and Nderera etc. The production and distribution of clean tubers is important in disease management. Farmers will learn how to get clean tubers on time in their own community.

b) ***Cultural control****:* The cultural manipulations and sanitation procedures are used to reduce losses due to late blight disease (P. *infestans).* It is important to delay initial infection as long as possible by using whole clean tuber seed, destruction of source of inoculums, hilling up and killing of infected vine near harvesting. The details of these practices are found in the potato IPM tool (copy attached) kit.

c) **Fungicides management***:* It is recommended to apply fungicide (e.g. Mancozeb), whether a farmer is growing a susceptible or resistant variety, especially when weather conditions are favourable for the spread of the disease. The potato farmers in the Northern Province are very much aware that the fungicide spraying is necessary when growing susceptible varieties. There is an increasing use of fungicide in Rwanda to control late blight, which at the same time controls the other fungal diseases like early blight *(Alternaria solani),* because fungicides used are broad spectrum. In general, fungicides used are essentially protectants, and for effective control, a continuous film over the entire surface of the plant is necessary. Many of the protective fungicides control late blight effectively and economically. They are applied at regular short intervals of 5, 7, or 10 days depending on weather conditions and the proximity of source of infestation. The mode of action of the protective fungicide is generally non specific in interfering with many vital functions of fungi. In contrast, systemic fungicides (e.g., Ridomil) penetrate the cuticle and are translocated throughout the plant making their action much more efficient. However, some systemic fungicides such as Ridomil/ Metalaxyl are highly specific in their mode of action.

Thus, their fungicidal action seems to depend on the interference with only one or a very few vital organs, and a single gene mutation in the pest organism can result in a modified system, which may be no longer sensitive to an attack of fungicide. Such change would result in an immune individual and provide the basis for a resistant population. As a result, a fungus population with resistance to that fungicide may probably arise. This message should clearly be understood by farmers.

Management of bacterial wilt (*Ralstonia solanacearum* , Bacterium) : Bacterial wilt disease is caused by the bacteria *Ralstonia (formerly known as Pseudomonas) solanacearum.* The external symptom is wilting of the vegetative parts in spite of a moist soil. A white bacterial mass oozes from the vascular tissue when the base of the stem or a tuber is cut. The main method of spread is by diseased seed tubers. Once the bacteria are in the soil, it remains there almost indefinitely and it can survive saprophytically since it parasitizes a number of very common weeds. The disease management plan includes the following:

a) **Resistant varieties**: Planting of resistant varieties is the only reliable means of combating bacterial wilt. There are a number of tolerant varieties including Mabondo, Kirundo, Mugogo, Mizero, Ngunda, Nderera. Currently, there is only one resistant variety in the list of RAB/RADA namely cruza which is not favoured by farmers.

b) **Use of clean seed**: Bacterial wilt is often transmitted in tubers. It is important to use clean seeds when growing susceptible variety on clean site. The use of bare fallowing during the dry season reduces the amount of inoculum by desiccation but it cannot eliminate it entirely. Infected tubers often show vascular discolouration. Typical wilting with bacterial exudation from the vascular tissue is clear symptom. Other cultural practices have very little impact.

Management of potato tuber moth (*Phthorimaea operculella*, Gelechiidae): The tuber moth is one of the main pests of potato. Infestations arise initially in the field and continue during storage of the tubers. Potato is the main hosts, while tomato, eggplant, tobacco and other Solanaceae members and *Beta vulgaris are al*ternative hosts. The potato tuber moth was in the past reported in the former Mutura district and was serious, but currently it is under control.

Cultural control*:* The cultural manipulations and sanitation procedures are used to reduce losses due to potato tuber moth (*Phthorimaea operculella).* It is important to delay initial infestation by hilling up to cover the tuber properly and delay infestation in the field. To avoid continuous availability of hosts in the field before the following season, encourage crop rotation with none host crops to ensure complete rotting of potato residues and rejected tubers. To possible pupa remaining in the litter, use selective insecticide. More details of these practices are found in the potato IPM tool kit.

Management of aphids in the potato production will depend on natural control. The heavy rainfall in the area is sufficient to minimize aphids problem. Aphids are usually a serious problem during dry season in the tropics.

2.3.2 Cassava

2.3.2.1 Current and anticipated pest and disease problems in cassava

In Rwanda, cassava production is currently constrained mainly by cassava mosaic disease (CMD) which has devastated major growing areas in the country. Therefore, among the biotic factors, the cassava mosaic disease (CMD) is the most important. Epidemics are particularly ravaging with root yield losses as high as 100 %. CMD is caused by at least three gemini viruses, which include the African cassava mosaic virus (ACMV), the East African cassava mosaic virus (EAMV) and the Uganda variant of the EACMV (EACMV-UgV), which is a hybrid virus of EACMV and ACMV. The CMD is commonly found in many fields of cassava, and farmers who cannot follow good crop management such as rouging out of infected plants and cannot access the CMD free cuttings are at high risk.

The use of resistant cassava planting materials would be the best alternative for smallholder farmers in Rwanda. Currently these varieties are still not enough and are expensive to buy as each hectare would need 10,000 cuttings. Combined effort of (RAB/Research (ex- ISAR), RSSP, and farmers organizations (Ingabo and Imbaraga) are on going to avail to farmers sufficient amount of healthy cuttings. The IPM support under RSSP-3 will strengthen access to the planting materials of resistant varieties including new release for diversification**.**

2.3.2.2 Current management of major pests of cassava

Management of CMD: Among the biotic factors, the cassava mosaic disease (CMD) is the most important. Epidemics are particularly causing yield losses as high as 100%. CMD can be managed and its damage and effects can be reduced by well coordinated efforts. The major strategies to be adopted in order to reduce CMD damage include: (i) phytosanitary, (ii) use of resistant varieties, (iii) improved crop husbandry, (iv) training of farmers and extension workers, (v) monitoring and diagnosis and creation of public awareness, and (vi) coordination and linkages.

The phytosanitary strategies include:

a) **Using of Clean Planting Materials**: Selection of symptom less plants in the field for planting.

b) **Rouging of infected plants**: The rouging of diseased plants with of age 1-3 MAP (months after planting) will reduce yield loss by 40%. However care should be taken to identify the CMD infection. The infection of plant older than three months may produce low yield but at least some roots may be obtained.

c) **Disposal & burning of crop debris:** Proper disposal & burning of crop debris removes alternative sources of infection. The uprooting of infected plants should be accompanied by destroying them; otherwise they may sprout and spread further the infection.

d) **Multiplication of Resistant Varieties**: The application of community based approach in the multiplication and the distribution of cassava planting materials is the only reliable means of timely distributing widely the available recommended resistant varieties. The RSSP supported Ingabo and Imbaraga farmers' federations and they have multiplied and distributed a large number of cuttings.

Training of trainers (TOT): Train the farmers on the effects of CMD and its management is the priority strategy in fight CMD. However, to make sure that it is sustainable, the field staff working with farmers should be trained as TOT to enable them to train farmers and coordinate their activities.

The staff to be trained as TOT include the GOV extension staff at District and Sector level, the staff of NGOs working on agriculture in rural areas, and CBOs. The training should also cover pests and disease identification, symptoms, causes, transmission and vectors.

The coordination of stakeholders is important for success of CMD management. RSSP-3 needs to establish strong stakeholder coordination down to Sector level, determine the roles and linkages between them, and organize regular stakeholder meetings to discuss CMD status, management and new varieties on pipeline and other cassava production technologies, markets and opportunities.

To ensure coordination of activities is sustainable, there will be a need for RSSP-3 in each District to assign some members of staff responsibility of pest management task force which includes CMD and other pest problem in the district and inputs availability and marketing. The RSSP in partnership with RAB needs to support districts to empower such a task force in pest management technologies. The main strategy of IPM is the production of health plants which tolerates small pest damage. CMD can be managed successfully by community empowerment and participation in phytosanitary, multiplication of available varieties, continuous research and bulking of new varieties. The involvement of local leaders is essential.

2.4 Current and anticipated pest and disease problems of target fruits

2.4.1 Banana (*Musa sp.*)

2.4.1.1 Current and anticipated pests and diseases of banana (Musa sp.)

The banana (dessert, cooking and brewing cultivars) production in Rwanda is found in highlands, above 1500 m asl**.** Currently, the major threat of bananas in the basin in Rwanda is the banana bacterial wilt, which is spreading in all banana growing areas and its management does not require the use of pesticides. The second most important disease in the country is the fusarium wilt (*Fusarium oxysporum fs musae*) which is soil borne disease and remain in the soil up to 30 years. It is not easily controlled by pesticides. It is very serious on exotic banana cultivars such Gros Michel etc. However, there are resistant new exotic cultivars under dissemination by MINAGRI and ISAR like FHIA 17 and FHIA 25 which are resistant to fusarium wilt.

The other pests of banana are not significant, however, they require close monitoring since their severity is limited by temperature due to high altitude above 1400 m asl. Basing on climate change threat which may adjust local climate, it is important to establish robust pests and disease monitoring. These pests include banana weevils (*Cosmopolites sordidus*), nematodes (like *Pratylenchus goodeyi*, *Helicotylinchus multicinctus*, and *Radopholus similis* and *Meloidogyne spp*.) and leaf spots (yellow sigatoka, black sigatoka and cladosporium etc) are not a threat because of altitude effect. These pests are threat below 1400 m above sea level, while major banana growing areas in Rwanda are above this altitude. Even if they occur, the use of pesticides is not economical.

2.4.1.2 Management of major pests of bananas

Management of banana insect pests: Highland bananas (*Musa AAA-EA*) are traditional food and cash crop in the East and Central Africa highlands, where they are largely produced and unique in the world. Highland cultivars (*Musa AAA-EA*) are endemic in the region and account for 75% of production in Africa and 20 % in the World. The major banana insects pests include lesion nematodes (*Rodophilus similis*, *Practeynchus goodyei*, *H.multincictus*) and banana weevil (*Cosmopiltes sordidus*). Banana weevil and Rodophilus are more serious and are limited to altitude below 1400 m asl. Since bananas in Rwanda are mainly grown above 1400 m asl, the insect pest problem is minor and can be checked using cultural methods such as postharvest residue destruction, mulching, clean planting materials, clean site selection, and proper fertility management. The improvement of crop management, using the following pest management strategies will be effective in increasing productivity. Similarly, it will also control the minor pests. These strategies are indicated in the following section.

a) **Use of clean planting material:** Cleaning through paring and hot water treatment reduces infestation to new plantations and delays pest population build up.

b) **Improved agronomic practices:** Practices such as weeding, mulching and application of manure encourage vigorous crop growth thus reducing pest attack. The use of mulches and manure has been shown to result into better bunch weight as a result of improved plant vigour. Good weeding reduces weed competition such as *Commelina bengalensis* (which is alternate hosts of the banana nematodes) and couch grass (*Digitaria scalarum*).

c) **Management of crop residues:** Destruction of crop residues of the harvested plants reduces breeding sites for the weevils. The use of pseudostem traps continuously to low or monitor weevil population and reduced damage to the bananas,

d) **Host resistance to weevil and nematodes**: Improved banana cultivars with high levels of resistance/tolerance offers one of the solutions to weevil and nematode damage.

e) **Use of neem in banana pest management**: Treatment of pseudostem traps with neem oil (1-5%) has been found to inhibit the growth of weevil larvae up to 14 days. Neem repels the insects and treatment corms show less weevil damage.

f) **Use of insecticides**: Insecticides may be used sparingly when the methods have been found to be ineffective.

Management of banana diseases: The major diseases of banana include**:** Banana Bacterial Wilt (*Xanthomonas campestris pv musacearum)* Fusarium wilt (*Fusarium Oxysporium fs musae*:

(a) ***Management of Fusarium wilt (Fusarium Oxysporium fs musae):*** The main foliar diseases of banana can be easily controlled in Rwanda mainly through culturally-based practices. The Panama disease caused by Fusarium oxysporum, is the only threat found in all banana growing areas in the country together with Banana Bacterial Wilt (*Xanthomonas campestris pv musacearum)* which is expanding in different banana growing areas. The Fusarium pathogen is spread between areas mainly through affected planting materials or equipments. The disease can be prevented through adoption of: (i) clean planting material, (ii) improved crop hygiene and (iii) good soil fertility. Moreover, the highland cultivars (*Musa AAA-EA*) which are endemic in the region and account for 90% are not susceptible. Farmers with problem of Fusarium wilt can plant local cultivars (*Musa AAA-EA*) and keep them for up to 30 years, because the fusarium spore can remain in the infested soil without host for about 30 years.

(b) Management of banana bacterial wilt (*Xanthomonas campestris pv musacearum) :* The banana bacterial wilt (BBW) is a serious disease attacking all cultivars of bananas. The incidence is very high and yield loss can go up to 90 – 100-%. The management is still under development by research. So far the following options are used:

(a) Cut the male bud after flowering and sterilize the equipment after every cut

(b) Disinfect equipments and tools after work and make sure they are sterilized before using another field

(c) Destroy and uproot infected plants and bury them to rot in the soil

(d) Destroy any re-growth from destroyed stools

(e) Restrict movement of bananas from infected areas (quarantine) to none infected zones

(f) Mobilize the threatened communities and involve them to enforce the restriction of banana movement to their area

(g) Monitor any new infestation and involve the community to give report on time

2.4.2 Pineapples (*Ananas cosmosus*)

2.4.2.1 Current and anticipated pests and diseases of pineapples (*Ananas cosmosus*)

The pineapple crop has relatively few pests and diseases if well managed. The major insects pests and diseases attacking pineapples include: (i) mealbugs (Dysmicoccus brevipes), (ii) attendant ants, (iii) Nematodes (*Meloidogyne spp*.), (iv) scales insects, (v) Top fruit rot and root rot (*Phytophthora spp*), and .(vi) Base rot and water blister (*Ceratocystis paradoxa*).

2.4.2.2 Management of major pests and diseases of pineapple

Pineapple is mainly produced all year-round. Commercial production is based on a series of fruit cycles whose number depends on the effectiveness of pest and disease management. The different diseases affecting pineapple can be grouped in the following main categories: leaf diseases, stem diseases, root diseases and fruit diseases.

Yellow spot disease. This disease is caused by a virus named Tomato spotted wilt virus (TSWV) previously known as Yellow spot virus. This virus is transmitted to pineapple by a vector *Thrips tabaci*. Infection with this pathogen is fatal.

Yellow spot **Disease management**: The disease management is done by use good cropping practices which decreases incidence and severity of the disease, use of clean planting materials free from virus, removal of all infected plants, weed control and rotating crops.

Pineapple mealybug *(Dysmicoccus brevipes):* The first symptoms of mealybug are leaf reddening usually at the margins of field due to root system collapse and cessation of root growth. This type of symptoms can be related also to nematodes or to root rot. Plants can be killed because can affect severely the root system. The severity of mealbug is due to the being vector of virus causing pineapple wilt which serious disease of pineapple. The control of mealbug controls also the viral disease, the pineapple wilt..

Pineapple mealybug **management:** The mealybug is the most serious and is best controlled by controlling attendant ants and allow natural enemies to reduce the mealbugs. Use of insecticide to control the attendant ants and mealybugs is also effective. The diseases and nematodes are controlled using good cultural practices. The attendant ants are controlled by spraying insecticide around the plant to keep them out, however, it should be done carefully, because it can also kill the natural enemies. The use of clean planting material is most effective by dipping the slips in a solution of insecticides, preferably systemic insecticides such as carbofuran (furadan) and leave them vertically for 24 hours to allow insecticide to accumulate in the leaf base. Then apply the insecticide granules in the planting hole to ensure that the plant is well protected.

The scales and nematodes may be a localized problem in some places, and they can be managed by use of systemic insecticides like furadan indicated above for mealbug, as it is broadspectrum insecticide.

Since furadan is soil applied insecticide, it is effective against both nematodes and scales, at the same time it does not affect natural enemies for scales. The scale is difficult to control using sprayed insecticides because of their cover of secreted materials.

The top fruit rot and root rot (*Phytophthora spp*), base rot and walter blister (*Ceratocystis paradoxa*) are easily managed using cultural practices like well drained soil, deep ploughing, planting on ridges, raised beds and use of fungicides such as captafol.

2.5 Current and anticipated pest and disease problems of target vegetables

2.5.1 French beans (*Phaseolus vulgaris*)

2.5.1.1 Current and anticipated pests and diseases of french beans (*Phaseolus vulgaris*)

The French beans (*Phaseolus vulgaris*) are among the major crops produced in Rwanda. It is the major source of protein for majority of people (both urban and rural areas). Bean crop has many pests (insects and diseases) both in the field and in the store. Some diseases are seed born and are easily transmitted through infected seeds. The major insects pests and diseases attacking bean are the following: (i) beans fly or bean stem maggot (*Ophiomyia spp*.), (ii) Angula leaf spot (*Phaeoisariopsis griseola*), (iii) bean anthracnose (*Colletotrichum lindamuthianum*), (iv) common blight (*Xanthomonas campestris pv phaseoli*), (v) halo blight (*Pseudomonas syringae pv phaseolicola*), (vi) bean common mosaic virus, (vii) White flies: *Bemissia tabaci* and *Trialeurodes vaporiorum*, (viii) cutworms (*Agrotis spp*.), (ix) Pod borers: African bollworm (*Helicoverpa armigera*) and Legume pod borer (*Maruca testulalis*), (x) Stinking bug (*Nezala viridula*), (xi) Flower and Pollen beetles: Blister beetles (*Mylabris spp*.) and *Coryna spp*., (xii) Aphids (*Aphis fabae*), (xiii) Thrips: African bean flower thrips (*Megalurothrips sjostedti*) and Blossom or cotton bud thrips (*Frankliniella schlultzei*), (xiv) red spider mites (*Tetranychus spp*.). These diseases are seed born and are managed through clean seed or treated seed.

