Foreword

By the Chairman of the Board of Directors

Rwanda Agriculture and Animal Resource Development Board (RAB) has mandate to develop innovations in agriculture and animal resources through research and extension to increase agriculture and animal productivity and sustainability and minimize postharvest losses. It is with great pleasure that I present to the Government and other stakeholders th Annual Report for Rwanda Agriculture and Animal Resource Development Board for the Fiscal Year 2018-2019. The implementation of the activities in this Fiscal Year was directed by key government policy documents: Strategic Plan for Agriculture transformation (PSTA-4) and National Strategy for Transformation (NST-1).

This report presents the key milestones achieved by RAB in effort to improve food security, address negative for crops and livestock climate change impact, and to provide strong foundation to generate income, improve wellbeing, create jobs, particularly for smallscale farmers, and intensify production of food and cash crops as well as modern livestock management to achieve higher and more sustainable yields. The presented here achievements for the Fiscal Year of 2018-2019 included research and extension for various crops, natural resource management, and animal resources in order to assist policy makers to to take informed decisions.

Last but not least, RAB implements its work in close collaboration with central and local government agencies, private sector, NGOs and CBOs, other local and international partners. We thank all stakeholders, which supported and worked closely with RAB to develop new technologies and address the emerging challenges. I also thank RAB management team and staff for their dedicative and passionate work.

Professor Egide ...

Chairperson of the RAB Board of Directors

Table of Contents

List of abbreviations

AI   –   Artificial Insemination

AGR   –   Animal Genetic Resources

ASF   –   African Swine Fever

AYT   –   Advanced yield trial

BTC   –   Belgian Technical Cooperation

CBSD   –   Cassava Brown Streak Disease

CIMMYT –   International Maize and Wheat Improvement Center

CIP   –   Crop Intensification Program

CIP   –   Centro International de la Papa

CMD   –   Cassava Mosaic Disease

CMT   –   California Mastitis Test

CUG   –   Closer User Group

DVM   –   Decentralized Vine Multipliers

ELISA   –   Enzyme Immuno Sorbent Assay

IITA   –   International Institute of Tropical Agriculture

IP   –   Innovation Platform

IPM   –   Integrated Pest Management

FAO   –   Food and Agriculture Organization

FGR   –   Forest Genetic Resources

FFS   –   Farmer Field School

FHIA   –   Fondacion Hondurena des Investigationes Agricola

FMD   –   Foot and Mouth Disease

FTF   –   Feed the Future

LN   –   Liquid Nitrogen

MCMV   –   Maize Chlorotic Mottle Virus

MLN   –   Maize Lethal Necrosis

MSV   –   Maize Streak Virus

NAEB   –   National Agriculture Export Board

NAP   –   National Agriculture Policy

NISR   –   National Institute of Statistics of Rwanda

OFSP   –   Orange Flesh Sweet Potato

PGR   –   Plant Genetic Resources

PPP   –   Peste de Petits Ruminants

REMA   –   Rwanda Environment Management Authority

RNVL   –   Rwanda National Veterinary Laboratory

RVF   –   Rift Valley Fever

SUSTAIN –   Scaling Up Sweet Potato through Agriculture and Nutrition

SWOT   –   Strengths, Weaknesses, Opportunities and Threats analysis

UNDP   –   United Nations Development Program

QPM   –   Quality Protein Maize

ToT   –   Training of Trainers

VCR   –   Value Cost Ratio

WCR   –   World Coffee Research

Executive Summary

In the Fiscal Year 2018-2019, RAB has worked on crop and animal resources research and technology transfer, natural resource management, land husbandry, irrigation and mechanization. In the different fields of agriculture and livestock, the major successes were:

Cereals: Maize research has bred 23 hybrid varieties (12 for high and 11 for mid-altitudes) with early maturity, drought, low N and MLN tolerance. Other 108 single cross hybrids were developed with tolerance to fall armyworm, MLN, drought and low N. Seventy seed producers were trained. MLN surveillance concluded strong reduction of the disease spread as compared to 2015. Rice research evaluated 43 varieties for cold tolerance, aroma and good grain quality. Survey of rice blast disease in Eastern Rwanda identified 2 varieties resistance to the disease. Rice value chain meetings including producers and millers from about 90% of rice area were organized to standardize requirements by market and millers to optimize seed production and demand for each variety type (long aromatic, long non-aromatic, medium non-aromatic and short non-aromatic). Wheat research breeding has produced 15 new varieties for preliminary yield evaluation. Other 141 lines were pre-selected for further evaluation, and several hundreds of new lines were obtained from CIMMYT for evaluation. Agronomic trials assessed optimum N rate, planting dates, sowing depths and use of mechanized ploughing. Wheat seeds were produced: 243 kg of breeder seed in Rwerere; 3,834 kg pre-basic seed in Kinigi and Rwerere; and about 21 tons basic seed were produced in Kinigi, Rwerere, Ruhunde and Masogwe.

Banana rehabilitation area reached a total of 14,956.99ha: 3,456.5ha (West); 3,836.15ha (South); 3,231.84ha (East); and 4,428.5ha (North). The yield of rehabilitated banana field is about 20 tons/ha per year, which is 80% higher than the yield of non-rehabilitated banana field.

Roots and Tubers: Irish potato research has evaluated tetraploid bio-fortified varieties, continued crossing of new varieties tolerant to biotic and abiotic stresses with high yield and marketable traits, evaluated yield of farmer's varieties. Five new potato varieties were released. Cassava research prepared crossing of 21 lines resistant to pest and disease and high yielding. It is expected to produce 10,000 cassava true seeds of full and half-sib cassava families for nursery and seedling evaluation. True cassava seed were harvested from crossing block, and a nursery of 3640 seedlings was established at Mututu, Muhanga station. Clonal selection from true seed has generated 542 clones, which are being evaluated. Preliminary yield trial resulted in selection of 63 clones out of 444, which show CMD symptoms on some clones and post-infection recovery of the CMD on other clones. Multi-location trials resulted in selection of eight elite clones. On farm trials for participatory variety selection of five pre-released cassava clones were established in 7 districts. Sweet potato breeding continued with 12 selected parents where true seeds are being harvested. Two advanced yield trials of 18 and 45 clones were established in 2018B season, where 10 and 18 clones were selected, respectively. Another trial evaluated 40 genotypes with 19 selected for further testing. On farm trials were established in Huye, Muhanga and Gakenke

with 10 best clones. Besides, 26 high yielding varieties were submitted to the release committee for possible release.

