REPUBLIC OF RWANDA

MINISTRY OF AGRICULTURE AND ANIMAL RESOURCES

Land-husbandry, Water-harvesting and Hillside-irrigation (LWH) project

Pest Management Plan (PMP) and Arrangement for LWH

FINAL DRAFT REPORT

THE GOVERNMENT OF RWANDA

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Consultant Report, July 2009

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LISTE OF ACRONYM

ASARECA: Association for Strengthening Research in East and Central Africa

BBW: Banana Bacterial wilt

BSM: Bean stem maggot

CABI: Commonwealth Agricultural Bureau International

CBD: Coffee berry disease

CBOs: Community Based organizations

CDC: Community Development Committee

CGIAR: Consultative Group on International Agricultural Research

CIP: International Potato Center /Centro Internacional de la papa

CLR: Coffee leaf rust

CYMMIT: International centre for maize and wheat research

EDPRS: Economic Development and Poverty Reduction Strategy

FAO: Food and Agriculture Organization

GDP: Gross Domestic Product

GOR: Government of Rwanda

IARC: International Agricultural Research Centre

ICIPE: International Centre for Insect Physiology and Ecology

ICRISAT: International Centre for Research in Semi Arid Tropics

IITA: International Institute of Tropical Agriculture

ILRI: International Livestock Research Institute

IPM: Integrated Pest Management

IRRI: International Rice Research Institute

ISAE : Institute of High Education in Agriculture and Livestock

ISAR: Institut des Sciences Agronomiques du Rwanda

LWH: Land husbandry, Water management and Hillside irrigation

MDG: Mallenium Development Goal

MINAGRI: Ministry Of Agriculture and Animal Resources

NGO: None Government Organization

NE:	Natural enemies
NPPO:	National Plant protection organization
NUR:	National University of Rwanda
PDO:	Project Development Objective
PMP:	Pest Management Plan
RAB:	Rwanda Agricultural Board
RBS:	Rwanda Bureau of Standards
RHODA:	Rwanda Horticultural Development Authority
RSSP :	Rural Sector Support Project
RADA:	Rwanda Agricultural Development Authority
RARDA.	Rwanda Animal Resources Development Authority
SNS:	Service National de semence
SWAp:	Sector-Wide Approach
TOT:	Training of trainers
TSWV:	Tomato spot wilt virus
UN:	United Nations
WHO:	World Health Organization

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Executive Summary

Agriculture is the backbone of Rwanda's economy, accounting for about 39 % of GDP, 80 % of employment, and 63 % of foreign exchange earnings and 90 % of the country's food needs. As a result, the agriculture has been identified in vision 2020 and EDPRS as engine of economy and means to attain MDG and poverty reduction. Moreover, Rwandan economy is agricultural 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. Therefore, the Government of Rwanda and the World Bank are preparing the implementation of the Land-husbandry, water-harvesting and hillside-irrigation (LWH) Project. The preparation of LWH project 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 LWH implementation.

In order to address the hillside intensification agenda, the Government of Rwanda has designed and developed a Land-husbandry, Water-harvesting and Hillside-irrigation (LWH) program under the first strategic program of SPAT. The successful agricultural intensification takes place in the context of a potentially fertile soil with good land husbandry and environmental protection as a necessity. However, the increase in crop production is achieved through increasing productivity rather than expansion of production area. Maximum productivity would therefore be achieved through a combination of appropriate use of agricultural technologies that would reduce losses in crop yields due to pests and diseases. In order to reduce crop losses, farmers are required to use appropriate and timely pest management actions; that needs clear understanding of requirements and techniques related to plant growth, pests and diseases problems, survival mechanisms and management methods that are available to make a timely and informed decision. The purpose of this consultancy is to prepare the LWH-Pest Management Plan (PMP).

This PMP is made up of 10 chapters with annexes. The PMP covers all elements of pest management. Chapters one covers background information of LWH. The second chapter describes the current and anticipated pests, their management, selected crop suitability background and scope of the PMP; while chapters 3, explains the current Rwandan law, regulations regarding to pesticides. The chapters 4 to 8 describe the components of PMP, implementation strategy, staffing, awareness creation and training and monitoring and supervision of PMP execution. The chapter 9 deals with the sustainability of IPM activities beyond LWH life span. The last chapter, 10, gives a tentative work plan for the first year of the LWH project.

It is important to note that, currently, the use of pesticides in Rwandan is very low and is primarily used in coffee, potato and tomato diseases. However, with irrigation on hillside, and promotion of horticultural crops, it is anticipated that more pesticides may be used despite the LWH emphasis on organic markets. Thus safe use of these chemical is necessary, and community capacity building in pesticides is a necessity.

1.0 Background

1.1 Rwanda's Hillside Irrigation Agriculture

The Government of Rwanda and the World Bank are preparing the implementation of the Land-husbandry, water-harvesting and hillside-irrigation (LWH) Project. The preparation of this project 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 LWH implementation. The purpose of this consultancy is to prepare the LWH PMP.

Agriculture is the backbone of Rwanda's economy, accounting for about 39 % of GDP, 80 % of employment, and 63 % of foreign exchange earnings and 90 % of the country's food needs. As a result, the agriculture has been identified in vision 2020 and EDPRS as engine of economy and means to attain MDG and poverty reduction. Moreover, Rwandan economy is agricultural 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 agricultural strategy (SPAT) 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 successful agricultural intensification takes place in the context of a potentially fertile soil with good land husbandry and environmental protection as a necessity. The later would require soil erosion control and maintaining high quality soil. Since total arable land in Rwanda is about 1.5 million ha, of which 90% is found on hillsides, the care and good management of hillside arable land is essential. Hillsides in the country are faced with severe erosion due to over cultivation and very steep slopes not recommended for growing crops. Currently, soil erosion causes a loss of approximately 1.4 million tons of fertile soils per year. Since biological strength of agricultural crops on non-fertile lands is weaker, there is a great need for a clear pest management plan that needs to be included in such an agricultural intensification project.

In order to address the hillside intensification agenda, the Government of Rwanda has designed and developed a Land-husbandry, Water-harvesting and Hillside-irrigation (LWH) program under the first strategic program of SPAT. The LWH program is a two-phased program to implement improved land-husbandry and increased productivity in 101 pilot watersheds covering 30,250 ha of land. The first phase was to cover the development of 32 sites, permitting a learning process before the second phase, which would see the completion of the program through the remaining 69 sites. It is targeting to irrigate 12,000 ha out of 30,250 ha total. LWH will make a vital contribution to the growth and poverty reduction agenda.

The LWH project is aligned with the proposed outcomes, indicators and policy actions agreed in the EDPRS policy and results matrix. It addresses the call for economic transformation to create employment and generate exports. It is the main vehicle for the EDPRS call for "increased agricultural productivity" on hillsides, where the majority of Rwanda's arable land is to be found. As such, it shares the outcomes and indicators found in the country's higher level strategic documents.

The proposed project is explicitly identified in the current CAS for Rwanda (2009-2012), which focuses on Bank engagement in support of Rwanda's four year medium-term development framework (EDPRS). The project will also provide an effective means to advance implementation of the Government-led sector-wide approach (SWAp) in the sector and its ongoing harmonization process, as per clear higher-order Government objectives for aid effectiveness.

The LWH project is guided by the principle which assumes that 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 is can be achieved by increasing productivity rather than expansion of production area which is already over-stretched. In order to achieve this, use of modern agricultural production technologies and reduction e losses in crop yields 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.

During the preparation of LWH the Government of Rwanda and the World Bank agreed 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) in reducing crop losses that can result from 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 intensification under LWH component (A) will focus on horticultural crops, cash crops and fodder crops. According to the agronomic and marketing criteria informing the LWH, the horticultural crops may include avocado, bananas, citrus, green beans, mangoes, pineapples, cabbages, strawberries and a number of other crops; while cash crops include coffee and tea, and feed-grasses such as Rhodes (*Chloris gayana*) and phalaris grasses etc and pasture legumes such as green leaf desmodium: *Desmodium intortum*. Such an integrated and comprehensive farming would require a well coordinated pest management plan. In all potential target crops, pests cause serious damage which reduces farmers' income.

Though some insect pests can be managed by different IPM tools, the diseases like coffee leaf rust (CLR) and coffee berry disease (CBD) on coffee will require timely protective fungicide application as a component of IPM to minimize yield loss. The CLR and CBD are serious disease of coffee. Therefore, the use of fungicides in coffee intensification may be a necessity action that needs to be considered during the LWH project implementation. This implies that a safe use of pesticide will be part of technology package given to farmers for these crops. Similarly, in meal bug on pineapple is a serious pest on Pineapple and requires use of insecticide as a component of IPM. It is only in crops such as bananas that serious pests and diseases can be managed using cultural practices and resistant varieties as IPM tools.

Based on the above information, capacity building for farmers in IPM practices will be an important component of technology transfer for crop intensification during the LWH. This will require good coordination and support among LWH staffs, farmer cooperatives, Provincial, Districts and other stakeholders. The research institutes and Universities will play a key role in adaptive research of IPM technologies to develop site specific technologies with farmers.

2.0 Pest problems in the LWH Project area

2.1 LWH Project Development Objective

The LWH Project Development Objective (PDO) is to increase the productivity and commercialization of hillside agriculture in target areas. in target areas. Specifically, the key outcome indicators for the project objective are proposed as follows: (i) increased productivity of targeted irrigated command areas ($/ha); (ii) increased productivity of targeted non-irrigated command areas ($/ha); and (iii) increased share in commercialized products from the targeted areas.

2.2 Project components

LWH Project uses watershed approach to introduce sustainable land husbandry measures for hillside agriculture on selected sites, as well as developing hillside irrigation for sub-sections of each site. The Project envisions the production of high-valued (organic) horticultural crops with the strongest marketing potential on irrigated portions of hillsides, and the improved productivity and commercialization of rainfed crops on the rest. The project represents transformation of subsistence hillside farming into modernization and intensification of agriculture in view of increasing productivity in an environmentally sustainable manner. Similar to other rural transformation initiatives, it requires high levels of community participation and ownership. Therefore, project will use participatory land-use processes to promote high level stakeholder involvement, to build awareness, and to empower the community members. This would enhance their buying-in of the comprehensive land management work. Therefore, LWH Project has ***two task components***: (A) developing the human and organizational capacity and (B) building the required physical infrastructure for hillside intensification and transformation.

Component A: ***Capacity Development and Institutional Strengthening for Hillside Intensification. The objective of Component -****A* is to develop the capacity of individuals and institutions for improved hillside land husbandry, stronger agricultural value chains and expanded access to finance. Using a value chain approach to the Project's PDO, Component A covers the capacity development and institutional strengthening for both production and marketing, including the access to finance issues. Component A includes four sub-components: *A1: Strengthening Farmer Organizations; A2: Extension; A3: Marketing and Finance; and A4: Capacity Development and Institutional Strengthening.*

Component B: Infrastructure for Hillside Intensification. B.1 The objective of this component is to provide the essential 'hardware' for hillside intensification to accompany the capacity development and institutional strengthening activities of Component A. Its three sub-components are organized around the L, the W and the H of LWH: (i) Land husbandry infrastructure supports the development of participatory and comprehensive land husbandry practices throughout the sub-watershed to improve productivity for rainfed and irrigated areas; (ii) Water harvesting infrastructure, including valley dam and reservoirs; and (iii) Hillside irrigation infrastructure, including the development of the conveyance structures for hillside irrigation. With the exception of a few very large sub-watersheds, the average size for potential LWH sites identified in the Government program so far is about 500 ha, although sites can range from 280 ha to 1700 ha depending on the catchment potential. Approximately one fifth of an average site will be irrigated (the irrigated 'command area'), roughly twice that area is under comprehensive land husbandry development (non-irrigated command area catchment), with the remaining area taken up by the water harvesting infrastructure of dam and reservoir (less than 5% of site surface) and downstream reservoir protection in the water catchment area, including a silt trap zone.

2.3 Integrated Pest Management and Use of Pesticides in the target crops of LWH.

2.3.1 Understanding Integrated Pest Management (IPM)

The term 'integrated pest management-IPM was originally developed as *Integrated Pest control* in 1959, focusing on pest scouting to determine threshold for application of pesticide. However, this approach was changed in 1970's to integrate farm and natural resource management, after realizing that the agricultural practices had influence on pest development, and that crop intensification often leads to increased pest problems. Therefore the pest management measures have to fit into farming system. This was followed by third generation in 1990's which integrated life sciences and social sciences. The involvement of farmer in decision making became evident. Site-specific agro-ecological and socio-economic conditions became also important. The current approach to IPM is therefore more participatory. Farmers have to participate in the technology development and/or adaptive studies in order to determine site specific solutions. Both farmers and experts focus on producing a healthy crop which in turn produces high yield for profitability.

Therefore in order to implement a successful PMP, we have to think on how to grow healthy plants on healthy environment and find out what they need in order to grow and give high yield and become profitable. All crops need fertile soils, enough water, and sufficient sunlight. They do not like damage. They hate suffrage from pests, diseases or weeds at any stage of their growth. Under these favorable conditions, crop plants will grow and produce abundant fruits and seeds. Therefore, in the absence of insect pests, diseases, weeds, poor soils and water shortage, crops will grow healthy and strong. We can now agree on how to define IPM in simple words as a strategy or system that combines all available methods to ensure that crop plants are growing healthy so that they produce high yields in accordance to their genetic potential. This is why the fundamental principle of IPM is to grow healthy crops through application of crop health management practices. This is the best approach to effective pest and disease management in the field and in storage which leads to healthy environment and sustainable agriculture for development.

LWH is based on the comprehensive land-husbandry measures that improve soil fertility, water holding capacity of the soil, mitigating acidifications and improved provision of water both for rainfed and irrigated crops. In a way, the very essence of LWH is improved land management for healthy cropping.

The intensification of agriculture would require the correct use of external inputs, their timely availability and affordability by the majority of farmers involved in the production process. The external inputs include pesticides, industrial fertilizers, high yielding varieties and crop management knowledge. Rwanda being at the upper part of Nile and Congo rivers, proper and safe use of pesticides is very important. Therefore the use of Integrated Pest Management (IPM) principles in the fight against pests and diseases is key strategy for safeguarding international communities as well.

LWH is to be implemented in rural areas where the prevalence of poverty is extremely high and application of modern agricultural technologies is very rare. Therefore, the promotional work on the benefits and uses of Integrated Pest Management (IPM) will be needed at all levels. IPM should be identified and adopted as a national tool to fight pests and diseases and should be promoted at different structures of rural communities to ensure successful application. Therefore a part of the LWH fund will be used to assist in developing and putting in place a national Integrated Pest Management (IPM) system. The development of IPM intends to assist LWH and beneficiaries to achieve proper application of improved agricultural technologies and protection of environment for sustainable development.

Integrated Pest Management is applicable because under the component –A, LWH will support intensification which is likely to use pesticides. The IPM policy supports safe, effective, and environmentally sound pest management. It promotes the use of different methods such as biological, cultural methods, resistant varieties and technology development and dissemination etc.

2.3.2 Suitability and importance of target crops production under LWH

Banana production: Banana is the most important crop in Rwanda occupying 23% of arable land and contributes 60-80 % of household income in banana growing area. The country produces about two million tons per year (Mt/yr), making it the 6th in production in Africa and 11th in the world. Its rate of consumption in Rwanda is 2nd in the world with about 144 kg/pers/yr after Uganda with 223 kg/pers./yr. Highland bananas (*Musa AAA-EA*) are traditional food and cash crop in the East and Central African highlands. They are largely produced and remain unique in the world. The banana fruit is available fresh throughout the year. It is an important food security crop and reliable household income. The crop is produced in all provinces, especially in Eastern and Western provinces. Banana is mainly produced by the subsistence farmers who are using traditional and indigenous technologies, without use of external input. This has resulted in low yield of about 5.6 t/ha/year. The decline in production may be due to both the biotic and abiotic factors. The biotic factors being pests, diseases and weed infestation, while the abiotic factors being mainly poor management, and lack of adequate pruning/de-suckering. This, in turn, induces competition between plants for nutrients and water making it easy to attack for insects and pests.

Fruit banana production (apple banana): Fruit bananas are found in all provinces as shown in fig 3.5 below. The Eastern Province tops the list with a total production of above 20000t. The Southern Province is second, followed by the Western Province with production of above 15000t and just below 15000t respectively. City of Kigali's contribution is negligible.

Coffee production: Coffee is an important foreign currency earner and important export crop. Rwanda climate is ideal for growing Bourbon Arabica production at an altitudes ranging from 1350 to 1850 meters above sea level. Coffee is produced mainly in the three out of four provinces of the country, namely western, eastern, and southern provinces. In the western province, coffee is produced entirely along the shore of Lake Kivu.

Rwanda has rich volcanic soils, fairly good rainfall regimes and moderate year long temperatures favor the slow maturation of the coffee beans, creating a distinctive taste in the cup. Rwandan coffee is produced using few chemical fertilizers and insecticides. Soil fertility is maintained using traditional mulching and manure application techniques. Coffee is harvested between the months of March and June. Coffee production is indeed a smallholder activity. Today some 430,000 households produce coffee, and the typical family farm has about 200 trees.

Green beans production: Common bean (*Phaseolus vulgaris*) is the second most important source of human dietary protein and the third most important source of calories of all agricultural commodities produced in eastern and southern Africa. This region also has the highest per capita bean consumption in the world, an indication of its importance in rural and urban livelihoods. For example, in Rwanda, bean contributes over half of dietary protein and a large part of the calories intake. Annual consumption in some areas in western Kenya, Rwanda and Burundi exceeds 60 kg per person. Beans are also a valuable source of vitamin-B complex, iron, zinc and other essential minerals. The crop is grown by smallholder farmers, especially women, and plays an important role in the sustainable livelihoods, providing for both food security and income generation. Beans are produced mainly in Eastern, Southern and Western Provinces; however, climbing beans are also produced in the Northern Province.

French (green) bean production is still at low scale with only 2327t/yr. Majority is produced in Gicumbi District (1846t/yr) in the Northern Province. This production is expected to increase when local consumption will be combined with export market. Rwanda has potential to produce French beans all year round due to high rainfall and rehabilitated numerous marshlands throughout the country.

Avocado production: The total annual national production of avocados is 81697t/yr Most of the avocados in Rwanda are produced in the Southern Province (49%), followed by Western Province (26%). Total avocado production is limited to the Eastern and Northern provinces. It accounts for 13% and 12% of national production respectively. Kigali City's contribution to national production (358t) is very negligible. The avocados are mainly produced in the 15 Districts out of 30. Ruhango district is the highest producer with an annual production of 9459t; followed by those producing in the range 6000 to 8000t which include Huye, Muhanga, Nyaruguru and Nyamasheke. Bugesera, Gatsibo, Musanze and Rulindo, Gisagara, Nyanza, Karongi, Ngororero, Rusizi and Rutsiro. Each produce between 2000 and 4000t per year. The rest of the districts produce less than 2000t per year and are not considered as main producers.

Pineapple production. The pineapple crop is produced mainly in the Northern Province, with an annual total production of 14823t/yr, accounting for about 47% of national production. This is due the influence of juice processing plant at Nyirangarama. The Southern province is the second largest producer with 12299t/yr, accounting for about 39% of national production. Eastern province accounts for about 12%, whilst the Western province accounts for 2% of national production. There are basically 11 major pineapple producing districts. Out of these 11, only 4 districts, namely Gakenke (14785t), Gisagara (7266t), Kirehe (3289t) and Muhanga (2340t) produce more than 2000t/yr, with the majority of the remainder producing less than 300t. This data suggest that, although the Northern province has the highest total production, the production is concentrated in Gakenke district as opposed to the Southern province were several districts have reasonable output.

Mango Production. The mango production is produced in all four provinces of Rwanda. However, it is well suited for the Eastern province. Mangos require hot low altitude climates with rainfall ranging from about 500 to 2500mm. Most importantly the Eastern province is characterized by dry periods of three months, a prerequisite for mango production which requires a dry period of about 3 months for successful flowering to take place. The rains during flowering period will interfere with mango pollination.

It is therefore not surprising that the Eastern Province is the highest producer with more than 3500t/yr. There are 14 major mango producing districts. Ngoma district is the highest producer with 2271t/yr, followed by Rulindo with 2015t/yr, Bugesera with 883t/yr, and Gisagara with 712t/yr, Huye with 676t/yr and Rusizi with 619t/yr. The rest of the districts produce below 100t per year and are not considered as producers.

Citrus Production: (i) Lemon Production: As can be seen in fig 3.15 below and annex 2, the Western province is by far the largest producer of lemons (2527t), accounting for about 62% of national production. The Southern province is second (1232t), contributing 30% to national production. Eastern province and the Northern Province have marginal production while there is virtually no production in Kigali City Province. Lemon production is very low. It is the Rutsiro district only which has more than 100t/yr with 1675t/yr, followed by Nyamasheke which produces 599t/yr. The other districts with reasonable production are Muhanga (428t/yr), Ruhango (313t/yr), Gisagara (219t/yr) and Nyanza (204t/yr). In general most districts produced less than 50t/yr.