2.5.1.2 Management of major pests of French beans

Management of French beans field pests (insects and pathogens): The successful management of pests and diseases of beans depends on the crop husbandry applied. The important beans diseases are seed borne and are transmitted by using infected seeds. Field insect pests have little effects on a health and vigorous plant. Therefore by applying recommended agronomic practices, the pests and diseases management can be easily achieved. The following are the general management options for producing health bean crop without significant pest damage effects.

a) **Clean seed**: Use treated clean seeds, and plant on clean soil which was not planted with beans for at least 2 years.

b) **Resistant variety**: Plant your crop using resistant varieties against major diseases where they are available, accessible and affordable.

c) **Crop rotation**: Rotation of beans with none legume crop such as tuber crops. This practice will reduce bean stem maggot (BSM) and root rot.

d) **Fertility management**: Make sure the soil is fertile, and if not, apply manure and inorganic fertilizers as recommended. A vigorous crop tolerates small infection without significant effect on yield.

e) **Weeding**: Timely weeding is important for producing healthy crop. While weeding, it is recommended to do hilling up soil around the stem of the seedlings to encourage development of adventitious roots and enhance recovery of plants from BSM damage.

f) **Crop residue management**: After harvesting, bury the crop residues, and do not use manure from livestock which were fed residues from legume crop.

g) **Fungicide**: In case the above methods fail, you can apply systemic fungicides like benomyl at recommended rates in your area.

2.5.2 Tomato

2.5.2.1 Current and anticipated pests and diseases of tomatoes

Tomato is one of the most important vegetables, relatively easy to grow, important source of nutrition (vitamin A and C) and income for smallholders. Tomato varieties can be divided into two main types. (1) *Bushy varieties* (also called *determinate* cultivars) which can usually grow without support (e.g. Roma variety), (2) *Vine varieties* (also called *indeterminate* cultivars such as Money maker) which need to be supported by *stakes,* and usually *pruned* to leave only one or two main stems.

The tomato crop is attacked by a variety of insect pests and a wide range of diseases attack leaves, fruit and roots, particularly in the rainy season when high humidity favours insects and pathogen development and transmission.

The major insect pests include***:*** Bollworm (*Helicoverpa armigera)*, Leafminer (*Liriomyza spp*.)**,** Cutworm (*Agrotis spp*.) African Spider Mites (*Tetranychus spp.),* Aphids (*Myzus persicae* & *Aphis gossypii*)**,** Whitefly (*Bemisia tabaci*)**,** Root-Knot Nematode (*Meloidogyne spp*.)***;*** while the major diseases include***:*** Late Blight (*Phytophthora infestans*), Damping Off (*Pythium spp*. & *Rhizoctonia solani*), Early Blight (*Alternaria solani*), Fusarium WiIt (*Fusarium oxysporum f. sp.lycopersici*), Verticillium WiIt (*Verticillium dahliae*), Powdery Mildew (*Leveillula taurica*), Septoria Leaf Spot (*Septoria lycopersici*), Anthracnose (*Colletotrichum spp*.), Leaf Mould (*Fulvia Fulva*), Bacterial Wilt *(Pseudomonas solanacearum* also known as *Ralstonia solanacearum***,** Tomato Yellow Leaf Curl Virus (TYLCV), Tomato Mosaic Virus (TMV) and Blossom End Rot. Farmers possess little knowledge of most of these pests. It is important to monitor the use of pesticides on tomatoes otherwise farmers may overuse them. Among these diseases, the late blight (*Phytophthora infestans*) is the most serious and is currently controlled using fungicides such as Dithane M45/Mancozeb or Ridomil/Metalaxyl. Both fungicides are category U and III respectively which are acceptable.

Staking practice helps to avoid diseases by improving air circulation in the crop, and preventing plant parts and fruits from touching the soil. Tomatoes are usually grown in seedbeds and then transplanted when they have grown to a height of about 10 to 15 cm. As with many crops, it is better sowing seeds thinly and to remove competing weeds to produce vigorous plants which are more likely to withstand pests and diseases. .

2.5.2.2 Management of major pests of tomato

Tomato is one of the most important vegetables, relatively easy to grow, important source of nutrition (vitamin A and C) and good source of income for smallholder farmers. In general tomatoes production is constrained by diseases and insect pests and all are economically important.

African Bollworm (*Helicoverpa armigera*): Bollworms are large caterpillars often seen feeding in tomato fruit. Adults are large brown moths (figure 1a) which fly at night. The larvae (caterpillars) feed on leaves, flowers and fruit. The leaf damage can reduce leaf area which slows plant growth and the flower feeding can prevent fruit formation.
When they burrow in the fruit they are difficult to reach and control with insecticide. The damage may cause the fruit to drop or make it more susceptible to secondary fungal and bacterial diseases. Management options include:

Figure 1a. Adult ***Figure 1b. Caterpillar***

(1) Scouting is important to detect infestations early, preferably for the presence of eggs, since the larvae are well-protected once they move into the flowers and fruits. When larvae have entered the fruit, the damage caused is severe, (2) crop rotation can only help to prevent build up of populations, if it is done over large areas, since adult moths can move quite long distances and is likely practical for smallholders in associations, (3) hand picking of eggs and larvae can be an effective method if infestations are not too severe.

Chickens can help by eating larvae and pupae at certain times of crop development, although they should not be allowed in seedlings or plants with fruit since their scratching and pecking will cause damage, (4) infested fruit should be destroyed, and after harvesting infested plants should be composted or burnt, (5) infested crop residues are carefully destroyed to prevent pest switching backwards and forwards between different hosts. Pesticide may be used as last resort when other options have failed. A number of pesticides are effective and commonly available in Rwanda e.g., Dimethoate

Cutworm (*Agrotis spp*.): Cutworms cause serious damage by cutting young plant stems at the base. Young larvae may feed on leaves and cause tiny holes, but they drop to the ground after a few days. Mature larvae are about 4 cm long, but because they hide in the soil during the day, and only emerge at night to feed on the crop, they are not often seen unless the farmer digs them up. The caterpillars are easy to recognize by their smooth skin, greasy grey/black colour and C-shaped posture when disturbed.

Cutworm infestations can appear suddenly (as a result of moths flying into the area) and are often associated with fields that are weedy, having high amounts of organic residue or very wet due to poor drainage or heavy irrigation. The following are management options: (1) prepare fields and eliminate weeds at two weeks before planting to reduce cutworm number. Ploughing can help to expose larvae to predators and bury others so that they cannot reach the surface, (2) early detection of cutworm infestations helps to initiate control before serious damage occurs. Cutworms are usually present when seedlings are found cut off at the base of the stem. However, small infestations can be controlled by digging near damaged seedling to find and kill the individual larva, (3) delayed transplanting slightly ensures bigger size seedlings that can be more tolerant to damage, (4) widespread outbreaks may require use of a pesticide application around the plant as drench or granules. Granules are best option when spread in a circle around the plant, (5) in the marshlands areas like Nyabarongo valley, flooding of the field for a few days before transplanting helps to kill larvae present in the soil.

Leaf miner (*Liriomyza spp*.): The main damage is caused by larvae mining inside the leaves and reducing the photosynthetic leaf area. Some species mine over 2cm per day. If the infestation level is high, when the weather warms up, the leaves may be killed and drop off, leading to yield loss, fruit sun scald or in serious cases, death of the plant. The management options are indicated in tomato IPM tool kit.

Spider mites (*Tetranychus spp*.): Infestations start first on the lower surface of leaves, particularly around the main vein. The leaves may become spotted, yellow, brown or silvery as a result of the spider mites' feeding activity. Yield can be greatly reduced as the plants are weakened or even killed as a result of feeding by large numbers of spider mites. Fruit can also be attacked, causing white speckling and loss of market value. The pest management options are indicated in the tomato IPM tool kit.

Aphids (*Myzus persicoe & Aphis gossypii*): Aphids damage tomato plants in two ways. (1) They suck plant sap which can reduce plant growth; and (2) they excrete sticky liquid called honeydew, which coats the leaves, causing sooty moulds and develop slow plant growth. Aphids infest upper and lower leaf surfaces and are often seen on tomato plant stems. Infested plants may show signs of curling, wrinkling, or cupping of leaves. This is a minor pest during rain season. Pest management options are indicated in tomato IPM tool kit.

Whitefly (*Bemisia tabaci*): Whiteflies damage plants in three ways. Firstly, by sap-feeding of adults and nymphal stages which distort and cause yellowing of the leaves and weakens the plant. Secondly, mould develops on the excreted honeydew deposits which reduces plant growth and fruit quality. Thirdly, whiteflies can carry some virus diseases tomato yellow leaf curl virus. Plants with heavy whitefly infestations will not yield well, however, a small numbers of whitefly can be tolerated, and pesticide sprays not necessary. When the tomato yellow leaf curl virus is known to be common in the area, even small numbers of whiteflies should be controlled. The white fly can be managed using the following options.

Figure 2. Whitefly adults on leaf

(1) Spraying the plant with soap and water solution controls whitefly. However, the mixture should be no more than 1 part soap to 20 parts water (1:20). If it is too concentrated, it can burn the plant, (2) the use of neem seed extracts in control of whitefly is effective, as it inhibits young nymphs to grow and develop into older nymphs, and reduce egg-laying by adults, (3) growing African marigolds has been reported to discourage whitefly, however, it is bad weed which is difficult to control when it is established, (4) in case the population of whitefly increases to high levels, application of pesticide by spraying may be necessary using effective and commonly available pesticides. The application of a systemic pesticide will be more effective than contact one.

The addition of soap to the spray solution will help the spray droplets spread on the waxy wings of the whiteflies. A single pesticide application may not be effective against eggs or nymphs, so a second application may be necessary to control the adults which have emerged from the immature stages. Whiteflies develop resistance to pesticides very quickly so pesticides should be rotated to prevent it.

Damping off (*Pythium spp. & Rhizoctonia solani*) : Damping off disease can occur in two ways, first as pre-emergence damping off when seedlings die before they have pushed through the soils, resulting in patches which appear to have germinated poorly. The second type is post emergence damping-off which occur after seedlings have emerge, which fall over and die while still small, and usually within two weeks after emergence. The fungus infects the roots and base of the stem, and the infected plant show water soaked and shrivelled stem at ground level. The damping off disease of seedlings in the seedbed is caused by fungi. Development and spread of fungi is influenced by wet soils, crowded seedbeds and high temperatures. Damping off usually occurs in small patches at various places in the seedbeds, and disease spots increase in size from day to day until the seedlings hardened after two weeks from emergence.

The fungi are common in moist soils and may survive for several seasons without crop. The infection of plants is through the roots or via leaves which are touching the soil or have been splashed by rain or irrigation water. The fungi can also be transmitted on seed which has not been treated. The management of damping off include the following options:

Use disease-free seed, and sow thinly to avoid crowding of seedlings in the seedbed and do not apply too much irrigation water or nitrate fertilizer. When buying seedlings, examine them in the seedbed to be sure they have been grown well. If there is doubt about the seed, for example, with farmer-saved seed, it can be given the hot water treatment (for 10 minutes at 50-52°C) or seed-treated with systemic fungicide. Use wax stick to bind a piece of metal and a floater tied on thread and stick which lay across the pot to monitor temperature. When temperature reaches 52^{O}C the wax will melt and the metal drops in water, the floater comes on surface. Destroy diseased seedlings by burning them; do not throw them in the field where tomato is to be planted. Make the seedbeds on land which is several metres from land which has previously produced crops of tomato or related crops such as potato, pepper or egg plant, and if there is a tomato field, make sure the seedbed is preferable located up-wind or upstream. Seedbed soil can be partly sterilized by fire, solarization, or by drenching with a fungicide. If damping off occurs in the seedbed, spraying may be effective using effective and commonly available fungicides. Make sure the seedlings are thinned to enable good air circulation.

Early blight (Alternaria solani): Early blight affects all aerial parts of the plant. Disease incidence increases in warm moist conditions (high temperature and humidity).

The disease may defoliate the crop in the seedbed; plants may develop dark, wet patches all around the stem *(girdling)* near the soil surface. This is sometimes called collar rot, and will damage or kill small plants. When older seedlings are infected, it causes stem lesions that are usually restricted on one side, to become elongated and sunken.

The affected leaves have brown circular spots with concentric rings (rings inside each other) and yellow halos, the pattern of which distinguishes this disease from other leaf spots on tomato. The leaf spots first appears early in the season on the older leaves and progress upward on the plant.

The greatest injury occurs as the fruit begins to mature. When this coincides with favourable conditions for disease development, it causes great loss of foliage, weakening the plant and exposes fruits to sunscald. When plants are larger, patches of disease *(lesion)* sink into the tissue of the stem forming dark hollows. Black sunken spots can also develop around the stalk of the fruit causing it to fall.

Figure 3a. Early blight on leaf ***Figure 3b. Early blight damage on fruit stalk***

Early blight can be seed-borne, resulting in damping off. Infected plant residues in the soil can carry early blight pathogen to the following season, particularly if the soil is dry. The spores are formed on the surface of infected tissue and can spread by the wind and splashes of water.

Control options are as follows: Avoid planting tomatoes next to related crops such as potato, pepper and egg plant, and remove Solanaceous weeds such as *Solanum nigrum.,* if there is doubt about the seed, for example, with farmer-saved seed, it can be given the hot water treatment (sink in hot water at 50-52^{0}C for 10 minutes with seeds lapped in cloth, use thermometer to monitor temperature) or treated with a fungicide. (See details above), when the crop is harvested, remove plant residues and use them for compost making or destroy them and do not plant consecutive tomato on the same land, if the problem of blight is serious, spray the crop using effective and commonly available fungicides such as mancozeb., and avoid windbreak and shade areas as they encourage dew and disease development, and keep the field free from weeds.

Late blight (*Phytophthora infestans*): Late blight is one of the most serious diseases in cool moist conditions, and may completely and rapidly destroy the crop (contrary to early blight which prefers warmer condition see above) causing 100% yield loss in absence of any intervention.

The disease causes leaves to develop irregular greenish-black, water soaked patches, usually at the edge of the leaves. The leaves turn brown and wither but often stay attached to the plant. Under humid conditions, a white dusty layer which contains spores can be seen on the underside of the leaves.

When conditions are good for the development and spread of the disease, the whole crop can be lost in a very short time. Grey green watery spots can develop on the upper half of the fruit, which later spread and turn greasy brown and bumpy. Stems can also develop long watery brown patches. However, it is usually a very minor or nonexistent problem in the dry season



Figure 4a. Damage on leaf

Figure 4b. Field crop damage

Figure 4c. Fruit damage

Cultural techniques can help to reduce the risk of blight outbreaks. Stake plants to keep them off the soil, mulch to reduce splashes, and remove or deeply bury in old crops after harvest. Pruning will increase air movement and allow good spray penetration if pesticides are to be used. Irrigating in the heat of the day should allow the crop to dry before nightfall and reduce transmission and development. If there is wet weather, apply fungicide as soon as the disease is seen or as soon as local experience suggests that the weather conditions are favourable for disease development. Use of effective and commonly available fungicides such as Mancozeb or Ridomil can provide adequate control.

Fusarium wilt (*Fusarium oxysporum f. sp.lycopersici*): Fusarium wilt disease affects the tubes which carry sap (water and nutrients) and blocks the supply to the leaves. The leaves turn yellow and die, usually the lower ones are the first to die The wilt is typically one-sided - at first only one side of a leaf is affected, then leaves on only one side of a branch, then leaves on only one side of the whole plant. If a stem is cut lengthways, the tubes appear brown/reddish. Light sandy soil and high temperatures both cause water stress which makes the disease worse. Fusarium wilt can be accidentally introduced to the field on infected seeds and seedlings. It can be in soil on farm tools, staking materials and shoes. Once it has been introduced, it can survive in the plant residues and weed hosts and can re-infect new crops. The fungus also produces special spores which can survive for many years even when no tomatoes are grown. Acidic soil and nitrogenous fertilizer favour the disease, and there is evidence that presence of root knot nematodes encourages Fusarium wilt.

Disease management includes the following options: Do not locate seedbeds on land where Fusarium wilt is known to have occurred, where soil is acidic, raise soil pH to 7 by liming or use of farmyard manure, avoid excessive nitrogen fertilisation and control root-knot nematodes.

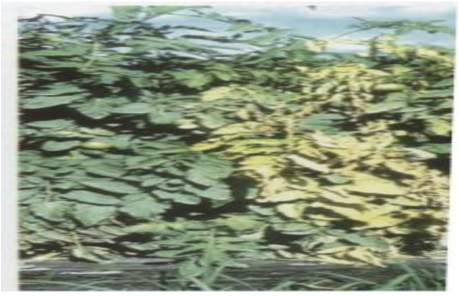

Figure 5a. damage on the plant ***Figure 5b. damage in the split stem***

Verticillium wilt (*Verticillium dahliae*): Verticillium wilt is a disease which affects the tubes carrying sap (water and nutrients) around the plant. The symptoms are similar to those of Fusarium wilt. The older affected leaves turn yellow and gradually wither and/or fall off, but the damage is not one-sided as with Fusarium wilt. Plants with early infections often wilt during the day and then recover at night, but eventually the wilt becomes permanent. When cut lengthways, the plant often shows symptoms of brown colouration of the tissues. The plant may develop a lot of extra roots at the base of stem. This disease can have a devastating effect on the individual plants, but nearby plants may not be affected

Verticillium wilt can be both seed-borne and soil-transmitted. Unfortunately it can remain in the soil for many years in a dormant form or as soil inhabitant. When a plant is infected the spores can also be blown by the wind to infect other plants. The disease is serious if there is any slight root damage when transplanting or cultivation which can allow the disease to establish, or due to root-knot nematode damage.

The control options include the following: avoid alkaline soil which is good for the disease development, control root-knot nematodes if present in the field, do not locate seedbeds on land with a history of the disease, destroy crop debris after harvest, rogue out and burn any diseased plants and fruit, if plant is grown in the valley, temporary flooding will help to reduce the verticillium pathogen in the soil.

Anthracnose (*Colletotrichum spp.)* : The anthracnose is indicated by small, slightly sunken circular spots developing on the ripe fruits. Even if green fruit is infected, they will not show any symptom until they begin to ripen. As the disease progresses, the spots spread and fruit cracks open. Leaves and stems of infected plants do not show any clear symptoms. The fungus can be seed-borne or can infect new crops from infected plant residue in the soil. Spores from the soil splash onto lower leaves of the new crop and infect them. Spores produced on these newly infested leaves can be carried by rain splash to the young fruit and spread around the farm by people moving through the crops.