Pulses: Bean breeding continued and 671 crosses of bush and climbing beans were evaluated. 14 trials evaluated 359 bean varieties in preliminary and advanced yield trials. A total of 18 varieties were selected for release. Yield evaluations of high Fe and Zn varieties are going on. Other 600 lines were introduced from CIAT and are being evaluated. A*bout 600 tonnes of certified seed were produced with seed companies, while* 11,077 kg of early generation seeds of bio-fortified bean varieties were produced by RAB. Soybean research has bred 12 new lines undergoing yield evaluation. The other 49 lines were identified with yield potential of 2-3.5 t/ha for advanced yield evaluation. Evaluation of 24 new soybean varieties introduced from Illinois University showed 7 varieties with good yield ranging from 2067 to 2641 g plot^{-1} and maturity of 134-147 days.

Horticulture research developed new approach for pest and disease management – fruit fly control using pheromone traps with methyl eugenol as the most effective, virus survey on hot pepper identified 5 different viruses using ELISA and further need for virus management package to reduce pepper yield losses. Stevia research developed optimized spacing and manuring. Horticulture center of excellence introduced 2 avocado, 3 mango and 4 citrus varieties from Ethiopia. *A total of 34,419 vegetable seedlings of tomato, eggplant, sweet pepper, watermelon, cabbage, onions were produced for both, protected and outdoor production.* The number of scions harvested and distributed is 353,660 for avocado, 193,400 for citrus and 240,500 for mango. A total of 50 kg of seeds was distributed in major production districts of tamarillo, which can cover 1,650 ha when planted.

Industrial crops: Coffee research bred five F1 hybrids with superior yield and quality, introduced 40 new varieties from World Coffee Research for further breeding, updated coffee pests and diseases, developed IPM package for coffee growers, produced and disseminated 1200 kg of seed of a newly released RABC 15 variety and 3,500 kg of clean seed from traditional varieties (BM139 and Jackson 1257), for 5,640 ha of land. Tea research evaluated 18 tea clones and selected 5 best. Four new clones were established for evaluation. Agronomic trials are going on to evaluate fertilizer doses and plant density.

Livestock research conducted embryo transfer on 51 cows, 15 from Muyira, 17 from Kibilizi and 19 from Songa with success rate of 25.5%. Calfs born from embryo transfer were four in Muyira, three in Kibilizi and six in Songa. The technology and skills are being improved with continuous practice. Promotion of good forage species continued. A total of 274 farmers established improved forages including *Chloris gayana*, *Brachiaria* spp. and *Panicum coloratum* on 600ha. A total of 1865 farmers and extension workers have been trained on feed and feeding management. About 40.5 ha of forages were established in Nyagatare, Songa, Gishwati, Musanze and Rubona stations for seed production. A total of 500 kg of seeds from Chloris and Panicum spp. have been collected. Under germplasm maintenance, at least 63 ha were maintained.

Research was conducted to characterize local chicken. Another study focused on artificial insemination of pigs and its success factors. National Artificial Insemination center obtained 4 high genetic merit bulls (2 Jersey and 2 Holstein-Friesian bulls) from Ireland with support of RDDP project and Heifer International. In FY 2018/2019 a total of 184,388 semen doses were produced and processed. To ensure accelerated genetic improvement, a total of 15,000 bovine semen doses have been imported in 2018/2019. To ensure availability of Liquid Nitrogen (LN2) and increased access to AI inputs for improved service delivery, RAB has ensured good operation of the two Liquid Nitrogen plants installed at Rubilizi and Rubona Stations. In the 2018/2019 fiscal year, a total of 102,829 cows were inseminated and 38,504 calves born on AI.

Aquaculture and fisheries research focused on sustainable fisheries management, enhancement of aquaculture productivity and promotion of fish value chain. A total of 24,877 MT of fish was produced in FY 2018-2019. A total of 9,390,740 fingerlings was produced against the targeted 8 million fingerlings. Capture fisheries produced 18,396 tonnes of fish from catches. Research on fish feed showed significant weight gain and growth increased with dietary protein levels at 25 - 35% monosex Nile tilapia fingerlings.

Girinka program has distributed 354,713 cows since the beginning and 27,749 cows in FY 2018-2019. A number of small stock was distributed to youth cooperatives with poultry: 47,991 (via earmarked funds: 44,806, and via partners: 3,185) and pigs: 3,511 (via earmarked funds: 2,149, and via partners: 1,362). Vaccination campaigns were conducted in high risk zones, and a total of 468,297 animals were vaccinated against Black Quarters; 659,151 cows were vaccinated against LSD; 334,433 cows were vaccinated against RVF; 58,169 were vaccinated against Brucellosis; and 75,220 animals were vaccinated against FMD.