(ii) Sweet orange production. The production of sweet orange is fairly distributed across the rest of the provinces. There is very little difference between production in the Southern and Eastern provinces, 1038t/yr and 954t/yr respectively. Similarly, the Northern and Western provinces have close production levels, 531t/yr and 630t/yr respectively. There are only seven districts with a production higher than 100t/yr, namely Ngoma, Burera, Gisagara, Muhanga, Ruhango, Karongi and Rusizi. Most of the remaining districts produced very little.

Tea production (Camellia sinensis (L.) O). The tea crop is an intensively managed perennial monoculture crop cultivated on large- and small-scale plantations. The evergreen and long-lived (over 100 years) tea plantations , consisting of genetically diverse cultivars provide a relatively steady microclimate and food supply for insect and mite communities. Tea plantations roughly resemble a "single species forest",and insect and mite species are thought to coexist by way of intratree distribution or well-defined stratification/ecological niche formation. Natural enemies (NEs) prefer to remain below the plucking table. Weeds are a major component of the tea ecosystem and serve as alternative hosts for pests as well as a refuge for NEs. Tea is produced in the Western and Northern provinces, it is the second export crop after coffee.

Tomato production. The tomato crop is produced in all provinces however, the Eastern province is the major producer with 46619t/yr. The major producer districts include

Rwamagana, with 37322t/yr, followed by Rusizi with 8019t/yr, Ngoma with 6475t/yr, Muhanga with 3402t/yr and Nyanza with 2433t/yr.

Carrot production. The carrot is a cool season crop, as a result the conditions in the western parts of Rwanda are most ideal, making the Western Province main producer with 87%, followed by Southern Province with only 8%. The highest producer District is Nyabihu district with 10821t/yr, followed by Rubavu with 3979t/yr. The remaining districts produce small amounts.

Onion and Leek production. The onions are produced throughout the country. However, the Southern Province the major producer with 48%, followed by the Western Province with 40%. The major producer districts include Kamonyi with 2742t/yr, followed by Rubavu with 2042t/yr, Nyabihu with 601t/yr, Ngororero with 558t/yr, Ruhango with 467t), and Gisagara with 455t/yr.

Cabbage production: The cabbage crop is an important vegetable produced in all Provinces. However, the Northern Province is the major cabbage producer with 38498t/yr, followed by Western Province (16094t), Southern Province (14780t), Eastern Province (2305t) and lastly Kigali City Province (346t). The major producing districts include Gicumbi, Burera Nyabihu, Kamonyi and Huye.

Passion fruit production: The purple passion fruit (Passiflora edulis) is subtropical and its optimal temperature is between 20 and 30 degree centigrade. The crop can grow in different type of soil, however performs well on deep (60 cm) medium texture light to heavy sandy loams with pH of 5.5 to 6.5, good drainage and aeration. The passion fruit is mainly produced in the Western province with 46% of national production, followed by the Northern Province with 43%. There are nine major passion fruit producing districts. However, the major producers include Rutsiro, Rulindo, Gicumbi, Ngororero and Musanze with at least 250t/yr. The remaining districts produce less than 50t/yr.

Production of the Japanese plum: The Japanese plum is is mainly produced in all provinces, however, the Northern Province, is the major producer with 3818t/yr, accounting for about 63% of national production, followed by the Western Province with 17% and the Eastern Province with 15%. The major producer districts are five including Gicumbi, Musanze, Rwamagana, Ngororero, Rutsiro and Gakenke. Each of the remaining districts produce a small amount less than 100t/yr..

Cape gooseberry and Strawberry production: The production of these two fruit crops is still at small scale in Rwanda, however, they are potential crops and will become major crops in the near future. Their national production data is still low. Baseline data will be needed before LWH promotion and awareness of their potential is essential.

2.3.3.. Current and anticipated pest problems in Rwanda that are relevant to LWH project,

2.3.3.1 Major insects pests and Diseases on banana

The banana production in Rwanda is found in highlands, above 1500 masl. 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.

The others pests of banana are not important, however, they require close monitoring since their severity is limited by temperature due to high altitude above 1400 masl. 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.

2.3.3.2 Current major insects pests and Diseases in French beans

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.

2.3.3.3 Major insects pests and diseases in coffee

Coffee is an import cash crop for Rwanda. It is attacked by many pests (about 850); however, only few of them are major pests which need control. They include coffee leaf rust (*Hemilea vastatrix*) and coffee berry disease.

Coffee leaf rust (*Hemilea vastatrix*) The coffee leaf rust causes damage on leaf, and as a result, it reduces photosynthetic capacity of infected leaves and causes premature defoliation or leaf drop associated with high infection levels. Vegetative growth and berry growth and size are reduced depending on the amount of rust in the current year. The impact of rust, however, can be long lasting. Leaf rust associated defoliation and the strong carbohydrate sink of the berries cause shoots and roots to starve and consequently to dieback, thereby reducing the number of nodes on which coffee will be produced next year. Since next year's production of coffee occurs on wood produced this season, the tip and shoot dieback caused by the rust can seriously reduce the following season's crop. On average, losses are believed to be about 15% annually.

Resistance varies with leaf age, particularly for susceptible varieties, young leaves being more susceptible than older leaves on the same plant. Plants with incomplete resistance, however, usually display the opposite response, with high resistance in young and low resistance in older leaves. Cultivars derived from Timor hybrid and the Icatu cultivar display this pattern (Eskes and da Costa, 1983; Eskes and Toma-Braghini, 1982). The important factors influencing leaf rust are planting density, host susceptibility, and predisposition of host due to high prior year yields. Disease severity is correlated with planting density and with berry yield. Generally, the lower the host density; the slower is the rate of disease development. Rain plays the most important role in disease development. It provides moisture for spore germination and aids in dispersal. Seasonal variation in disease incidence is largely due to variation in rainfall patterns. Temperature also influences rust development. The lower limit for germination is 15°C.

Light intensity influences cultivar reactions. Leaves exposed to high light intensity are generally more susceptible to rust, varying up to 10 fold depending upon pre- and post-inoculation light intensity. Overbearing coffee may exacerbate rust intensity; leaves supporting rapidly growing coffee berries are more susceptible to infection than leaves that only support vegetative growth. High yielding coffee varieties are more susceptible than low yielding varieties.

Coffee berry disease (*Colletotrichum coffeanum*). The disease was first discovered in Kenya in 1920 and is caused by the virulent strain of *Colletotrichum coffeanum*. The fungus lives in the bark of the coffee tree and produces spores which attack the coffee cherries. Spraying has been determined to be the best way to avoid the coffee berry disease. Captafol and copper-based fungicides have been effective. The Kenyan coffee hybrid Ruiru I I is resistant to both coffee berry disease and coffee leaf rust.

Where the virulent strains of CBD occur, serious losses have been reported. The loss of up to 80% has been reported. More conservative estimates of losses are 20%. Successful fungicide control programs frequently double or triple yields. Hedgerow planting and improved pruning practices to open the canopy improves fungicide penetration and coverage. The more open canopy is also less conducive to prolonged wetting and spore exudation and spread, resulting in lower CBD incidence.

Antestia Bug (*Antestiopsis spp.).* The antestia bug is a major pest of coffee and there are different species of this bug throughout Africa. It attacks flowers buds, green berries, and growing tips of coffee. As they feed, they inject saliva containing the spores of the fungus *Ashbya.* This fungus is thought to cause the taste defect, i.e. marked "potato" (very similar to a freshly cut raw potato) or "green, pea/peasy" taste defect.

Coffee berry borer (*Hypothenemus hampei*). The coffee borer is a serious pest of low altitude Arabica coffee and robusta. It attacks hardened maturing coffee bean. They feed by tannelling in the tissue of the beans. The female fly from tree to tree to oviposit eggs. The infestation is carried over between peaks of fruiting by in over-ripe berries left on the tree or fallen to the ground.

Management: Remove and destroy all over-ripe and dried berries, destroy old crop remains, and prune the coffee to remove heavy shade or trees around the coffee plant which cause unsuitable conditions for natural enenmies.

2.3.3.4. Major insects pests and diseases in Mangoes (*Mangifera indica*)

The mango crop support an extensive insect fauna, due to permanent stable microclimate condition. However, a well managed tree can tolerate most of them. The major insect pests and diseases include: (a) **Insects pests**: (i) mango fruit flies *(Ceratitis spp.*), (ii) aphids (, (iii) bugs, (iv) mango seed weevil (*Sternochetus mangiferas*), (v) mealbugs, (vi) scales, (vii) thrips; (b) **diseases**: (i)anthracnose (*Colletotrichum gloeosporioides*), (ii) bacterial spots, (iii) powdery mildew (*Odium mangiferae*), and (iv) stem rot.

2.3.3.5. Major insects pests and diseases in 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*).

2.3.3.6. Major insects pests and diseases in Citrus

The citrus is attacked by different insects pests and diseases. The major pests include. (i) false condling moth (*Cryptophlebia leucotrea*), (ii) Mediteranean fruit fly (*Ceratitis capitata*), (iii) Citru rust mites (*Phyllocoptruta oleivora*), (iv) citrus bud mite (*Aceria sheldoni*), (v) red scale (*Aonidella aurantii*), (vi) green scale (*Coccus viridis*), (vii) aphids (*Toxoptera spp.*), (viii) quick die back disease (*Tristeza virus*), (ix) Foot rot, gummosis (*Phytophthora spp.*), (x)

2.3.3.7. Major insects pests and diseases in Avocado

Avocado, *Persea americana*, is one of the major fruit crops in Rwanda. The insects and diseases pest load on avocado is low, thus pest problem is minor importance. Nevertheless, there are scales, fruit flies, and caterpillars attacking the plants. The major diseases are: (i) avocado root rot and decline caused by Phytophthora cinnamomi, (ii) Anthracnose caused by two different fungal species; *Colletotrichum gloeosporioides* and *Colletotrichum acutatum*., (iii) cercospora blotch caused by *Cercospora prupea.*

2.3.3.8.. Major insects pests and diseases in Tea

The pest spectrum on tea (*Camellia sinensis*) is very large, however, a small number of pests (about 3%) are common throughout the world and are pests of economic importance at different localities. However, each geographic region may have its own distinctive pest complex All parts of the plant, leaf, stem, root, flower, and seed, are fed upon by at least one pest species, resulting in an 11%–55% loss in yield if left unchecked. The major tea pests and diseases include: mirids (Mosquito bugs: *Helopeltis spp.*), mites (red crevice mite: *Brevipalpus phoenicis*), yellow tea mite (*Polyphagotarsonemus*), black tea thrips (*Heliothrips haemrrhoidalis*), tea root weevil (*Aperatus brunneus*), root rot disease (*Armellaria mellea*), nematodes and termites.

2.3.3.9. Major insects pests and diseases in pasture grasses (e.g. Rhodes grass and Phalaris)

The most important forage plants are the grasses. About 75% of forage consumed in the tropics is grass. The term forage is defined as herbaceous plants or plant parts fed to domestic animals. The pasture grasses produced in tropical are hundreds in number and constitute an enormous and economically important resource of the tropics, and for the small farm it is not necessary to know or to cultivate a large number of grasses. Tropical grasses vary in adaptability. They are more prevalent in semi-arid and wet monsoon type climates than in climates characterized by year round rain. Grasses are either adapted to medium temperature (15-20 °C) and medium light intensities with C-3 type of photosynthesis or, as in the case of most tropical grasses, their growth rate will increase with increased temperature and light intensity up to more than 30 degrees C. Such grasses have the C-4 type of photosynthesis. Most tropical grasses are day neutral; that is, they flower equally well throughout the year; or short day sensitive, flowering best during short days of the year.

Grasses differ remarkably in adjustment to particular soils and rainfall patterns or drought resistance. Grasses differ in their need for nutrients and ability to survive on poor, unfertilized soils. Grasses differ in their uses. Some grasses are best cut and carried to the animals that will use them. This is often the case when the grass is very tall and could easily be tramped to the ground by grazing animals, or when animals are likely to damage or destroy the grass plants by their grazing. On the other hand, some grasses are especially suitable for grazing in pastures. *Chloris gayana.* is an important grass specie in many pastures.

Tropical pastures grasses provide the substrate for a wide spectrum of pests and diseases such as pathogenic fungus, nematodes, insects, viruses, and bacteria. The incidences of pests and diseases reduces productivity of pasture and may reduce the nutritive value. The study of pests spectrum for Rwanda pasture is lacking in literature and at ISAR.

2.3.3.10. Major insects pests and diseases in pasture legumes (e.g. green leaf desmodium)

The pasture legumes are the second major group of forages, however, they are not as prominent in tropical pastures as are grasses, mainly because they are difficult to maintain in a mixed pasture. Nevertheless, they are extremely important in improvement of the fertility of the soil, and in furnishing protein to the diet of grazing animals. They are very important fodder crop and their importance in the pasture or field of forage is double. First, legumes contain large amounts of protein and thus enrich a diet of grass when the two are combined. Second, probably all legumes have the ability to enrich the soil with nitrogen, although this probably does not occur until the plant or part of its roots die. The acidity reduces the need for nitrogenous fertilizer. A few legumes can be grown in pure stand, but most grow and serve better in mixed plantings with grass. Mixed plantings are easy to establish but difficult to maintain. Heavy grazing almost always eliminates the legume and leaves the grass.

Most legumes are planted from seeds. Seeds are sown in normal ways, often alternated with rows of grass. Problems are often encountered with hard seeds that do not imbibe water readily and thus germinate irregularly. Seeds are sometimes scarified in hot water or sulfuric acid, something that must be done very carefully in order to avoid damage to the seed. After scarifying and as soon as possible after applying inoculants, seeds can be planted and watered. In spite of their ability to fix nitrogen, legumes benefit from light application of nitrogen at planting and normal quantities of phosphorous and potassium. One of the fodder legumes is greenleaf desmodium.

The greenleaf desmodium, *Desmodium intortum* (Mill.) is a large and vigorous perennial with upright stems or much branching. It is now especially popular in Australia but can be grown well elsewhere. It can be grown either in pure stands or with grasses. Since the foliage is sometimes not highly palatable, desmodium is frequently grown with tall grasses. This desmodium prefers a warm, rather wet, climate but otherwise is widely adapted. It is established from small seeds, and it needs specific inoculation for satisfactory establishment. Established pastures should not be overgrazed or cut too low. The legumes are subject to some pests and diseases including nematodes. However, it is not recommended to use pesticides on the legumes of the small farm, because it is a dangerous practice. The pest can be controlled using IPM approach. The information on pests and diseases attacking pasture legumes in Rwanda is not available.

2.3.3.11 The major pests and diseases tomatoes,

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 Wilt (*Fusarium oxysporum f. sp.lycopersici*), Verticillium Wilt (*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.

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.

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 1 5cm. 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. .

2.3.3.12. The major pests and diseases for passion fruit (*Passiflora edulis*),

The passion fruit plant is more attacked by disease than the insect pests. The disease level in the passion fruit has increased in proportion to the increase of production mainly due to using farm saved seeds which are not clean while most diseases are seed borne. The poor disease management, coupled with poor advisory services and lack of knowledge in disease management led to an increase in disease problem to the extent that some producers are at risk of losing this important means of income generation. The major diseases and insect pests include, (i) passion fruit woodness diseases, (ii) Septoria spots (*Septoria passiflora*), (iii) Anthracnose (*Colletotrichum gloeosporioides*), (iv) Cucumber mosaic virus (CMV), (Brown spots (*Alternaria passiflorae*), (vi) Fusarium wilt (*Fusarium oxysporum* f.sp.*passiflorae) and* (vii) Bacterial disease *(Xanthomonas campestris pv passiflorae*), and (viii) Aphids (*Aphis gossypii and Myzus persicae).*

2.3.3.13The major pests and diseases cabbages.

Cabbages is attacked by many insects 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.

2.3.3.14The major pests and diseases Tree tomato (*Cyphomandra betacea*),

The tomato tree is in Solanaceae family. It is attacked by many insects pests and diseases which include: (i) aphids, (ii) nematodes (*Meloidogyne spp.*), (iii) thripds, (iv) Whitefly, (v) Red spider mites, (vi) powdery mildew, (vii) white mildew , and Downy mildew. However, their economic importance not well documented in Rwanda.

2.3.3.15 The major pests and diseases carrots (*Daucus carota*),

The carrot crop is usually free from major pests and diseases. Howevr, 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. The study on their pest status under different cropping system is needed.

2.3.3.16 The major pests and diseases onions (*Alliums cepa.*)and leeks (*Allium ampeloprasum*)

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.

2.3.3.17 The major pests and diseases of cape gooseberry (*Physalis peruviana*),

The cape gooseberry is attacked by few insects pests and diseases. It few pests attacking this crop include (i) nematodes, (ii) cutworms, (iii) red spider mites, (iv) root rot, (v) powdery mildew and (vi) Fusarium wilt. However, the study on their economic importance of these pests is not yet done in the country. It requires a research on both crop performance in different ecological zones and related pests and diseases.

2.3.3.18 The major pests and diseases strawberry (*Fragaria x ananassa*),

The straw berry suffer from a number of pests and diseases which include: (i) aphids, (ii) mites, (ii) birds; (iv) nematodes, (v) leaf spots (*Mycosphaerella fragariae*), (vi) leaf scorch (*Diplocarpon earlianum*), (vii) anthracnose (colletotrichum fragariae), (viii) grey mold (*Botrytis sp.*), and (ix) virus diseases.

2.4 Integrated pest management (IPM) under LWH

Pest management during LWH will focus on major pests and diseases of target crops namely avocadoes, mangoes, citrus, French beans, bananas, pineapples, coffee, tea, fodder crops (grasses and legumes). 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 neighborhood. 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.

2.4.1 Pest management in mango

A great diversity of diseases affects mango at different development stages inducing damages at the nursery stage, decrease of fruit production and retention. At the level of fruit, damages are recorded at pre-harvest as well as at post-harvest stages. Most of the diseases affecting mango are caused by fungal agents.

Fungal Mango black spot disease *(Alternaria alternate):* This disease attacks different plant organs like leaves, panicles and fruits. On fruits, this disease induces to development of a post-harvest fruit rot. Most of the commercial cultivars are susceptible to this pathogen. The disease is easily recognised by its typical symptoms appearing as round and black spots of 1-3 mm of diameter more particularly on the underside of leaves. Similar lesions are also observed around lenticels on fruits on which they can expand and merge to cover much of the fruit surface. The damages caused by this disease are significant only in arid environments. At the epidemiological level, infected leaves and inflorescences constitute an important source of inoculum for fruits. Fruit infections are favoured by long periods of humidity higher than 80%. These infections happen mainly after ripening begins.

Mango black spot *disease Management:* The disease management is done through limiting source of inoculum. In the field the elimination of the leaves with symptoms limits the presence of inoculum for fruit. At the post harvest level, hot water brushing treatment combined for 15 - 20 s of hot water spray and fruit brushing can be efficient in control of the disease and thus contributes to reduction of post-harvest pesticide application.

Mango anthracnose (*Colletotrichum gloeosporioides, Colletotrichum gloeosporioides* var. *minor* and *Colletotrichum acutatum*)

This disease is the most important, causing major pre- and post-harvest problem. The new leaves emerging during rainy periods are most susceptible. Leaf lesions appear as small, dark brown spots that are surrounded by chlorotic haloes with irregular margins and are not limited by leaf veins. When humidity conditions are favourable, these lesions enlarge and coalesce to form irregular patches. Centres of old lesions deteriorate and fall from the leaf resulting in a perforated, tattered appearance. Three closely related fungal taxa are responsible of mango anthracnose:

Mango anthracnose disease Management: The Infected leaves and inflorescences constituting the main sources of innoculum for fruits. It is important to apply control measures prior to flowering. Prophylactic measures aiming at reducing the quantity of inoculum should be useful in terms of decreasing the probability of fruit infection. However, fruit to fruit transmission is also possible during storage or shipment of fruits. For that, hot water treatments as well as fungicide dips can improve the control conditions of this disease.

Mango bacterial black spot (black canker)(*Xanthomonas campestris.* pv. *Mangiferae indicae.*)

The disease is very common in many production areas where it can induce fruit losses higher than 50% on the most susceptible cultivars. The disease is characterized by symptoms on leaves, stems and fruits. On leaves, the lesions begin as water-soaked spots with an initial diameter of 1-3 mm. When they enlarge, they become raised and present an angular aspect because limited by veins. Defoliation occurs in severe cases. Dissemination of the disease is achieved by wind-driven rain as well as by infected propagation material and infected fruits.

Mango bacterial black spot *disease management:* The management of this disease is done by use of clean planting materials when new orchards are established. The infected twigs should be removed and destroyed to reduce inoculums pressure in the canopy.

Powdery mildew (*Oidium mangiferae):* Powdery mildew symptoms affect leaves, panicles and fruits in mango. The causal agent is inducing in some conditions yield losses reaching 90%. On affected panicles, all the tissues can be covered by the powdery resulting in a brown and shrivelled necrosis.