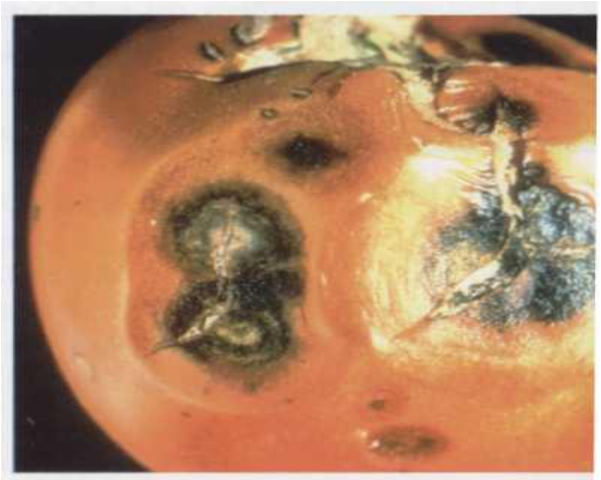

Figure 6. Anthracnose infection on fruit

Disease management include the following options: (1) cultural techniques can help reduce the risk of infection by staking plants to keep them off the soil and remove lower leaves, application of mulch to reduce soil splashes, and removal or dig out old crops after harvest; also removal severely infected plants and harvesting fruit before fully ripens can help. If the conditions favour development of anthracnose, a preventative spray program may be required to give adequate control using mancozeb or Ridomil fungicides.

Bacterial wilt (*Pseudomonas solanacearum also known as Ralstonia solanacearum*): Bacterial wilt disease causes rapid wilting of the whole plant and the plant usually collapses and dies without any yellowing or spotting of leaves. All branches wilt at about the same time. If the stem of a wilted plant is cut, the centre appears brown and water-soaked and hollow. Squeezing the cut stem may cause white or yellowish bacterial slime to appear and if the stem is held in glass of water for a few minutes, the milky bacterial slime starts streaming down from the cut end. Roots turn brown and may become soft and slimy in wet conditions.

The bacterium is soil-born and can survive in the soil for long periods. It has a very wide host range and infects all members of the Solanaceae family, including egg plant, peppers and Irish potato and some common weeds like lantana, black nightshade etc. It infects plants through theroots and when diseased plants are removed, the pieces of infected root which remain can infect new crops.

Figure 7. tomato plant collapse due to bacterial wilt attack

It is often introduced to fields via diseased seedlings which have been raised in infected seedbeds, in drainage and irrigation water. The disease develops best under warm (above 24^{0}C), wet conditions, and in slightly acidic soil, not favoured by alkaline soil (high pH). Root-knot nematodes can increase the severity of the disease. When the roots of diseased plant decay, the bacteria are released back in the soil.

Disease management include the following practices: growing varieties which have some tolerance; do not grow tomatoes in soil where bacterial wilt has occurred before; removal of wilted plants to reduce spread of the disease from plant to plant; control root-knot nematodes since they may help the disease to establish and spread; liming the soil to raise soil PH; maintain high nitrogen level. If possible prolonged flooding of the field can reduce disease levels in the soil. Spraying pesticides will not help to control this disease.

Tomato yellow leaf curl virus (TYLCV): Infection of young plants causes severe stunting of leaves and shoots which results in the plant looking very small and bushy. The small leaves roll up at the edges and yellow between the veins. Fruit set is severely affected with less than one in ten flowers on infected plants producing fruit. There are no signs of infection on fruit. TYLCV is neither seed-borne nor mechanically transmitted - it is spread by the whitefly *Bemisia tabaci* and can be accidentally introduced on infected seedlings. High temperatures and very dry conditions favour whitefly populations and therefore help the spread of leaf curl virus. The earlier plants are infected, the more serious the impact on them. Tobacco can also be infected and, although there are no symptoms, it becomes a carrier which can be the source for re-infection of tomato crops.

Disease Management options include**:** Rogue out diseased plants (in the seedbed and the field) and destroy them. Replace them with healthy plants; protect seedbeds from whitefly, because when plants are infected when are old/large enough, they are less affected, have low yield loss; spraying with oil is said to be effective against the disease, probably because they reduce the infestation of whiteflies. Use different methods to reduce the ability of whiteflies to find the crop, for example, planting in a new area away from previous tomato cultivation, or planting maize around tomato fields, apply mulches (straw, sawdust etc) to control the whitefly as vector. However, whitefly control may be not be sufficiently effective to control the TYLCV in areas where the disease incidence is high, because very small numbers of whiteflies can transmit the disease between plants. Cultivars such as Roma and Marglobe are highly susceptible and should not be used in areas where the disease is common

Tomato mosaic virus (T0MV) management: Affected plants show light and dark green mottling and some distortion of the youngest leaves which may be stunted or elongated, a condition called "fern leaf" This refers to the resemblance of these leaves to leaves of many kinds of ferns. Under high temperature and high light intensity, the mottling can be severe. Under low temperature and low light intensity, stunting and leaf distortion are severe. If fruit is infected when nearly mature, they can develop discoloration and brown streaks inside the flesh. The disease can be seed-borne, but can also survive on plant debris in the soil and so re-infect newly planted crops. The virus is easily mechanically transmissible by contact between plants, or through human activities, for example, transplanting seedlings or pruning.

Disease Management are as follows**:** Remove crop debris and roots from the field, and do not overlap tomato crops; remove any crop or weeds in the Solanaceous family from within and around the field; workers should not smoke or take snuff when working in tomato fields as it is believed that ToMV can be transmitted from the tobacco.

When working with plants, it is claimed that dipping the hands in milk or skimmed milk prevents spread from plant to plant; and field tools should be washed thoroughly.

Blossom end rot : Blossom end rot usually begins as a small water-soaked area at the blossom end of the fruit. This enlarges, becomes sunken and turns black and leathery sometimes turning the core of the fruit brown. In severe cases, it may completely cover the lower half of the fruit, becoming flat or concave. Secondary pathogens can invade the fruit and destroy it. The problem is caused by calcium deficiency brought about by rapid changes in soil moisture and poor root development. Other factors that reduce calcium uptake, such as use of ammonium nitrate and high humidity, can make the problem worse. Rapidly growing plants are more susceptible to the disease.

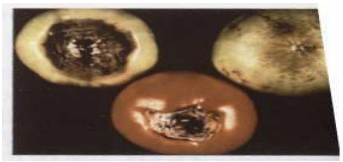

Figure 8. damaged fruits

If blossom end rot is a known problem on the farm, avoid growing varieties which are known to be susceptible such as the processing cultivars Roma. Get the soil tested and if necessary, calcium deficient soils should be limed with high calcium limestone before planting. Soil moisture should be kept constant if possible especially during the flowering and fruiting period. Foliar application of calcium chloride or soil applications of gypsum at transplanting time may help.

2.5.3 Carrots (*Daucus carota*)

2.5.3.1 Current and anticipated pests and diseases of carrots (*Daucus carota*),

The carrot crop is usually free from major pests and diseases. However, it is attacked by the following insect pests and diseases. (i) carrot blight (*alternaria dauci* and *cercospora carotae*), (ii) Carrot yellows, (iii) root rot, (iv) carrot rust fly maggot, (v) carrot weevil, (vi) carrot caterpillar (*Papillio polyxenes*) and (vii) leaf hoppers. These are all minor pests, the study on their pest status under different cropping system is needed.

2.5.3.2 Management of major pests of carrots

The major pests of carrots are managed by good cultural practices. Crop rotation for 2-3 years may be effective against major pests. Use of pesticides may also be effective when pest pressure is high, destroy crop residue after harvesting, destroy source of inoculums around the field.

Likewise carrot diseases are controlled by application mainly good practices such as: rotate with cereals such as maize, crop sanitation, avoiding injuries and bruises at harvesting, dry roots in the sun before storage, clean store, avoiding hipping roots in store, keep temperature in store at around 0-2^{o} C and 90 RH. However, in the field plant the clean seed, use clean fields, when the signs of carrot blight appear on leaf spray bordeau mixture, zineb or dithane as recommended in area.

2.5.4 Onions (*Alliums cepa.*)

2.5.4.1 Current and anticipated pests and diseases of onions (*Alliums cepa.*)

The onions and leeks are produced in many parts of Rwanda, and commonly used by many people, especially in urban areas. These crops are attacked by many pests and diseases.

The major pests include: (i) onion thrips (*Thrips tabaci*, (ii) cut worms , (iii) Nematodes, (iv) (iv) Aphids (*Myzus persicae*), (v) downy mildew (*Peronospora destructor*), (vi) Purple blotch (*Alternaria pori*), (vii) Blast and neck rot (*Botritis spp*.) (viii) and other minor pests and diseases which may attain higher significance with time and need close monitoring.

2.5.4.2 Management of major pests of onion

The onions and leek have less pest problem. They are easily managed using the cultural practices such as:

(i) Good cultural practices,

(ii) destruction crop residues and off season or continuous production,

(iii) use resistant varieties,

(iv) plant on clean soil, avoid infested soils where previous crop was attacked,

(v) apply pesticide like furadan against thripswhen necessary, in its granule formulation applied on soil. However, dimethoate may also be effective. The right dose and timing will be established through field trials with farmers

2.5.5 Cabbages

2.5.5.1 Current and anticipated major pests and diseases of cabbages

Cabbages are attacked by many insect pests and diseases causing yield loss in quantity and quality. The major insect pests include: (i) cabbage aphids, (*Brevicoryne brassicae, Myzus persicae*), (ii) diamond-back moth (*Plutella xylostella*), (iii) Cutworms (*Agrotis ipsolon*), (iv) cabbage sawflies (*Athalia spp*.), (v) black rot (*Xanthomonas campestris pv campestris*), (vi) damping off (*Pithium spp., Fusarium spp., Rhizoctonia spp.), and (vii)* bacterial soft rot (*Erwinia carotovora var. carotovora)*, and there are other minor diseases attacking the cabbage plant.

2.5.5.2 Management of major pests and diseases of cabbages

The cabbage crop is attacked by many insect pests and diseases. However, they are well controlled using integrated pest management plan as indicated below. (i) Use clean seed free from seed born disease or treat them using hot water, (ii) take maximum care of seedlings in nursery to ensure good growth vigour, (iii) apply recommended cultural practices like proper fertility management, spacing, weeding or mulch application for vigorous plants, (iv) apply good crop hygiene and sanitation and destruction of crop residues after harvesting, (v) scout the crop to check diseases and insect presence, (vi) apply pesticides such as dimethoate which is systemic and broad spectrum insecticide when necessary using recommended dose.

2.5.6 Mushroom

2.5.6.1 Current and anticipated major pest and disease of mushroom

Mushroom production is completely different from growing green plants. Mushrooms do not contain chlorophyll and therefore depend on other plant material (the "substrate") for their food. Generally, each mushroom species prefers a particular growing medium, although some species can grow on a wide range of materials. Choosing a growing medium, Pasteurizing or sterilizing the medium, Seeding the beds with spawn (material from mature mushrooms grown on sterile media), Maintaining optimal temperature, moisture, and other conditions for mycelium growth and the conditions that favor fruiting. Spawn, Substrate, Environment are important factors of mushroom cultivation.

Environment: The appropriate environment is an important factor for mushroom production for both vegetative and reproductive growth. They are easily affected by their growing conditions. The success or failure of mushroom cultivation depends on the control of growing conditions. The environmental factors affecting mushroom cultivation include temperature, humidity, light and ventilation. Optimal levels of them at vegetative stage differ from those at reproductive stage. Mushroom mycelia can survive between 5 and 40^oC depending on the species. Mushroom mycelia grow well with the temperature range between 20 and 30^oC. Substrate moisture content should be 60-75 % and log moisture content, 35-45 %. During fruiting, different relative humidity levels, ranging from 80-95 % are needed at the early, mid and latter stage. Though mycelia like dark to grow but some species require light for fruiting body formation. Being aerobic fungi, mushrooms need fresh air during growing and ventilation is more required for reproductive stage. In conclusion, among the three factors, the most important is environmental control. By maintaining optimal conditions at each growing stage and for each species, growers can produce the desired yield of quality mushrooms (Imtiaj and Rahman, 2008).

Mushroom pests infestation: Mushroom are attacked by many pests and diseases in particular: mushroom flies (Phorid fly= genus *Megaselia and* Sciarid fly=The genus *Lycoriella).* The larvae like to eat mushrooms and can cause great damage, nematodes, mites (also act as vectors of Trichoderma and other diseases), slime molds (*Physarum compressum.and Stemonitis herbatica)* make mushrooms unappealing; *Verticillium (*cause dry bubble, distortion and spotting), and virus (cause change in color).

Pests and diseases attack and destroy both mycelia and fruit body of edible fungi, which greatly affects the growth and value of edible fungi. Sometimes the edible fungi may even die. Edible fungi may be contaminated by the weed fungi or bacteria during the whole process of cultivation. The weed fungi compete with the edible fungi for nutrients, oxygen and water 'or even secret toxin to inhibit the mycelia growth of edible fungi. Consequently, the yield and quality of edible fungi will be influenced significantly. Therefore the prevention and control of weed fungi and pests is main point for the successful cultivation of edible fungi with high quality and yield. The main prevention measure is sanitation or hygiene.

Mushroom flies (Sciarid fly: *Lycoriella spp and Heteropeza spp*). The sciarid fly is the major pest problem among cultivated mushrooms. They are attracted by smell of decaying vegetation such as mushroom substrates. The larvae (maggots) do damage, as they live on wild mushroom as their natural food.

2.5.6.2 Pest management in mushroom production

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Mushroom pest management: Integrated pest management (IPM) is the least-toxic approach for managing pests of mushroom. The integrated pest management is accomplished by altering the environment to the disadvantage of that pest. You may be able to encourage natural enemies that will keep the population of the pest below the economically damaging level

Sanitation/hygiene: The basic pest management principle in mushroom production is prevention crop from pests and diseases.. It is also important to sterilize the growing room and the preparation areas on a regular basis. Mushrooms are produced mostly in an enclosed environment and the risk of pests and diseases spreading rapidly within the crop is high, therefore it is important to monitor the crop on a daily basis for incidence of pests and diseases, to prevent losing at least some of the crop.

When pests or diseases are detected, control measures should be applied immediately. This may involve removing infected mushrooms by carefully picking them off without spreading the disease, then applying a pesticide. The type of pesticide required should be carefully chosen from a list of registered chemicals and used strictly in accordance with the directions given on the label. For example, screening the mushroom house ventilation system will keep adult flies out. Double doors and positive atmospheric pressure within the structure also prevent flies from entering. Since adult flies are drawn to standing pools of water on benches, walks, or floors, places where water can collect should be eliminated. Biocontrol is another option for several mushroom pests, the sciarid fly among them. A predatory nematode attacks this fly in its larval form. Therefore, this nematode can be added to the composting substrate.

2.6 Integrated Pest Management (IPM) experience of RSSP 2 and in Rwanda

The IPM experience among farming community is very low; however, it is increasing because of RSSP-2 training of lead farmers, and Farmer Field School (FFS) of IPM-BTC project in MINAGRI. Otherwise, majority of farmers have adopted over time cultural practices and resistant varieties which are useful in IPM development. Development and promotion of IPM and safe use of pesticides is an urgent issue to address low knowledge on pesticides hazards among extension staff, farmers and retailers in rural areas. This is an important activity because the future of agriculture in Rwanda is dependent on crop intensification and more use of agricultural inputs including pesticides.

The pesticide survey done in 2005 revealed that the trade of the pesticides inside the country is made mainly by farmers' organizations which deal with a particular crop without sufficient knowledge of safe handling of pesticides. Training of people involved in storage, handling, marketing and uses of pesticide is urgent to develop capacity at all levels.

The current pest management practices commonly applied by majority of farmers include a combination of cultural practices, resistant varieties and pesticides. The pesticides application is limited to crops of high value like tomatoes, potatoes, rice and coffee etc, while pest management in staple crops like maize depends mainly on cultural practices and resistant varieties. It is very rare for farmers to buy pesticide for controlling maize field pests unless there is a serious pest outbreak like African armyworm problem and availability of external support like projects or NGOs. Some farmers may avoid producing a particular crop during a certain season of a year because they are anticipating high disease attacks. For instance, farmers avoid growing tomato during rainy season since they know that they may face high yield losses due to diseases.

The MINAGRI has already a plant protection draft bill to regulate pesticides use in the country and reduce risks of pesticides : In addition, there are different laws which (i) The MINITERE environmental law of June 2004 prohibiting the introduction and the use of the products dangerous for human health and the environment and bearing creation of the Rwandan Environment Management Authority (REMA); (ii) The MINICOM law creating Rwandan Office of Standardization (RBS: Rwanda Bureau of Standards) which makes it possible to control the quality of the pesticides introduced into the country, the use and supervision of stocks of pesticides, and (iii) at the institutional level, the MINITERE is responsible for the formulation of the policies and laws that aimed to protect human health and the environment, which includes the management of pesticides.

Theoretical trainings of agronomists and certain lead farmers have taken place but there is a need to continue and strengthen this important activity. It is important that pesticides are used safely and in a way which is not hazardous to the users, consumers of the produce, livestock, and/or to the environment. The farmers should be aware and observe the safe use of pesticides as specified in a pesticide guide. All pesticides should be treated with care whether they are known to be particularly poisonous or not.

During RSSP3, it is anticipated that there will be capacity building at all levels including farmers, extension staff, pesticide traders, local leaders and politicians. The base line data for pesticide use in each target crop is not available at the moment because the cooperatives can buy and supply fungicides only and individual farmers buy insecticides and fungicides on their own. This makes it difficult to establish reliable pesticides quantities used. A rough estimate may be established using area per crop, number of sprays per season and amount per spray. The M&E may be able to establish this information during baseline study at the beginning of RSSP-3.

2.7 Circumstance of pesticide use, capability and competence of end-user

2.7.1 Circumstances of pesticide use in different crops

The circumstance of pesticide use under RSSP-3 will be mainly in disease management using fungicides and few insect pests for some crops like cabbage.