Land husbandry, irrigation and mechanization: During 2018-2019, a total of 4,063.5 ha of radical terraces and 12,161.6 ha of progressive terraces have been developed at national level, this led to a cumulative area of 94,443.6Ha under radical terraces and 122,455.5 hectares under progressive terraces. A total of 572 ha of marshland were developed with irrigation facility (110 Ha of Kanyonyomba and 462 Ha of Rwinkwavu marshlands); 2,316 Ha under SSIT Irrigation developed. The total land under irrigation has reached 55,063 ha by end June 2019. A total of 1,924 Farmers and Technicians were trained on the use of SSIT Equipment. A total of 205 demonstrations and awareness campaigns were conducted to adopt Small Scale Irrigation Technology. Land tilled using machine from 41,010 ha to 47,060 Ha. Besides increasing the number of mechanized land, cumulatively 2,080 farmers were trained on use of machinery in various farm operation, 213 tractors operators and 180 agronomists were also trained through the conducted on farm demonstration campaigns. A number of h*ouseholds adopted agroforestry practices*. A total of 235,112 trees and fruit seedlings were distributed at Bugesera and 111,100 at Gishwati (Nyabihu and Rubavu).

List of Photos

List of Tables

List of figures

Part 1. Crop Research and Technology Transfer Department

The Department of Crop Research and Technology has seven Programs namely (1) Cereals, (2) Banana, (3) Pulses and Oil Cops, (4) Roots and Tubers, (5) Horticulture, (6) Industrial Crops, and (7) Crop Protection. This report covers the main achievements of fiscal year 2018/2019.

1.1   Cereals program

1.1.1 Maize sub-program

In the fiscal year 2018-2019, maize research focused on the following: there was identification of Three Way Cross Hybrids to be officially released after completion of multi-location trials. Furthermore, parent selection for Single Cross Hybrids for high altitudes and mid altitudes with tolerance or resistance to various stresses including fall armyworm, Maize Lethal Necrosis (MLN), drought and low N tolerance was done. Awareness, demonstration and field days of RAB three hybrid varieties: RHM104, RHM1402 and RHM1407 adapted to mid altitudes was done.

Identification of varieties to submit for official release

Twenty-three new maize hybrid varieties we identified from multi-location trials conducted earlier. The multi-location trials for mid altitudes were conducted at Bugarama (968 masl, 2°31'49''S, 29°00'36''E), Rubona (1691masl, 2°28'55''S, 29°46'15''E) and Cyabayaga (1372 masl, 1°24'25''S, 30°17'08''E) in the seasons A and B whereas the trials for high altitudes were conducted at Rubona (1691masl, 2°28'55''S, 29°46'15''E), Rwerere (2110 masl, 1°29'17''S, 29°52'42E), Kinigi (2332 masl, 1°26'24''S, 29°35'39''E) and Tamira (2440 masl, 1°33'57''S, 29°23'24''E). They comprised of 12 new varieties for high altitudes and 11 for mid altitudes. The materials for high altitudes encompasses some varieties adapted across the high altitudes while other are specifically adapted to transitional altitudes. The varieties for mid altitudes include those adapted across the mid altitudes, adapted to moist mid altitudes and those adapted to semi-moist mid altitudes. Specific traits comprise general adaptability, early maturity, drought, low N and MLN tolerance, and resistance to foliar disease such as Grey Leaf Spot (GLS), MSV (Maize Streak Virus) and TLB (Turcicum Leaf Blight) diseases (Table 1).

Table 1: New maize hybrid varieties identified for submission to official release

No	Names	Type	Ecology	Specific adaptation	Specific traits
1	RHH1801	TWCH	HA	Across high altitudes	General adaptability

2	RHH1806	TWCH	HA	Transitional altitudes up to 2000 m	General adaptability
3	RHH1807	TWCH	HA	Across high altitudes	General adaptability
4	RHH1808	TWCH	HA	Transitional altitudes up to 2000 m	General adaptability
5	RHH1816	TWCH	HA	Across high altitudes	General adaptability
6	RHH1826	TCH	HA	Transitional altitudes up to 2000 m	General adaptability
7	RHH1604	TWCH	HA	Transitional altitudes up to 2200 m	Early
8	RHH1628	TWCH	HA	Across high altitudes	General adaptability
9	RHH1707	TWCH	HA	Transitional altitudes up to 2200 m	General adaptability
10	RHH1708	TWCH	HA	Across high altitudes	General adaptability
11	RHM1631	TWCH	HA	Across high altitudes	General adaptability
12	RHH1817	TWCH	HA	Across mid altitudes	General adaptability
13	RHM1810	TWCH	MA	Moist mid altitudes	MSV, TLB, GLS
14	RHM1820	TWCH	MA	Moist mid altitudes	MSV, TLB, GLS
15	RHM1823	TWCH	MA	Moist mid altitudes	Drought
16	RHM1842	TWCH	MA	Semi-moist mid altitudes	Drought
17	RHM1843	TWCH	MA	Across mid altitudes	Drought, MLN
18	RHM1853	TCH	MA	Across mid altitudes	General adaptability
19	RHM1704	TWCH	MA	Across mid altitudes	General adaptability
20	RHM113	TWCH	MA	Semi-moist mid altitudes	Early
21	RHM1848	TWCH	MA	Semi-moist mid altitudes	Drought, MLN
22	RHM1709	TWCH	MA	Across mid altitudes	Early
23	RHM1710	TWCH	MA	Moist mid altitudes	Early

HA: High altitudes; MA: Mid altitudes; TCH: Top Cross Hybrid; TWCH: Three Way Cross Hybrid

Formation of parents Single Cross Hybrids (SCHs)

In the fiscal year 2018-2019, a total of 108 parent Single Cross Hybrids (SCHs) were formed by using parent inbred lines introduced from CIMMYT and inbred lines developed by RAB. They comprised 52 SCHs for high altitudes and 56 SCHs for mid altitudes. The mid altitudes crosses comprised nine SCHS tolerant to fall armyworm, ten SCHS tolerant to MLN, 30 drought and low N tolerant and nine tolerant to foliar diseases while in the high altitudes the main target was general adaptability and earliness.