Powdery mildew *disease Management:* When infections are observed, it is necessary to proceed to application of fungicides. However, it was demonstrated that alternating fungicide applications and phosphate fertilizers can be used in an integrated control scheme of the disease. These measures can be adapted to local conditions. Moreover, cultural practices leading to reduction of favourable conditions for the disease can also be used to increase its control efficacy.

Insect pests of mango: Mango is susceptible to a diversity of insect pests including swarming beetles, fruit flies, termites and mango seed weevil. There are other insects occurring more commonly red banded thrips, mango tip-borer and various scale insects.

Insect pests management: To ensure control of these pests, it is important that monitoring of pest population be performed as regularly as possible. For that, Growers who monitor their mango trees can detect insect pest problems in the early stages before damage becomes severe. The grower can then decide whether to increase or decrease the periods between monitoring checks and to assess if natural controls or specific control treatments are necessary. When pests are sprayed in the early stages of development, pesticides are usually more effective and a less toxic chemical may be used. Outbreaks of pests, when caught at this early stage may be controlled by spot spraying instead of the over-all cover spray which would be required in a larger outbreak.

2.4.2 Pest management in avocado

Anthracnose *(Colletotrichum gloeosporioides* and *Colletotrichum acutatum)***:** This disease is the most common cause of rot on avocado mature fruits where it can induce fruit losses up to 37%. On leaves, symptoms appear as chlorotic, then necrotic brown spots which coalesce to generate more large lesions. In case of great severity, the disease can lead to avocado defoliation. On new shoots, severe infections lead to shoot dieback while dark lesions develop on the inflorescence causing its death or abortion of fruit. The pathogens survive by producing conidia on dead tissues (twigs and leaves). These spores are disseminated by rainsplash and contaminate all the aerial portions of avocado plants. High temperature (28°C) and high moisture levels are the most favourable condition for spread of the pathogens and for infection of new tissues.

Mango anthracnose *disease management:* The management of this disease is done by a combination of different strategies like resistant cultivars, cultural practices in the field, pre-harvest and *postharvest* treatment, correct storage conditions and rapid marketing to avoid long storage periods which can result in rot development. At the level of cultural practices, it can be noticed that elimination of lower leaves leads to decrease of the humidity in the canopy while removing the dead tissues (dead twigs, leaves and fruits) contributes to reducing inoculum in the field. Storage conditions can also be taken into consideration to reduce the impact of the disease as it is established that anthracnose development is severe when avocados are stored under temperatures higher than 24°C[1]. In fact, temperatures ranging from 5 to 18°C are not favourable for disease development. It is however preferable to let the fruits ripening and then proceed to their conservation at 2-4°C for extended periods.

Bacterial soft rot: This particular disease is caused by two different bacterial agents, *Erwinia herbicola* and *Erwinia carotovora*. The disease occurs in the field as well as at the postharvest level in wet tropical and subtropical climates. Skin of the affected fruits becomes dark while internally, the fruit is brown and liquefied and generates a putrid odour. The causal agents are generally common saprophytic organisms on leaves, stems and fruits. However, they become pathogenic under stressful conditions like wounding.

Bacterial soft rot *disease Management:* Preventing injuries during the harvest process contributes to significantly reduce the probability of pathogen penetration within the fruit. In that way, it is important to let the pedicels attached to the fruits to limit entry of the pathogen in the harvested fruits. It is also important to avoid harvesting when the fruit are still wet because it is well established that high humidity conditions are favourable to the disease development.

Pseudocercospora spot (blotch) *(Paracercospora purpurea):* The disease is known under different names like blotch, Cercospora spot and black spot. The disease is frequent under warm, humid and rainy conditions. The damages caused by this disease can lead to yield losses up to 69%. Symptoms of the disease appear on different aerial organs (leaves, stems and fruits) as small lesions (1-5 mm) with an angular aspect. With time, these lesions are surrounded by chlorotic haloes. Conidia of the pathogen are produced on leaves and can be present the whole year on the infected leaves if environmental conditions are favourable. After infection, the incubation period can be as long as 3 months. Young fruits and fruits near maturity are immune while fruits from a quarter to three-quarter size are very susceptible. All the cultivars of *P. americana* are affected by the pathogen.

Pseudocercospora spot d*isease management:* Cultural practices consisting in pruning and elimination through grounding or removal from the orchard can improve the disease control conditions.

***Phytophthora* cankers** *(Phytopthora. cinnamomi):* Phytophthora cankers occur on avocado plants where they provoke lesions starting from underground organs and may extend 3 m up to trunk and branches. Cankers exude brownish red viscous sap which becomes brownish powder after drying. This powder incrusts the provoked lesions. In Africa the pathogens reported to cause this disease is only *P. Cinnamomi;* and it provokes important damages on avocado roots. It is considered as being one of the most limiting production factors in avocado. The disease can be extremely destructive spreading rapidly and killing most of the trees. The affected roots become black and when the disease is advanced, the feeder roots become scarce.

Phytophthora* cankers *disease management: It is important to avoid wounding during the different field operations. In the same context, to avoid plant to plant transmission of the pathogens, it is advised to disinfect pruning tools. When the risk of Phytophthora cankers is high, it can be recommended to protect wounds from pruning by chemical protection. To avoid spreading of this dangerous disease, it is necessary to implement strict certification programmes to ensure that clean nursery practices are followed in view of using clean for propagation. In the same frame, seeds should be treated with hot water (49-50°C for 30 min) prior to use. Affected plants must be destroyed rapidly to reduce the chance of inoculum multiplication.

2.4.3 Pests management on 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

***Pineapple mealybug* management:** The mealbugs are most serious and are best controlled by controlling attendant ants and allow natural enemies to reduce the mealbugs. Use of pesticide to control the ants and mealbugs is also effective. The diseases and nematodes are controlled using good cultural practices.

2.4.4 Management of major pests of Bananas

Management 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 masl. Since bananas in Rwanda are grown mainly grown above 1400 masl, The insect pest problem is minor and can be checked using cultural methods. 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 (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

2.4.5 Proposed 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.

2.4.6 Proposed Management of major pests of coffee

Coffee is an import cash crop for Rwanda. It is attacked by many pests (about 850); however, only few of them are major pests which need control. These include coffee leaf rust (*Hemilea vastatrix*), coffee berry disease.

Antestia Bug (*Antestiopsis spp.)* **management:** The antestia bug is a major pest of coffee and there are different species of this bug throughout Africa. It attacks flowers buds, green berries, and growing tips of coffee. As they feed, they inject saliva containing the spores of the fungus *Ashbya*. This fungus is thought to cause the taste defect, i.e. marked "potato" (very similar to a freshly cut raw potato) or "green, pea/peasy" taste defect. The antestia bug management includes the following actions:

a) Pruning to remove the dense foliage that the insect prefers.

b) Hand collection can be practical for small plots of coffee. One allows the smoke from smoldering plant material is allowed to drift through the leaves and fruit, driving the bugs to the center of the tree where they can be more easily collected and dropped into a tin containing kerosene or other substance

c) Leaves with egg masses must also be removed. It is suggested that the collected leaves with eggs be placed in a small basket and hung upwind from the coffee. This allows the egg parasites to blow back to the coffee, hopefully eventually killing more eggs.

d) Pesticides are recommended when the average number of bugs per tree exceeds two (2500/ha).

e) Natural enemies of the antestia include hymenopterous parasites and parasitic flies that feed on the eggs and mantids and assassin bugs that feed on adults.

Coffee leaf rust (*Hemilea vastatrix*): Management of *H. vastatrix* is not easy task. The coffee leaf rust cause damage on leaf as a result it reduces photosynthetic capacity of infected leaves and causes premature defoliation or leaf drop associated with high infection levels. Vegetative growth and berry growth and size are reduced depending on the amount of rust in the current year. The impact of rust, however, can have a longer term impact. Leaf rust associated defoliation and the strong carbohydrate sink of the berries cause shoots and roots to starve and consequently to dieback, thereby reducing the number of nodes on which coffee will be produced next year. Since next year's production of coffee occurs on wood produced this season, the tip and shoot dieback caused by the rust can seriously reduce the following season's crop. On average, losses are believed to be about 15% annually.

(a) **Non-chemical management**: the non-chemical control consists of: (a) pruning infected leaves, (b) Use of resistant cultivars, (c) Early intervention to prevent the spread of disease, (d).Shade culture may be useful in avoiding epidemics because monocultures of all crops tend to promote outbreaks, (e) better understanding of the life cycle may lead to further advances in the control of *Hemileia vastatrix*, (f) good cultural management to produce healthy plant

(b) **Chemical control:** Fungicides have been used successfully to control rust for a quite a number of years. The metallic copper fungicides have been the least expensive and most effective, with copper oxychloride formulations being the best. The dithiocarbamate protectant fungicides have been useful, but their short residual life and instability at higher temperatures and humidity have limited their widespread adoption. Their performance is better when mixed with copper fungicides. The systemic triazole sterol biosynthesis inhibitors have been effective, but high cost and occasional problems with severe defoliation (phytotoxicity) have been observed.

Fungicide efficacy depends both on timing of application and complete placement or coverage of the toxicant. This latter factor is important, since redistribution by rain is very limited. Important factors are spray volume, droplet size, and coverage. In timing the application of fungicides, rainfall was generally the most important factor to consider. Sprays during the rainy season were recommended, and sometimes recommended before the onset of the rainy season. Only 2-3 fungicide applications were required during low yield years and 4-6 applications during high yield years.

Coffee berry disease (*Colletotrichum coffeanum*) management. CBD Management includes both none chemical and chemical methods. The disease was first discovered in Kenya in 1920 and is caused by the virulent strain of *Colletotrichum coffeanum*). The fungus lives in the bark of the coffee tree and produces spores which attack the coffee cherries. Spraying has been determined to be the best way to avoid the coffee berry disease. Captafol and copper-based fungicides have been effective. The Kenyan coffee hybrid Ruiru 11 is resistant to both coffee berry disease and coffee leaf rust. Where the virulent strains of CBD occur, serious losses have been reported. The losses of up to 80% have been reported. More conservative estimates of losses are 20%.

(a) None-chemical. The none-chemical method includes: (a) Hedgerow planting to reduce wind carrying innoculum, (b) improved pruning practices. The more open canopy is less conducive to prolonged wetting and spore exudation and spread, resulting in lower CBD incidence. Also the open canopy improves fungicide penetration and coverage

(b) Use of resistant variety: Differences in susceptibility to CBD are known. Kenyan variety, Ruiru-II is resistant to both CBD and coffee rust.

(c) Chemical control: Successful fungicide control programs frequently double or triple yields. Several different and effective fungicides for control of CBD are known, however, their use in the field is inconsistent. Numerous studies suggest that fungicide applications early in the season are effective only in those seasons when both flowering was early and the rainy season finished early. In the years when flowering is normal or late, and the rainy period extends longer into the season, early season fungicide applications is ineffective and CBD become worse during the season. The key issue is to protect the immature crop throughout the rainy season. Numerous fungicides have been evaluated for CBD control, and most are effective such as 50% copper formulation, which is also affordable to farmers. The systemic fungicides are also quite effective (e.g. benomyl) but more expensive. A mixture or rotation with non-systemic protectant fungicides is recommended.

Management of coffee berry borer (*Hypothenemus hampei*). The coffee borer is a serious pest of low altitude Arabica coffee and robusta. It attacks hardened maturing coffee bean. They feed by tannelling in the tissue of the beans. The female flies from tree to tree to oviposit eggs. The infestation is carried over between peaks of fruiting by in over-ripe berries left on the tree or fallen to the ground. Remove and destroy all over-ripe and dried berries, destroy old crop remains, and prune the coffee to remove heavy shade or trees around the coffee plant which cause unsuitable conditions for natural enemies.

2.4.7 Proposed Management of major pests of tea

The pest management in tea under LWH would focus on the following approaches: (a) Cultural practices in particular: (i) pruning and plucking, (ii) sanitation and crop residue destruction, (iii) tillage of soil and soil amendments, (iv) trap crops and shade trees. These are methods for preventing the pests population build up and thus reduce severity. (b) chemical control where the population is high and where it is necessary like use of systemic herbicide against couch grass (*Digitaria scalarum*) to avoid digging up. (c) establish pest spectrum in tea plantation, their biology, pest status and monitoring system for their population. The information on tea pests in Rwanda is not sufficient for making informed decision.

2.4.8 Proposed Management of major pests of citrus

The citrus is attacked by many pests like, insects, mites, nematodes, aphids, scales and pathogenic fungus. However, few of them are serious pests of economic importance, and the key pests in the pests complex tend to vary from locality to locality. They are controlled by natural enemies due to stable micro climate under citrus perennial system. The general guideline in pest management of citrus pests is to avoid pesticides application whenever possible to allow natural enemies reduce the pest population. It is also recommended to use resistant root stock when grafting, which are resistant to prevailing disease. Fungicide application is recommended during rain season, especially on sweet orange.

2.4.9 Proposed Management of major pests of pastures grasses and legumes

The tropical pastures provide substrate for wide spectrum of pests such as insects, fungus, viruses, bacteria, and nematodes. However, few of them are pests of economic importance and their attack is usually local in character and sporadic in incidence. Information of these pests is limited and in Rwanda not reported.

Therefore the major thrust in pest management in pasture legumes and grasses under LWH would be to identify the pest species present in Rwanda, study their biology and population development, and establish their pest status. The use of chemical control measures is not recommended because of their residues in meat and milk and their high agro-chemical price as compare to animal product income.

Therefore the LWH thrust would be to establish pest spectrum and biodata in Rwandan pastures and forages where the target species will be grown. The Rhodes grass (*Chloris gayana*) and Greenleaf desmodium (*Desmodium intortum*) are well known, however, their pest problems are not well documented under Rwandan agroecology.

2.4.10 Major pest management for 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:

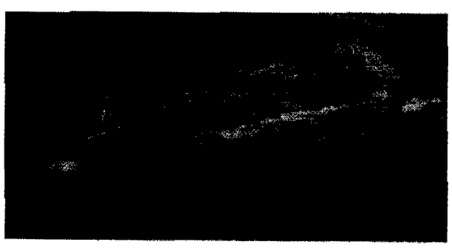

Figure 1a. Adult

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.

Leafminer (*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.

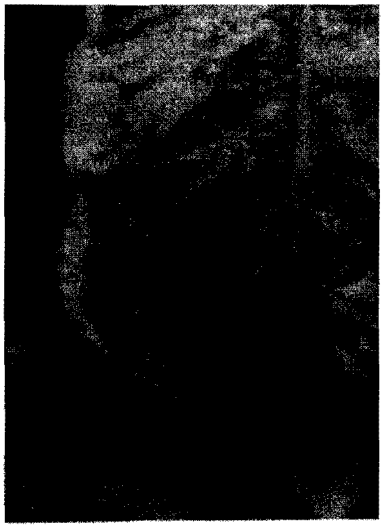

Figure 3a. Early blight on leaf

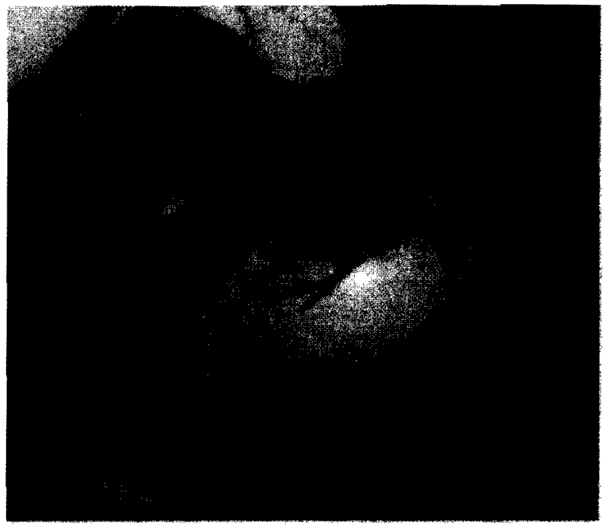

Figure 3b. Early blight damage on fruit stalk

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 non existent problem in the dry season

Figure 4a. Damage on leaf

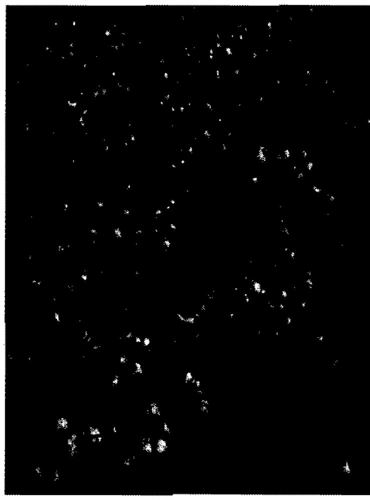

Figure 4b. Field crop damage

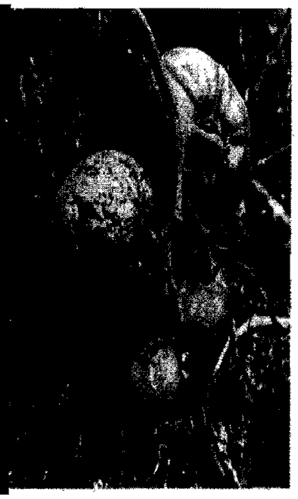

Figure 4c. Fruit damage

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.

Fugure 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.

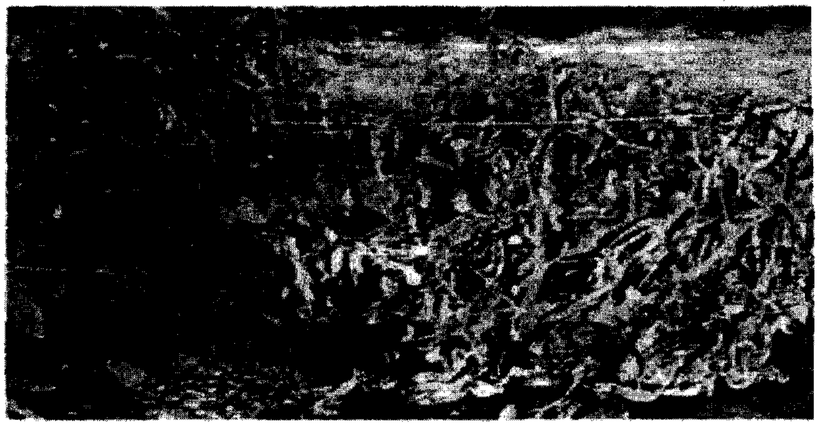

Figure 7. Plant collapse due to bacterial wilt attack

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 24^0C), 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.

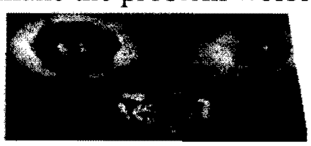

Figure 8. Damaged fruits

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.

2.4.11 Major pest management for passion fruit (*Passiflora edulis*)

The pest and disease management in passion fruits is mainly through preventive measures. The following are key management practices applied in combination which will minimize the pest problem.

Selection of growing environment: Plants given the optimal growing conditions, are less likely to be stressed and therefore predisposed to disease development. Passion fruit requires a well drained soil; therefore, valley bottoms where soils tend to be humid much of the time should be avoided.

Seed selection: The seed extraction should be left exclusively on National seed Seed (SNS) because the serious diseases in passion fruits are seed born. Currently, this activity is left out to farmers and they used poor unclean seeds.

It is preferable to select fruit from a plant which shows no symptoms of disease, grown vigorously and produces pure purple fruit. It is recommended to allow the fruit to fully mature on the plant before harvesting for seed extraction.

Seed Extraction: First dip the fruit into a solution of sodium chloride (one part to 3 parts clean water); this will kill any surface borne pathogens.

- ❖ Cut the fruit to remove the seed and pulp. If the seed does not have to be planted immediately, it is best to ferment the seed plus fruit pulp in a closed jar for 10 to 14 days.
- ❖ The fermentation can eliminate propagules of *Septoria* which are on the seed coat, and helps to soften the seed coat which facilitates germination. After fermentation, the seeds are washed, dried in the shade and stored in a cool place.
  - ❖ The germination rate falls with time in storage, and seed stored longer than 2 months may yield only a low percentage of plants. If seed is to be used immediately after extraction, wash it to remove the pulp, dry in a shaded area then sow.
  - ❖ Note that *30 – 40 fruits are needed to provide enough seed to plant 1 ha of passion fruit is.*
  - ❖

Hygiene at the nursery level: Nurseries should be located in a place isolated from other passion fruit plants, together with cucurbits and bananas. It is preferable to rotate the nursery site, if possible, or at least to change the part of the nursery where passion fruit seedlings are raised each year (being careful to destroy all old passion fruit plants first). If the seeds are first sown into beds ("germoirs") and later transplanted to pots/other beds, it is essential to space the seeds 1 cm apart in the lines, with 10 cm between lines. Closer spacing fosters development and spread of disease. Once they have emerged and have 2 true leaves, seedlings should be "pricked out", preferably into plastic bags/pots.

The nursery should be carefully inspected every day, and all seedlings exhibiting any signs of disease or insect infestation removed and destroyed.