Pesticides use in bananas. The use of pesticides on banana is very little. Currently, the major threat of bananas in the basin in Rwanda is the banana bacterial wilt, which is spreading in all banana growing areas and its management does not require the use pesticides. The second most important disease in the country is the Fusarium wilt (*Fusarium oxysporum fs musae*) on exotic banana cultivars, which is soil borne disease and does not depend on pesticides for control or management.

The others pests of banana are not important but needs close monitoring due to climate change which may adjust to local climate. These include banana weevils (*Cosmopolites sordidus*), nematodes (like *Pratylenchus goodeyi*, *Helicotylinchus multicinctus,* and *Radopholus similis* and *Meloidogyne spp*.) and leaf spots (yellow sigatoka, black sigatoka and cladosporium leaf spot) are not a threat because of altitude effect. These pests are threat below 1400 m above sea level, while major banana growing areas in Rwanda are above this altitude. Even if they occur, the use of pesticides is not economical.

Current pesticides use in potato: In the potato crop, the commonly used pesticide is the fungicide, and the most commonly used fungicides are Dithane M45/Mancozeb (contact preventive), and Ridomil/Metalaxyl (systemic). Both of them are unlikely to cause hazard because they are categorized as U and III under WHO respectively. Farmers apply Dithane M45 (protective fungicide) when rainfall is not continuous, and use Ridomil (systemic fungicide) when rainfall is continuous and can wash out protective fungicides. This experience is good and is an important tool in IPM development, since it is farmers' knowledge of their local conditions.

Current pesticides use in cassava: The pests and diseases of cassava are managed using resistant varieties and cultural practices. The use of pesticides is not economical.

Current pesticides use in rice: Farmers producing rice apply in rare occasions fungicides (such Kitazine/IBP) against blast disease. The most commonly used fungicides are not uniform for all marshland and depend on seasons. Similarly they apply insecticides whenever required only after observing large number of insects in the field, although the actual threshold is not established in Rwanda. The field observation as a guide to apply insecticides is a good practice which will be improved further through rice IPM development.

Current pesticides use in maize: The pesticides use in controlling insect pests is not common except for a few farms where the problem is severe and there is external support from some projects or NGOs to control maize stalk borers. The diseases are managed using resistant varieties.

Current pesticides use in tomatoes: The tomato crop suffers a large number of diseases. However, the pesticides are used only to control late blight (*Phytophthora infestans*). The latter is major constraint especially during the rainy season. The disease is controlled using the fungicides such Mancozeb/Dithane M45 or Ridomil/Metalaxyl (category U and III respectively).

Pesticides use in French/green beans: The use of pesticides in pest management in the bean crop is very low under field condition. The use of systemic fungicides like benomyl is effective, however, not applied because the cost of control is very high while the value of beans is very low.

Pesticides use in cabbage: The cabbage crop is attacked by various major pests causing loss in yield, quality, and marketability. The major pests include cabbage sawfly, diamondback moth, flea beetles, whitefly, aphids, thrips and mites. The pesticide use in cabbage is anticipated for the control of cabbage sawfly and diamondback moth (DBM).

The DBM is known to develop fast resistance to many known pesticides due its short life circles (about 12 generations per year) and fast population build up of resistant generation.

Pesticide use in other target crops: The pesticides use in other target crops in particular onions, carrots, pineapple, wheat and mushroom is expected to be very rare. The circumstance leading to pesticide use in the other target crops for RSSP-3 will occur in isolated cases and could be easily handled.

2.7.2 Capability and competence of end-user to handle pesticides

Due to small pesticides market in Rwanda, the legal framework, end-user capability and competence are not well developed for wider community. However, for those directly involved in the pesticides application like in coffee producers, they have been trained through support offered by their cooperatives and coffee authority]. However, for wider community of stakeholders in agriculture, they are not aware on the hazardous nature of pesticides and their effects on health of people, animals and the environment. The farmers are not informed on dangers of over use or sub-lethal dose on pests and environment, on how in long run the pests develop resistance and cause more crop losses.

Similarly, the consumers are not sensitized on the dangers caused by pesticides treated food and impact on their health. Community sensitization on hazardous nature of pesticides and implication on their health in short term and in long period is urgently needed. The adoption of IPM depends on many factors including the community involvement in the process of IPM development in order to understand why it is needed, and that pesticides can be used safely and timely when necessary. Therefore, the RSSP-3 should include in their budget the cost of capacity building and sensitization of safe pesticides use at all levels from production, trading and consumers.

The current pesticides use in Rwanda is limited to few crops of high value and is not guided by legal obligation; moreover, pesticides are profitable for limited crops of high value and in most cases are either not affordable or not accessible in many parts of the country. According to MINAGRI reports, the national average of pesticide use is below 1kg/ha and is mainly fungicides used on coffee and potatoes. The data available are more than ten years old, however, they are indicative. During a three year period (1997 – 2000) the proportion of different pesticides, fungicides, insecticides and herbicides was 75%, 23% and 2% respectively. This is trend may persistent for some time, because fungal diseases are more a threat than insect pests.

The Ministry of Agriculture and Animal Resources is currently addressing the problem of pesticides by re-enforcing pesticides laws and regulations as the draft bill is with the parliamentary committee for review as of November 2011. Currently the regulatory legal framework is not strong enough to address all problems which may arise during intensification of agriculture without support of capacity building among crop producers.

According to the national pesticide survey conducted in 2005, the following actions were recommended: (i) Registration of the pesticides to regulate importation, storage, handling and marketing; (ii) formation of associations for pesticides distributors and importers; (iii) training of all pesticides dealers and distributors; and (iv) introduce competence licence in pesticide handling for importers and distributors, in addition to trade licence. Meanwhile international regulations will be used for storage and handling of pesticides.

Source of pesticides: In Rwanda, there are two major sources of importation of the pesticides: (i) importers having trade licences of importation and (ii) donations coming from development partners (e.g. European Union, FAO, Japan, NGO etc).

The pesticide marketing is liberalized and supply is done by private sector. There are only a few importers in Rwanda dealing with import, wholesale and retail of pesticides. Pesticide retailers based in the country (e.g. Agrotech) have their own storage, transport and disposal of containers.

However, due to low purchasing power of farmers and high price of pesticides (e.g. insecticides and some fungicides), the retailers have tendency to buy in large quantities and repack in small containers.

2.7.3 Pre-requisite measures to reduce specific risks associated with pesticide use

Legal framework and enforcement: The plant health law and agrochemical law will address all issues concerning pesticides use in the country. As indicated above, MINAGRI has already a draft bill for plant health, and draft bill for agrochemical in final stage with parliamentary committee. The agrochemical law will regulate the use of pesticides in the country. However, there are other laws and texts making it possible to reduce the risks of pesticides such environment law etc.

Capacity building: RSSP-3 will expand the work done during RSSP1&2 and address issues of capacity building at all levels (farmers, traders, extension staff, local leaders and decision makers etc). Rwanda has small market for pesticides, as result distribution and marketing of various pesticides is small moreover many farmers depend on cultural practices and resistant varieties. Nevertheless, the training of farmers, extension staff and retailers of pesticides is an urgent and important activity during RSSP-3. Most extension staff employed by farmers' cooperatives have educational background in pesticide technology, but these skills need to be continuously updated Extension staff education was initiated during RSSP1 and currently is on-going for RSSP2 at the farmer level. The agronomists who have been trained are now educating farmers involved in RSSP activities. Additional training will be needed during RSSP-3.

Pesticide technology: The training should include more information for safe use of pesticides which should be taught to all farmers, like poisonous effect of pesticides thus safe handling, storage, protective clothes, disposal of containers, sprayer maintenance and calibration, etc. Since farmers will continuously produce potatoes, tomatoes or rice for greater part of their life, the safe use of pesticide is important for their safety, other people's safety and environment in general. Therefore, to ensure safe use of pesticides capacity building exercises will be important at all levels during RSSP-3 implementation, including local leaders, traders and policy makers. In addition, as some of the pests of target crops of RSSP-3 (e.g.Diamondback moth of cabbage) are known worldwide to develop resistance to pesticides very fast. This gives another reason to give priority to training on pesticide management.

Minimum requirements for a pesticide store
Any pesticide store should answer the following criteria:

- Impermeable floor
- Adequate ventilation
- Locked store
- Secured site
- Location that does not pose specific health or environmental hazards (distance from homes, schools and water)
- Managed by store-keeper with knowledge about hazards and capable of handling leakage and other emergencies

- Emergency materials and protective gear needed to deal with emergencies (including emergency plan, Material Safety Data Sheets for products kept in store, fire extinguisher, emergency shower for staff)

3 CURRENT PEST MANAGEMENT PRACTICES RELEVANT TO RSSP-3

The 13 target crops for RSSP-3 are among the national priority crops in the country and the execution of IPM will involve different partners. Moreover IPM is normally executed at community level rather than at individual plot level; the execution of IPM plan will therefore involve MINAGRI, MINALOC, District authorities, NGO’s, farmers’ organizations and farmers.

The Ministry of Agriculture and Animal Resources needs to recommend IPM as a national approach in pest management and develop IPM policy to promote its use in addressing pest problems. In addition, improvements to legal framework and enforcement at all levels is needed, as part of the law for plant protection, in the areas of pesticide registration, handling and use. The District authorities should accept IPM as an important activity and include it in their performance contracts on an annual basis.

The execution of IPM at project level alone is not sufficient, resources will be needed to sensitize the community about the plant protection law and some IPM practices like closed season which require cooperation with the community and Local leaders and extensive training of farmers. It is recommended to establish IPM at community level, not at individual farm level only. The plots in the same locality should apply the same principles to avoid source of infestation from the neighbourhood. Therefore, the IPM options should be taught to farmer groups and not to individual farmers. Farmers should be organized into groups to work together, make regular field observations, discussions and agree on the best IPM approach to apply at the various growth stages of their crop.

Training of farmers in IPM is an important activity because they should be able to know and distinguish pests and none pest insects, recognize and appreciate damage caused and associate it with particular pests, diseases or weeds. Finally, they should be able to make decision on pest management action to take control of pests, diseases and weeds and the reasons that are underlying the decision to take a particular action.

Currently, the common pest management practices in Rwanda include, (i) informal cultural practices for diverse crops, (ii) use of resistant varieties, (iii) natural control (use of natural enemies), and (iv) Pesticides application, mainly on cash crops and horticultural crops. The pest and diseases control is essential component in crop production. The insects and pests are part of biodiversity of any ecosystem and they cause great losses if not well managed. They become pests only when they multiply and exceed a certainly population level as a result of supply of good and high nutritive food from crops. When the damage causes economic loss, then they become major pest worth of investing in cost for control and stop further yield loss. In Rwanda, there will be continuous cropping because of reliable water availability and there will be more pests and diseases of economic importance that require cost effective control for improved productivity.

3.1 Informal cultural practices use in pests and disease management

The use of cultural practice is the most common practices among farmers. Although not formally developed into IPM package, it is still the only method which keeps the pest below damage threshold while preparing their own fields. The cultural practices applied in Rwanda have some important elements useful in pest management. In most crops apart from irrigated rice and potatoes, other crops are planted in rotation or under mixed cropping system. The crop residues are normally destroyed by burying, burning or hipping or feed to livestock.

All these methods do not allow population increase of the insect or diseases. The burning of crop residues is no longer allowed, because the recent Government ban. Crop rotation is generally practiced by the majority of farmers.

3.2 Resistant varieties use in pests and disease management

Currently the use of resistant varieties is the most reliable, affordable and sustainable pest management method in the country, in particular for diseases control. Among the most recently released crop varieties, the majority are resistant to particular disease; and both farmers and Government are much interested in such varieties as they provide affordable and sustainable solution to the disease problem. For example, during the last three years, the Government has been involved in assisting farmers to get resistant cassava varieties against cassava mosaic disease.

3.3 Natural control (use of natural enemies) in pests and disease management

The use of natural enemies is an important tool and method in biological control. In Rwanda, the biological control is not one of formal crop protection practices. However, due to very low pesticide use, the effect of pesticides on natural enemies is very low, and conservation of natural enemies is of course effective. In absence of side effect of pesticides, some pests are kept down by a combination of conserved natural enemies with good cultural practices. A field visit in different parts of Rwanda will indicate the importance of this combination. The field observation will indicate that there is much more disease problem at farm level than insect pests.

Since, protective fungicides have little effects on natural enemies as compared to insecticides; it is obvious that the natural enemies of some insect pests are not much affected. However, research on natural enemies distribution and population dynamics for major and minor pests need to be established and funding for research is essential.

3.4 Current Pesticides use in pests and disease management

Under this report pesticides means insecticides, herbicides, fungicides, rodenticides and other chemicals used to control, prevent, destroy, repel, or regulate pests. As toxicants (poisons), they detrimentally affect living organisms and usually have adverse effects on other forms of life. Because of their poisonous nature, pesticides can injure or kill people, pets, and livestock; damage beneficial insects, birds, fish, and other wildlife; and can harm desirable plants. It is mandatory that all such materials be very carefully managed and handled during storage, transport, mixing and loading, application, and disposal. It is critical to stress the importance of safe pesticide use and need for IPM program.

In general, pesticide use in Rwanda targets mainly plant diseases management and nearly 75% are fungicides while the remaining 25% is composed of different insecticides and a few herbicides. Among the fungicides imported, more than 90% of the products are Mancozeb and Ridomil which are applied to potato and tomato against the late blight (*Phytophtora Infestans*), coffee leaf rust and coffee berry disease..

Nevertheless, the impact of pesticides use is very high especially in the fungal diseases control such as late blight (*P. infestans*) in potato and tomato, coffee leaf rust (***Hemilea vastatrix***), CBD (***Colletotrichum coffeanum***), and rice blast (*P. oryzae*). These diseases are mainly managed using fungicides , and their impact can be tremendous. For example, the late blight without fungicide application can cause up to 100% yield loss on tomato crop in heavy rainfall areas of the country. As a result, fungicides use is more than other pesticides.

During a three years period (1997 – 2000) the proportion of different pesticides was as follows: fungicides (75%), insecticides (23%) and herbicides (2%). Although, the amount used is very small, pesticides use is associated with both positive impact through pest control and negative impact through risks on humans (producers and consumers) and the environment.

In Rwanda, there are two major sources of importation of the pesticides: (i). importers having trade licences of importation and (ii) gifts coming from the European Union (Stabex), FAO, or NGO (e.g., World vision). The pesticide marketing is liberalized and supply is done by private sector, and directly sold to retailers, while the capability and competence of end-users to handle products within acceptable risk margins is negligible. In general farmers and extension staff have very little capability to handle and use pesticides at low risk.

Basing on the national pesticide survey in 2005 for the whole country, it was realised that there was a need for the following actions: (i) legislation of the pesticides to regulate importation, storage, handling and marketing; (ii) initiating the formation of associations of the distributors and the importers of pesticides; (iii) organizing sessions of training for all distributors of the pesticides; and (iv) importers and the distributors must have not only trade licence but also pesticide dealing licence indicating their competence in pesticide handling delivered by the competent Ministry. Currently there is no policy or regulation as regards to safe pesticide handling and use as required by international code of conduct.

It is important that pesticides are used safely and in a way which is not hazardous to human (producer and consumers), animal/livestock, and to the environment. The farmers should be aware and observe the safe use of pesticides as specified in a pesticide guide. All pesticides should be treated with care whether they are known to be particularly poisonous or not.

It is urgent to do capacity building at all levels including: farmers, extension staffs, pesticides traders, local leaders and politicians. A brief description of current pesticides use in few selected crops is indicated in the following sections. The base line data for pesticides for each crop is not available because some cooperatives can buy and supply fungicides to farmers as loan deductible after harvest, while individuals buy insecticides using their own cash. This makes it difficult to establish reliable data on pesticides quantities used in each crop.

Due to the nature of Rwanda land terrain, coupled with high rainfall, the use of pesticide should be limited or used judiciously to minimize side effects to human, animals and environment downstream of watershed and in riparian countries. The alternative pest control means non-chemical methods (cultural, physical and biological) should be explored first before embarking on chemical pesticides application. The use of IPM accepts pesticides as last resort, i.e. if they cannot be avoided. The list of pesticides (insecticides, fungicides, herbicides, rodenticides and nematicides) allowed in Rwanda is provided in annex section, together with prohibited pesticides.

Pest management during RSSP-3 will focus on major pests and diseases of target crops. It addition, it will support other crops on demand driven basis as need arises. Moreover IPM is normally executed at community level rather than at individual plot level; the execution of IPM plan will therefore involve Ministry of Agriculture and Animal Resources, District authorities, NGO's, farmers' organizations and farmers.

The Ministry of Agriculture and Animal Resources needs to recommend IPM as a national approach in pest management and develop IPM policy to promote its use in addressing pest problems. In addition, it needs to improve the legal framework and enforcement at all levels. The pesticide registration, handling and use is required as soon as possible as part of the law for plant protection. The District authorities should accept IPM as an important activity and include it in their performance contracts on an annual basis.

The execution of IPM at project level alone is not sufficient as it will not bring the much needed impact. Resources will be needed to sensitize the community about the plant protection law and some IPM practices like good agricultural practices which require cooperation with the community and Local leaders and extensive training of farmers.

It is recommended to establish IPM at community level, not at individual farm level only. The plots in the same locality should apply the same principles to avoid source of infestation from the neighbourhood. Therefore, the IPM options should be taught to farmer groups and not to individual farmers. Farmers should be organized into groups to work together, make regular field observations, discussions and agree on the best IPM approach to apply at the various growth stages of their crop.

Training of farmers in IPM is an important activity because they should be able to know and distinguish pests and none pest insects, recognize and appreciate damage caused and associate it with particular pests, diseases or weeds. Finally, they should be able to make decision on pest management action to take control of pests, diseases and weeds and the reasons that are underlying the decision to take a particular action. The following section will outline a range of IPM practices for major pests and diseases of each target crops which will form a part of training package for farmers.

4.0 IPM AND PESTICIDE USE UNDER RSSP-3

4.1 Proposed and /or envisaged pesticide use during RSSP-3

Among the crops that will be supported by RSSP-3, pesticides will be continuously used on potato, tomato, cabbage and rice. The use of pesticide on other target crops will be very minimal depending on scouting of field damage, but in general, it will be reduced or avoided without any significant yield loss. The project will not increase pesticide use because of promoting IPM and safe use of pesticides and needs to be strengthened in the marshlands with double cropping.