Building the capacity of seed producers in hybrid seed production

Around seventy seed producers were trained in hybrid seed production procedures. The training was both organized in class and field. The field training was in seed production plots at major stages of development such as: planting, rogueing, detasseling and harvesting. Furthermore nine seed producers that comprised: RISCO (Rwanda Improved Seed Company Ltd), IABM (Iterambere ry'Abahinzi ba Makera), Rumbuka Seeds Ltd and EMFAGM (Ebenezer Mixed Farming & General Merchandise Ltd), NV-General Supply, PRODEV, University of Kibungo, Kilimo General Supply and

Nzalex were backstopped for certified seed production using RAB maize hybrid varieties. They were to produce and supply 1,000 MT of seeds.

Increase awareness and adoption of RAB hybrid varieties

Twenty-three demonstration plots using three RAB maize hybrid varieties: RHM104, RHM1402 and RHM1407 with an Open Pollinated check: ZM607 were conducted in mid-altitudes of Rwanda with farmers' cooperatives. In each plot, the four entries were planted side-by-side following the agronomic recommended practices.

The management of the demonstration plot was ensured by farmers themselves. Furthermore, one field day at national level was organized on 28th June at Bushoga Site, Bushoga Village, Bushoga Cell, Nyagatare Sector, Nyagatare District. The field day attracted 85 people including 65 men and 20 women from RAB, universities and high learning institutions, public and private organizations, and seed producers, NGOs operating in Rwanda, agro-dealers and Farmers Promoters. The variety RHM1407 was highly appreciated by the Participants (Photos 1 and 2).

Photo 1: Introductory remarks during the field day on 28th June 2019

Photo 2: The variety RHM1407 highly appreciated during the field day

Maize Lethal Necrosis country wide distribution

A survey of MLN disease was conducted in May 2019 in all 30 districts of Rwanda by using Agristrips, a new quick, efficient and inexpensive method of MLN detection developed by CIMMYT. Agristrips detect the presence of Maize Chlorortic Mottle Virus (MCMV) whose presence implies the presence of MLN. A total of 448,000 samples were analyzed. Only 75 samples (0.016 %) tested positive for the presence of MCMV. Thus, the MLN disease is still present in Rwanda with, however, significantly reduced incidence as compared to year 2015 (Figures 1 and 2).
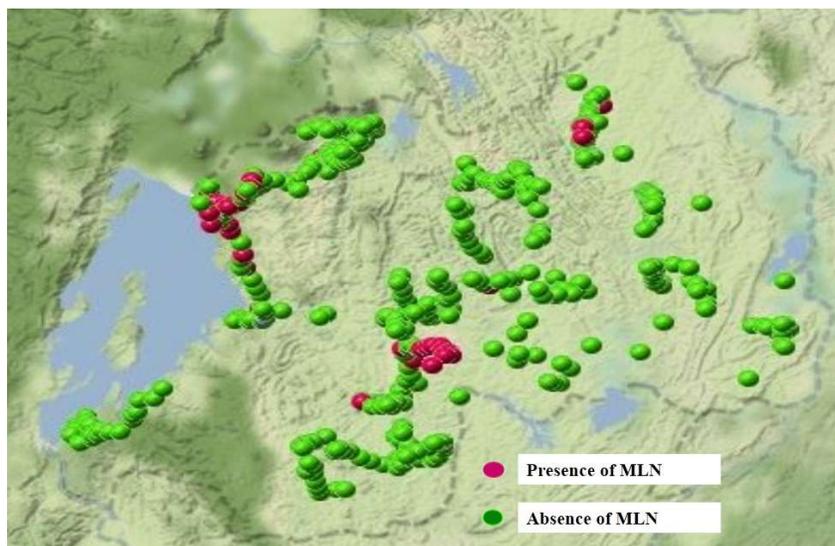
Figure 1: Prevalence of Maize Lethal Necrosis, May 2019
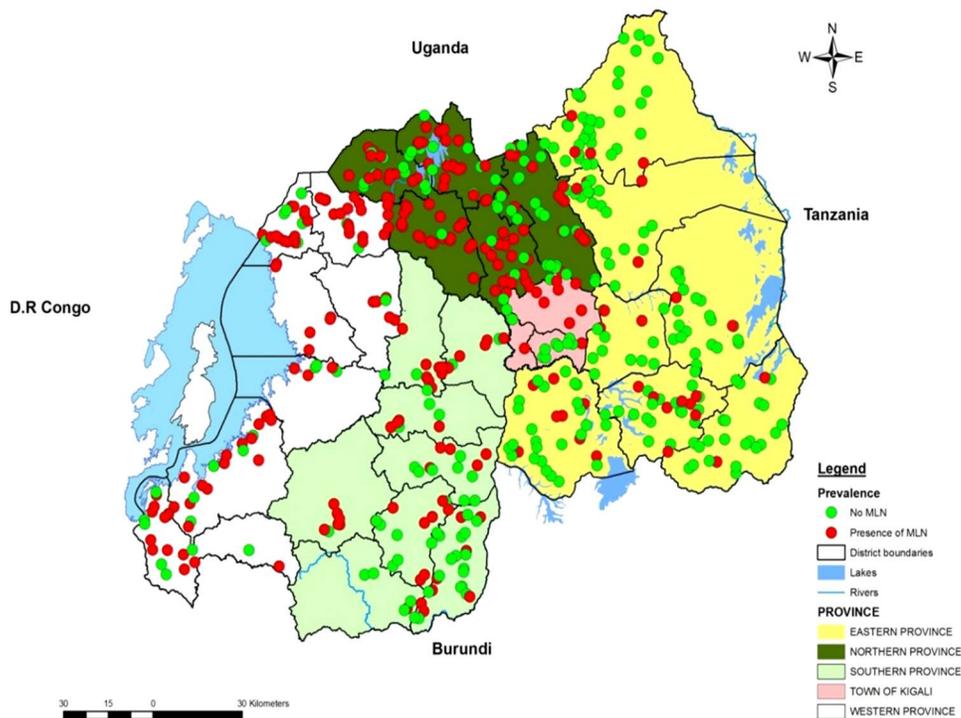
Figure 2: Prevalence of Maize Lethal Necrosis in July 2015

1.1.2 Rice sub-program

Rice is one of the most important staple food in Rwanda and leading other crops in irrigated agriculture. It can yield 8-9 tonnes per hectare (attainable yield), but the average yield at farmer level is still around 4-5 tonnes per hectare. Rice cultivation is facing various challenges related to ecologies where rice is grown, diseases and poor agriculture practices at farmer fields. Low night temperatures are common in Rwanda except Bugarama in Rusizi district and major diseases observed are Blast and Rice yellow mottle virus. Many activities were carried out in research and extension to overcome some of those challenges.