Rotation and Separation: Land on which passion fruit has been grown must undergo a period of at least 3 years fallow before replanting to new passion fruit. The new plantings of passion fruit should be at least 50 m and upwind of all existing passion fruit plantations. Where possible, it is advisable to plant windbreaks such as Napier grass to reduce wind-blown dispersal of diseases and insects.

Fields inspection: Fields should be inspected at least once a week and the following measures applied:

- plants found exhibiting symptoms of woodiness virus should be uprooted, taken out of the field and destroyed.
- Leaves/fruits/shoots with signs of fungal disease should be removed and destroyed.
- All fallen plant material (fruits, leaves) must be regularly collected and removed from the field.
- Any "volunteer" passion fruit plants, along with any cucurbits, found growing in or near a passion fruit crop must be uprooted and removed from the vicinity.
- Volunteer" passion fruit should be destroyed rather than replanted in another location.
- Destroy residues**, ie a**ll old passion fruit plants must be uprooted and burned once they have ceased to be productive.

: The tools used in passion fruit fields such as secateurs and knives should **Tools hygiene** be sterilized; either in a 25% solution of sodium chloride. This need not be complicated, it's just a matter of dipping the tools into the solution between each plant. Hoes and workers hands should be cleaned after working in one field before going to the other. Ideally, the soles of workers boots/shoes should be dipped into disinfectant; however this might not be feasible for most of passion fruit producers. Workers should always start in the youngest plantations and move from them to progressively older ones; this will reduce likelihood of diseases/pests being carried from the older into the younger plantings.

Pruning of the plants: one of the factors predisposing passion fruit crops to fungal diseases is that many producers do not practice pruning. As a result, the plant develops a dense, heavy canopy, humidity levels around the foliage are high and fungal diseases more likely to infect the plant. Passion fruit crop will be more productive over the long run if plants are pruned regularly. In the initial stages of growth, the plant is pruned to develop a "fruiting framework" consisting of two main vines which grow up to a height of 2 m, and then trained in opposite directions along a horizontal support. Selected, well spaced secondary vines which develop from these main ones grow from the top down towards the soil (cutting them off 15 cm before they reach the soil), forming a single layered "curtain" of vines, which will bear fruit.

By reducing the amount of fruit borne on a plant at one time, the stress provoked by a high assimilate demand is reduced, and the plant is better able to resist diseases. Moreover, this stretches out the production period so that fruit is available over a longer period of time. Vines which have already produced fruit, along with old/dead vines must be pruned and removed from the field. Many producers are tempted to leave old plant materials in the field, believing them to be a source of "fertilizer"; it is better, however, to not risk leaving potentially infected material in the field where it can contaminate the crop.

While pruning is in all cases advised, pruning tools must be cleaned between plants to prevent spread of disease.

Plant Spacing: Use a wide spacing between passion fruit plants, and intercrop where Possible. A spacing of at least 2 m x 3 m is recommended to both reduce the likelihood of disease transmission, and prevent build-up of humidity within the crop's environment., The viral diseases, are more likely to occur in mono-cropped passion fruit, particularly when planted at a close spacing and in proximity to other passion fruit crops.

Plant vigour management: The health passion fruit plants which are not subjected to stress of any sort will be more likely to tolerate certain level of disease infection. The following are general practices which are recommended in all situations to promote passion fruit health:

- **Mulching**: Keep the soil covered with a thick layer of straw or other organic matter as mulch. This helps maintain soil humidity during the dry season, reduces splash of soil-borne diseases on the plant during heavy rains, and impairs the emergence of pests such as thrips which pupate in the soil.
- **Weeding**: Regular weeding to reduce competition with the crop for nutrients and soil moisture and to remove potential alternative hosts for viral diseases.
- **Wounding**: Avoid wounding the plant during field operations. Passion fruit has rather superficial roots which can be injured during cultivation if care is not taken.
- **Fertilizer**: Provide plants with adequate fertilizer, both before planting and at regular intervals throughout the year. Well decomposed manure should be

incorporated into the soil to a depth of 40 to 50 cm at least 4 weeks before planting.

- **Uprooting of diseased plants**: When a large percentage (about 50%) of a field is infected with woodiness virus, a decision should be made as to whether or not to uproot and destroy the entire crop.

Suitable spray program: Application of pesticide as need arises to reduce the insect pest population or when the weather is favourable for fungal diseases development. The spray should cover the whole plant. The safe use of pesticide should be abided for during the application.

2.4.12 Major pests management in 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 inoculum around the field.

2.4.17 Management of major pest of cabbages.

The cabbage crop is attacked by many insect pests and diseases. However, they are well control 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 vigor, (iii) apply recommended cultural practices 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 when necessary using recommended pesticide and dose.

2.4.13 Major pest management for tree tomato,

The major pests of tree tomato are managed using a combination of different control methods. Most pests and diseases are a problem only during dry season. The following are the control options which can minimize pest . These include. (i) crop rotation for nematodes management, (ii) good cultural practices, (iii) Minimize pesticide use on the crop and surrounding to encourage natural enemies.

2.4.14 Major pest management for onion and leeks

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, (iii) plant on clean soil, avoid infested soils where previous crop was attacked, (iv) apply pesticide when necessary, preferable granules applied on soil.

2.4.15 Major pest management for gooseberry,

The cape gooseberry is attacked with less pests and well managed plant can recover from most of them. The following cultural control methods are useful. (i) use clean seed and plant on clean soil, (ii) Avoid over fertilization of the crop which encourages overgrowth, (iii) prune the crop as necessary, (iv) crop rotation where possible, (v) if mildew is severe, apply systemic fungicide.

2.4.16 Major pest management for strawberry,

The strawberry is attacked by many pests. However, crop rotation is essential to reduce the pests and diseases problem. Therefore the strawberry pests and diseases in the tropics can be managed by integrating good cultural practice with other control options. Such as tolerant varieties, use of clean seeds, encourage natural enemies, destruction of crop residues. The use of pesticides is difficult because of continuous harvesting of mature fruits. The application of fungicides should be timely at blossom period.

2.5. Pest management and pesticide use policy

Currently, the common pest control practices in Rwanda include, (i) use of resistant varieties and (ii) informal cultural practices for diverse crops, (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 in crop and fodder production. The insects and pests are part of biodiversity of any ecosystem. 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 the LWH project area of 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.

2.5.1 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 of them are resistant against 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.

2.5.2 Informal cultural practices use in pests and disease management

The use of cultural practice is the most common practices. 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 Government has banned it. In general crop rotation is generally practiced by the majority of farmers.

2.5.3 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 pesticides 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.

2.5.4 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.

However, pesticides use in Rwanda is very low and limited only to high income crops like coffee, potatoes and vegetables (e.g. tomatoes etc). Pesticides are either not affordable or not accessible in many parts of the country. According to the Ministry of Agriculture and Animal Resource report, the national averages of pesticides use is below 1kg/ha and it is mainly fungicides which are unlikely to cause major dangers when properly handled..

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 results, 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.

2.6. Expected IPM experience of the project (LWH) and within the country

The development of sound IPM goes through various stages including: (i) insect or disease identification, (ii) Life cycle and mechanism of spreading, (iii) symptoms of damage, (iv) damage levels and effect on yield, (v) damage threshold, (vi) Scouting mechanism, (vii) pest management options. These are mainly activities done by research institutes, Universities and their partners, such as International Agricultural Research Institutes (e.g. CIAT, IITA, ICIPE, ICRISAT, CIP, IRRI, CYMMIT, ILRI CABI etc) and members of Regional Agricultural Research Networks (e.g. ASARECA). Currently there is only IPM project under MINAGRI in the RADA, and in general the Government policy supports IPM.

Nevertheless , most crops grown in Rwanda, are also produced in many countries, the designing IPM in Rwanda would most likely be through adaptive research of technologies which are working in other countries. This could be done in collaboration with competent Research Institute or University through ASARECA. Currently, the capacity to develop IPM in Rwanda is still weak, due to lack of experience in some areas like insect or disease identification. The number of subject matter specialists is still small and systematic are lacking in all Rwanda knowledge institutes.

However, the capacity to execute IPM through participatory approach exists in the country. Due to weakness in the plant protection at any one Agricultural Institution (Research, University or agencies of MINAGRI) in Rwanda, the National Plant Protection Organization (NPPO) is formed by shared responsibility between institutions to maximize national human resource available.

The implementation of IPM activities will be undertaken through decentralized system. The Districts and Sector will execute IPM activities with farmers organization under guidance of MINAGRI agencies (RADA, RARDA, RHODA and ISAR), together with Universities (NUR and ISAE) and Rwanda Bureau of Standards (RBS) are organized under National Plant Protection Organization (NPPO) which is a Biosecurity system established to share responsibilities in phytosanitary and plant protection, as no single institution in Rwanda had sufficient capacity to carry phytosanitary role effectively..

Current IPM approach integrates life sciences and social sciences. The involvement of farmer in decision making became evident and took into consideration site specific agro-ecological and socio-economic conditions. The current approach to IPM is therefore more participatory and the farmers have to participate in the technology development or adaptive studies in order to determine site specific solutions. Both farmers and experts focus on producing a healthy crop which in turn produces high yield and profitability.

Therefore in order to implement a successful IPM, we have to think on how to grow a healthy plants on healthy environment and find out what they need in order to grow and give high yield profitably. All crops need fertile soils, enough water, and sufficient sunlight and do not like damage (Suggestion: Replace in red by "and usually suffer") from pests, diseases or weeds at any stage of crop growth. Under these favorable conditions, crop plants will grow and produce abundant fruits and seeds. Therefore, in the absence of insect pests, diseases, weeds, poor soils and water shortage, crops will grow healthy and strong. We can now agree on how to define IPM in simple words as a strategy or system that combines all available methods to ensure that crop plants are growing healthy so that they produce high yields according to their genetic potential. This is why the fundamental principle of IPM is to grow healthy crops through application of crop health management practices. This is the best approach to effective pest and disease management in the field and in storage which leads to healthy environment and sustainable agriculture for development.

The Government of Rwanda (GOR) is guided by vision 2020 in long term and EDPRS in medium term. Under both documents, agriculture has been identified as an engine for national development for alleviation of poverty through revitalizing the rural economy, thereby increasing rural income, and reinforcing national stability. The agricultural intensification and commercialization of products together with diversification of economic activities has been identified as a means to revitalize the rural economy. MINAGRI plays key role in assisting GOR to achieve vision 2020 and EDPRS.

The intensification of agriculture would require the correct use of external inputs, their timely availability and affordability by the majority of farmers involved in the production process. The external inputs include pesticides, industrial fertilizers, high yielding varieties and crop management knowledge. Proper and safe use of pesticides and fertilizers is very important. This would be achieved through application of Integrated Pest Management (IPM) principles in the fight against pests and diseases.

Since the overwhelming majority of the population of Rwanda live in rural areas where the prevalence of poverty is extremely high, and the application of modern agricultural technologies is very rare, the promotion of Integrated Pest Management (IPM) will be needed at all levels. IPM should be identified and adopted as a national tool to fight pests and diseases and should be promoted at different structures of rural communities to ensure successful application. The IPM policy supports safe, effective, and environmentally sound pest management. It promotes the use of different methods such as biological, cultural methods, safe pesticides use etc.

Therefore all projects are targeting crop improvement are setting stage for IPM success, these are not only those focusing pests, but also those focusing on improving production system and vigorous crop, like fertilizer program, one cow per household, rural financing, decentralization, performance contract, IPM project in MINAGRI/RADA etc. All those programs will contribute to IPM successful dissemination adoption. Apart from MINAGRI/RADA IPM project, there is no other formal IPM activity going on in the country. Farmers have been applying informal cultural control methods on their own, and adopting resistant varieties without focusing on IPM.

3.0 Rwandan laws, regulations, responsible authorities and their mandates and programs related to IPM and pesticide management.

3.1. Legal framework and enforcement

Currently, there is law on pesticide. There are two draft bills in process, one for agrochemicals (pesticides and inorganic fertilizers) and another plant health which addresses issues of plant protection and quarantine. The later (plant health bill) is at advanced stage, while the farmer (agrochemical bill) is at early stage. However, there are other laws and texts making it possible to reduce the risks of pesticides such environment law etc. Nevertheless, the plant health focuses more on phytosanitary (inspection of imports and exports) and safe trade than on plant protection while growing in the field. The section of protecting growing crops in the field is not well elaborated; as a result there is very little mention of different pests' management strategies such as integrated pest management and other methods. It is anticipated that another law covering all aspects of production will be developed in the near future.

The IPM was born out of concern on pesticides use and their negative impact on humans, animals and the environment. The absence of pesticide regulations could be understood because of small market available in Rwanda. However, as the country is now promoting horticultural crops and focuses on diversification of export, the pesticides used in the production should be known and application guided by policies. The pesticides regulation should set out conditions and system of safe pesticides use in the country.

3.2 Circumstances of pesticide use and the capability and competence of end-users to handle products within acceptable risk margins

3.2.1 Circumstances of pesticide use

The pesticide under LWH will be used mainly in disease management using less toxic fungicides. Due to small market of pesticides in Rwanda, the capability and competence is not well developed for wider community. However, for those directly involved in the application like in coffee production, they have capacity through support offered by their cooperatives and coffee authority (Ocir-Cafe). As for wider community 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 LWH should include in their budget the cost of capacity building and sensitization of safe pesticides use at all levels from production, trading and consumers.

3.2.2 Anticipated pesticides use in different crops under LWH

3.2.2 .1 Pesticides use in coffee

Coffee crop is the largest user of pesticides in Rwanda. It was reported during the 2005 study to use 90% of imported fungicides (75% of all pesticides) in the country. This amount is used against mainly coffee leaf rust (*Hemileia vastatrix*) and coffee berry disease (*Colletotrichum caffeanum*) as preventive measure. The insecticides sprayed against antestia bug (*Antestiopsis spp.*).

3.2.2 .2 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.

3.2.2 .3 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.

3.4 Environmental and public health risks associated with the transport, storage, handling and use of pesticides under local circumstances, and the disposal of empty containers and obsolete stocks.

3.4.1 Environmental and Public health risks/impacts

The pesticide transport, storage, handling, and use under local conditions need much improvement. Similarly the disposal of containers and obsolete stocks require much more effort especially in teaching people involved in pesticide marketing and use since there is little understanding on risks involved at all levels. Moreover, there is no report on water contamination, food safety or pest resistance because insecticides are used in small quantities and on few crops. However, with agricultural intensification, and horticulture promotion there is a fear that misuse of pesticides may cause risks on environment and human health explaining the need for extensive sensitization.

3.4.2 Legal framework and enforcement

There are two draft bills in process, one for agrochemicals (pesticides and inorganic fertilizers) and another plant health which addresses issues of plant protection. The later (plant health bill) is at advanced stage, while the farmer (agrochemical bill) is at early stage. However, there are other laws and texts making it possible to reduce the risks of pesticides such environment law etc. Nevertheless, the plant health focuses more on phytosanitary (inspection of imports and exports) and safe trade than on plant protection while growing in the field. The section of protecting growing crops in the field is not well elaborated; as a result there is very little mention of different pests' management strategies such as integrated pest management and other methods. It is anticipated that another law covering all aspects of production will be developed in the near future, moreover, the bill was developed without policy guideline on key issues to address and how.

3.4.3 Capacity building for pesticide users and traders

The capacity building in pesticides at all levels (farmers, traders, extension staff, local leaders and decision makers etc) is an urgent issue to be addressed. Rwanda is landlocked country, and has small pesticide market, and farmers with small purchasing power. As a result the distribution and marketing of various pesticides is done in small packets without original label, and instructions associated with labels. Moreover many farmers do not use pesticides so often, as they depend on cultural practices and resistant varieties for pest management. Nevertheless, the training of farmers, extension staff and retailers of pesticides is needed as an urgent and important activity required in Rwanda. Most extension staffs employed by farmer's cooperatives are not aware of hazardous nature of pesticides. They have knowledge from school which is not enough skill needed in the field. They need regular updating and more guidance on safe pesticide handling.

3.5 Pre-requisites and/or measures required to reduce specific, identified risks associated with envisaged pesticide use under the project (e.g. protective gear, training)

3.5.1 Legal framework and enforcement

The plant health law will address all issues concerning pest management in the country. MINAGRI has already a plant protection draft bill allowing the control pesticides in the country. However, there are other laws and texts making it possible to reduce the risks of pesticides such environment law etc

3.5.2 Capacity building:

LWH will address issues of capacity building in IPM and pesticide safe use 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 LWH implementation. Most extension staffs employed by farmer's cooperatives were taught pesticide technology during their college life. However, they need updating and more guidance. Some may not be aware about hazardousness of pesticides.

3.5.3 Pesticide technology knowledge (training)

There is a minimum knowledge for safe use of pesticides which should be taught to all farmers. Since farmers will continuously produce crops 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, the most important pre-requisite for safe use of pesticide will be capacity building at all levels during LWH including consumers' sensitization, local leaders, traders and policy makers on pesticides issues like: (i) poisonous effect of pesticides thus safe handling, (ii) storage, (iii) disposal of containers, (iv) sprayer maintenance, (v) calibration, and (vi) use of protective clothes etc. Under agricultural intensification, and a need for more food for an ever increasing population, farmers will need to protect their crops continuously (e.g. potatoes, tomatoes or rice etc) using pesticides for greater part of their life.

3.6.0 IPM and Pesticide use under LWH

The pesticides commonly used in Rwanda and intervention needed on pesticides are presented in the table 1 and 2 below with their characteristics. They are in general broad spectrum pesticides and moderate hazardous nature.

Table 1: Pesticides products envisaged for pests and diseases control in LWH and health aspects

Chemicals/product type	Nature of the chemical	Health aspects for people and animals	Application/frequency and precautions required	Way of disposal	Remarks
Chlorpyrifos (Dursban)	Insecticide (I): Organophosphate (OP)	Moderate hazardous insecticide: Use with maximum care	• To follow label instruction. • Train farmers and other users	• Depends on type of container • Follow instruction on label	• Farmers and extension staffs should be trained • Retailers of pesticides should be registered and trained • Law for pesticides use should be re-enforced
Dimethoate	Insecticide (I): Organophosphate (OP)	Moderate hazardous insecticide	• To follow label instruction. • Train farmers and other users	• Depends on type of container • Follow instruction on label	• Farmers and extension staffs should be trained • Retailers of pesticides should registered and trained • Law for pesticides use should be re-enforced
Cypermethrin	Insecticide(I):Pyrethroid (PY)	Moderate hazardous insecticide	• To follow label instruction. • Train farmers and other users	• Depends on type of container • Follow instruction on label	• Farmers and extension staffs should trained • Retailers of pesticides should be registered and trained • Law for pesticides use should be re-enforced
Deltermethrin	I-PY	Moderate hazardous insecticide	• To follow label instruction. • Train farmers and other users	• Depends on type of container • Follow instruction on label	• Farmers and extension staffs should trained • Retailers of pesticides should be registered and trained • Law for pesticides use should be re-enforced
Mancozeb (Dithane M45)	Fungicide (Preventive: contact)	Unlikely to cause hazard	• To follow label instruction. • Train farmers and other users	• Depends on type of container • Follow instruction on label	• Farmers and extension staffs should trained • Retailers of pesticides should be registered and trained • Law for pesticides use should be re-enforced
Ridomil	Fungicide (systemic)	Unlikely to cause hazard	• To follow label instruction. • Train farmers and other users	• Depends on type of container • Follow instruction on label	• Farmers and extension staffs should be trained • Retailers of pesticides should be registered and trained • Law for pesticides use should be re-enforced

Table 2: Proposed IPM research areas of intervention in PMP under LWH (area where information in Rwanda not sufficient for making informed decision in IPM)

Nature of intervention	Responsible	Expected gain	Conducive issues
• Research to establish pests status in different agro-ecological zones	• Research and Universities	• Focus on major pests for control • Monitoring the control practices • Monitor pests situation on different crops • Develop appropriate technologies	• Availability of fund for carrying on research • Joint effort between Institutes
• Conducting adaptive research with farmers in different agro-ecological zones	• Research, • Universities	• Working technologies approved and adopted by farmers • Dissemination of approved technologies	• Availability of fund • Willingness of Research and Universities
• Training of Extension staffs and farmers on available IPM technologies	• MINAGRI • MINALOC • Research • Universities • NGOs	• Farmers knowledge on IPM increased • Yield increased due to reduced pests damage • Environment, human and animal health improved due to proper use of pesticides • Researchers and Academia experience increased	• Funding availability • Coordination effort to network all actors • Sharing responsibilities according to proximate • Development of technical manual for all pests and diseases used by any actor • Making researchers and academia responsive to farmers needs as a part of their workload
• evelopment of IPM materials	• MINAGRI • Research • Universities	• Technical IPM information available • Develop approval mechanism	• Funding for these materials development
• Development of IPM policy, • Pesticides law and regulation	• MINAGRI • MINALOC	• IPM policy and procedures established • Pesticides laws and regulations available	• MINAGRI accepts IPM as an approach and develops policy to guide its application • MINAGRI hastens the bill on pesticides use and regulations

3.7 Justification of pesticide use in both technical and economic terms

The pesticides used in Rwanda are fungicides applied on three crops namely, coffee, potatoes and tomatoes. These fungicides are unlikely to cause hazardous effects to users. In general, these users were trained and supported by MINAGRI through different organs, like OCIR-Cafe, cooperatives etc. Many farmers had indicated that they had training in pesticide use, however, they need additional training and more awareness. Moreover, the fungicides are bought and distributed through cooperatives; however, farmers do buy insecticides on their own.