4.1.1 Pesticides use in management of potato and tomato pests and diseases

The pesticides will be used mainly against late blight (*Pytophthora infestans*). This diseases is very stubborn, and is not easily managed even when potato resistant varieties are planted, fungicides are also applied to minimize yield loss. This calls for frequent use of pesticides. The frequency depends on the rainfall, but usually varies from 5 - 10 days between sprays. However, a combination of resistant varieties and fungicide may reduce the amount used. The IPM research should focus on this combination of different options to find the most economical approach.

Protective fungicides: Currently, the commonly used protective fungicide in large amount is Mancozeb/Dithane M45 which is categorized as unlikely to present acute hazard in normal use. Mancozeb is wettable powder which is mixed with water and applied using knapsack sprayer. This fungicide will continuously be used against late blight in both potato and tomato crops because there is no resistant varieties available at the moment in tomato, while in potatoes, the resistant variety need also fungicide application because they are not sufficiently resistant.

Systemic fungicides: When there is wet weather with a combination of heavy rainfall and humidity, farmers prefer to use systemic fungicide, Ridomil/Metalaxyl to control late bright. The alternation of protective and systemic is working among potato farmers and they are conversant with the approach. Since Ridomil is categorized in III, slightly hazardous, and mancozeb as category U, the two fungicides will be useful as IPM component of on both potato and tomato during RSSP-3. The researchers will establish an alternative fungicide.

Insecticides use in potatoes: It is anticipated that potato tuber moth (PTM) in potatoes will not need the use of insecticides. However, in tomato pest management, the insect pests are also major pests and pesticides will be used as a component of IPM.

4.1.2 Pesticides use in management of rice pests and diseases

A combination of cultural methods and chemical options are necessary in the management of rice blast. There is a wide range of systemic fungicides with specific actions available such as Isoprothiolane which is systemic and active against rice blast and it is rated slightly hazardous; and IBP/Kitazin which is also systemic and effective against rice blast and it has insecticide action. The latter is rated category III.

4.1.3 Pesticides use in management of cabbage pests and diseases

The pesticides will be used mainly against cabbage sawfly and diamond back moth (DBM). These two pests are major pests and require regular monitoring, scouting and timely application of right recommended safe pesticide, at right dose and frequency.

The frequency of insecticides is major problem among farmers because they do mix with fungicides and apply at the same time irrespective of recommended interval.

4.1.4 Pesticides use in management of pests and diseases of other target crops (maize, wheat, banana, onions, pineapples and cassava)

It is anticipated that very little pesticides will be used against the pests of these crops. In case it occurs, the researchers will determine the most appropriate pesticide, rate and frequency of application.

4.2 RSSP- 3 Plans for implementing IPM in target crops

4.2.1 Capacity building of extension staff in IPM, safe pesticide handling and use

The objective of capacity building in IPM and pesticide technology is to improve extension staff and farmers knowledge in alternative pest control methods at an economical level and safe use of pesticides without compromising the environment. The training will cover in detail 13 target crops of RSSP-3 and pesticides technology. RSSP-3 will likewise provide training for farmers over season long period on weekly basis on the pests and diseases identification, damage problems, yield loss caused, control methods, and safe pesticide use.

The staff of RSSP-3 and Local Government will need different training sessions in IPM. RSSP-3 will finance the initial two week residential training. This will include both RSSP and district extension staff. The training will produce work plans for the first year of the project, which will be updated every year during end of season and year workshops as indicated earlier. The additional training will be organized according to demand. However, RSSP-3 will fund some short courses for key staff members. These will be attended as TOT, and when they come back, RSSP will organize seminars to train others. It is the only way to train many staff, and make sure participants understood the short courses.

The training in IPM and pesticides technologies will use all nine IPM tool kits developed during RSSP-1. It will focus extension staff in the Sectors and Districts where RSSP is working with farmers. The training will also create among them the habit to be accountable to the farmers through implementation and close monitoring of plan activities developed during the training.

The training will cover PMP plus pesticide technology irrespective the crop specialized by the participants. The proposed IPM participatory technology dissemination is an extension training methodology where members of association or cooperatives in the community are trained by extension staff using the demonstration plot as experiential learning in one of their own field as a training site. The extension staff will be trained before training farmers in different IPM technologies. Since the IPM application is community based and not individual farmers alone, the training would include the Sector agronomists irrespective of whether he/she is directly involved in RSSP-3 activities. As long the IPM activities are in his/her operation area, he/she will be trained to enable his/her involvement and whole community mobilization when need arises.

If project funds allow and the project feels that it is important; it would be useful to train all 416 Sector level extension officers for at least a shorter period of 3 – 5 days and give them IPM tool kits for reference. This would cost additional 60,000 USD above IPM targeted extension staff training cost.

The training of target extension staff will be followed by an on-site training during execution through experiential learning. Since the application of IPM technologies/practices are site specific; it is therefore recommended to go on training of extension staff on new concepts, options and strategies for them to gain specific skills and knowledge for their respective areas, and share with others experience gained during execution period. The initial training will be for four weeks (one month) as follows below:

The first two weeks will cover the three crops IPM strategies and safe pesticides use. This is equivalent to three days per crop, and three days for pesticides which is an intensive training. The assumption is that they already have field experience and previous training from their institutions.

The third week will cover pesticides, seed technologies and field and institution visits to assess field situations. This will include a visit to RAB, NAEB, NUR, ISAE, and agrochemical suppliers etc as need arises.

The fourth week will be used for planning and budgeting the demonstration and reporting systems. The resource person will guide them on the planning and costing the demonstrations and other related training such as field days, study tours etc. Every extension staff will produce a plan suitable for the site. It will also indicate the link with the whole community. The District and Sector participants will indicate the cost of monthly meetings and reporting and on how it fits in with their plans.

4.2.2 Capacity building of farmers in IPM

The training of farmers will be a continuous activity for a season. Each demonstration or study plot will have at 30-40 farmers. The number of learning plots are estimated to be very large (two /District/target crop for RSSP-3); equivalent 2x30x8=480, but may increase as need arises. The total number of farmers trained per season may be in a range of 480 x 30 or 40 = 14,400 -19,200. Since nine out of 13 crops are annual, the number per year may double when every season (A&B) is used for training farmers, making 28,800 to 38,400 trained farmers per year. This activity is important and should be given priority during RSSP-3. This plan is not FFS, but has its main elements. The extension officer will continuously be updated in all aspects of IPM and crop production to enable him/her train farmers in new improvements. The linkage with research institutes and Universities is an important activity.

Apart from IPM technologies, farmers will be trained in farm record and cost assessments of all inputs (fertilizers, pesticides, seeds etc) including labour spent for each operation (person days or hours) throughout the season. The importance of farm record knowledge will enable farmers and extension staff to assess crop productivity by comparing different crop gross margins and make use of this facility in planning for the following season.

The RSSP-3 will provide numbered farm record books for all demonstrations to record all farm activities, inputs and outputs for future use in evaluation and gross margin calculations at the end of season. The effective use of farm record books by farmers will help them to make appropriate decisions and proper improvements to their own production.

4.2.3 Study plots for IPM technologies

In most cases, farmers training in the application of various IPM techniques and practices will be conducted at the study plots (training sites) established at lead farmer field or other plots of the association, in case the lead farmer does not have suitable site.

The lead farmer or cooperative/ association will offer a plot for establishing the demonstrations, and RSSP will supply all inputs required. Therefore, the site must be accessible and suitable for the crop. The harvest from the demonstration belongs to the owner of the plot. Farmers learn fast when they immediately practice what was taught. It is anticipated that some farmers will start using IPM approach in the following seasons. The latter will be monitored during the project period. The extension officer will establish a demonstration plot for each crop to address problems identified by farmers, he will also establish control plot with farmers own practices.

The activities on control plot are always done a day before the actual demonstration. The two plots will be used to train farmers in all aspects of crop husbandry, from land preparation, planting and pest and disease assessment and timing of management practice etc.

The demonstrations will be established for each crop. Farming community in the District will get access to learn and practise improved techniques within their reach, since the demonstrations will be more or less accessible to all. The demonstrations are training sites and are useful to farmers willing to learn new technologies which will be well illustrated.

The extension staff together with the farmers will prepare activity plan for the whole cropping season to address the IPM problems arising during the season for each demonstration. The extension staff will make sure that the activities programmed are executed, and weekly training is clearly shown according to crop growth stages.

The extension staff will organize the farmers into small groups of at least 20 - 30 farmers per group from the whole cooperative or association for weekly training sessions. The farmers in each group, and the extension staff responsible, will decide on the frequency of the training, weekly or biweekly, and the IPM topics to be covered at each session basing on the crop grown. The members of the group may be the lead farmers in the area for large cooperatives.

Each group will be organised by choosing its leadership (chairman, secretary) and together with the extension staff, prepare work programs to be implemented during the whole cropping season.

During the field visits, the extension and cooperative leaders will invite farmers and local leaders from neighbouring areas to participate. This is an occasion for sensitizing the community on IPM technologies.
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In addition to demonstration of new technologies, some members may need special training outside project target crops for diversification, such as the searching for external markets, meeting market demands and producing sufficient quantities and in right qualities, promotion of processing and conservation of different crops, demonstration of new crops which are not widely produced but have potentials to assist the farming community in wealth creation and poverty reduction like fruit production and marketing e.g. egg plants, pineapples, macadamia and vanilla etc. This flexibility is recommended for strengthening farmers knowledge and capacity.

4.2.4 Organizing field days on demonstration site

The field visit is an occasion at each demonstration to reach the whole community with the message of improved technologies and it is very important in agricultural development. During every major field visit, actions such as planting, fertilizer application, pesticide application and harvesting can benefit the wider community and local leadership.

The extension staff will organise the field day and explain the IPM technology and reasons behind the practice, its application, and importance in improving productivity and production. The community will learn about the technology and will be able to follow up the progress throughout the growing season.

In addition, during the growing season, the extension staff will organise farmer to farmer visits for the cooperative or association in which farmers get opportunities of sharing and gaining skills and practical experiences within themselves and from other farmers near the demonstration which does not require transport.

The extension officer will train farmers on farm record keeping as a tool to follow up and assess productivity and cost of different activities and inputs; to enable assess of the profitability or loss of their agricultural activities in terms of resources, input and labour applied. During the farmer to farmer visits and field days, the farmer will show and explain the record he/she has been taking and their importance in the modern farming in their demonstration. The record keeping is compulsory for every demonstration.

4.2.5 Study tours for extension staff and farmers

The training of farmers is a continuous activity involving different approaches to accelerate the adoption process. Farmers learn fast when explained to by other farmers who are practicing similar approaches. The extension staff and farmers will learn and acquire the new technologies when they are exposed to a variety of improved technologies applied by other farmers in different parts of the country or neighbouring countries.

The RSSP-3 would finance study tours to other Districts, Provinces or neighbouring countries as need arises and when the experts feels that both the farmers and extension can gain benefit from the knowledge from such a trip. There are many places within the country and Region where farmers may profit from the experience of other farmers on pest problem, thus accelerating their adoption of new technologies. In particular, visiting institutes of research or cooperatives such as in Kenya like KARI, ICIPE, and CAB with proper focused guidance will benefit many farmers, extension and research staff in improved technologies available within the region, elsewhere in the world and on how to diversify.

The RSSP-3 would finance the study tours with focused objectives to address specified problems identified by farmers during execution of their work plan. This will be a follow up training to strengthen the first training. It is better to organize such study tours after first season/year of execution to allow enough time for application and adjustment before the beginning of the following season/year depending on the field experience. The experience elsewhere has shown that the focused study tours give good results.

4.2.6 Strengthening capacity in seed technology

The seed technology is not properly covered by academic training institutes. Many extension staff are not conversant with the basic principles of seed technology. Since use of resistant varieties is one of important IPM tool, RSSP-3 will invest in training of extension staff and farmers in seed technologies. The first step will be the training of extension staff at District, sector and lower levels (farmers' cooperative extension staff) who in turn will train farmers.

RAB will commission the trained extension staff to undertake field seed inspection under Quality Declared System (QDS), a Ministerial decree is expected to be available soon concerning QDS as required by seed law.

The RAB will prepare seed production curriculum and train extension staff before planting season starts. The training will cover both theory and practical skills required for quality seed production. It will also offer continuous on job training to both extension staff and farmers during the season. In case the variety was introduced from the neighbouring country, RSSP-3 may pay for an expert to come and train the RAB and extension staff on the characteristics of the variety and carry an adaptive study for one or two seasons. This is allowed under seed law harmonization for East Africa. In general the training in seed technology will include the following items: (i) Selection of suitable sites for seed production and the factors leading for quality seed production, both genetically and physical purity, (ii) seed production, pest control and field inspection methodologies, (iii) seed certification procedures and conditions required to all standards, (iv) seed processing, storage and marketing, (v) input marketing and handling under different conditions, (vi) participatory approaches and application in seed business.

4.2.7 RSSP-3 staffing and IPM execution

RSSP-3 will assign responsibility of IPM to one staff as a part of monitoring team**.** This staff will be trained in IPM and seed technology. Similarly one of staff at District level will be assigned responsibilities of IPM coordination. These staff will be trained in IPM as train of trainers (resource people) and offered short course on regular basis to strengthen their capacity in crop protection (plant pathology, applied entomology, pesticides technologies, participatory variety evaluation etc).

The responsibilities of IPM will take at least **two – three days a week** on monitoring weekly training sessions done at community level. It will require also regular field visits at one week per month during the cropping season. This is very important in particular during the first two years of the project when the staff at District and Sector are in need of support to develop experience in IPM.

The RSSP-3 district staff will supervise and monitor whether all IPM activities are executed at right time in all site as planned. This includes weekly field visit for training of farmers, attending the field visits, and some farmer to farmer visits organized by sector extension staff etc. The staff at District level will make regular field visits to all farmer groups and will spend at least two to three days on IPM per week with farmers to make sure that IPM activities are done correctly.

SPIU-Environmental Officer: He will be responsible to organize the annual national IPM workshops for monitoring progress and document them, and plan the following year based on lesson learnt from the previous year. He/she will link with National, regional and international IPM sources and link with RSSP-3-IPM groups as needed depending on crop produce.

He/she will link up with pesticides organization and monitor closely recommendations on safe use. He will be plan and report IPM activities and progress for all RSSP-3 operational area. He/she will spend at least 12 days per month in the field and/or IPM activities, an average of three days in each Province.

District RSSP staff: The RSSP-3 staff assigned IPM responsibility in the District will be responsible to organize the appropriate study tours to other Districts or Provinces where a particular IPM observation can help farmer to understand clearly the approach. For example, pest or disease problems and the successful management of these diseases and pests. He/she will also monitor monthly meetings and ensure they are organized as planned and may participate in some of them.

4.2.8 Implementation arrangement for promoting IPM and pesticide safe use

RSSP-3 will finance the PMP activities in the project areas on thirteen crops (rice, maize, potato, tomato and cassava from RSSP2 plus cabbage, french beans, carrots, mushroom, wheat, pineapple, bananas and onions). The PMP activities will include (i) training farmers in improved production technologies to produce healthy plants for target crops, (ii) training on life cycle of pest and diseases, (iii) how to avoid pest movement from place to place (distribution mechanisms) for major pests and diseases, (iv) pest and diseases impact on productivity, (v) development of different control methods, (vi) promotion of safe use of pesticides and (vii) integrated pest management for each crop. The PMP activities will be carried out as a learning plot for lead farmers or other selected by cooperative members. However, it will be re-enforced by local authorities when it comes to community wide execution of some activities like closed season.

Whereas the area of operation is very wide as it includes many districts, RSSP-3 will need to involve District authorities in PMP execution. The PMP activities will form a part of district activities and the later should own it for sustainability.

National level: The RSSP3-PSCU and RAB will coordinate PMP implementation. This will include organizing annual IPM workshops for sharing experience and planning. In addition, RSSP3-PSCU will work with different research institutes (ISAR, IITA, CIP, ASARECA, IRRI, WARDA, CYMMIT, etc) for new technologies, taking advantage of East Africa community seed law harmonization system. The CGIAR System Wide Program on IPM will give them access to all CGIAR centers, and ICIPE.

District level: RSSP-3 has staff at some District levels. RSSP-3 Environmental Officer will coordinate the PMP activities in partnership with the officers responsible for agriculture at District and Sector levels as well as Cooperative Agronomists and will monitor and report on progress made. This will include also organizing study tours to different provinces or districts to re-enforce the training offered to farmers. The agricultural staff at District levels will be trained in both IPM and seed technology to enable them supervise and coordinate IPM activities including production, marketing and distribution of seed for resistant varieties as a part of IPM package.

Sector level: Although RSSP-3 does not have staff at Sector level, the PMP coordination will be the responsibility of the agricultural officer at the Sector and Cooperative Agronomists. They will coordinate the PMP execution as a part of crop intensification in his/her operational zone. Similarly staff at sector level will receive training in both IPM and seed technology to enable him to supervise and coordinate these activities.

Farmers' cooperative: The farmers are responsible to learn and apply IPM tools in the pest war. The cooperative will identify members to participate in training of trainers (TOT). Each group will comprise of 20-30 farmers for training and not more than 40 at a single training/learning plot. Every farmer on training will also have 20 farmers for training at his/her site.

In most cases every farmers on training represent sub groups forming the whole cooperative. In total, the training session will have a target audience of 400 to 600 farmers.
After their training which will last season long, they will in turn train their fellow members in both IPM and seed technology. The lead farmers or the cooperative will provide study plots.

This would mean that the PMP and its implementation will form part of farmers' cooperatives and District authorities key activities. The RSSP-3 will therefore give support to extension officers at District and Sector level where the project is operating to facilitate PMP execution.

5 AWARENESS RAISING AND TRAINING PROGRAM FOR IMPLEMENTING THE PMP-RSSP-3

5.1 National IPM sensitization workshop

To initiate the promotion of IPM and sound pesticide use, RSSP-3 will organize the IPM launching workshop for two days involving different stakeholders, policy makers and partners such as donors, UN agencies, NGOs, and research institutes (national, regional and international), politicians, local leaders and different technical staff in different ministries. This will streamline the IPM agenda and improve training curriculum. The national IPM workshops will be held annually and will cover the progress and plan in all areas concerning PMP.