Breeding for grain quality
Experimental trials were conducted in RAB Ntendezi, Rubona, Ngoma stations. Two experiments were done with different objectives 1) to test lines with cold tolerance; 2) to test lines with Aroma and good grain quality.

For the experiment 1, 43 varieties were tested in greenhouse at RAB Rubona for disease control. Another part of experiment 1 was established as field trial in Cyili/Gisagara, Kirimbi/Nyamasheke and Rwabutazi/Kirehe sites. The same 43 varieties and two local checks were included, namely. Yun Yin 4 as national check, and Mbakungahaze as local check. Routine maintenance was done with 2 splits fertilisation of 80 N-34 P-34 K (at tillering and as panicle initiation). Data were collected on yield, cold tolerance and diseases. For the experiment 2, seeds of 47 varieties were planted in Bugarama site and 3 local checks and same management standards as in experiment 1. The harvesting and post-harvest activities are going on. Preliminary results showed significant differences between lines at Kirimbi and Rwabutazi with $p=4.86^{-16}$, SED= 4.04 and LSD=8.05 for period to heading at Kirimbi whereas at Rwabutazi, the $P=9.24^{-21}$, SED=3.65 and LSD =7.27. The heritability of traits for both sites was 0.91 for Rwabutazi and 0.78 for Kirimbi. Good performers were preliminary selected at Kirimbi (13), Cyili (12) and Kirehe (11). For experiment 2, at Bugarama, the harvesting operations are going on.

Diseases characterization

Rice blast disease caused by *Magnaporthe oryzae* is one of major production constraints. A survey was designed and aimed to establish incidence and severity of rice diseases in major rice schemes of the Eastern province (Cyabayaga in Nyagatare, Gatore and Rwinkwavu in Kirehe). Site selection was made considering disease pressure, vicinity and practicability. For all these 3 sites, major rice diseases were evaluated incidence and severity and only in Cyabayaga, a trapping nursery was conducted for assessing pathogen diversity and identifying resistance genes.

The results indicated that there was a significant difference on the reaction of the differential lines to the different strains of *M. oryzae.* Means separation has also clearly indicated that based on the virulence spectrum of the rice blast causing pathogens, 19 different groups were observed, where 2 varieties namely MODAN (37) and MOROBEREKAN (8) have been proven to be resistant to different strains or rice blast that were able to overcome other differential varieties that were in the trial during the season 2019B. The incidence of diseases was high in the Nyagatare district especially at early stages and mostly in the early tillering, the incidence of rice blast was very high and decreased overtime as rice advanced in mature stages.

Distribution of rice varieties, demand for certified seed and supply of paddy by farmers

Rice sub-program conducted a survey, focus group and joint planning meetings with cooperative managers, seed producers and millers to determine the quantities per variety and quality requirements by market/miller, to assess the capacity and readiness of rice farmer cooperatives, and sign agreement to formalize their commitment. A total of 69 farmer cooperatives, 25 seed producers and 21 millers in 15 districts were involved and the coverage was more than 90% of the total rice area.

The varieties grown in Rwanda are grouped in 4 categories : **Long aromatic** (Basmati 370, Nerica 9, Buryohe), **Long non aromatic** (Rumbuka, Mbakungahaze, Fashingabo, Mpembuke, Nemeyubutaka, Ndamirabahinzi, WAB 188, Fac 56, Muturage, Ngaruye, Dutsinde, Rurambi, Ndamirabana, Bwiza), **Medium non aromatic (**Cyizere, Ramba, Tubuka, Instindagirabigega (Wat), Br, Gakire, Imbaturabukungu, Icyerekezo, WAT64TGR, Jyambere) and **short non aromatic** (Yunyin**,** Umujagi**,** V30, Yun er tian, Zhong geng, Yun keng, Akarusho)**.** Short grain rice (Kigori) is very starchy and cooks up soft and sticky, long grain rice contains less starch and cooked grains are drier and more separate where aromatic varieties have distinctive flavor and may be short, medium or long (Table 2). The volume of rice production per variety type and the estimated volume of paddy for 2019B was summarized in Tables 2 and 3.

Table 2: Distribution of variety type and estimated volume of paddy in Eastern province (tonnes, 2019B)

Variety type / district	Nyagatare	Gatsibo	Kayonza	Kirehe	Rwamagana	Ngoma	Bugesera	Total	%
Long aromatic	2011	450	437	0	0	0	2226	5124	18
Long non aromatic	1506.6	675	2400	1748	16	62	120	6528	23
Medium non aromatic	1920.2	0	56	18	549	340	1168	4052	14
Short non aromatic	3620.7	2370	2026	2234	699	1179	847	12976	45
Total	9058	3495	4919	4000	1265	1582	4361	28680	

Table 3: Distribution of variety types and estimated volume of paddy in Southern and Western provinces (tonnes, 2019 B)

Variety type / district	Kamonyi	Ruhango-Muhanga	Nyanza	Gisagara	Huye	Nyama-sheke	Rusizi	Total	%
Long aromatic	1242	71	0	0	7	0	594	1914	7.7
Long non aromatic	887	252	441	1179	0	228	1346	4332	17.4
Medium non aromatic	124	522	0	3219	92	0	6055	10012	40.3
Short non aromatic	914	1679	412	2523	1801	1240	0	8569	34.5
Total	3167	2524	853	6920	1900	1468	7995	24827	

The rice industry in Rwanda is engaging many value chain actors and this survey helped to understand the requirements of millers and the capacity of farmers to fulfil them. The issue of shortage of quality seeds and varieties were tackled in deep and farmers-seed producers were engaged in seed farming contract based on specific varieties required by rice cooperatives to meet the requirements of their target market (rice millers). The seed needs for each seed category and seed production quantities are summarized in Table 4 below.