Among the crops that will be supported by LWH, pesticides will be continuously used on coffee only. The use of pesticide on citrus, mangoes, pineapple, avocado, tea, French beans, bananas and pastures (grass and legumes) 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. Of course, this needs to be strengthened in all sites.

3.7.1 Pesticides use in management of coffee diseases and pests

The pesticides will be used mainly against two major diseases: coffee leaf rust (*Hemileia vastatrix*) and coffee berry diseases (*Colletotrichum caffeanum*). These diseases are very stubborn, and is not easily managed without timely fungicides application.. This calls for frequent use of fungicides. The frequency depends on the rainfall..: 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 and blue copper which are categorized as unlikely to present acute hazard in normal use. Mancozeb and blue copper are wettable powders which are mixed with water and applied using knapsack sprayer. These fungicides will continuously be used against coffee diseases (CLR and CBD) because there is no resistant varieties available at the moment

Insecticides use in coffee: It is anticipated that coffee pests will need the use of insecticides. However, it is not huge volume because only antestia bug is the major insect pest which is controlled using IPM approach. The pesticides will be used as a component of IPM.

3.7.2 Pesticides use in management of other crops under LWH

It is anticipated that very little pesticides will be used against the pests on the remaining crops targeted by LWH. In case it occurs, the researchers will determine the most appropriate pesticide, its rate and frequency of application. The pesticides will be used in combinations using IPM approaches. Moreover, most of them are perennial crops with stable habitat which promotes the natural enemies control of pests. The LWH would fund research in establish pest status before investing in control.

4.0 Components of the Pest Management Plan (PMP)

4.1 Objectives

The objective of PMP is to combine together several different control methods to fight against the pests, while minimizing environmental hazards and maximizing economic benefits for producers and consumers.

4.2. Integrated pest management (IPM) under LWH

Integrated pest management during LWH will focus on major pests and diseases of target crops namely avocadoes, mangoes, citrus, French beans, bananas, pineapples, coffee, tea, fodder crops (grasses and legumes). 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 neighborhood. 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 scope IPM under LWH

4.3 Scope of the Pest Management Plan (PMP) under LWH

LWH will finance the PMP activities in the project areas on all target horticultural crops, fodder crops and other demand driven crops. The PMP activities will include (i) training farmers in improved production technologies to produce healthy plants, (ii) Training on life cycle of pest and diseases, (iii) Pest distribution mechanisms (movement from place to place) 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, (vii) integrated pest management for each crop and (viii) adaptive or new research where necessary, . The PMP activities will be carried out as a learning plot for farmers or other selected members selected from their communities. 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, LWH will need to involve District authorities in PMP execution. The PMP activities will form a part of district activities and the later they should own it and include in performance contracts for sustainability .

National level: The LWH and MINAGRI will coordinate PMP implementation. This will include organizing annual IPM workshops for sharing experience and planning. In addition, LWH will work with different research institutes (RAB) and International Agriculture Research Centres (eg IARC members etc) for new technologies, taking advantage of East Africa community and Africa Union. The CGIAR System Wide Program on IPM will give them access to all CGIAR centers, and ICIPE for new IPM technologies.

Province and District level: LWH has staff at provincial but not at District and Sector levels. Whereas the LWH Provincial Officer will coordinate the PMP activities in partnership with the officers responsible for agriculture at District and Sector level and will monitor and report on progress made by CBOs. This will include also organizing study tours to different parts of the country (provinces or districts) where is success to re-enforce the training offered to farmers. The agricultural extension staffs at Provincial and District levels will be trained in both IPM and seed technology to enable them supervise and coordinate IPM activities at local level including production, marketing and distribution of grains, inputs and improved seed for resistant varieties as a part of IPM package. Since the project will operate demand driven approach, it should establish mechanism to support the local community for timely and affordable inputs (seeds, fertilizers and other agrochemicals and farm equipments etc)

Sector level: Although LWH does not have staff at sector level, the PMP coordination will be the responsibility of the agricultural officer at the Sector. The IPM activities can not be left to CBOs alone. He/she will coordinate the PMP execution as a part of crop intensification in his/her operational zone. Similarly, staffs at Sector level will receive training in both IPM and seed technology to enable them to supervise and coordinate these activities effictively.

Community Based organization (CBOs): The farmers are responsible to learn and apply IPM tools in the pest war. The CBOs 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 trained farmer will be responsible to train other 20 farmers at his/her site. In most cases every farmers on training represent a cooperative. The training will last at least one season long. This would mean that the PMP and its implementation will form part of farmers' cooperatives and District authorities as key activities to include in performance contract. The LWH will therefore give support to provincial, District and Sector level extension where the project is operating to facilitate PMP execution.

5.0 Implementation Strategy

5.1 **Capacity of the country's regulatory framework and institutions to promote and support safe, effective, and environmentally sound pest management.**

5.1.1 National IPM Workshop

To initiate the promotion of IPM and sound pesticide use, LWH will organize the launches workshop two days involving different stakeholders 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.

5.1.2 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 five target crops of LWH and pesticides technology. They will likewise train 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 training in IPM and pesticides technologies will focus extension staffs in the Sectors and Districts where LWH 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 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 as train of trainers (TOT). Since the IPM application is community based and not individual farmers alone, the training would include the Sector extension staff irrespective of whether he/she is directly involved in LWH 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 60000 USD above IPM targeted extension staff training cost.

The training of target extension staffs 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, 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.

5.1.3 Capacity building of farmers in IPM

The training of farmers will be a continuous activity for a season long. Each demonstration or study plot will have 20-30 farmers and not more than 40 farmers. If the number of demonstrations are estimated to be 45 (three per district/ extension officer); but may increase as need arises. The total number of farmers trained per season may be in a range of 900 to 1350 or more. The extension officer will continuously be updated in all aspects of IPM and crop production to enable him/her to train farmers in new improvements. The linkage with research institutes 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 labor 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 LWH 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.

5.1.4 Demonstrations of IPM technologies

In most cases, farmers training in the application of various IPM techniques and practices will be conducted at the demonstration 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 LWH 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 practice 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 neighboring areas to participate. This is an occasion for sensitizing the community on IPM technologies.

In addition to demonstration of new technologies, some members may need special training outside project to focus on crop 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

5.1.5 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 organize 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.

5.1.6 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 neighboring countries.

The LWH project 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 LWH project 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.

5.1.7 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, LWH 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/SNS 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 RADA/SNS 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 neighboring country, LWH may pay for an expert to come and train the RAB/SNS 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.

6.0 LWH staffing and PMP execution

LWH will assign responsibility of IPM to one its senior staff and an assistant. These staff will be trained in IPM and seed technology. Similarly, one staff each at province and District level will be assigned responsibilities of IPM coordination. These staffs will be trained in IPM as short course to strengthen their capacity in crop protection (plant pathology, applied entomology and pesticides technologies).

The responsibilities of IPM will take at least **two 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 district extension 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.

LWH staff/Provincial Agriculture: He/she will be responsible to organize the annual 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 LWH-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 LWH 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 extension staffs: The District extension staff will responsible IPM 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 the approach. He/she will also monitor monthly meetings and ensure they are organized as planned and may participate in some of them.

7.0 Awareness raising and training program for implementing PMP

7.1 National IPM sensitization workshop

To initiate the promotion of IPM and sound pesticide use, LWH 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.

7.2 Training and sensitization of stakeholders for PMP

LWH 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 according to needs and focus. 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:

7.2.1 Politicians and local leaders

Two days seminar: LWH will organize a two days seminar for politicians and local leaders linked with LWH 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.

7.2.2 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.

7.2.3 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

8.0 Capacity building in IPM for LWH and District extension staffs

The staffs of LWH and Local Government will need different training sessions in IPM. The LWH project will finance the initial two week residential training. This will include both LWH and extension staffs. The training will produce work plans for the first year of the project, which will be updated every year during end of season and yearly workshops as indicated earlier. The additional training will be organized according to demand. However, LWH will fund some short courses for key staff members. These will be attended as TOT, and when they come back, LWH will organize seminars to train others. It is the best method of training many staffs at a time. However, it is necessary to have regulatory mechanism for making sure that participants understood these short courses. These short IPM courses are planned to be offered on annual basis at different Universities.

8.1 Plan for monitoring and supervising the implementation of the PMP

LWH is targeting to work on eight crops and three types of fodder crops. Initially it will continue to work with at least 45 extension staffs from 15 District for pilot phase. Every extension officer will organize at least one demonstration of 0.1ha per season and train 20 – 30 farmers per season. This is equivalent to about 5 ha per season or 10 ha per year of demonstration for all crops (season A &B) making a total 40 ha of IPM and improved production technologies. The total farmers trained per year will be from 800 to 1350 per season or 1600 to 2700 farmers per two seasons, making total number of 6400 to 10800 farmers in four years. To enable the execution of PMP under LWH, the project will train 16 LWH staffs (four/Province), 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 is working.

8.2 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 annual crops (eg tomato, onions etc) which grow very fast. The perennial crops may be adjusted for two weeks observation instead of weekly and adjusted as season progresses. The weekly plant growth changes and pest damage understanding in annual crops is an 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, labor used in person-days and costs will be reported on monthly basis 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 is applied where possible (e.g., fertilizer application). The District staff compiles reports for all demonstrations and forwards to the Province with a copy to LWH Programl Manager at MINAGRI

The Province reports should have details of pesticides use as indicated in sections 8.3 and 8.6 below, and more specifically, indicating training on safe pesticides use, number of participants involved, and their categories. The report should reach LWH program Manager at MINAGRI not later than **15th of every month**. This will give LWH program manager 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.

8.3 District level IPM monitoring and planning meetings

During every three months all stakeholders (including CDC members and NGOs) interested in IPM activities will meet to discuss the progress report and activities plan for the following three months. LWH may consider financing such quarterly planning meetings in every District. The Sector extension staff, cooperative/association extension staff sponsored and none sponsored by LWH 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 LWH provincial coordinator should plan to make sure that this meeting is planned jointly with the monthly monitoring meetings. This should include:

- Name of crop and area under demonstration,
- Activities performed during the month,
- Number of farmers involved and trained,
- Dates of various activities,
- Pesticides and other inputs used

- Pest and diseases observed and control methods
- Types of pesticides and quantities used
- Person hours or days spent on each activity
- Field days and number of people attended
- Farmer to farmer visits done and number of participants
- Leaders invited and attended any of IPM events
- Lessons learnt and problems during the month
- Other activities done by the group
- Future plans
- Observation and suggestions

8.4 District end of season IPM planning workshop

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. 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. LWH 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.

LWH 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.

8.5 LWH -National end of year IPM planning workshop

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 LWH-related 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 important documents. They include farmers experience and reports from all Districts in the country where LWH is operating.

8.6 LWH –Pesticide use Monitoring

The LWH will support both annual and perennial crops. These will apply IPM approach in pest management and may apply pesticides if necessary. The LWH will monitor the pesticides use on each crop. The pesticide use will form a section of LWH reporting at all levels. In order to build capacity for such reporting activities, the staff of LWH and all stakeholders will receive training on safe use of pesticidesand will be updated on new pesticides whenever necessary. The LWH will also train the pesticides traders; and it will continue to work closely with them to know the pesticide stock, new pesticide types and the trend of use.so that quantities purchased can be monitored. Table 3 below includes sufficient costing to fund such activities. . Any pesticides under trial will also be reported as a part of monitoring, should such trials occur.

9.0 Sustainability of processes and results

The training of farmers, local leaders, input dealers and other stakeholders will ensure sustainability. The participatory approach will ensure that members gain local capacity to handle many pest problems on their own. The knowledge on pesticide safe handling will ensure protection of producers, consumers and sellers.

10.0 Work Plan and Budget

- Provide a budget for implementing and supervising the PMP, including core LWH aspects (staff, person-weeks, travel, etc.) as well as costs for awareness raising/training sessions (venues, external trainers, communications, etc.)

10.1 Tentative IPM work program for the first year (12 months)

Table 3. Promotion, awareness for IPM and safe handling of pesticides during LWH

Month	Activities	Cost (USD)	Responsible/Remarks
Month I	• Training local leaders (District and Sector) in IPM concepts, safe use of pesticide and hazards for 2 days	25000$	• Train 4 leaders per District = 60 • Train 45 Sector leaders where LWH is running IPM demonstrations • 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 traders in monitoring of pesticide stock, new pesticide types and, the trend of use • Train for 2 days	25000$	• Train 45 pesticides traders in Districts and Sectors where LWH 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 in record keeping for pesticide monitoring • Train for 2 days	25000$	• Train at least 90 cooperative leaders working with LWH • Shared cost by covering transport on their own
Month-2	• IPM awareness and promotion launching National workshop and safe use of pesticides and Rwanda Crop protection law/draft bill requirement	25000 $	• 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 • Review of monitoring information on pesticide use	25000 *4 =100000	• At least 50 participants • Shared cost with stakeholders • 2 days meeting Participants to cover all sub component Specific activities to be done in sub groups
Sub total cost		200000$	Budget to be covered by the whole LWH program

Table 4 Tentative work program for farmers' training in IPM during first year of LWH

Month	Activity	Weeks				Cost in (USD)	Responsible/remarks
1st QUARTER PY1		1st	2nd	3rd	4th		
Months-1&2							
	Planning for extension staff training					0	i) LWH staffs ii) Part of official activities
Months-2&3	Training extension and LWH staffs in crop production IPM technologies.					68040$	i) Two weeks training for 12 LWH staffs (two @province) and ii) 45 Extension staffs working with LWH iii) Specialist consultants cost iii) Cost to be covered from other iv) Experts consultant for training costed under consultant budget
	Training in pesticide technology						i) LWH staffs ii) Extension staffs working LWH iii) Specialist consultant
	Planning demonstrations with costing						i) LWH staffs ii) Selected extension staff
	IPM launching workshop					costed above	i) LWH staffs ii) Invited people
3rd Month	site selection, suitable and accessible for demonstration					-	• Extension staffs working with LWH • Normal duty
	select members of IPM group in addition to lead farmers					-	• Extension staffs working with LWH • Normal duty
	training of lead farmers and other selected members with more emphasis on safe pesticide handling					10000$	• LWH province staffs • Extension staffs working with LWH • 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)					2500$	• Extension staffs working with LWH2 • 250$/season for fertilizers and 250$ for other inputs/season • 2500$ per year
						148,040	•

2nd QUARTER							
2nd QUARTER PY1		**Weeks**				**Cost**	**Responsible**
		1st	2nd	3rd	4th		
4th Month	Weekly Training sessions,					-	Extension staffs working with LWH
	1st planting					-	i) Extension staffs working with LWH ii) Farmers
	1st Field day at planting					-	i) Extension staffs working with LWH ii) Farmers trainees and community iii)Local leaders
	Field observation for germination					-	i) Extension staffs working with LWH ii) Farmers trainees
	Observation on pest damage at germination					-	i) Extension staffs working with LWH ii) Farmers trainees
	Decision making on crop, pest management and pesticide use					-	i) Extension staffs working with LWH ii) Farmers trainees
	Observation on crop growth					-	i) Extension staffs working with LWH ii) Farmers trainees
	Record keeping for all activities					-	i) Extension staffs working with LWH ii) Farmers trainees
						-	
5th Month	❖ Weekly training sessions,					-	i) Extension staffs working with LWH ii) Farmers trainees
	❖ Weekly field observation , ❖					-	i) Extension staffs working with LWH ii) Farmers trainees
	❖ Crop growth assessment and recording					-	i) Extension staffs working with LWH ii) Farmers trainees
	❖ 1st weeding,					-	i) Extension staffs working with LWH ii) Farmers trainees
	❖ Pest damage assessment					-	i) Extension staffs working with LWH ii) Farmers trainees
	❖ Decision making on crop ,pest management and pesticide use					-	i) Extension staffs working with LWH ii) Farmers trainees
	❖ 1st Monthly meeting for monitoring and reporting					-	i) LWH staff ii) Extension/agronomist
6th Month	❖ Weekly training sessions,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weekly field					-	i)Extension staffs working with LWH

	observation,						ii)Farmers trainees
	❖ 2nd Weeding	—	—			-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Crop growth assessment at vegetative and flowering and recording	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Pest damage assessment	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 2nd Monthly meeting for monitoring		—			-	i) LWH staff ii) Extension/agronomist iii) Cost to be covered by LWH
3rd QUARTER PY1							
		Week					
3rd QUARTER PY1		**1st**	**2nd**	**3rd**	**4th**	-	
7th Month	❖ Weekly training session,	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weekly field observation,	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Crop growth assessment and recording	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Pest damage assessment and recording	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities	—	—	—	—	-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 3rd Monthly meeting for monitoring		—			-	i) LWH staff ii) Extension/agronomist iii) Cost to be covered by LWH
	❖ Field day on preparation for harvesting for short maturation crop					- —	i) Extension staffs working with LWH ii) Farmers trainees and community iii)Local leaders
	❖ Preparation for 2nd season, site, inputs and materials					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Selection of new group members for 2nd season			—		-	i)Extension staffs working with LWH
	❖ Decision on use of demonstration site for the following season				—	-	i)Extension staffs working with LWH2

8th Month	❖ Weekly training sessions,					-	i)Extension staffs working with LWH2 ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with LWH2 ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with LWH2 ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 4th Monthly meeting for monitoring and					-	i) LWH staff ii) Extension/agronomist iii) Cost to be covered by LWH
	❖ End of season meeting for short maturation crop					-	i) LWH staff ii) Extension/agronomist ii) Farmers trainees
	❖ Preparation for new demonstration (land and inputs)					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖					-	
10th Month	❖ Weekly training sessions,					-	i)Extension staffs working with LWH2 ii)Farmers trainees
	❖ Planting 2nd season crop					-	i)Extension staffs working with LWH2 ii)Farmers trainees
	❖ Field day for planting 2nd season crop					-	i) Extension staffs working with LWH2 ii) Farmers trainees and community iii)Local leaders
	❖ Germination assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 5th Monthly meeting for monitoring and evaluation					-	i) LWH staff ii) Extension/agronomist iii) Cost to be covered by LWH

4th QUARTER PY1							
						-	
11th Month	❖ Weekly training sessions,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weeding and fertilizer application for 2nd season crop					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Field day for fertilizer application on 2nd season crop					-	i) Extension staffs working with LWH ii) Farmers trainees and community iii)Local leaders
	❖ Crop growth assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 6th Monthly meeting for monitoring and reporting					-	i) LWH staff ii) Extension/agronomist iii) Cost to be covered by LWH
	❖ End of season meeting for medium maturation crop					-	i) LWH staff ii) Extension/agronomist iii) Farmers trainees at each site
						-	
12th Month	❖ Weekly training sessions,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weeding for 2nd season crop					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Crop growth assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 7th Monthly meeting for monitoring and reporting					-	i) LWH staff ii) Extension/agronomist iii) Cost to be covered by LWH
						-	

13th Month	❖ Weekly training sessions,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Crop growth assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 8th Monthly meeting for monitoring and reporting					-	i) LWH District staff ii) Extension/agronomist iii) Cost to be covered by LWH
						-	
14th Month	❖ Weekly training sessions, ❖					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Weekly field observation,					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Pest damage assessment and recording					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Decision making on crop, pest management and pesticide use					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ Record keeping for all activities					-	i)Extension staffs working with LWH ii)Farmers trainees
	❖ 9th Monthly meeting for monitoring and reporting					-	i) LWH staff ii) Extension/agronomist iii) Cost to be covered by LWH
	❖ End of year IPM planning workshop					-	i) LWH ii) LWH province iii) Invited people iv) Farmers representatives
	❖					-	

11.0 Annexes

Annex 11.1: List of banned pesticides

.