5.2 Training and sensitization of stakeholders for PMP

RSSP-3 will organize different sessions on IPM technologies and safe use of pesticides. It will focus on all people involved at all levels: policy makers, local leaders, pesticide and inputs traders, extension staff, NGOs members, cooperative members. These are people involved in PMP execution at different stages. It may be as delivery of service like input traders or NGOs staff working with farmers. The training will also create partnership among members and habit to be accountable to the community.

The training will be of different duration according to category. It will cover overview of PMP and safe pesticide use irrespective of background of participant. The duration of training for each category is as follows:

5.3 Politicians and local leaders

Two days seminar: RSSP-3 will organize a two days seminar for politicians and local leaders linked with RSSP-3 operations. It will cover PMP, pesticide safe use and policy or trade related issues, the problems caused by pests on productivity and amount of loss due to pest damage, the role played by policies and regulation in pest management and how they are linked to farmers' income, poverty reduction and environment. The details of how IPM is executed at community level, not at individual farm level and the role they can play as policy makers and leaders. This will be better if organized at least twice during the project life.

5.4 Pesticides traders

Two days seminar: The seminar for pesticide traders will last for two days only, and will cover safe use of pesticides and equipments for efficient application, and importance at individual, national and global level. The risks involved at all level from sellers, users of pesticides and consumers. The emphasis will be on proper guidance to users of input and pesticides in particular. The importance of proper use on longevity of pesticide effectiveness in business will be discussed at the seminar. The role of proper pest controls in national development and poverty reduction, hence their contribution to national revenue. The seminars may be organized in different districts to encourage more participation.

5.5 Cooperative leaders

Three days seminar: The cooperative members are key players in PMP execution. The seminar for them will last for three days. It will focus on pest problems, pest management and safe use of pesticides. The importance of proper use of pesticides, handling, transportation, storage and application will be discussed at the seminar. Among other topics, the risks involved at all levels, the loss of income and alternative options of pest management under PMP and their roles and responsibilities in executing the PMP.

6. PLAN FOR MONITORING AND SUPERVISING THE IMPLEMENTATION OF THE PMP

RSSP-3 is targeting to work on 13 crops, of which 10 are annual crops (cabbage, carrot, green beans, mushroom, tomato, potato, maize, rice and wheat), two are biannual (cassava and pineapple) and one perennial (banana). This would mean that each annual crop will be planted twice per year. Initially it will continue to work with 45 extension staff as in RSSP-2. Every extension officer will organize at least one learning plot of 0.1ha per season and train 30– 40 farmers. This is equivalent to {[0.1ha/crop/season/staff x10 annual crops x 45 staff] x 2seasons} about 45 ha per season or 90 ha per year of study plot for 10 annual crops (season A &B) making a total 180 ha when combining IPM study plot of improved production technologies and farmers plots. When the three other crops added, it will be 3 x 0.1 x 45= 13.5. Making IPM plot to be 103.5 ha, and total study plot area to be 207 ha. The total number of farmers trained per year will be from 30-40/crop x 10 crops x 45 staff x 2 seasons=13,500 –18000 per season or 27000 to 36000 per two seasons, making total number of 108 000 to 144,000 farmers in four years. To enable the execution of PMP under RSSP-3, the project will train 36 RSSP-3 staffs, 45 extension staffs, 90 lead farmers, 90 cooperative leaders, 60 local leaders, 45 pesticides traders, and 200 participants in four annual IPM workshops. At least 45 study tours between districts will be done during the project period. Detailed indicators will be established after baseline on current inputs used to enable assessment of impact of PMP on pesticide and fertilizer use and crop production and income generation in the area where RSSP-3 is working.

6.1 Monthly IPM reporting

The monthly District meeting will be organized during the **1st week of every month**. At least three training sessions at each demonstration site are expected per month unless specified during monthly planning. This will initially be done during the beginning of the season and apply to all crops, but more focused on four annual crops (maize, rice, potato and tomato) which grow very fast. The cassava may be adjusted for one or two weeks as season progresses. The weekly plant growth changes and pest damage understanding is important lesson throughout the growing season.

The information on what was trained, observations made, pest damage, pest management decisions made and other related activities like study tours to farms with disease or pest problem of particular interest for farmers, farmers attendance and visits to demonstration, input use and costs, labour used as man’s days and costs will be reported in the monthly report for each demonstration.

The pest damage may be clearly seen in other place and the trainers may need to take farmers to make observations in these fields. The trainers should be sensitive on how to make farmers understand properly pest problems and pesticide handling.

Each IPM demonstration will be about 0.1 ha or less and parallel comparison as farmers own practices. The latter should be treated usually a day before IPM management applied where possible (e.g., fertilizer application). The District staff compiles reports for all demonstrations and forwards to RSSP3-SPIU. These reports should reach RSSP3-SPIU not later than **15th of every month**. This will give RSSP-SPIU time to attend to some of the constraints raised during the month.

The District rural development staff will monitor the progress through established monthly reports and regular field visits to backstop them and give on- spot advice.

In addition, the members of CDC at each Sector will oversee the activities of IPM in the Sector, and they will review the IPM reports and plans for their respective areas.

6.2 District level IPM monitoring and planning meetings

During every three months, all interested in IPM activities will meet to discuss the progress report and activities plan for the following three months. RSSP-3 may consider financing such quarterly planning meetings in every District. The Sector extension staff, cooperative/association extension staff sponsored and none sponsored by RSSP and representative of farmers responsible for IPM execution will give quarterly reports and planned activities for the following quarter, and should reflect the approved work program for each in association or cooperative. The RSSP-LO should plan to make sure that this meeting is planned jointly with the monthly meetings. This should include:

i. Name of crop and area under demonstration,
ii. Activities performed during the month,
iii. Number of farmers involved,
iv. Dates of various activities,
v. Inputs used
vi. Pest and diseases observed and control methods
vii. Person hours or days spent on each activity
viii. Field days and number of people attended
ix. Farmer to farmer visits done and number of participants
x. Leaders invited and attended any of IPM events
xi. Lessons learnt and problems during the month
xii. Other activities done by the group
xiii. Future plans
xiv. Observation and suggestions

6.3 District IPM planning workshop (end of season)

At the end of the season, each group organizes end of season evaluation and planning meeting where all farmers in the groups participates and assess the production and yield. This is the day when they plan activities for the following season for the group basing on the ending season experience. The group leaders compile their group's success, constraints and plans for the following season into a comprehensive report. RSSP District staff will organize the end of season workshop where all group leaders will present their reports. These will be compiled as an end of season report and submitted to the province and SPIU. RSSP provincial coordinator may plan to attend the district planning meetings. The two season reports will make up end of the year report for presenting at the National IPM Planning workshop.

RSSP-3 should finance such monitoring and planning workshops at the National and District level, where every District IPM extension officer will give a presentation on the progress, achievement and constraints met during the previous year and the plan for the following year. The representatives of farmers will also be invited and present reports on their participation and their views on performance of extension service. The farmers report may be verbal, not necessarily written, to enable participation of farmers who do not know how to write or read but are key people in the execution of IPM in their area to present their experience.

The monitoring and planning workshops have the objective of obtaining input from the IPM implementers and share experience with beneficiaries in different Districts on the activities performed.

6.4 RSSP-*3* -National IPM planning workshop (end of year)

At the end of every year, a senior agronomist/IPM will organize an evaluation and planning workshop where farmers will participate. The workshop will discuss the execution during the year, success and identify key problems met during the ending year. During the workshop, every District RSSP staff and extension officer will give presentations on the progress, achievements and constraints met during the previous year and the plan for the following year.

During the second year, the representatives of farmers will also be invited and present their reports on their participation and views on performance of IPM extension service and improvement needed. The farmers report may be verbal, not necessarily written to enable participation of farmers who do not know how to write or read but are key people in the execution of IPM in their area to share their experiences with others.

It may also involve different stakeholders such as Research and High Education Institutes, NGOs, and Donors interested in IPM and environmental protection. The proceedings from workshop are an important document, since it includes farmers experience and reports from all Districts in the country where RSSP is operating.

7 TENTATIVE IPM WORK PROGRAM AND BUDGET FOR THE FIRST YEAR

7.1 Promotion, awareness for IPM and safe handling of pesticides during RSS*P-3*

Month	Activities	Cost (USD)	Responsible/Remarks
Quarter-1 (awareness creation)	❖ Training local leaders (District and Sector) in IPM concepts, safe use of pesticide and hazards for 2 days	50000$	• Train 2 leaders per District = 60 • Train 45 Sector leaders where RSSP-3 is running IPM study plots • Shared cost by covering transport on their own
	➢ Training pesticides traders in safe handling as in Rwanda crop protection law/draft bill, IPPC and SPSS of WTO ➢ Train for 2 days	50000$	• Train 45 pesticides traders in Districts and Sectors where RSSP is operating • Shared cost by covering transport on their own
	• Train cooperative leaders on safe handling, storage, use and disposal of containers • Rwanda crop protection law/draft bill • Train in IPM concepts • Train for 2 days	50000$	• Train 90 cooperative leaders working with RSSP-3 • Shared cost by covering transport on their own
Quarter-2	• IPM awareness and promotion launching National workshop and safe use of pesticides and Rwanda Crop protection law/draft bill requirement	50000 $	• Workshop for 2 days involving different stakeholders in IPM at national, regional and international level. • Shared cost by covering transport on their own for nationals • Regional and inter-national participants to cover their own cost.
Annual IPM planning workshop	• Review progress in executing IPM and pest problems encountered, actions taken • Plan for the following year • Farmers experience and reactions • Constraints encountered in execution	20000 *4=80000	• At least 50 participants • Shared cost with stakeholders • 2 days meeting • Participants to covers all component 2 • Specific activities to be done in sub groups
Sub total cost		280,000 $	Budget to be covered by the whole component 2

7.2Tentative work program for farmers' training in IPM during first year of RSSP-3

Month	Activity	Weeks				Cost in (USD)	Responsible/remarks
1st QUARTER PY1		**1st**	**2nd**	**3rd**	**4th**		
July/ August							
	Planning for extension staff training					0	i) RSSP-3 staff ii) Part of official activities
Aug/ Sept.	Training extension and RSSP staffs in crop production IPM technologies.					136, 080$	i) Two weeks training for 36 RSSP-3 staffs (one @district level) and ii) 45 Extension staff working with RSSP3/agronomists iii) Specialist consultants cost covered under SPIU iii) Cost to be covered from sub components 2. iv) Experts consultant for training costed under SPIU
	Training in pesticide technology						i) RSSP staffs ii) Extension staffs working RSSP3/agronomé iii) Specialist consultant
	Planning demonstrations with costing						i) RSSP staff ii) Selected extension staff
	IPM launching workshop					costed above	i) RSSP staffs ii) Invited people

Sept.	site selection, suitable and accessible for demonstration					-	• Extension staffs working with RSSP • Normal duty
	select members of IPM group in addition to lead farmers					-	• Extension staffs working with RSSP-3 • Normal duty
	training of lead farmers and other selected members with more emphasis on safe pesticide handling					60,000$	• RSSP3 district staffs • Extension staffs working with RSSP-3 • 90 lead farmers, for 3 residential days followed by weekly training on site together with other farmers
	1st training session, land preparation and procurement of inputs (seeds, fertilizers, fungicides, equips, sprayers etc)					7,500$	• Extension staffs working with RSSP-3 • 250$/season for fertilizers and 250$ for other inputs/season • 2500$ per year
Sub total Q1						**203 580$**	

2nd QUARTER PY1		**Weeks**				**Cost**	**Responsible**
		1st	**2nd**	**3rd**	**4th**		
Oct. 2012	Weekly Training sessions,					-	Extension staffs working with RSSP-3
	1st planting					-	i) Extension staffs working with RSSP-3 ii) Farmers
	1st Field day at planting					-	i) Extension staffs working with RSSP-3 ii) Farmers trainees and community iii)Local leaders
	Field observation for germination					-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	Observation on pest damage at germination					-	i) Extension staffs working with RSSP-3 ii) Farmers trainees

	Decision making on crop, pest management and pesticide use			—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	Observation on crop growth			—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	Record keeping for all activities	—	—	—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
						-	
Nov	❖ Weekly training sessions,	—	—	—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	❖ Weekly field observation , ❖	—	—	—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	❖ Crop growth assessment and recording	—	—	—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	❖ 1st weeding,		—			-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	❖ Pest damage assessment	—	—	—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	❖ Decision making on crop ,pest management and pesticide use	—	—	—	—	-	i) Extension staffs working with RSSP-3 ii) Farmers trainees
	❖ 1st Monthly meeting for monitoring and reporting		—			-	i) RSSP-3 District staff ii) Extension/agronomist
Dec.	❖ Weekly training sessions,	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weekly field observation,	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ 2nd Weeding	—	—			-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Crop growth assessment at	—	—	—	—	-	i)Extension staffs working with RSSP-3

	vegetative and flowering and recording						ii)Farmers trainees
	❖ Pest damage assessment	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ 2nd Monthly meeting for monitoring		—			-	i) RSSP District staff ii) Extension/agronomist iii) Cost to be covered by SPIU

3rd QUARTER PY1

		Week					
3rd QUARTER PY1		**1 st**	**2nd**	**3rd**	**4th**	**-**	
Jan.13	❖ Weekly training session,	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weekly field observation,	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Crop growth assessment and recording	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Pest damage assessment and recording	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ 3rd Monthly meeting for monitoring		—			-	) RSSP District staff ii) Extension/agronomist iii) Cost to be covered by SPIU
	❖ Field day on preparation for harvesting for short maturation crop					- —	i) Extension staffs working with RSSP-3 ii) Farmers trainees and community iii)Local leaders
	❖ Preparation for 2nd season, site, inputs					-	i)Extension staffs working with RSSP-3

	and materials						ii)Farmers trainees
	❖ Selection of new group members for 2nd season					-	i)Extension staffs working with RSSP-3
	❖ Decision on use of demonstration site for the following season					-	i)Extension staffs working with RSSP-3
						-	
Febru ary. 2013	❖ Weekly training sessions,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ **4th** Monthly meeting for monitoring and					-	i) RSSP District staff ii) Extension/agronomist iii) Cost to be covered by PSCU
	❖ End of season meeting for short maturation crop					-	i) RSSP-3 District staff ii) Extension/agronomist ii) Farmers trainees
	❖ Preparation for new demonstration (land and inputs)					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖					-	
Marc 2013	❖ Weekly training sessions,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Planting 2nd season crop					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Field day for planting 2nd season crop					-	i) Extension staffs working with RSSP-3 ii) Farmers trainees and community iii)Local leaders
	❖ Germination assessment and					-	i)Extension staffs working with RSSP-3

	recording						ii)Farmers trainees
	❖ Pest damage assessment and recording			—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use			—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities			—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ 5th Monthly meeting for monitoring and evaluation			—		-	i) RSSP-3 District staff ii) Extension/agronomist iii) Cost to be covered by PSCU
4th QUARTER PY1							
						-	
April 13	❖ Weekly training sessions,	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weekly field observation,	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weeding and fertilizer application for 2nd season crop		—	—		-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Field day for fertilizer application on 2nd season crop		—	—		-	i) Extension staffs working with RSSP-3 ii) Farmers trainees and community iii)Local leaders
	❖ Crop growth assessment and recording	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Pest damage assessment and recording	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities	—	—	—	—	-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ 6th Monthly meeting for monitoring and reporting		—			-	i) RSSP District staff ii) Extension/agronomist iii) Cost to be covered by SPIU
	❖ End of season					-	) RSSP District staff

	meeting for medium maturation crop						ii) Extension/agronomist iii) Farmers trainees at each site
						-	
May 13	❖ Weekly training sessions,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weeding for 2nd season crop					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Crop growth assessment and recording					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ 7th Monthly meeting for monitoring and reporting					-	i) RSSP-3 District staff ii) Extension/agronomist iii) Cost to be covered by SPIU
						-	
June 13	❖ Weekly training sessions,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Crop growth assessment and recording					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees

	❖ 8th Monthly meeting for monitoring and reporting					-	i) RSSP-3 District staff ii) Extension/agronomist iii) Cost to be covered by SPIU
						-	
July 13	❖ Weekly training sessions, ❖					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with RSSP-3 ii)Farmers trainees
	❖ 9th Monthly meeting for monitoring and reporting					-	i) RSSP-3 District staff ii) Extension/agronomist iii) Cost to be covered by PSCU
	❖ End of year IPM planning workshop					-	i) RSSP-SPIU District staff ii) Invited people iii) Farmers representatives
	❖					-	

7.3 Draft budget for the PMP actions for RSSP-3: Human resources

Expenses	Unit	# of units	Unit rate (in USD)	Costs (in USD)	Remarks
1. Human Resources					
1.1 Salaries (RSSP-3 staff)					
1.1.1 Senior IPM staff RSSP-3-SPIU	Per month				Under SPIU
1.1.2 Assistant IPM staff SPIU-RSSP-3	Per month				Under SPIU
1.1.3 Assistant IPM staff District	Per month				Under SPIU
1.1.4 Salaries/consultant fee for IPM 4 man-days/month @300$/man-day	Per month				Under SPIU
1.3 Per diems for study tour/missions/travel[5]					
1.3.1 Abroad (staff assigned to the IPM Action)					
1.3.1.1 Study tour to EAC region (e.g. Kenya, Tanzania etc) for 5 staffs @ 7 days (28@250$/days)	Days	35	250	8750	Under SPIU
1.3.1.2 Study tour to EAC for 4 farmers for 7 days (28 @120$/days)	Days	28	150	4200	Under component
1.3.1.3 Short courses in IPM for 2 RSSP-3 staff for @14 days (28@250$/days)	Days	28	250	7000	Under SPIU
1.3.1.4 Seminar/conference participation - associates to attend meetings, 1 staff/year @7 days (Africa-28 days @250$)	Days	28	250	7000	Under SPIU
1.3.2 Local (staff and farmers assigned to IPM)					
1.3.2.1 Field allowances (RSSP-3 staff assigned to IPM) - RSSP-3 staffs/month for 48 months @ 10 days/month (480 days @ 80$)	Days	480	80	38400	Under SPIU

Expenses	Unit	# of units	Unit rate (in USD)	Costs (in USD)	Remarks
1.3.2.2 Seminar/conference participation - associates to attend meetings, 2 staff/year , 8 staff/4years for 7 days (Rwanda-56 days @250$)	Days	56	250	14000	Under SPIU
1.3.2.3 Per diems training in IPM for 480 lead farmers/4years for 7 days (3360 days @ 50$)	Days	3360	50	168,000	Under component 2
1.3.2.4 Per diems training in IPM for 120 local leaders/4years, 30staffs/year for 2 days (240 days @ 100$)	Days	240	100	24,000	under component 2
1.3.2.5 Per diems training in IPM/pesticide for 60 retailers /4years for 3 days (180 days @ 50$)	Days	180	50	9,000	under component 2
1.3.2.6 Per diems training in IPM/pesticide for 60 policy makers /4years for 1 days (60 days @ 50$)	Days	60	100	6,000	under component 2.
1.3.2.7 Participation in stakeholders' and end of season District meetings (stakeholders = 10, Districts=10, (2meetings/year/District) = 80/4years)	Meeting	80	500	40,000	SPIU
2. Travel					
2.1. International travel - flights		12	1500	18 000	Under component 2.
2.2 Local transportation					Under SPIU
3 Contingency reserve (maximum 5%)				13250	
Sub-total Human Resources(less salaries)				**378,668**	SPIU+**comp.2.**
Grand total				**962,248**	

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ANNEXES

Annex 1. IPM for potato tool kit

Purpose of this Guide

The current IPM manual is made for use by extension staffs working with potato crop in all production zones of Rwanda. The extension staffs have been focusing on the use of pesticides in the control of both insect pests and diseases. The use of pesticides has been used without consideration whether the pest damage level justifies its use and whether the farmer will benefit from the control method recommended. The presence of the insect in the field or the damage of one few tomatoes plants does not justify spraying with insecticide in the whole field. The control method should base on the cost –benefit ratio, and what the farmer expects to benefit from the recommended control method. The answer to this question will be obtained from the end of season evaluation of costs of inputs including labour and revenue from sales of produce.