Table 4: Volume of certified and basics seeds needed per District

	Basic seeds (RAB)	Certified seed producers	Cooperatives	Rice area (ha)	Certified seed needed (tonnes)	Seed rate (kg/ha)
Rusizi	445	4	4	1525	59.3	40
Nyamasheke	83	1	8	299	10.7	40
Kamonyi	172	1	3	575	23	40
Ruhango	217	2	6	574	29	50
Nyanza	76	0	3	209	10	50
Huye	160	4	10	577	21.3	40
Gisagara	318	4	7	1099	42.4	30
Nyagatare	819	3	5	2104	109	45
Gatsibo	235	2	2	746	31	40
Kayonza	272	0	4	1170	37	30
Rwamagana	54	1	5	240	7.2	30
Ngoma	71	0	4	314	9.4	30
Kirehe	141	1	5	804	22	30
Bugesera	155	2	3	666	20	30
Total	3218	25	69	10902	431.3	40

During the same period farmers under each consortium had the opportunity to visit and tour factory premises of their off takers to understand how paddy is processed and the losses caused by poor quality of paddy.

1.1.3 Wheat sub-program

Development of new varieties

A total of 24 F3 and 24 F4 progenies were selected and advanced to F4 and F5, respectively, for further evaluation in Musanze, Kinigi and Rwerere in 2019B season. From F4 and F5, 16 and 18 families were respectively selected for being advanced to the next stage for further testing. Fifteen populations were advanced to Preliminary Variety Trial (PVT) Rwerere in 2019B. A set of 41 genotypes selected from 814 genotypes composing 6 CIMMYT nurseries planted in Kinigi, and 100 genotypes selected from 381 genotypes composing 17CIMMYT nurseries evaluated in Rwerere in 2019A. Selected lines were advanced in 2019B for further evaluation. Additionally, 2380 newly-introduced wheat genotypes were obtained from CIMMYT-Mexico for being tested

in 2019B for adaptability. One set of 1215 genotypes was evaluated in Musanze and Rwerere Stations. Most of agronomic data have been collected and recorded and collection of yield information is going on. A total of 11 on-farm trials were established in Ruhunde, Rwerere, Rusarabuye, Cyumba, Manyagiro, Butaro, Nyagatare, Nyamagabe and Gataraga sites.

Development of new approaches of pests and diseases management
Three prevalent yellow rust isolates of PstS11 were identified from yellow rust samples collected from Kinigi and Rwerere Stations. The Global Rust Reference Centre (GRRC) in Denmark and John Innes Centre in UK assisted in race analyses.

Development of good agronomic practices
Testing for N fertilizer rates: Five farms were randomly selected in Gataraga Sector in 2019A. Each farm was used as a replicate in the evaluation. The experimental design was a randomized complete block comprising three treatments as follows: T1: 50; T2: 273 and T3: X kg N/ha (X varying depending on the Normalized difference vegetation index (NDVI) reading. A plot size was of 5m x 5m. All plots were ploughed manually and received the same amount of phosphorus (P) in the form of triple phosphate. Wheat seed from Njoro BW2 was sown in rows spaced at 0.20 m. Plots were surrounded by a ridge, to avoid runoff of N from one plot to the next. Plots were constantly kept weed-free. Parameters that were measured included plant population (plants per m^2), days to emergence, anthesis (flowering), and maturity, grain yield (kg DM per ha), stover yield (kg DM per ha), number of fertile tillers per plant. Data collected have been handled for further analysis and reporting. Similar exercise has been repeated in the same area (Gataraga) with 6 farmers.

Establishment of mechanization trials in Kinigi Station: The comparison between the modernized and traditional technologies resides on the time it takes to sow seed and apply fertilizers, weed, harvest, the cost of labor compared to the fuel, and grain yield. Three treatments including hand sowing, 4 row and 6 row sowing machines were established in 3 replications.

Planting dates: Experiments on planting dates in 6 staggered planting periods were established in 2019A and B in 3 sites of Musanze, Kinigi and Rwerere to determine the right planting time while considering the continuous climate change. Two varieties, namely, Nyaruka and Gihundo, have been used and planted in 6 rows of 3-meter long each variety with two replications. Data have been collected on agronomic parameters and rainfall, then recorded for further analysis and reporting.

Planting depth: The purpose of this activity is to determine the right sowing depth for wheat seed and update the recommendation to farmers. Seed was sown at different depths starting from

1cm, 2cm up to 10 cm deep. The experiment has been established in Musanze since 2019B in two replications. Data were collected on number of plants germinated, the dates of emergence, booting, flowering and maturity, and plant vigor. Data collected will be analyzed and results reported. The experiment will be repeated and extended to other locations in the 2020 A season for further observations.

Seed production
During the season 2019A, a quantity of 243 kg of breeder seed was produced in Musanze and Rwerere; a total of 3.834 tons of pre-basic seed was produced from Kinigi (2.9 tons) and Rwerere (934 kg); and about 21 tons were produced in 2019A from Kinigi, Rwerere, Ruhunde and Masogwe. In 2019B season, more seed of different categories was produced in different stations as follows. Breed seed was produced on 1.95ha (including 0.15ha in Kinigi and 1.8ha in Rwerere); Pre-basic seed produced on 10.67ha comprising 0.65ha in Rwerere; 0.6ha in Kinigi; 4.42ha in Ruhunde; and 5ha in Masogwe; and Basic seed produced on 47.79ha (including 2.25ha in Rwerere; 9.34ha in Kinigi; 1ha in Kitabi; 12ha in Sigira; 16.2ha in Gakuta and 7ha in Rufungo). Yield data of seed produced in season B are not yet fully ready, as harvesting and postharvest handling activities are still going on in different sites.