Name	Category
1. Aldrin	Organochloré
2. DDT	Organochloré
3. Dieldrin	Organochloré
4. 1-2 Dibromoethane	Dérivé bromé
5. Fluoroacetamine	Dérivés fluorés
6. H.C.H Gamma(lindane)	Organochloré
7. Choldimeforme	Organochloré
8. 2 , 4 , 5-T	Acide phénoxyacetique
9. Captafol	Phtalimide
10. Chlordane	Organochloré
11. Dinoseb et sels de dinoseb	
12.H.C.H (melandes d'isomeres)	Organochloré
13. Heptachlore	Organochloré
14. Hexachlorobenzene	Organochloré
15. Composés de mercure	Dérivés de mercure
16. Chlorobenzilate	Organochloré
17. Penchlorophenol	Chloronitrophenol
18. Monocrotophos	Organochloré
19. Methamidophos	Organochloré
20. Phosphamidon	Organochloré
21. Methyle-parathion	Organochloré
22 Parathion	Organochloré
23. Toxaphène	Hydrocarbure chloré
24. Binapacryl	Dérivé benzenique
25. Endosulfan (Thiodan)	Organochloré

Annex11. 2: Crop and livestock protection products approved by MINAGRI

11.2.1 Agricultural inputs and pesticides

11.2.1.1. Fertilizers

*Agricultural lime
*Ammonium sulfate
*CAN
*Compound fertilizers; DAP 18-46-0; NPK 17-17-17; NPK 20-10-10; NPK 20-5-5
*Micro-nutrients fertilizers
*Nitrogen fertilizers: urea 46%
*Others fertilizers
*Phosphates fertilizers
*Potash fertilizers: KCL

11.2.1.2. Seeds and plant material

11.2.1.3. Insecticides and acaricideS

*Abameclin
*Acephate
*Acrinathrin
*Alphacypemethrin EC
*Alphamethrin EC
*Amitraz EC
*Azocyclotin WP
*Beta-cyfluthrin 2.5% EC
*Betacypermethrine EC
*Bifentrhin 0.05%PP,80g/l
*Bromopropylate EC
*Carbofuran 2.5%, 5% Granules
*Chlorpyriphos-ethyl 48%EC, 5% Granules
* Chlorpyriphos-methyl 50%EC
*Clofentezine
*Clofenzine EC
*Confidor super
*Cyfluthrin EC
*Cyhalothrin (15g)+Chlorpyriphos(300g)
*Cypermethrin 10%EC
*Deltamethrin (12g) +Chlorpyrifos(300g)
*Deltamethrin 2.5% EC,WP, Tablets
*Detamethrin
*Dichlorvos EC
*Dienochlor WP
*Dimethoate 40% EC
*Fenazaquin SC
*Fenbutatin oxyde SC
*Fenitrothion EC
*Fenthion 50% EC
*Fenvalerate EC
*Fipronil 0.05 RB, 25g/IFS
*Flufenoxuron EC
*Flumethrin EC
*Hexythiazox WP
*Imidachlopride 200g/l SL, EC, 300g/l SL, EC
*Lambda-cyalothrin 50g/l EC

*Malathion, PP
*Methomyl 90 WP
*Methomy SL
*Nimbecidine
*Omethoate EC
*Permethrin 0.5%PP; 0.7%EC; 20%EC; 25%EC
*Phosphure d'aluminum(PH3):pillis, tablets and plates for fumigation
*Pyrimiphos-methyl 2%PP
*Tau-fluvalinate EC
*Tebufenpyrad WP
*Teflubenzuron SC
*Teradifon EC

III.2.1.4. Fungicides

*Azoxystrobin SC
*Benalaxyl
*Benomyl 50%WP
*Bitertanol EC
*Bupimate EC
*Captan
*Carbendazime+chlorothalonil EC
*Chlorothalonil
*Cuivre+chlorothalonil 250g/l WP
*Cuivre+propineb 37%+17%WP
*Cuivre de l'oxyde de cuivre cuivreux
*Cuivre hydroxyde WP
*Cymoxamil+propineb
*Dichlofluanid WP
*Difenaconazole EC
*Dimethomorphe+mancozeb 69%WP
*Dithianon SC
*Dodemorph
*Epoxiconazole+carbendazime EC
*Fenarimol
*Flutriafol+thiabendazole EC
*Flutriafol 125g/SL, EC
*Fluzilazole EC
*Folpel 50WP
Folyoxin-al
*Fosetyl-aluminium WG
*Hexaconazole SC
*Iprobenfos 480g/EC
*Iprodione SC
*Kresoxim-methyl WG
*Mancozeb+metalaxyl 62.5% WP
*Mancozeb 80% WP
*Metiram WP
*Micronised Sulphur WG
*Oxychlorure de cuivre WP
*Penconazole EC
*Propamocarb hydrochloride SL
*Propineb 70% WP
*Pyrimethanil SC
*Tebuconazole WP, EC
*Thiabendazole EC
*Thiophanate methyl SC

*Thirame 80% WP
*Tricyclazole 75% WP
*Triforine EC
*Vinchlozoline 50% SL

11.2.1.5. HerbicideS

*2,4 D(ACIDE DICHLORO-2.4 PHENOXY ACÉTIQUE)

*Acide organique halogéné: dalapon 85% WP
*Alachlor+Atrazine
*Amerthrym 50SC
*Diuron
*Diuron 80 SC
*Gluphosate 360 LC
*Glyphosate 360g/l SL, Granulés
*Lasso-atrazine,EC
*Methribuzin
*Metolachlor 960g/l EC
*Paraquat 40g/L SL
*Propanil 360 g/l EC
*Triazine : Atrazine 500g/l SC, Ametryne 500g/SC
*Trrifluraline+linuron EC

11.2.1.6. Rondenticides

*Brodifacoum
*Bromadialone
*Bromadialone+Cumatetralyl+Sulfaquinox
*Coumatetryl
*Difenacoum

11.2.1.7. Nematicides

*ALDICARBE
*Dazomet 98% G
*PHENAMIPHOS

11.2.1.8.molluscicides

*Mercaptodimethu
*Methaldehyde 5 G

11.2.1.9. Regulateurs de croissance

*Daminozide 85% SP
*Substances à composition complexe : rootone ; speedone ;etc

11.2.1.10. Huiles adjuvantes

*ALKYL PHENOL/ETHYLENE

11.2.1.11. Moyens biologiques

* BACILLUS THURENGIENSIS

Annex 12.0: The PMP development methodology and documents and people consulted

a) Consult existing documents and reports
b) Consult RADA, RHODA, ISAR and extension staffs
c) Consult buyers
d) Consult inputs sellers

Annex 13.0: All documentation on Consultation for PMP.

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Annex 14: Development of an Integrated Pest Management (IPM) strategy in the frame of the LWH project in Rwanda.

I. Global concept and introduction remarks to IPM

I.a. General consideration relative to biotic constraints

The main goal of agriculture is production of food for human beings and generation of incomes for those who operate mainly in this primary sector of economy. However, agricultural production is hampered by various limitation factors including (i) low soil fertility, (ii) soil erosion, ((iii) limited access to various production factor (seeds for example), (iv) use of inappropriate cropping practices, (v) damages caused by biotic constraints (pests and diseases). This last category of constraints (pests and diseases) is a high limitation to the agricultural development in Rwanda. In fact, it is considered that in the country, biotic constraints induce yield losses at levels reaching 25-30% before harvest and 20% at the post harvest level[2]. In the same frame, a progressive increase of the problems due to pests and diseases was in Rwanda[3] . Some recent examples of pests and diseases which occurred in Rwanda as well as in the Eastern and Central African Region illustrate well how these constraints constitute a permanent threat for sustainable development based on agricultural production.

One example is the cassava mosaic disease (CMD) caused by several virus species belonging to the *Begomovirus* genus and inducing the typical symptoms of CMD[4]. Maruthi *et al.*[5] evoked existence of the following virus species inducing the CMD : (1) *African cassava mosaic virus* (ACMV), (2) *East African cassava mosaic virus* (EACMV) and (3) *Indian cassava mosaic virus* (ICMV). Each of the previous viruses was

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[2] Youdeowei, A. (2006). Proposal for a Pest Management Plan (A.), WB/ARMD

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[5] Maruthi M.N., Colvin J., Seal S., Gibson G. and Cooper J. (2002). Co-adaptation between cassava mosaic geminiviruses and their local vector populations. Virus Research, 86: 71-85

considered to have a restricted specific geographical localisation with ACMV and EACMV occurring respectively to the west and east of the African Rift Valley while ICMV is found in the Indian sub-continent.
Recent development of the disease in Rwanda affected most of the traditional clones leading thus to a very significant decrease of cassava production in the country.

A second biotic constraint which is reaching high importance in Rwanda is the Banana xanthomonas wilt (BXW) caused by the bacterial agent *Xanthomonas vasicola* pv. *musacearum* (formerly *Xanthomonas campestris* pv. *musacearum*)[6]. This disease is already established in Rwanda where it is observed in different districts of banana production. Given there are no resistant varieties, control measures have to be adopted in view of limiting the widespread of the disease throughout the country.

A third significant example of biotic constraint which is posing serious production problems in Rwanda is the Passion fruit woodiness disease induced by a potyvirus agent PWV[7]. In fact, development of passion fruit production in Rwanda was considered as being a strategic aspect due to the high value added of passion fruit. However, presence of woodiness disease in Rwanda was announced by ADAR/Chemonics[8] to have been identified for the first time in May 2002.

All these previous examples illustrate how control of pests and diseases has to be considered as a main priority. For that, it seems interesting to highlight the different control methods prior to IPM consideration in relation with the different crops.

I.b. Various methods of pests and diseases control

To reduce and/or limit damages induced by pests and diseases in crop production, different methods can be exploited. The different control methods can be grouped in the following main categories (i) use of appropriate cropping practices, (ii) use of genetic host resistance, (iii) chemical control methods, (iv) physical methods and (v) biological methods.

Cropping practices.

- By using the appropriate cropping measures, it is necessary to have a good understanding of the biotic agents (pests and/or pathogens) biology in view of reducing favourable conditions for them and thus making that plants escape their attacks. For example, crop rotation is a suitable cropping practice allowing limiting development of some specific pathogens and/or pests for a given crop. Its utilisation can thus lead to a sustainable control of biotic constraints in a context of intensive production system. It is considered that the purpose of crop

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[6] Biruma M., Pillay M., Tripathi L., Blomme G., Abele S., Mwangi M., Bandyopadhyay R., Muchunguzi P., Kassim S., Nyine M., Turyagyenda L. and Eden-Green S. (2007). Banana *Xanthomonas* wilt: a review of the disease, management strategies and future research directions. African Journal of Biotechnology, 6: 953-962.

[7] Silva de Novaes Q., Marques Rezende J.A. (2003). SELECTED MILD STRAINS OF *Passion fruit woodiness virus* (PWV) FAIL TO PROTECT PRE-IMMUNIZEDVINES IN BRAZIL. Scientia Agricola, 60: 699-708

[8] Anne Turner (2003). Integrated management of passion fruit diseases in Rwanda. ADAR/Chemonics.

rotation is to provide optimal growing conditions for cultivated plants by means of timely sequencing or grouping together the cultivation of various types of crops suitable to the location[9]. In fact, in systems where rotation of crops is not respected, there is a continuous selection pressure favouring development of pests and pathogens adapted for the crop of interest and this results rapidly in high levels of production losses.

Genetic resistance

- The use of genetic host resistance relies on the choice of varieties presenting resistance against the biotic constraints prevailing in a given area. In this frame, it is important to notice the existence of different types of resistance with specific resistance (vertical resistance) and non-specific resistance (horizontal resistance)[10]. These main categories of genetic resistance can be differentiated by the fact that specific resistance is efficient against some races within a given species of biotic constraint while the non-specific resistance is efficient against all the races within a given species of biotic constraint. By using a resistant variety, it becomes possible to easily control pests and/or diseases. This method of control seems to be very suitable in the context of farmers who have a limited access to the different production fact (pesticides for example). However, it is interesting to notice that specific resistance can be overcome through the process of resistance breakdown. An example of resistance breakdown is presently observed in different Asian countries where the banana variety 'Goldfinger' previously selected and widely used for its resistance against the Black Sigatoka disease has now lost its resistance properties leading to a very important development of disease symptoms.

Figure 1. Evolution of the resistance behaviour of the Goldfinger variety in Samoa (source: BAPNET Bulletin, volume 13 N° 1, January to March 2009).

Goldfinger in 1995 in Samoa

Goldfinger in 2006 in Samoa

[9] Heitefuss R. (1989). Crop and plant protection: The practical foundations. John Wiley & Sons, pp 261.
[10] Schumann G.L. and D'Arcy C.J. (2007). Essential Plant Pathology. The American Phytopathological Society, St. Paul, Minnesota USA, pp 338.

Based on this particular example, it appears clear that resistance to biotic constraint can evolve and a variety presenting resistance in a given area can become highly susceptible after a more or less long period of cultivation. In these conditions, it is important to adopt measures which can prolong durability of a given resistance.

To ensure sustainable efficiency of resistance, durable management of resistant varieties can be achieved through some particular schemes like the use of multilines and/or mixtures of varieties[11]. Efficiency of these strategies of multilines and/or mixtures is due to three main effects known as (i) dilution phenonmenon, (ii) barrier effect and (ii) induced resistance phenomenon. This explains the long efficiency in control of pests and diseases which is observed with common bean mixtures utilization in Rwanda and other countries in the Region.

Durable management of resistance has to take into consideration different data relative to the origin of inoculum (auto-infection or allo-infection) as well as to the pathogen (or pest) population evolution during the different successive cropping seasons.

Chemical control

- Chemical control of pests and diseases consists in application of chemical plant protection agents belonging to different groups according to the plant enemies to combat (fungicides, insecticides, acaricides, nematicides, herbicides etc...). According to the effect of the chemical product application, it is possible to differentiate (i) eradicative methods, (ii) protective methods and (iii) curative methods. For the eradicative methods, chemical plant protection agents are applied to destroy the damaging organisms outside or on host plants. In the frame of protective methods, plants are protected by having their surface covered by the chemical protection agent in view of preventing attack and invasion of the damaging organisms. Finally, for the curative methods, treatments of the already infested plants are achieved in view of ensuring that they are cured. In that context, the active ingredients of the chemical compounds must be capable of penetrating into the plant.

  Whatever the type of protection offered by the different main types of methods using chemical protection agents, it is essential to notice that although the efficiency in pests and disease control, the use of chemical protection agents leads to several types of negative consequences in terms of (a) effect on the ecosystem, (b) development of resistance and (c) residue problems (residues in foodstuffs, possibility of accumulation in the ground and risks of accumulation via the food chain).

  Now it is well established that intensive chemical plant protection results in negative effect on the ecosystem due to unbalanced and excessive application of

[11]Schumann G.L. and D'Arcy C.J. (2007). Essential Plant Pathology. The American Phytopathological Society, St. Paul, Minnesota USA, pp 338.

the plant protection agents. This phenomenon was already observed for insecticides, acaricides, herbicides and fungicides. One of the effects of high utilisation of chemical protection agents is the destruction of natural balances between the pests to be controlled and their natural enemies and/or indifferent organisms. This is unintentional removal of factors regulating populations.

On the level of development of resistance, there is possibility to observe a phenomenon of development of the ability in a population of damaging organisms to tolerate doses of a compound which are lethal to the majority of individuals in normal, untreated populations of the same species[12]. In these conditions, it becomes necessary to change chemical plant protection agents but the most common consequence at the farmer level is the increase of doses applied or to increase the frequency of treatments.

Physical methods for control of pests and diseases.

- Use of physical methods to combat damaging organisms in crop production remains limited. However, it is obvious that in some cases some physical treatments can be achieved to ensure control of pests and/or diseases. Physical methods can be subdivided into two main categories as following: mechanical methods and thermal methods. In mechanical procedures, the most known practice is the mechanical weeding which is widely in application under various tropical areas. Moreover, removal and destruction of diseased plants or part of plants from the field is a very common practice in different situations allowing limiting multiplication of inoculum in the field and thus limiting the importance of damages during the cropping season. Another example of mechanical action to control biotic constraint is in relation with flooding the ground. For example, to control damages induced by Panama disease in banana caused by *Fusarium oxysporum* f.sp. *cubense*, it can be proceeded to flooding the ground.

  In the same area of physical methods, it is feasible to combat damaging organisms by adopting methods using high temperatures; these methods are known as thermal procedures. This is only possible if the cultivated plants or their parts in need of treatment react to these temperatures less sensitively than the damaging organisms (pests or pathogens). The method is widely used through thermotherapy treatment to eliminate virus from already infected material. This treatment method aiming at eliminating virus infections is combined with meristem tip culture. It is also interesting to mention the efficiency of low temperatures to eliminate some pathogenic infections in plants. Treatments aiming at using very low temperature to eliminate pathogen infections are known under the name of cryotherapy[13]. For this method, shoot tips are briefly treated in liquid nitrogen by using cryopreservation protocols allowing eliminating pathogens like viruses, phytoplasmas and bacteria.

Biological control methods

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[12] Heitefuss R. (1989). Crop and plant protection: The practical foundations. John Wiley & Sons, pp 261.

[13] Wang Q. and Valkonen J.P.T. (2009). Cryotherapy of shoot tips: novel pathogen eradication method. Trends in Plant Science, 14: 119:122

This category of control methods consists in man-directed utilization of organisms (including viruses) and their performance or products to protect plants against stresses caused by biotic and abiotic factors[14]. In that frame, it can be deduced that biological control of pests and diseases relies on the deliberate exploitation of living organisms in view of reducing inoculum and thus protect plants. One of the most impressive facts related to biological control is the phenomenon of suppressive soils. It was observed that the pathogen populations are in competition with other living organisms playing a role of biological control agents. Biological control methods can be developed and used to combat pests, diseases and weeds.
Although the different advantages related to biological control methods, it is obvious that some limitations can reduce the efficiency of biological control methods. For example, the main limitation of biological control methods is due to the fact that the biological efficiency of biological organisms is often highly dependent on environmental conditions. Moreover, it is also essential to notice that selection and development of a biological control agent is labour and time-consuming.

I.c. Necessity of IPM (integrated pest management)

Limitations of the classical control methods
In the previous paragraphs, we have briefly presented description of the main categories of pests and diseases control methods which are available for crop protection practitioners. It appears that a diversity of methods can be performed in view of limiting production losses provoked by the various biotic constraints. The common property among the different main control methods is their efficiency to limit or reduce the damages due to pests and diseases.
However, to each individual main category of pests and diseases control method different limitations are associated. For example, the use of genetic resistance is hampered by the long period required for the selection process leading to availability of resistant varieties. Moreover, given different crop species are affected by diverse biotic agents, it is impossible to select a unique variety presenting resistance against the different pests and diseases which can affect the species. On the other side, there is also the phenomenon of resistance breakdown. A crop variety can present resistance for only a very limited period of time. This type of observation is already known by farmers in Rwanda more specifically with rice and potato. Resistance breakdown is mainly a result of selection pressure happening on pathogen and/or pest population leading to a significant increase of the frequency of some particular strains or races with ability to overcome the resistance properties of the variety.

If we consider the chemical control of pests and diseases, it is important to highlight the non durability of efficiency of the control because of the possible development of resistant strains which can lead to excessive utilisation of pesticides. Moreover, different

[14] Heitefuss R. (1989). Crop and plant protection: The practical foundations. John Wiley & Sons, pp 261.

other negative consequences[15] are related to the large utilization of chemical control. In fact, toxicity of pesticides can affect health of workers and/or consumers via different ways like ingestion, inhalation and contact with skin. It is also possible that the pesticides destroy populations of other living organisms which are not damageable for crops. Finally, the costs of crop protection based on the use of pesticides is high and thus non accessible for most of the farmers in developing countries.

On the side of biological control methods, it was previously mentioned that their efficiency is highly dependent on environment conditions. For that, strict biological measures are not sufficiently effective when it is necessary to perform a rapid control of suddenly occurring population outbreaks of damaging organisms.

[15] Lassoudière A. (2007). Le bananier et sa culture. Editions Quae, Versailles, France, pp 383.

Concept and interests of integrated pest management (IPM) strategy

The diverse control methods presenting specific limitations which make them non sustainable, it is essential to develop control strategies giving rise to a more durable efficiency in the management of pests and diseases. For that, combination of the existing control methods in a manner allowing avoiding the disadvantages of each individual control method can be highly beneficial in terms of control efficiency, economic profit, environment protection (natural resources preservation) and human health quality. In fact, there are interactions and synergies between the different control methods which can be exploited through their integrated use for pests and diseases control.

For example, a suitable cropping system involving crop rotation, removal of infested debris and care in application of fertilisers result in reduction of the pathogen population and opportunities for infection. On the other side, when resistance genes are used, probability of selecting pathogen strains able to overcome the resistance can be limited by adopting good cropping practices. Finally, when pesticides are used, it is less likely that pesticide resistance problems arise if the pathogen population is reduced.

In this frame, the Integrated Pest Management (IPM) has different definitions whose the common sense is the beneficial combination of the different control methods. For example, Heitefuss[16] considers that 'Integrated plant protection is a system in which all economically, ecologically and toxicologically suitable procedures are utilized in maximum harmony, for maintaining noxious organisms below the economic threshold; whereby the conscious exploitation of natural regulatory factors is of paramount importance'. On their side, Schumann and D'Arcy[17], Integrated pest management (IPM) is a site-specific, information-based, multitactic decision making process for the management of pests that is profitable for the grower and promotes health and environmental quality. The site specific aspect of IPM means that application of control measures with the IPM philosophy is not general and applicable in all the sites. Information from each site is essential and determines the way by which the control measures have to be achieved. The multitactic aspect states about the combination of more than one control method in view of taking a maximum of profit from the control strategy. It is thus essential to combine the different advantages related to each individual control method and by the same occasion overcoming the disadvantages of each individual control method.