The decision making in pest management in this manual recommends consideration of the cultural practices used by farmers and their implication on pest population and damage levels. However, it has to be practiced together with farmers over a period of time about two to three seasons before teaching individual farmers to practice in their own field. The evaluation of farm records kept for all activities including labour at the end of season will reveal the profitability of approach against the farmers practices.

This manual is not meant to distribute to lead or individual farmers to practice on their own without guidance of extension staff (agronome). It should be practiced under study plots, and thereafter, the lead farmers can use the modified manual to suit their area.

Summary integrated pest management of potatoes

When several methods of controlling pests and diseases are used together, the methods are said to be integrated, hence the term integrated pest management (IPM). The alternative measures that may control pests and diseases or maintain them at acceptable levels without use of pesticides include cultural and biological methods. These should be considered as the first line of defence. When they are successful they prevent the pest or disease becoming a problem at all. Even when they are not completely effective, they can delay the need for spraying or reduce the *number* of times that spraying is required.

Every farming system is different from the other and the best pest management solutions are not known for all of them, so there is need for site specific IPM development. Therefore, there is a pressing need for more research into IPM technologies and into ways of combining them in IPM packages that are cheap, safe and effective for small-scale potato farmers at their own locality. On-farm experimentation by farmers developing their own 1PM systems is essential, but often needs to be supported by scientists researching specific aspects on field stations.
The general principles of potato IPM should be as follows:

- Choose a suitable crop variety which is likely to grow well in the area and if possible has resistance to diseases e.g. Roma variety is easy to manage
- Use clean disease-free seed (from known input stockist) or if difficult to get, you can treat carefully your own seed using hot water at 50 to 52°C. for 10 minutes, wrapped loosely in cloth, hanged and submerged in water. This should be tried for a period before adoption and should be used in areas where there is no other source of packed seeds.
- Give plants a good start by ensuring that seedbed soil and seedlings are free of pests, diseases and weeds.
- Use cultural practices which prevent and reduce pest and disease problems, such good crop hygiene and sanitation including sterilisation of plant stakes, post season destruction of debris by burning, composting or deep ploughing of residues, and cleaning of tools between fields.
- Avoid field activities when vegetation is wet with dew, rain or irrigation water.
- Conserve and encourage natural enemies of pests
- Scout the crop regularly to check on pest, disease and natural enemy status (details covered in pesticide guide).
- Apply pesticide if pests or diseases appear to be getting out of control. Use the safest pesticide available and spray at low volumes, doses and frequencies. One or two pests and diseases require more preventive action. For example, late blight can rapidly destroy a potato crop once it has become established so in areas where it is frequently a problem, preventive fungicides spray should be applied whenever the weather is wet and cool. The farmer should be able to predict the weather situation in their area, if not, they can follow calendar spraying..

1.0 Introduction

The potato *(Solanum tuberosum)* is one among temperate crops which are generally grown successfully in the high altitude of tropics where optimum temperature for tuber development is about 15^{o}C and not above 27 ^{O}C. In Rwanda, it is well established itself in the Virunga zone.and is among priority crops in the country and important food and cash crop.

It is an annual herbaceous branched plant with a height of 0.3 - 1 m; which produces the swollen stem tubers containing 2% protein, 17% starch.. The potatoes are propagated vegetatively from tubers and the production of healthy 'seed tubers' is a major aspect in pest management and potato cultivation. As result, if not well managed, they spread pests and diseases with the planting materials. Potato is one among temperate crops which is generally grown successfully in the cooler regions of tropics at high altitude, where usually both pest load and spectrum are greatly diminished in relation to the numbers encountered in temperate countries.

Field observation: The experience from the field visit is that the major pest problems are: 1). Late blight, 2). Potatoes tuber moths and 3). aphids (serious when rain is low). The farmers are very conversant with both protective and curative measures fungicide use against late blight. They apply dithane M45 (protective fungicide) when rainfall is not continuous, and apply rodomil (systemic fungicide) when rainfall is continuous and can wash out protective. This knowledge is good and their experience is an important tool in IPM because it is based on their observation. The only risk is that they mix the insecticide with fungicide apply on weekly basis even when there is no insects seen on the crop. However, the fertilizer application is not satisfactory. They apply DAP and NPK at planting only, and when plants are not vigorous, they mix urea with Dithane M45. They also do rotate potato with maize but prefer to plant potatoes continuously because maize takes 6-8 moths while potatoes take about 4 months and thus give two crops per year.

1.2 Overview of potato pest management

Why should we therefore be concerned with IPM in potatoes? The potato crop is produced continuously in the North province and farmers are not aware of disastrous effects of pesticides used, moreover, they combine both fungicide and insecticides during spraying leading to over use of insecticides. Therefore we need to avoid the problems of pest resistant to insecticides, undesirable residue levels in food, unfortunate effects on wildlife, rapid resurgence of target pest populations following treatment, outbreaks of unleashed secondary pests, and the obvious hazard of extremely toxic chemicals to farmers. Moreover, the potatoes are among the major crops using large quantities of pesticides in Rwanda. Since Rwanda environment is delicate due to land terrain, there is a great need of significantly reducing the quantity of pesticides used in the country for human, animal and environmental health.

In general the principles behind the concept of integrated pest management (IPM) are commonly used by potato farmers in Rwanda and many of them have long been employed for controlling pests and diseases without calling them IPM. The major components of pest management programs are the use of cultural practices or agro-ecosystem manipulations, host resistance or genetic control, biological control through conservation of natural enemies by reduced insecticide use, and the minimum use of pesticides. The cultural methods of potato insect control such as: sanitation practices, tillage, rotations, time of planting, trap-cropping, effect of fertilizers, destruction of weeds and other alternate hosts, crop spacing, harvesting procedures, water management, etc., need to be more intensively studied. Potato pests can be controlled by a combination of most all of these means.

2.0 Potato IPM Strategies

The pest management in potatoes is complicated and difficult, as the potato is vegetatively reproduced, using tubers for seed, which carry easily bacteria, viruses, fungi and insects, and some are rapidly disseminated by cutting knives. Therefore the source of relatively pest-free seed is essential for healthy potatoes production. This is complicated by the quantities needed as seed rate per unit area. For example, 1.8 tons of tubers are used to plant an 1.0 ha of potatoes at a spacing of 75 cm between rows and 25-30 cm between plants on row..

The sheer bulk of the potato seed, which is difficult to store more than six months, makes seed production programs far more difficult as compared to cereal or other crops using seed. Since, diseases are more important than insect pests, and are easily transferred by planting materials, it is very important for farmers to understand clearly the mechanism involved. The experience from the field visit in the northern Province, almost all potato fields are sprayed with protectant fungicide in particular mancozeb (dithane M45) mixed with insecticide. Therefore, a reduction in quantities of pesticides use in particular insecticide is possible and achievable without reducing efficiency through a combination of methods such as increasingly use of cultural practices, resistant varieties, improved public awareness for environmental health and safe use of pesticides

2.1 Cultural Practices

Much of the yield increases in potatoes are due to better cultural methods such as fertilizer practices, weed and disease control, and insect and disease control. There is a wide variety of cultural practices and agro-ecosystem manipulations used to control potato pests. Some of them which can be integrated into pest management programs in Rwanda are presented below.

2.1.1 Use of Clean Seed

The best IPM tool is the use of healthy planting material, and is of primary importance since most of the major diseases of potato can be carried by ‘seed tubers’. The production of healthy seed tubers requires the use of specially prepared virus-free mother parts. These are often produced by micro-propagation techniques; and are grown under disease-free condition, and must include the absence of aphid virus vectors. The virus-free mother plants produce virus-free seed tubers.
The basic prerequisite for improved agricultural production is the availability of a reliable source of relatively disease free seed. The potatoes seed producers should obtain their seed from “foundation” seed produced in isolated areas either at ISAR or certified fields, where they maintained extremely high standards for freedom from disease.

2.1.2 Rotations

The general phytosanitary techniques such as crop rotation are also essential . Potatoes rotations with other crops is a component of both traditional and modem agriculture. Crop rotation is recommended as a means of disease control, and is especially important for the long-term control of diseases such as verticillium wilt, and fusarium wilt *(Fusarium* spp.) etc. It is important that the crop rotation does not include plants that are also hosts of the potato pathogens, like tomatoes since that may make the problem more serious.

2.1.3 Cultural manipulations and sanitation

The cultural manipulations and sanitation procedures are used to reduce losses due to disease organisms such late blight disease (*Phytophthora infestans)*, as it is important to delay initial infection by *P. infestans* possible by use of clean seed, destruction of source of inoculums, hilling up and killing of infected vine near harvesting.

2.1.4 Resistant Potato Cultivars

The use of potatoes varieties with resistance to pathogens are a major element in potatoes IPM. Since it is costly and takes long to get a resistant variety, farmers should be taught how to maintain, care, give them due value and not to mix with other varieties.
Probably the single most important disease of potatoes in Rwanda is late blight, caused by *Phytophthora infestans.*. Although the late blight is controlled by fungicides and not by resistant varieties. P. *infestans* is a highly variable organism; thus the use of specific resistance contributed little to controlling late blight, because the pathogen rapidly overcame such resistance

2.2 Pesticides Management

The chemical control of foliage diseases is required against *Phytophthora* and *Alternaria* blight. The IPM is not organic farming. The pesticides are used but at a critical time when necessary. Therefore the management of pesticide used is one of IPM strategies to reduce the hazardous effects on none targets organisms. The majority of fungicides used in Rwanda are used to control late blight (*Phytophthora infestans),* which at the same time controls also the early blight *(Alternaria solani),* and other fungi because they are broad spectrum. There are two categories of fungicides, the protectants and systemic.

Protectant fungicides: The protectant fungicides (eg Mancozeb/Dithane M45) are effective in fungal control. However, they need a continuous film over on the entire surface of the plant. Many protective fungicides can control late blight effectively and economically; and most are applied at regular intervals of 5, 7, or 10 days depending on weather, and the proximity of late blight in the growing area. The mode of action of the protective fungicides was generally non specific, interfering with many vital functions of fungi.

Systemic fungicides: In contrast to protectant fungicides; the systemic fungicides penetrate the cuticle and are translocated throughout the plant, and their action is much more efficient. Some systemic fungicides such as benomyl or Rodomil are highly specific in their mode of action. Their fungicidal action seems to depend on the interference with only one or a very few vital organ, and a single gene mutation in the pest organism can result in a modified system which may be not sensitive to attack. Such a change would result in an immune individuals and provide the basis of a resistant population. As a result, a fungus population with resistance may probably arise, and resistance to systemic fungicides will probably become a problem in control of late blight. Therefore, the use of systemic fungicides should be used with care as not to over use them.

Insecticides: The misuse of insecticide applications usually result in resurgence or considerably higher populations due to insect resistance. What is needed under IPM approach is to avoid the problems of insect populations resistant to insecticides, rapid resurgence of target pest populations following treatment, outbreaks of unleashed secondary pests, and the obvious hazard of extremely toxic chemicals to farmers and other none target organisms.

3.0 Management Of Serious Potato Pests

Although the crop is attacked by both insect pests and diseases, the diseases are usually the main constraint in potato production, since only the potato tuber moth remains the only serious insect pest both in the field and in stores. The aphids are virus vectors and transmit several important diseases but are not themselves serious pests.

3.1 Potato Tuber Moth (*Phthorimaea operculella*, Gelechiidae)

It is an important pest of potato. Infestations arise initially in the field and continue during storage of the tubers. Potatoes is the main hosts, while tomato, eggplant, tobacco and other Solanaceae members and *Beta vulgaris are al*ternative hosts. The potatoe tuber moth was in the past reported in the former Mutura district and was serious.

3.1.1 Biology of potato tuber moth

The eggs are laid singly on the underside of the leaf, or on tubers (usually in storage) near the eye or on a sprout. The eggs on the leaves hatch in *3—15* days and the first instars larvae bore into the leaf, where they make mines. The caterpillars are pale greenish. They gradually eat their way into the leaf veins and into the petioles, then gradually down the stem and sometimes into the tuber. The larval period lasts 9—33 days. Pupation takes place in a cocoon in the surface litter or just under the surface of the tuber; and requires 6—26 days, according to temperature. The adult is a small moth and are very short lived. One generation takes some 3-4 weeks, and there can be up to 12 generations per year, but development is very dependent upon temperature.

3.1.2 Damage on potato

The caterpillars caused damage on both foliage and tubers and they suffer extensive damage. This is caused by the larvae, which normally spend their entire lives in either of these food sources. The only exception to this is when infested foliage is destroyed, forcing larvae to abandon it and search for tubers. Foliage mining. The caterpillars feed on the leaves by mining between the upper and lower epidermis, create transparent leaf blisters and may also mine the petioles (leaf stalks) or fastening two leaves together and feeding between them causing silver blotches. They tunnel leaf veins, petioles and stems. The mines increase in size as they approach the base of the stem. This is followed by wilting of the plants. Foliar infestation may be sufficiently severe to destroy the plant.
Eventually the larger caterpillars bore into tubers and the later often become infected with fungi or bacteria as secondary infection. The tuber-mining larvae usually enter through the "eyes" from eggs laid nearby, and make slender, dirty-looking tunnels throughout the tuber. An infested tuber can be identified by mounds of frass (droppings) at the tunnel entrances.
High levels of tuber infestation occur in the field before harvesting, and stored potatoes can suffer severe damage all the year round.

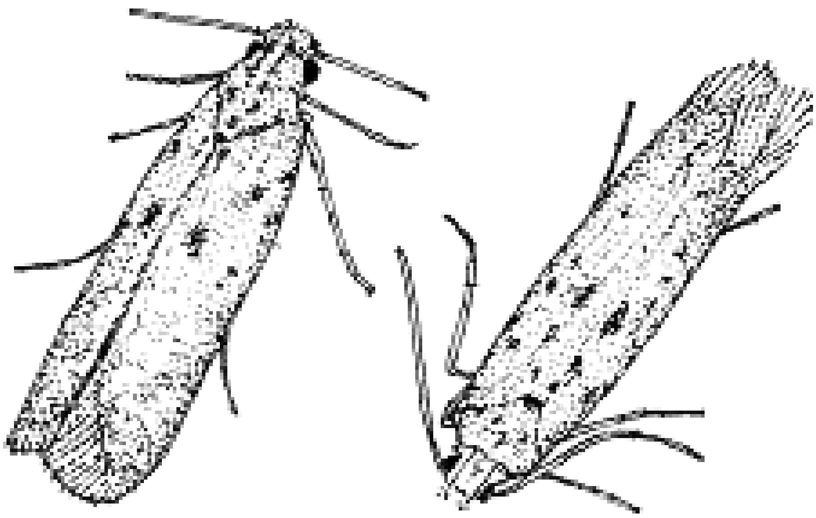

Figure 1 : Adult potato tuber moth

3.1.3 Management of potato tuber moth.

3.1.3.1 Cultural methods

- Hilling up to cover the tuber properly and delay infestation in the field
- Closed season to avoid continuous availability of hosts in the field before the following season crop.
- Encourage crop rotation with none host crops to ensure complete rotting of potatoes residues and rejected tubers.
- Destroy crop residue to residue possibly pupa remaining in the litter
- Use of selective insecticide like systemic ones which does not kill some insects visiting the crop
- Use repellants in store like botanicals (eg neem, lantana and eucalyptus)
- If the situation continue use pesticide, as indicated below.

3.1.3.2 Chemical Control

Spray the crop using the following effective insecticides: carbaryl (l-2 kg a.i./ha), dimethoate (350 g a.i./ha), demephion (250 g a.i./ha) and permethrin (75 g a.j./ha) as sprays.
Rate and frequency: as a preventative measure insecticides sprays should be applied every 14 days after the first mines are found in the leaves. Aldicarb, disulfoton and phorate may be used as granules, incorporated into the soil at rates from 1-3 kg a.i./ha, and other pests (e.g. nematodes) will be controlled because these are broad spectrum insecticides.