Technology transfer
Trainings: A two-day training was conducted in January 2019 on wheat crop production and marketing. Training consisted of four major topics, namely, (1) Appropriate crop management practices; (2) Seed production and handling; (3) Post harvest practices; and (4) Estimation of wheat production costs and profitability. The training session was regarded as an opportunity to discuss issues that wheat value chain has been facing in Rwanda and propose possible solutions. The training mainly involved wheat farmers, seed producers, agro-dealers, processors and local leaders, namely, agronomists of the target Districts of Musanze, Burera and Gicumbi and Sector agronomists from Gataraga, Butaro and Cyumba, and trainers from RAB. All the participants were from three wheat innovation platforms (IPs), namely, Gataraga (Musanze), Butaro (Burera) and Cyumba (Gicumbi).

Farmer-to-farmer exchange field visit: A field tour was organized on January 10, 2019 and involved key-stakeholders from wheat innovation platforms (IPs). A field visit was organized in wheat farmer's field in Nyambare Cell, Cyumba Sector, Gicumbi District, to learn from demonstration plots and surrounding farmer fields established, to allow participants to share knowledge, information and experience among them. Participants appreciated the informative discussions over the field visit and suggested that it would be better to regularly organize similar sessions through IPs to popularize appropriate wheat technologies and learn new lessons from the information exchange and experience sharing among stakeholders.

Meeting: A mid-term review and planning meeting on the progress of SWPSI Project has taken place from 5-7 February 2019 in Musanze. The purpose was to assess the achievements, failures, efficiency, value-for-money, management and general direction of the project. The participants were from the International Maize and Wheat Improvement Center (CIMMYT), Rwanda Agriculture and Animal Resources Board (RAB), Zambian Agricultural Research Institute (ZARI) and the Centre for Coordination of Agricultural Research for Development in Southern Africa (CCARDESA), the International Fund for Agricultural Development (IFAD), and representatives from spill-over countries, namely, Tanzania and Mozambique and Madagascar. Participants presented their achievements and generated lessons learned during the past two and half years of the project implementation period. Partners also reviewed and co-planned the implementation of the remaining project activities, and mapped the way forward in scaling achievements.

National Agricultural Show: The varieties namely Nyaruka, Gihundo, Majyambere, Keza, Nyangufi, Reberaho, Cyumba, Kibatsi, Rengerabana and Mizero were exhibited in the 14th National Agricultural Show organized by MINAGRI in June 2019 at Mulindi Show Ground. About a half kilo of wheat seeds picked from each of the 10 varieties were separately packed in different labeled plastic pots that were placed on a stand for exhibition.

Dissemination of extension materials: During various fora such as trainings, meetings, agricultural show and community works (umuganda), more than 500 extension materials comprising leaflets and factsheets on key wheat pests and diseases, crop and post-harvest management practices were produced and distributed.

Demonstration plots: A total of 30 demos/FFS plots were established in wheat growing areas of Gataraga, Butaro, Nyamagabe, Rwerere, Ruhunde, Cyumba, Manyagiro, Nyamagabe and Nyagatare

1.2   Banana program

In the FY 2018-2019, the activities of banana Program were focused on (1) Banana rehabilitation, (2) Development of new banana varieties, (3) Banana field genebank maintenance, (4) Farmer promoter trainings, (5) Evaluation of agricultural practices for BXW control, and (6) Development of new application for BXW control (ICT4BXW project).

Banana rehabilitation

Banana rehabilitation continued in the close collaboration within the targeted districts, and the progress was monitored by visiting banana rehabilitation sites and progress monitoring at district level with the help of district and sector agronomists. During the Quarters 1 and 2, a total of 3,132 ha were rehablitated in Western districts. During the Quarter 3, 324 more ha were rehabilitated as following: Karongi 52ha, Rusizi 72ha, Nyamasheke 15ha, Nyabihu 19ha, Ngororero 96ha and Rubavu 46ha. *By June 2019 banana rehabilitation area reached a total of 14,956.99ha: 3,456.5ha (West); 3,836.15ha (South); 3,231.84ha (East); and 4,428.5ha (North).* The yield of rehabilitated banana field is about 20 tons/ha per year, which is 80% higher than the yield of non- rehabilitated banana field. However, the yield increase is observed one year after rehabilitation work was completed.

Development of new banana varieties

A total of 29 banana varieties are being evaluated under Rubona conditions. Yield data were collected for the first cycle (Table 5).

Table 5: Yield components of new banana varieties in Rubona

	Variety	Number of fruits	Number of hands	Bunch weight , kg
1	26285	34.7	4	5.7
2	25333-590	92.8	6.5	10.5
3	2628 5	no data		
4	2666 36-2	24.7	3.7	2.3
5	4479-1	63.7	5.7	8.7
6	NSH 42	123.3	6.5	13.3
7	NARITA 2	86.3	6.8	13.3
8	NARITA 3	flowered		
9	NARITA 4	93.5	6.5	11.9
10	NARITA 6	92.4	6.8	5.6
11	NARITA 9	84	7	8.6
12	NARITA 10	106	8	10.7
13	NARITA 12	89	6	10
14	NARITA 13	107.7	8.5	14.3
15	NARITA 14	84.3	7	13.3
16	NARITA 15	63	6	5
17	NARITA 17	108	8.5	14.5
18	NARITA 18	127	8.8	10.8
19	NARITA 21	flowered		
20	NARITA 22	91.9	7	12.6

21	NARITA 23	114.8	10.8	16.3
22	NARITA 24	111.6	7.8	10.6
23	NARITA 26	96	7.3	13.5
24	TMPX 76	48.3	5	5.3
25	TMPX 69	38.7	4.3	3.7
26	PITA21 TMPX 69	dropped after flowering		
27	PITA23 TMPX 123	100	6.8	9.8
28	PITA -24-TMPX-124	96	9	16
29	PITA 27 TMPX 133	55.8	5.5	7.8

Banana field genebank maintenance

Two field genebanks were routinely maintained in RAB stations, one in Rubona and one in Ngoma (Rukira site). A total of 113 varieties were conserved in Rubona and 117 in Ngoma field genebanks. Routine maintenance focused on BXW prevention, manuring, weeding and mulching. Yield data per variety were collected at Ngoma.