Integrated pest management (IPM) is a control system that in the context of the associated environment and the population dynamics of the damages causal agents (pests and/or pathogens), utilises all suitable techniques and methods in as compatible manner as possible and maintains the biotic agent (pest or pathogen) populations at levels below those causing economic injury. In fact, it is important to notice that damages due to biotic constraints can be induced by pests and/or pathogens. These living organisms (pests and pathogens) are present in environment where crops are

[16] Heitefuss R. (1989). Crop and plant protection: The practical foundations. John Wiley & Sons, pp 261.

[17] Schumann G.L. and D'Arcy C.J. (2007). Essential Plant Pathology. The American Phytopathological Society, St. Paul, Minnesota USA, pp 338.

grown. Their interactions with crops are not stable, leading to evolution of pests and pathogens populations following the cropping practices which aim at producing foods and or other agricultural production.

IPM involves the integration of cultural, physical, biological, and chemical practices to grow crops with minimal use of pesticides. Monitoring, sampling, and record keeping are used to determine when control options are needed to keep pests below an economically damaging threshold. Pest management, not eradication, is the goal of IPM. The well documented decision making process in relation with the control of pests and diseases generates multiple profits in relation with economic costs of control, environment quality, health of growers and consumers and finally sustainability of the control measures.

In summary, IPM is a sustainable approach to managing damaging agents (pests and pathogens) by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health, and environmental risks.

IPM strategy in the frame of the LWH project in Rwanda.

The Rwandan LWH project aims at reaching different objectives among which transformation of hillside intensification with a view to increasing productivity in an environmentally sustainable manner. Production of high-value (organic) horticultural crops is one component of the project.

It is well documented that intensification of crop production has to take into account aspects relative to crop protection. As observed on different crops in Rwanda (passion fruit, cassava, banana, and rice), pests and diseases constitute major limitations which have to be managed in a suitable manner. To reach this target, it will be essential that the LHW project develop a global IPM strategy in view of ensuring production of high-value (organic) product. By adopting well adapted IPM strategies, it would be possible to generate productions of different horticultural products without using pesticides. In the following chapters, the different horticultural crops and description of the IPM strategies to implement according to the main biotic constraints will be developed. The concerned horticultural species are mango (*Mangifera indica*), avocado (*Persea americana*), banana (*Musa* sp.), Passion Fruit (*Passiflora* sp.) and pineapple (*Ananas comosus*). Prior to describing IPM strategies for these crops in view of the LWH implementation, it will be necessary to proceed to description of the different main biotic constraints affecting the horticultural crops under tropical conditions.

II. Implementing IPM strategy on mango in the frame of the LWH project.

II.a. Introduction to mango production system.

Mango is considered as being the fifth most important fruit crop in the world with global production estimated to reach 24.8 million tonnes in 2000[18]. India is the main producer of this fruit crop followed by the different major producing countries like China, Mexico,

[18] FAO (2000). FAOSTAT online database at :http://www.fao.org/default.htm.

Thailand, Pakistan, Philippines, Indonesia, Nigeria and Brazil. Only a small proportion of the total production of this fruit is exported, the majority of production being consumed locally.
A great diversity of diseases affects this fruit species at different development stages inducing damages at the nursery stage (seedlings and grafted plants), decrease of fruit production and retention. At the level of fruit, damages are recorded at pre-harvest as well as at post-harvest stages[19]. Most of the diseases affecting mango are caused by fungal agents. In the following paragraphs, a brief description of the main diseases affecting mango production is developed as well as the control strategy to implement in view of durably limiting the damages due to these diseases.

II.b. Description and management of the main biotic constraints affecting mango

II.b.1. Fungal Mango black spot disease

This disease is caused by a fungal pathogen, *Alternaria alternata* which attacks different plant organs like leaves, panicles and fruits[20]. On fruits, this disease induces to development of a post-harvest fruit rot in different regions (Australia, Egypt, India, Israel, South Africa). Most of the commercial cultivars are susceptible to this pathogen.
The disease is easily recognised by its typical symptoms appearing as round and black spots of 1-3 mm of diameter more particularly on the underside of leaves. Similar lesions are also observed around lenticels on fruits on which they can expand and merge to cover much of the fruit surface. The damages caused by this disease are significant only in arid environments. At the epidemiological level, infected leaves and inflorescences constitute an important source of inoculum for fruits. Fruit infections are favoured by long periods of humidity higher than 80%. These infections happen mainly after ripening begins.

Control
For its management, it seems interesting to limit source of inoculum. For that, progressive elimination of the leaves presenting symptoms could limit the presence of inoculum for fruit. At the post harvest level, the HWB (hot water brushing) treatment that combines a 15 - 20 s of hot water spray and fruit brushing can be efficient in control of the disease and thus contributes to reduction of post-harvest pesticide application.
However, as many farmers will be involved in the production of mango in the frame of the LWH project, it will be essential that a technical supervision be given to farmers in order of training them at the field level to recognise the disease symptoms and to achieve the recommended control measures.

II.b.2. Mango anthracnose

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[19] Ploetz R.C. and Prakash O. (1997). Foliar, floral and seedbornediseases. In: Litz, R.E. (ed.). The mango, Botany, Production and Uses. CAB International, Wallingford, UK, pp. 281-326.
[20] Ploetz R.C. (2003). Diseases of Mango. In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 327-363

This disease is the most important affecting mango in all but arid production areas where it constitutes a major pre- and post-harvest problem. The following picture illustrates aspect of mango fruits affected by anthracnose.

Figure 2: Picture of mango anthracnose symptoms on fruits (obtained from the article of Pitkethley, 2007).

At the epidemiological level, new leaves emerging during rainy periods are most susceptible. Leaf lesions appear as small, dark brown spots that are surrounded by chlorotic haloes with irregular margins and are not limited by leaf veins. When humidity conditions are favourable, these lesions enlarge and coalesce to form irregular patches. Centres of old lesions deteriorate and fall from the leaf resulting in a perforated, tattered appearance. Three closely related fungal taxa are responsible of mango anthracnose: *Colletotrichum gloeosporioides*, *Colletotrichum gloeosporioides* var. *minor* and *Colletotrichum acutatum*.

Control

Infected leaves and inflorescences constituting the main sources of inoculum for ruits, it is important to apply control measures prior to flowering. Prophylactic measures aiming at reducing the quantity of inoculum should be useful in terms of decreasing the probability of fruit infection.

However, fruit to fruit transmission is also possible during storage or shipment of fruits. For that, hot water treatments as well as fungicide dips can improve the control conditions of this disease.

II.b.3. Mango bacterial black spot (black canker)

The disease is very common in many production areas where it can induce fruit losses higher than 50 on the most susceptible cultivars. The disease is characterized by symptoms on leaves, stems and fruits. On leaves, the lesions begin as water-soaked spots with an initial diameter of 1-3 mm. When they enlarge, they become raised and present an angular aspect because limited by veins. Defoliation occurs in severe cases. The causal agent is a bacterial pathogen named *Xanthomonas campestris*. pv. *mangiferaeindicae*. Dissemination of the disease is achieved by wind-driven rain as well as by infected propagation material and infected fruits.

Control
To control the disease, it is important to ensure the use of non infected planting materials when new orchards are established. The infected twigs should be removed and destroyed to reduce inoculum pressure in the canopy.

II.b.4. Black mildew and soot moulds

These diseases are provoked by different fungal species which form layers of hyphae that may block sunlight and reduce photosynthesis. On the other side, these contaminations reduce the aesthetic quality of the fruits. Black mildew is caused by *Meliola mangiferae* which is an obligate parasite. On the other side, the fungi causing sooty moulds are diverse saprophytes requiring honeydew produced by insects to colonise plant surface.

Control
Given the relation between the fungal pathogens and the associated insects (aphids, mealybugs, scales and other sucking insects), a suitable control of the insect development allows dissipating the problems.

II.b.5. Powdery mildew

Powdery mildew symptoms affect leaves, panicles and fruits in mango. The causal agent is *Oidium mangiferae* inducing in some conditions yield losses reaching 90%. On affected panicles, all the tissues can be covered by the powdery resulting in a brown and shrivelled necrosis.

Control
When infections are observed, it is necessary to proceed to application of fungicides. However, it was demonstrated that alternating fungicide applications and phosphate fertilizers can be used in an integrated control scheme of the disease[21]. These measures can be adapted to local conditions. Moreover, cultural practices leading to

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[21] **Reuveni M., Harpaz M. and Reuveni R. (1998). Integrated Control of Powdery Mildew on Field-grown Mango Trees by Foliar Sprays of Mono-potassium Phosphate Fertilizer, Sterol Inhibitor Fungicides and the Strobilurin Kresoxym-methyl. European Journal of Plant Pathology, 104: 853-860.**

reduction of favourable conditions for the disease can also be used to increase its control efficacy.

II.b.6. Insect pests of mango

Mango is susceptible to a diversity of insect pests including swarming beetles, fruit flies, termites and mango seed weevil. There are other insects occurring more commonly redbanded thrips, mango tip-borer, flatids and various scale insects.

Control

To ensure control of these pests, it is important that monitoring of pest population be performed as regularly as possible. For that, Growers who monitor their mango trees can detect insect pest problems in the early stages before damage becomes severe. The grower can then decide whether to increase or decrease the periods between monitoring checks and to assess if natural controls or specific control treatments are necessary. When pests are sprayed in the early stages of development, pesticides are usually more effective and a less toxic chemical may be used. Outbreaks of pests, when caught at this early stage may be controlled by spot spraying instead of the over-all cover spray which would be required in a larger outbreak.

II.c. Global conclusion about IPM in mango

A great diversity of pests and diseases is affecting mango under tropical conditions. Most of the diseases are caused by fungal pathogens. For the control, it is important to notice that genetic resistance cannot be enough to control the different diseases and pests. In fact, it is impossible to obtain one variety with resistance against the different pests and diseases affecting mango. The same fact is true in relation with chemical control by which should be impossible to get a product with efficacy against the different pests and diseases. To overcome the different difficulties, it should be interesting to develop IPM protocols based mainly on cropping practices, education of farmers to recognise pests and diseases as well as natural enemies. Implementation of a diversity of mango cultivars would be of a high importance. In fact, if only a very limited number of cultivar is used in the frame of LWH project, the practice would result in a generalised selection pressure which could compromise the durability of mango production in the country. Prophylactic measures consisting in eliminating parts or entire infested plants would allow reducing the inoculum pressure in the future production sites. Finally, regular monitoring of the mango orchards would constitute a suitable strategy to take the better decision in terms of managing the insect pests problems in mango production system.

III. Implementing IPM strategy on avocado in the frame of the LWH project

III.a. Introduction to avocado production system

Avocado, *Persea americana*, is considered as being one of the major fruit crops in tropical and subtropical regions. Globally, there are three races within the species, *P.*

americana var *drymifolia*, *P. americana* var *guatemalensis* and *P. americana* var *americana*.
Diversity within the species is very high in a way such seed-propagated trees usually bear no resemblance to the mother tree. In that context, cultivars have to be maintained clonally[22]. The different avocado cultivars are generally kept through grafting on rootstock cultivars that are usually selected for different characteristics among which resistance to cold, root diseases and vigour. Avocado production is hampered by different biotic constraints due to a diversity of noxious agents.

III.b. Description and management of the main biotic constraints affecting avocado

III.b.1. Anthracnose

This disease reported from the majority of avocado producing areas in the world is the most common cause of rot on avocado mature fruits where it can induce fruit losses up to 37%[23].
The disease is caused by two different fungal species; *Colletotrichum gloeosporioides* and *Colletotrichum acutatum*. On leaves, symptoms appear as chlorotic, then necrotic brown spots which coalesce to generate more large lesions. In case of great severity, the disease can lead to avocado defoliation. On new shoots, severe infections lead to shoot dieback while dark lesions develop on the inflorescence causing its death or abortion of fruit.
At the epidemiological level, the pathogens produce survive by producing conidia on dead tissues (twigs and leaves). These spores are disseminated by rainsplash and contaminate all the aerial portions of avocado plants.
High temperature (28°C) and high moisture levels are the most favourable condition for spread of the pathogens and for infection of new tissues.

Control
For the control of the disease, a combination of different strategies like resistant cultivars, cultural practices in the field, preharvest and *postharvest* treatment, correct storage conditions and rapid marketing to avoid long storage periods which can result in rot development. At the level of cultural practices, it can be noticed that elimination of lower leaves leads to decrease of the humidity in the canopy while removing the dead tissues (dead twigs, leaves and fruits) contributes to reducing inoculum in the field. Storage conditions can also be taken into consideration to reduce the impact of the disease as it is established that anthracnose development is severe when avocados are stored under temperatures higher than 24°C[24]. In fact, temperatures ranging from 5 to

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[22] Menge J.A. and Ploetz R.C. (2003). Diseases of Avocado. .In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 35-71.
[23] Fitzel R.D. (1987). Epidemiology of anthracnose diseases on avocados. South African Avocado Growers' Association Yearbook, 10: 113-116
[24] Prusky D. (1994). Anthracnose. In : Ploetz R.C., Zentmeyer G.A., Nishijima W.T., Rohrbach K.G. and Ohr H.D. (eds). Compendium of Tropical Fruit Diseases. APS Press, St Paul, Minnesota, pp. 72-73.

18°C are not favourable for disease development. It is however preferable to let the fruits ripening and then proceed to their conservation at 2-4°C for extended periods.

III.b.2. Bacterial soft rot

This particular disease is caused by two different bacterial agents, *Erwinia herbicola* and *Erwinia carotovora*. The disease occurs in the field as well as at the postharvest level in wet tropical and subtropical climates. Skin of the affected fruits becomes dark while internally, the fruit is brown and liquefied and generates a putrid odour.
The causal agents are generally common saprophytic organisms on leaves, stems and fruits. However, they become pathogenic under stressful conditions like wounding.

Control

Preventing injuries during the harvest process contributes to significantly reduce the probability of pathogen penetration within the fruit. In that way, it is important to let the pedicels attached to the fruits to limit entry of the pathogen in the harvested fruits. It is also important to avoid harvesting when the fruit are still wet because it is well established that high humidity conditions are favourable to the disease development.

III.b.3. Pseudocercospora spot (blotch)

The disease is known under different names like blotch, Cercospora spot and black spot. The disease is frequent under warm, humid and rainy conditions. The damages caused by this disease can lead to yield losses up to 69%.
Symptoms of the disease appear on different aerial organs (leaves, stems and fruits) as small lesions (1-5 mm) with an angular aspect. With time, these lesions are surrounded by chlorotic haloes. The causal agent is a fungus named *Paracercospora purpurea*. Conidia of the pathogen are produced on leaves and can be present the whole year on the infected leaves if environmental conditions are favourable. After infection, the incubation period can be as long as 3 months. Young fruits and fruits near maturity are immune while fruits from a quarter to three-quarter size are very susceptible. All the cultivars of *P. americana* are affected by the pathogen.

Control

Cultural practices consisting in pruning and elimination through grounding or removal from the orchard can improve the disease control conditions.

III.b.4 *Phytophthora* cankers

Phytophthora cankers occur on avocado plants where they provoke lesions starting from under ground organs and may extend 3 m up to trunk and branches. Cankers exude brownish red viscous sap which becomes brownish powder after drying. This powder incrusts the provoked lesions.
Different pathogenic agents are responsible of the disease: *P. boehmeriae*, *P. cinnamomi*, *P. citricola*, *P. heveae* and *P. palmivora*[25]. Among these different pathogens causing the disease, only P. cinnamomi is reported in Africa and it is the single to provoke important damages on avocado roots.

[25] Menge J.A. and Ploetz R.C. (2003). Diseases of Avocado. .In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 35-71

Control

It is important to avoid wounding during the different field operations. In the same context, to avoid plant to plant transmission of the pathogens, it is advised to disinfect pruning tools. When the risk of Phytophthora cankers is high, it can be recommended to protect wounds from pruning by chemical protection.

The case of Phytophthora cinnamomi: Phytopthora root rot.

As mentioned above, P. cinnamomi is the only agent to known provoke also significant damages on avocado roots. It is considered as being one of the most limiting production factors in avocado. The disease can be exptremely destructive spreading rapidly and killing most of the trees. The affected roots become black and when the disease is advanced, the feeder roots become scarce.

Control

To avoid spreading of this dangerous disease, it is necessary to implement strict certification programmes to ensure that clean nursery practices are followed in view of using clean for propagation. In the same frame, seeds should be treated with hot water (49-50°C for 30 min) prior to use. Affected plants must be destroyed rapidly to reduce the chance of inoculum multiplication.

III.c. Global conclusion about IPM in avocado

The above mentioned biotic constraints are caused by diverse agents and cause damages at different levels at the pre-harvest and post-harvest stages in avocado. The common fact between the different management schemes is that avoiding inoculum production and multiplication in the orchards remains and determinant action to undertake to limit losses due to the different diseases.

An important aspect to be considered for a sustainable control of avocado biotic constraints is in relation with the quality of planting materials. In fact, using planting materials free of any infection allows is a basic condition to start crop growth in favourable conditions. For that, elimination of the infections in the planting materials occupies a central place in the global control of pests and diseases. Achieving the technical protocols aiming at eliminating infections from the planting materials relies to the global practices of biotic constraints agent exclusion.

It is also important to notice that observing the different conditions surrounding the development and spread of the different constraints remains essential. For example, it well known that planting avocado in places where crops susceptible to Versticillium wilt were grown previously is to be prohibited.

IV. Implementing IPM strategy on bananas in the frame of the LWH project

IV.a. Introduction to banana production systems

Bananas are considered as being one of the most fascinating and important crops in the word. Their production are used in different ways determining the main categories of bananas among which the (i) cooking bananas, (ii) dessert bananas and (iii) plantains.

All the cultivated bananas varieties arose from two species, *Musa acuminata* and *Musa balbisiana*. They provide hundreds of millions of people throughout the tropics and subtropics with an essential staple food and account for one of the most widely exported fruit in the world[26]. Bananas are vegetatively propagated with either suckers or rhizome pieces. Moreover, plantlets produced from meristems are widely used though the process of in vitro tissue culture.

In the different producing areas, banana production is strongly hampered by a diverse series of biotic constraints including diseases and pests[27]. The diseases are induced by diverse main categories of pathogens; it can be differentiated diseases caused by: (1) fungal pathogens, (2) bacterial pathogens and (3) viral pathogens. On the side of pests, the most important ones are: banana weevil, nematodes, and different insect species acting as vectors of diseases (aphids and melybugs). The importance of losses due to pests and diseases justified implementation of different breeding programmes. In that context, to overcome the limitations imposed by these different biotic constraints met in banana plantations, different control methods were developed in view of a durable production of bananas.

IV.b. Description and management of the main biotic constraints affecting bananas

IV.b.1. Black Sigatoka disease.

This fungal disease caused by Mycosphaerelle fijiensis is currently considered as being the most important constraint of banana production at the economical view point[28]. Damages due to this disease are mainly recorded in commercial plantations where only one variety (Cavendish type) is cultivated. In this context, chemical control is the most

[26] Teycheney P.Y., Marais A., Svanella-Dumas L, Dulucq M.J. and Candresse T. (2005). Molecular characterization of banana virus X (BVX), a novel member of the *Flexiviridae* family. Arch Virol, Online publication June 22, 2005.
[27] Lassoudière A. (2007). Le bananier et sa culture. Editions Quae, Versailles, France, 383 p.
[28] Fouré E (1994) Leaf Spot Diseases of Bananas and Plantain caused by *Mycosphaerella musicola* and *M. fijiensis*. In: Fullerton R.A. and Stover R.H. (eds), Sigatoka Leaf Spot Diseases of Bananas. INIBAP, Montferrier sur Lez, pp. 37-46

widely used method. The disease was first reported in Fijian island in 1963 and its spread worldwide has occurred recently. In fact, it was first reported in Africa in 1973[29]. In Rwanda, the disease is also present and that fact must be taken into account for a durable management of banana production in the country.

The pathogen infects plant when contacts between its spores (conidia and/or ascospores) with plant tissues are established. These spores are produced under high moisture conditions and are disseminated by wind. Ascospores play a major role in dissemination of the disease within plants and plantations.
Infected plant movement as well as leaves used as packing materials can facilitate and contribute to long distances movement of the pathogen.

Control
Control of the disease is determined by different factors like (i) the grown cultivars, (ii) the environment and the intended market for the production. In export plantations, control is mainly based on application of fungicides. However, it remains possible to improve control of the disease by using suitable cropping practices based on removal of leaves with mature spots, reducing humidity within plantations by increasing spacing between plants.
Given the high diversity of pathogen races, it is possible to improve the disease management conditions by promoting the maintenance and utilization of the crop diversity.