3.2. The potato aphid (*Aulacorthum solani* (Family: Aphidiae)

The potato aphid is a polyphagous pest with potato as main hosts. The alternative hosts include a very wide range of wild and cultivated Solanaceae plants, also some plants in other families; polyphagous. It is a sporadically serious pest of potatoes in the field; usually only a minor pest of sprout potatoes. A polyphagous pest, and vector of several virus diseases of potato and other cultivated plants; 30 viruses in all.

3.2.1 Biology of patato aphids

The adults are pale green, and with long conspicuous conicles on the abdomen. There are winged and wingless forms. The wingless form has a dark green patch at the base of each conicle. The winged form has broken transverse blackish spots (or bands) on the abdomen, which in some specimens fuse and appear as an irregular black patch. Both winged and apterous forms produce pale green, living young. One generation takes about 2 weeks in favourable weather.

3.2.2 Damage on potatoes

The clusters of small pale green aphids on young shoots on the undersides on young leaves distort them and they turn quite yellow. Drops of sticky honey-dew and/or patches of sooty mould on the upper sides of leaves.

3.2.3 Management of aphids.

Usually aphids are not a problem where rainfall is reliable and falls on regular intervals. Therefore, not a major pest in the North province. sted on page

4.0 Management of major potato diseases

4.1 Late blight (*Phytophthora infestans* (Oomycetes)

The late blight disease is caused by the fungus *Phytophthora infestans*. The epidemics are more severe in the North of Rwanda and are the most important limiting factor for high potato yields in the country.

The first reason for the severity of blight epidemics is the absence of a prolonged dry period to check the disease in the North Province; where it thrives throughout the year not only on potato crops, which are planted in many months of the year, but also on volunteer potatoes, tomatoes and alternative species. The second reason is that the climatic requirements of both the fungus and the crop are identical and are met in most months of the year in the North Province.

4.1.1 Symptoms of Late blight

The first symptoms of blight are irregular brown, necrotic patches on the leaves. These spread rapidly especially if the weather is overcast, wet and humid, and all the vegetative parts may finally be destroyed. The lesions starts as small pale water soaked irregular spots on leaves. These spread and coalesce to form large areas of dark necrotic tissue surrounding by a pale water-soaked margin on which the fungus can often be seen sporulating profusely in damp conditions. Sporulation is most evident on the undersides of leaves. Eventually whole leaflets die and shrivel up and large areas of the plant canopy are blighted. Lesions also spread to the stem.

Tubers can become infected from inoculums washed off the foliage onto the soil. Tuber lesions appear as sunken brown areas with a dry rot of the tissue beneath. Secondary organisms can extend the rot to destroy the whole tuber. However, the diseases of the tubers, i.e. discolouration and rotting, may be seen in tropics although they are common in temperate countries.

4.1.2 Epidemiology and transmission

The most important method of spread of late blight is by spores which are blown in the air or which are splashed from one leaf to another. The fungus requires fairly cool moist conditions for spread and infection. Sporangia are dispersed by wind and rain but germinate to release mobile zoospores so that infection can only take place in the presence of liquid water. Sporulation and lesion development are also favoured by long periods of leaf wetness. The diseased tubers and inter-seasonal survival are also important suitable hosts grown throughout the year. They can be spread also by infected seed and possibly by infected debris in the soil.
Late blight is widely spread in all potatoes growing of Rwanda in particular the highland humid areas of Virunga area in the North Province, where it is troublesome.

4.1 3 Late blight disease management

4.1.3.1 Resistant varieties

The most effective method of preventing blight is growing resistant varieties which have a high level of the type of resistance that does not break down. The resistant varieties do not need to be sprayed with fungicides. Their availability and distribution on time to all farmers is important for the potato production as it make potatoes a very much more popular food security crop, since fungicidal control is expensive and time consuming and is beyond the means of a smallholder growing potatoes for food security and income for poverty reduction
Resistant cultivars are important tool in disease management. but because of the highly variable pathogenicity of the fungus, resistance is often temporary as new races of the fungus develop.

4.1.3.2 Cultural control

The cultural manipulations and sanitation procedures are used to reduce losses due to late blight disease (P. *infestans),* as it is important to delay initial infection as long as possible by use of clean seed, destruction of source of innoculum, hilling up and killing of infected vine near harvesting.

Clean seed: Use of seed tubers free of *P. infestans* is essential.

Phytosanitation: Destruction of sources of inoculum is very importance to reduce sources of inoculum such as old tubers, volunteers, piles of reject tubers etc.

Hilling up/Earthing up: Tuber infection results from sporangia of the fungus being washed into the soil from blighted foliage. Consequently, good coverage o**f** tubers with soil by adequate "hilling" is important to reduce tuber infection.

Killing the vines: If foliage does become infected by *P. infestans* late in the season, tuber infection can be prevented or greatly reduced by killing the vines at least two weeks before harvest. This prevents further tuber infection; tubers already infected will not sufficiently in the ground so that they will not be harvested. Before tubers are stored, they should be carefully examined and blighted tubers should be discarded.

Use whole tubers: As potato tubers for seed are commonly cut into pieces for planting, the knives or machinery such as mechanical, seed cutters used to cut seed can rapidly spread bacteria and viruses. Furthermore, most potatoes are planted using mechanical picker-planters with "picks", which are ideal for inoculating tubers with bacteria and other pathogens.

4.1.3.3 Fungicides management

It is worthwhile to apply fungicide (e.g. Mancozeb), when growing late blight susceptible varieties as a cash crop, and weather is favourable for the spread of disease. The potato farmers in the North Province are very much aware that the fungicide spraying is necessary when growing susceptible varieties.

There is an increasing use of fungicide in Rwanda to control late blight, which at the same time controls the other fungal diseases like early blight *(Alternaria solani)*, and because the fungicides used are broad spectrum. In general the fungicides used are essentially protectants, and for effective control, a continuous film over the entire surface of the plant is necessary. Many of the protective fungicides control late blight effectively and economically and are applied at regular short intervals of 5, 7, or 10 days depending on weather condition and the proximity of source of infestation where a host crop is growing. The mode of action of the protective fungicides is generally non specific in interfering with many vital functions of fungi.

In contrast, systemic fungicides penetrate the cuticle and are translocated throughout the plant, so that their action is much more efficient. However, some systemic fungicides such as benomyl are highly specific in their mode of action. Thus, their fungicidal action seems to depend on the interference with only one or a very few vital organs, and a single gene mutation in the pest organism can result in a modified system, which may be no longer sensitive to an attack of fungicide. Such change would result in an immune individual and provide the basis of a resistant population. As a result, a fungus population with resistance may probably arise, and resistance to fungicides may probably become a problem in control of late blight

4.2 Early blight (*Alternaria solani*, Fungus imperfectus)

4.2.1 Symptoms of early blight

The early blight attack potato, tomato and many other Solanaceae plants. A leaf lesion starts as a small necrotic fleck which expands radially to produce a more or less circular zonate spot with concentric light and dark bands. Lesions may become delimited by veins and take on an angular shape. They are often surrounded by a chlorotic halo. Severely diseased leaves may become completely chlorotic and be shed. The fungus produces a toxin which diffuses through the leaves causing damage in excess of that caused by the necrotic spots. Older mature leaves are most susceptible but young tubers can be affected, the pathogen causing dark sunken necrotic patches.

4.2.2 Epidemiology and transmission

Spores are mainly air-borne, but they require liquid water for germination and infection. Hot and showery weather seems to favour disease development, and epidemics can develop rapidly under optimal conditions 0f *25—30°C,* when the latent period is only a few days. Older leaves are more susceptible and any stress which can cause premature senescence predisposes the plants to infection. The pathogen survives on volunteer plants, in crop debris and Solanaceae weeds. The spores, being fairly large and pigmented, are very resistant to desiccation.

4.2.3 Early blight management

Monitoring: The disease is not yet a problem and was not observed in the North province, however, it needs to be monitored especially due to changes in weather which may reach 25 – 30 ^{0} C**,** a suitable environment for disease expression.

Phytosanitation: General phytosanitary practices through destruction of sources of inoculum is very importance to reduce sources of inoculums such as old tubers, volunteers, piles of reject tubers and delay disease development and are particularly important for preventing early infection of plants.

Chemical control: The fungicide application is required as plants mature and the disease becomes noticeable. Chlorothalonil, dithiocarbamates, or copper-based fungicides used at 0.2—0.3% a.i. are apparently most effective.

Resistant varieties: Some cultivars show resistance to the disease, but none are immune or highly resistant.

4.3. Bacterial Wilt (*Pseudomonas solanacearum* , Bacterium)

Symptoms: This disease is caused by the bacteria *Pseudomonas solanacearum.*

The external symptom is a wilting of the vegetative parts inspite of a moist soil. A white bacterial mass oozes from the vascular tissue when the base of the stem or a tuber is cut.

Spread: The main method of spread is by diseased seed tubers. Once the bacteria is in the soil remains there almost indefinitely both because it can survive saprophytically and also because it parasitizes a number of very common weeds.

4.3.1 Disease management:

Resistant varieties: Planting of resistant varieties is the only reliable means of combating bacterial wilt.

Use of clean seed: An important precaution when growing susceptible varieties on clean land is to use clean seed. The use of bare fallowing during the dry season reduces the amount of inoculum by desiccation but it seems that it cannot eliminate it entirely. Typical wilting with bacterial exudation from the vascular tissue; it is often transmitted in tubers. Infected tubers often show vascular discolouration.

4.4.0 Fusarium Wilt DiseaseS

Fusarium solani, and *Rhizoctonia solani* (Fungi imperfecti)

These fungi can infect a very wide range of host plants and are common soil fungi.

4.4.1 Symptoms

Initially seen on young plants as stunting with chlorosis and wilting of young shoots. Some shoots may collapse, and maturity is delayed.

On older plants chlorosis and premature senescence occurs as the stems collapse and tubers show surface blemishes, and Alternaria vascular discolouration. Examination of the stems below ground level usually shows that they have a brown cortical rot below soit level. The seed tuber itself has often rotted away and young roots produced from the stems may also have rotted. Later infection often does not involve a cortical rot and resembles a truc vascular wi)t with vascular discolouration. Symptoms depend to some extent on the *Fusarium* species concerned. *F. solani* can also cause a serious dry rot of tubers. This usually gains access via tuber wounds. *R. solani* also causes 'black scurf' of tubers.

4.4.2 Epidemiology and transmission

The pathogens are both soil and tuber-borne, and susceptibility to the disease is greatly influenced by the physiologic state of seed tubers and by climatic conditions. Damage by *Fusarium* spp. is most severe under hot dry conditions which is why the disease is more important in the tropics. In cooler areas similar diseases occur involving different pathogens. Often a complex of soil borne pathogens is involved with the shoot damage and root rot.

4.4.3 Disease management:

- Crop rotation has some effect on the disease incidence as diseased residues from previous crops build up soil-borne inoculum.
- Using clean seed tubers is also important. Those with much black scurf', (the dark flattened sclerotia of *R. solani* occurring on the tuber surface), or showing signs of dry rot, (caused by *F. solani,)*, should not be used.
- Application of fungicidal dusts to seed tubers also helps to control seed-borne infection.
- Seed tubers should be carefully stored; sudden temperature changes, long storage, wounding and allowing cut seed tubers to stand in hot or wet conditions before planting tend to predispose plants to infection.

4.5 Leaf Roll (Potato leaf roll virus)

4.5.1 Symptoms

The potato leaf roll virus attacks the potato and other Solanaceous plants. It is one of the most widespread and damaging of potato viruses. It causes upward rolling of leaf edges, first on the youngest leaves and later spreads to lower leaves. The leaves become coarse in texture, rather pale and tend to be stiffer and more upright than usual. Plants become noticeably stunted as growth is reduced, particularly where there has been primarily tuber infection. Internally, there is a phloem necrosis which shows up in tubers as a pattern of dark necrotic dots when the tuber is cut across.

4.5.2 Epidemiology and transmission:

The virus in tuber-borne and infected seed tubers are a major source of the pathogen in new crops. Volunteer plants also act as major sources of the pathogen. The virus is transmitted in a persistent manner by several aphid species and can be spread over large areas from distant sources by wind-borne winged aphids. Late season infection often has little effect on the crop. Greatest yield tosses occur from early season infection.

4.5.3 Disease Management/Control :

- Eliminating sources of the virus is of greatest importance.
- The use of certified disease free seed tubers:
- Disease-free plants can be obtained by growing tubers in hot conditions and tissue culturing shoot tips, or by selecting healthy plants grown up from tuber bud ('eye') cultures.

- Virus-free planting material is usually produced in areas where the virus vectors are absent during the main stages of growth.
- Rogue volunteer plants is of primary importance
- Insecticidal control of the vector also prevents the spread of the disease as it is spread in a persistent manner. The potato sprayed with insecticide on regular recommended interval have less attack.

5.0 Basic Principles For Potatoes Production

Potatoes are important root crops in Rwanda and are among priority crops for intensification. At the higher altitudes they have a greater yielding potential than other food crops and are a more suitable than maize, which may take longer time to mature up to Six months while potatoes take 4 months only. Most potatoes are consumed as food security crop although surplus is marketed internally, often reaching towns far from the growing areas, such as Kigali, Butare and even Bujumbura etc

5.1 Plant characteristics

A potato tuber is a swollen underground stem. On its surface are a number of 'eyes', at each of which is a bud in the axil of a scale leaf. After undergoing a period of dormancy, which is usually two to three months, some of these buds sprout and produce stems. One 'eye' can produce more than one stem owing to branching at the base of the original stem. The nodes of the stems produce roots and, later, short stolons whose ends swell into tubers.

The potato plant produces flowers; the petals are white, pink or blue or purple according to the variety. As a general rule, varieties with white skinned tubers have flowers with white petals, whilst varieties with coloured tubers have coloured petals. Seedlings often grow in the field from true seed dropped by the previous crop.

Tuber growth often continues after flowering, provided that there is adequate soil moisture. In the absence of diseases the productive life of the potato plant is therefore governed primarily by the duration of the rains.

5.2 Production requirements

Rainfall. and water requirements : A steady rainfall of about 25 cm a week is enough to maintain optimum growth of potatoes on most soils. A good yield should be obtained if the rains continue for 3 months, provided that damage by diseases is not serious.

Altitude and temperature: In warm conditions the potatoes give poor tuber growth. They are best suited to the cooler conditions above 1800 masl although they are occasionally seen on smallholdings between 1500-1800 masl. They can be grown successfully as high as 2 900 masl

Soil requirements : Soil must be free draining. Heavy soils restrict tuber expansion *and* make harvesting difficult. Potatoes only give good yields when they have a good supply of nutrients, either from a naturally fertile soil or when fertilisers or manures are applied.

Varieties: Almost all potato varieties produced by farmers in Rwanda are obtained from ISAR Ruhengeri station, which also obtained and evaluated in partnership with International Potato Research Institute (CIP) and its research network (PAPACE).

Propagation: Small tubers, called 'seed' or 'setts', are used for propagation. They should be between. 3-6 cm in diameter. About 1.85 tons of seed is needed to plant a hectare. Sprouting is

strongly recommended. It involves spreading the seed in a layer no more than two or three tubers deep in diffuse light. This encourages the development of short, green, healthy sprouts.
Complete darkness must be avoided because this causes the development of long, white, thin sprouts which are easily broken before or during planting.

When subjected to light, buds take several weeks to produce sprouts about in. 1.3 cm long; the seed can be stored in this form for a further two or three months during which the sprouts grow little, if at all, provided that they are not kept in darkness.

The main advantage of sprouting is that stem growth commences immediate the seed is planted, thus making maximum use of the available rainfall and causing rapid and even emergence. Crops grown from sprouted seed yield more than those from un-sprouted seed. Cutting seed tubers into two or more pieces is sometimes practised. It should be strongly discouraged because it spreads bacterial wilt from infected tubers to clean ones, by means of the implement used for cutting.

5.3 Field Operations

Land Preparation : Planting on ridges which are 0.75 cm apart is recommended; it conserves soil and water and gives the ideal conditions for tuber expansion. Planting on ridges is the general rule, but is very seldom practised by small scale farmers although they often heap soil around the stems whilst weeding. Heaping soil around the stems should be greatly encouraged because only when the lower nodes are covered with soil can they produce tubers; the more nodes that are covered, the higher are the yields.

Planting: All potatoes planting in Rwanda is done by hand. The seed is usually placed about 10 cm deep. When potatoes are planted on the flat it is recommended that they should be planted at the bottom of holes about 15 cm deep and covered with a shallow layer of soil; they can then be earthed up easily during normal weeding operations, thus encouraging tuber production at many of the lower nodes.

Spacing: The recommended spacing for the varieties currently grown is 0.75 m between rows with plants 23—30 cm apart within the row. With the introduction of varieties with greater vegetative growth and with a wider spread of tubers, a spacing of 0.45 m within the row may be necessary. In practice small scale farmers almost always use a considerably wider spacing than that recommended, even when they plant a pure stand.

Fertilisers and manures: Potatoes respond well to fertilisers and manures wherever it is produced. Economic responses have been obtained from applications of nitrogen at a rate of 22-45 kg/ha and phosphate (P205) at .a rate of 45-65 kg/ha; however, rate of application for optimum yield is reported by site specific research. The yield response to potassium application is minimal. Potatoes give greater responses to farmyard manure than most other crops. The use of manure by smallholders, however, is very limited. The reason for this is possibly that potatoes usually suffer from black scurf when the seed is placed near organic manure; for successful results it is essential that manure is dug deeply into the soil. A combination of fertilisers and manures give high yields.. It is economic to apply manure and fertilizer in combination of fungicide when late blight susceptible varieties are grown to avoid crop losses due to disease.

Weed control: Weeding of potatoes is important during the first six weeks after emergence, and should not be necessary thereafter they will not cause economic loss if there a good stand. When potatoes are planted at the correct spacing, they rapidly cover the ground and suppress weeds. During weeding; they heap soil around the stems at the same time as killing weeds.

Harvesting: All potatoes in Rwanda are harvested by hand. Tubers must be exposed to the minimum of direct sunlight during harvesting, otherwise they turn green. Since most tubers will be transported to Kigali after harvesting, it is highly advisable to cut or pull the tops off two or three weeks before lifting. The effect of this is to harden the skins of the tubers by preventing further growth. Hard skins are less likely to be bruised during transport. Potatoes cannot be stored for long because the high temperatures encourage sprouting.