IV.b.2. Other Mycosphaerella leaf spots diseases
Other diseases due to pathogen agents belonging to the Mycosphaerella genus hamper banana production. These are the following diseases: (i) Yellow Sigatoka caused by *Mycosphaerella musicola*, (ii) *Mycosphaerella* Speckle caused by *Mycosphaerella musae* and (iii) *Eumusae* leafspot caused by *Mycosphaerella eumusae*. The yellow Sigatoka disease was the most important leaf disease before the spread of Black Sigatoka.
The different methods previously evoked for the control of of Black Sigatoka disease can also allow limiting the impact of these other foliar diseases.

IV.b.3. Panama disease
This disease caused by the fungus *Fusarium oxysporum* f.sp. *cubense* is characterized by a first internal symptom appearing as a reddish brown discoloration of the xylem in feeder roots which are the initial sites of infection. When the disease is advanced, there is a yellowing of oldest leaves. The Gros Michel variety was abandoned in the banana industrial production and replaced by Cavendish varieties due to this disease.

Control
Good cultural practices consisting in avoiding growing bananas on soils already affected by the pathogen as well as on using planting materials which is not already infected by the fungus. In fact, if the planting materials are obtained from an area already affected

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[29] Ploetz R.C., Thomas J.E. and Slabaugh W.R. (2003). . Diseases of Banana and Plantain. In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 73-134

by the fungus, this would constitute an important factor of the disease dissemination. In that frame, the use of tissue-cultured plantlets should allow establishing new plantations without high risks of Panama disease if the soil is not already contaminated.

IV.b.4 Other main fungal diseases

In addition to the previously described diseases, other fungi are causal agent of diverse diseases. These include (i) *Cladosporium* speckle caused by *Cladosporium musae*, (ii) anthracnose caused by *Colletotrichum musae*, (iii) cigar-end rot caused by *Trachysphaera fructigena* and *Verticillium theobromae*.

Control

The different diseases can be controlled by prophylactic measures consisting in eliminating the diseased parts in view of avoiding inoculum accumulation. These measures can be completed by other good cropping practices as well as by some chemical control through application of fungicides. However, fungicides have to be used only in some exceptional situations when the other control measures cannot reduce the pathogen populations.

IV.b.5 Banana bacterial diseases

Diverse bacterial diseases affect bananas in production areas. However, it is important to highlight those having an high impact on banana production and more particularly in the Eastern and Central Africa.

* *Moko disease*

One of the most important bacterial diseases is the Moko disease caused Race 2 of *Ralstonia solanacearum*. It is characterized by development of chlorosis on oldest leaves, wilt, buckle and death of these affected leaves. The vascular system in the rhizome, pseudostem and peduncle is discoloured light to dark brown. There is great similarity between external and internal symptoms of Panama disease and Moko disease. However, only Moko disease affects fruits

Control

This disease is managed by regular inspection and eradication programmes based on (i) early recognition of the disease, (ii) removal of the male bud, (iii) destruction of affected and neighbouring plants.

* *BXW*

Another bacterial disease which is now widespreding in the Region and in Rwanda is the banana xanthomonas wilt caused by *Xanthomonas campestris* pv *musacearum* presently known as *Xanthomonas vasicola* pv. *musacearum.*

Control

Control measures are mainly cultural based on the use of non infected planting materials, early identification of infected plants, destruction of infected plants, limiting vector dissemination of the disease by removing male buds. It is important that there is no chemical treatment to control this type of disease.

IV.b.6. Banana virus diseases

In banana production systems, virus infections are highly difficult to combat as they are transmitted through the different ways of vegetative propagation[30] of bananas and plantains. Different viruses including the Cucumber Mosaic Virus (CMV, RNA virus), the Banana Bunchy Top Virus (BBTV, DNA virus), the Banana Streak Virus (BSV, DNA virus), the Banana Bract Mosaic Virus (BBrMV, RNA virus) and the Banana Mild Mosaic Virus (BanMMV, a RNA virus) are known to naturally infect *Musa* genotypes[31 32 33].

Most of these viruses are widely distributed in *Musa* accessions throughout the different continents. The case of BBTV, which is not present in Latin America, is an exception necessitating very strict control measures to avoid introducing this quarantine pathogen in the Region.

The endemic presence of *Musa* viruses in producing regions is a serious threat to health of the planting materials and thus for global management of these viruses. For example, there is no resistance against BBTV which is the virus having the highest impact on banana. On the other side, all the virus infections don't result in development of symptoms. This situation complicates the process of identification of virus infected accessions and thus contributes to dissemination of these pathogens to different planting regions.

The different viruses infecting *Musa* are transmitted by vectors, except the case of BanMMV for which the potential vector is not yet identified.

Control

At the management side, it is important to ensure utilization on non-infected planting materials to avoid dissemination of the different viruses. For genotypes of interest, operations of virus eradication can be undertaken to eliminate the infections and thus regenerate materials without any virus infection. These protocols can be easily performed in tissue culture laboratories where treatments of thermotherapy, chemotherapy, meristem tip culture can be achieved to eliminate the different viruses. To ensure success of the operations, highly sensitive detection methods have to be used to control health of the treated materials in terms of virus detection.

In parallel to these treatments and protocols, farmers would have to be trained in recognising virus symptoms and monitoring of the vector populations. Materials showing virus infections are to be eliminated progressively from the field to avoid virus dissemination by the way of vectors.

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[30] Diekmann M. and Puetter C.A.J. (1996). FAO/IPGRI Technical Guidelines for the Safe Movement of Germplasm, No.15, Musa, second ed. Food and Africulture Organization of the United Nations/International Plant Genetic Resources Institute, Rome.

[31] Sharman M., Thomas J.E. and Dietzen R.G. (2000). Development of a multiplex immunocapture PCR with colourimetric detection for viruses of banana. Journal of Virological Methods, 89: 75-88.

[32] Thomas J.E., Lockhart B.E.L., Iskra-Caruana M.L. (1999). Banana mild mosaic. In: Jones D.R. (ed.) Diseases of Banana, Abacá and enset. CABI, Wallingford, pp 275-278

[33] Gambley C.F. and Thomas J.E. (2001). Molecular characterisation of Banana mild mosaic virus, a new filamentous virus in Musa spp. Archives of Virology, 146: 1369-1379

IV.b.6. Pests of bananas

** Banana weevil*

Among the diverse pests affecting bananas, *Cosmopolites sordidus* (banana weevil) is considered as being of world importance[34]. Most of the banana cultivars are susceptible to this pest. Cultural control is very valuable in preventing the establishment of the weevil and is the only means currently available by which resource-limited, small-scale growers can reduce established population.

Control

For that, the quality of planting materials is an important parameter to take into account for durably controlling the banana weevil problems. According to God and Messiaen[35] Wherever possible, new production areas should be established in uninfested fields using clean planting material. Where tissue culture is not available, farmers should pare suckers to remove weevil larvae and eggs. Badly damaged suckers should not be used for planting. Hot-water treatment has also been widely promoted for weevil and nematode control. Recommendations suggest immersing pared suckers in hot-water baths of 52-55°C for 15-27 minutes. These baths are very effective in eliminating nematodes, but kill only a third of the weevil larvae.

Thus, clean planting material is likely to provide protection against weevil for several crop cycles only.In the same frame, other research aiming at developing other control methods like the biological ones as well as genetic resistance are under development. These different methods would be integrated to perform an integrated management system of the problems affecting bananas.

** Banana nematodes*

Around the world, 43 genera of nematodes have been reported to affect *Musa* sp. However, the most important are *Radopholus similis* followed by *Pratylenchus coffae* and *Pratylenchus goodeyi* and Helicothylenchus multicinctus[36 37].

Control

Management of nematodes problems is mainly based on cultural methods consisting in avoiding planting bananas in places where these problems are already declared. Moreover, a special care must be put on the quality of planting materials. Materials issuing from in vitro multiplication are free of nematodes and should be used to plant in new production areas. However, when it is not possible to get this type of materials, traditional suckers can be treated by hot water (52-55°C for 15-20 min) after removal of all symptomatic tissues[38]. When it appears that soil is already infested by nematodes,

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[34] Lassoudière A. (2007). Le bananier et sa culture. Editions Quae, Versailles, France, 383 p.

[35] Gold C.S. and Messiaen S. (2000). The banana weevil *Cosmopolites sordidus*. Musa pests fact sheet, N° 4.

[36] Lassoudière A. (2007). Le bananier et sa culture. Editions Quae, Versailles, France, 383 p.

[37] Ploetz R.C., Thomas J.E. and Slabaugh W.R. (2003). . Diseases of Banana and Plantain. In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 73-134

[38] Ploetz R.C., Thomas J.E. and Slabaugh W.R. (2003). . Diseases of Banana and Plantain. In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 73-134

fallowing for at least a period of 12 months and/or rotation with non hosts crops are recommended measures.

IV.c. Global conclusion about IPM in bananas

In the previous sections, it was highlighted that bananas are affected by a great diversity of pests and diseases. In these conditions, it should be impossible to have a single method allowing performing the different potential biotic constraints. There is a real interest for integrated pest management in this frame. Cultural practices aiming at avoiding increase of pests and pathogen populations will have to be promoted in the frame of the LWH project. This will necessitate that farmers be trained and accompanied in order to allow them becoming experts in recognising the biotic constraints to production as well as in taking the suitable decision at the level of cultural practice to perform.
It was shown that for a great majority of problems, using planting materials free of any infection is a fundamental step in the control of the different problems. In that way, the LWH project should support the national infrastructures (tissue culture laboratories and nurseries) to produce enough quantities of clean planting materials.
Finally, given the existence of a genetic diversity of bananas in terms of varieties, there are possibilities to manage the different problems through a sustainable utilisation of these varieties. It would be essential to avoid favouring selection pressure by proceeding to exploitation of the genetic diversity of banana in the country. It is not recommendable to use a limited number of varieties because this type of management could lead to a rapid selection of some particular races.

V. Implementing IPM strategy on Pineapple in the frame of the LWH

V.a. Short introduction to pineapple production

Pineapple is mainly produced in Thailand, Philippines and Brazil where fruits for export are produced on large plantations due to the need for year-round production[39]. Which cannot regenerate when damaged. 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. Given the diversity of diseases affecting the species, an overview will be given to some of them leading to high damages in African conditions.

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[39] Rohrbach K.G. and Schmitt D. (2003). Diseases of Pineapple. In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 443-464

V.b.1. Yellow spot disease and the thrips vector.

This disease is woldwide distributed and is caused by a virus named TSWV (Tomato spotted wilt virus) previously known as Yellow spot virus. This virus is transmitted to pineapple by a vector *Thrips tabaci.* Infection with this pathogen is fatal. The virus has a wide range of hosts including tomatoes, peppers, celery, eggplant, peanuts, lettuce, pineapple, many legumes, many ornamentals and weeds species. This diversity of hosts complicates control of the virus in pineapple plantations.

Control

However, by promoting the use of good cropping practices, it is possible to decrease of incidence and severity of the disease. For that, it can be undertaken to crop by starting with virus-free plant material, removing all infected plants controlling weeds, and rotating crops.

V.b.2.Mealybug wilt

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. These pests are by mealybug parasites and predators and this strategy contributes to significantly reduce the problems due to these pests.

V.b.3. Phytophthora heart rot

This disease has been reported in different production areas and is characterized by the fact that leaves of affected plants fail to elongate and develop chlorosis. This disease is caused by different species of Phytophthora: *P. cinnamomi*, *P. nicotianae* and *P. palmivora*.

Control

To perform the disease control, it is essential to improve soil drainage. In some cases, resistant varieties can be found and they can be used to increase the disease control level.

VI. Implementing IPM strategy on Passionfruit in the frame of the LWH

VI.a. Introduction to Passionfruit

The genus *Passiflora*, within the *Passifloraceae* family contains around 400 species among which only 60 give rise to edible fruit. The passionfruit, *Passiflora edulis* Sims., which originated from South America became very popular and is nowadays cultivated in many areas under tropical and subtropical conditions where the fruit production is eaten as fresh fruit or used commercially for juice production.

Adaptation of the passionfruit genotype to a given area depends on temperature and elevation conditions. In this frame, the golden (yellow) passionfruit, *Passiflora edulis* f. *flavicarpa* Deg, which is considered as the most important cultivar worldwide is cultivated in lowland conditions while the purple passionfruit, *Passiflora edulis* f. *edulis* is adapted to highland conditions with cool night temperatures.

Around the world, passionfruit production is hampered by a series of diseases caused by pathogens belonging to fungi, bacteria, nematodes and viruses.

VI. b. Passiofruit woodiness disease

The Passiofruit woodiness virus (PWV), a member of potyviruses constitutes one of the main constraints reducing significantly the crop production. Described for the first time in Australia during the 1980s, the PWV is now known to have a worldwide distribution in tropical and subtropical areas. Its presence was confirmed within countries like Brazil, Nigeria, South Africa, Taïwan, Hawaï, India, Japan, Kenya, Malaysia and Philippines. The appearance of PWV in Taiwan during the 1980s resulted in the first great limitation to passionfruit production on the island[40]. Recently, the presence of woodiness disease in Rwanda was announced by ADAR/Chemonics[41] as being identified for the first time in May 2002. The disease is characterized bypericarp malformed, thickened and hardened with a much reduced pulp cavity and fewer seeds. Other symptoms related to the disease are leaf mosaic, mottle and ringspot.

Some works have associated the woodiness symptoms with different types[42] of infection like (i) single infection with PWV (a member of the Potyvirus genus), (ii) single infection with CMV (a member of the Cucumovirus genus) and (iii) mixed infections with PWV and CMV. PWV is only transmitted by aphids and mechanically by grafting while CMV is transmitted by aphids, mechanically and through seed transmission which is a common way of transmission for CMV.

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[40] Chang C.A. (1992). Characterization and Comparison of Passiofruit Mottle Virus, a Newly Recognized Potyvirus, with Passiofruit Woodiness virus. Phytopathology, 82 :1358-1363

[41] Anne Turner (2003). Integrated management of passion fruit diseases in Rwanda. ADAR/Chemonics.

[42] Manicom B., Ruggiero C., Ploetz R.C. and de Goes A. (2003). Diseases of Passion Fruit. In: Ploetz, R.C. (ed.). Diseases of Tropical fruit crops. CAB International, Wallingford, UK, pp. 413-441.

Control
To perform control of the woodiness disease, it is essential to consider they transmission way of the causal agents. As PWV is not transmitted by seeds (this is also the case for the other potyviruses infecting passion fruit plants), strict measures for seed selection from producers can facilitate eliminating this pathogen. However, it is important to notice that CMV being transmitted by seeds, it is important to operate a rigorous selection in the nurseries to avoid this CMV agent. In this frame, it can be noticed that difficulties for this step are due to the fact that symptoms can be latent. It would be necessary to develop highly sensitive detection protocols and this would be easy in Rwanda because laboratories with molecular biology equipments are available and can serve in that way to increase the health control of Passionfruit nurseries.
For a long term control, it would also be envisaged to create hybrids between purple form (*edulis*) and the yellow form (*flavicarpa*) which are more resistant to the woodiness disease. Finally, the research programmes would investigate the possibility of finding mild strains in the country which could be used in view of inducing resistance in the cultivated clones.

VI. c. Other viruses infecting passionfruit

Different other viruses can infect passionfruit crops. One important group is that of Potyviruses: Passionfruit ringspot virus, Passionfruit mottle virus, Soybean mosaic virus, Passionfruit Sri Lankan mottle virus.

Other viruses affecting Passionfruit belong to the Carlavirus genus (Passionfruit latent virus PLV), the Rhabdovirus genus (Passionfruit vein clearing rhabdovirus), the Tymovirus genus (Passionfruit yellow mosaic virus.

Control

Although all these other viruses are not yet reported in Rwanda, it would be risky to introduce new materials without taking strict measures of controlling their health quality. In that way, it would be highly useful to adopt measures similar to those proposed for the woodiness disease but strict control of the quality in the seed multiplication system remains essential.

VI. *d. Bacterial diseases of passionfruit*

Different symptoms of diseases are caused by several bacteria like Erwinia carotovora ssp. carotovora (causing soft rot), Ralstonia solanacearum (causing a vascular wilt), Pseudomonas syringae pv. syringae, Pseudomonas syringae pv. passiflorae and Pseudomonas viridiflava causing leaf spots

Although this diversity of bacterial diseases, the most important one is the bacterial spot caused by Xanthomonas campestris pv passiflorae. The disease is characterized by development of circular spots occurring on any part of the leaf. When the disease progresses, there can be a defoliation. Leaf infection can also become systemic affecting thus the branches. The pathogen penetrates plants through stomata but injuries can also constitute an entry point. Humid conditions are favourable for this disease (high relative humidity, presence of a water film on the surface, frequent rainfall). Long distance dissemination of the pathogen occurs on seedlings or on seeds.

Control

Control of the bacterial disease is mainly to based on the quality of planting materials. For that, seeds and seedlings have to be obtained from healthy plants and ideally from disease-free regions. If there is suspicion of infection on seeds, these can be treated at 50°C for 15-30 min. Other measures which can be observed are relative to (i) avoiding planting passionfruit in fields where the disease had been declared for the 2 preceding years, (ii) disinfecting pruning tools, (iii) avoiding work on plants when they are wet and (iv) respecting the recommended doses of fertilisers.

VI.e. The main fungal diseases of passionfruit

VI.e.1. Anthracnose and fruit canker

These diseases occur on this crop under humid environments[43]. All the aerial organs of plant are attacked by anthracnose symptoms appearing like oily spots of 2-3mm in diameter becoming dark brown, round or irregularly shaped with diameter higher than 1 cm. When the symptoms become severe, leaves are killed while affected flowers abort and immature fruits abscise. A dieback phenomenon characterized by reduced elongation of shoots, shortened internodes , wilting and death of the affected structures can also happen following anthracnose attacks. The causal agent is *Colletotrichum gloeosporioides* producing conidia in lesions and dead and senescent tissues of the plants[44] . Local dissemination of the disease can be facilitated by wind-blown rain and irrigation and by workers handling wet plants. For long distance dissemination, seedlings, cuttings and affected seeds are the main way of disease widespread.

Control

For the control, it is important to have a particular care in relation with the quality of seeds and seedlings which have to be obtained from healthy plants. It is also important to use adequate spacing between plants. Moreover, it is important to avoid harvesting fruits during wet periods. Pruning operations are recommended when plants are dry.

[43] Wilcan S. and Larran S. (2000). First report of anthracnose cause by Glomerella cingulata on passion fruit in Argentina. Plant Disease, 84: 706

[44] Dodd J.C., Estrada A. and Jeger M.J. (1992). Epidemiology of Colletotrochum gloeosporioides in the tropics. In: Bailey J.A. and Jeger M.J.(eds). Colletotrichum: Biology, Pathology and Control. CAB International, Wallingford, UK, pp. 308-325.

VI.e.2. Brown spot

The disease is caused by different species of Alternaria. However, the most common pathogens are A. passiflorae (causing reddish brown spots on leaves) and A. alternate (causing smaller spots with chlorotic haloes on leaves). Other species of the Alternaria genus are also found on passionfruit.

Control

As infected seedlings are an important way of disease dispersion, it is important to keep in mind that using healthy planting materials is an essential step in controlling of this disease.

VI.e.3. Septoria blotch (spot)

This disease caused by three different species (Septoria fructigena, Septoria passifloricola and Septoria passiflorae) is characterised by necrotic leaf lesions which are light brown of 2-8 mm in diameter and normally accompanied by a yellow halo. These pathogens can be transmitted through seeds and they can survive in infected tissues.

Control

For thhe control, it is important to limit primary inoculum by using non infected planting materials (seeds and seedlings). Elimination of plant residues is also another important operation to promote in view of improving control of the disease. These cultural practices' measures can be accompanied by some fungicide applications when the inoculum pressure seems to be very high. When limited number of plants present symptoms, the infected parts or entire plants can be eliminated rapidly to avoid production and dissemination of inoculum in the field.

VI.e.3. Fusarium wilt

This soilborne disease is caused by *Fusarium oxysporum* f.sp.*passiflorae* appears like a pale colour of new growth which proceeds to a wilt of some shoots 24 to 48 hours after the first symptoms. This wilt symptom can affect the entire plants or can develop unilaterally.

Control

Control of Fusarium wilt can be accomplished by planting on non infested soils. Moreover, it was already observed in different countries that resistance to Fusarium wilt can be improved through research programmes. This should be undertaken in a similar way as the scheme proposed for the control of woodiness disease.

VI.f. Conclusion relative to management of biotic constraints on passion fruit

As shown above, passion fruit is affected by a diversity of biotic constraints. Their control involves implementation of various management methods. Globally, production of seeds has to be performed with the greatest care as several diseases are transmitted by seeds. Moreover, the global field management (planting density and spacing, elimination of plant debris, pruning) must be achieved by taking into account biology of the main pests and diseases affecting the crop.

Application of prophylactic measures constitutes another strategy which allows reducing the pressure of inoculum. Finally, for most of the constraints, resistance properties can be improved by proceeding to interspecific hybridization. In this frame, it should be useful to build research programmes with a goal of creating and selecting new hybrids adapted to conditions prevailing in Rwanda and presenting resistance to the main biotic constraints affecting passion fruit.