Farmer promoter trainings

Although not funds were allocated to this activity, Banana program technical staff were invited to provide trainings to farmer groups in Kayonza (through Kayonza district administration); Gisagara (through Care International and DUHAMIC-ADRI), and Rubavu, Muhanga and Gisagara (through FAO banana planting project). In total, more than 300 farmers were trained by RAB Banana Program staff.

Good agricultural practices availed

Research work continued with established on farm trial at Gisagara, Rulindo, Kayonza and Rubavu. The following banana field management practices are being evaluated for disease control (Banana wilt disease): whole mat removal of sick plants; single diseased stem removal; prevention against no control, under unlimited intercropping practices conditions and farmers willingness to intercrop. Single stem removal has lower disease incidence after 5 months of trial. Data are to be collected til the end of 12 month period.

ICT 4 BXW project

New research project in collaboration with IITA aimed to develop and test with farmer promoters new smart phone application for the control of the BXW disease. The application was developed (BXW APP) and is available on Google Play Store. The testing is going on.

1.3   Pulses and Oil Crops program

The Pulses and Oil Cops Program includes soybean and beans sub-programs. Soybean (*Glycine max* L) is an important crop for human consumption and animal feeds. Soybean like other legumes, has an advantage of fixing nitrogen from the air in symbiosis with *rhizobium* bacteria, and thus contributes to soil fertility improvement. However, the average annual production in the country is below the increasing demand for local consumption and processing. The main constraints to soybean production in Rwanda include poor germplasm leading to lack of improved varieties suitable for the country, poor soil fertility; climatic variability, post-harvest losses, low price, limited farmers knowledge on good agronomic practices. The common bean (*Phaseolus vulgaris* L.) is a priority pulse crop in Rwanda due to its prominent contribution to food, nutrition and income security. Beans are consumed in various forms; fresh or dry grain, fresh leaves, or as green pods (snap/french beans) and as processed or blended products (flours) and contributes generously as a source of quality protein, energy, fiber and micronutrients: vitamin A, folic acid, iron, and zinc in the daily diets of Rwandans. Two major types of beans according to growth habit are cultivated; the bush beans and climbing beans. Rwanda is considered as major centre of bean diversity according to the different grain market classes that are cultivated in the country. The release and commercialization of high yielding and marketable climbing bean varieties in Rwanda has enhanced production, internal and regional trade and farmers' incomes. This report highlights the main activities conducted for both legumes in the fiscal year 2018/2019.

On Station Trials: Crossing, screening and evaluation in soybean and bean yield trials
Soybean breeding was done at RAB-Rubona and aimed high yield and early maturity. In 2019A and B, 12 lines were selected for preliminary yield trial and other generations in F3 and F4 are still under evaluation. A total of 49 stable soybean lines were planted in advanced yield trials at Rubona, Nyagatare, Ngoma and Gashora to evaluate their yield performance. The results showed very promising 10 lines with an average grain yield ranging from 2000 to 3500 kg ha^{-1}. This yield is greater than the one of the local check Peka 6. Their physiological maturity ranged between 98 and 106 days, which is comparable to the local check, Peka 6, and lower to SB 24.

A total of 671 crosses of bush and climbing beans were performed at Rwerere and Rubona and planted in F1 during 2019B, while a total of 1221 segregating lines at different generations were planted in different nurseries for advancement and further studies.

A total of 14 different trials were established where 359 bean entries were evaluated in preliminary and advanced yield trials and 18 entries in adaptability and acceptability test for

selection of best bean varieties to be recommended for release. Most of trials have been harvested but evaluations are still in progress. Nine climbing bean lines were evaluated in adaptability and acceptability trial on station and on-farm. The experiment was recommended to be repeated in 2020. Participatory variety selection will be performed and best leads will be characterized and applied for official registration in 2021. Entries tested among others including MBC 134, RWV 2425 and MAC 71 performed better in most sites. Five bush bean lines evaluated in adaptability and acceptability trial on station and on-farm. Field observations in different sites showed that RWR 1668*SMC 21 F3-1-3-1; RWR 2154 *RWR1668F3-1-1-3 and BFS 32 were good. Evaluations are still ongoing for yield related parameters, iron and zinc content. The experiment is recommended to be repeated in 2020 A&B when participatory variety selection will be performed and best leads planted for characterization and application for official registration in 2021A.

In partnership with the Soybean Innovation Lab of Illinois University, 24 varieties have been introduced and evaluated for adaptability in both seasons 2019 (A&B) at Rubona, Gashora, Ngoma and Nyagatare Stations. The variety Peka 6 was included as a local check. Prior to planting, seeds were inoculated with rhizobia inoculants. The results showed 7 varieties with good grain yield ranging from 2067 to 2641 g plot^{-1}, maturity (134 – 147 days) and the remaining had low to medium yield ranging between 885 – 1685 g plot^{-1}, and maturing between 130 – 139 days. Although the 7 varieties were promising, their maturity periods were higher as compared to Peka 6 and SB 24. We retained 5 varieties on farm in 2020 A.

Among 600 introduced bean lines from CIAT, only 89 survived severe bean common mosaic necrotic virus (BCMNV) and adapted to test conditions (Rubona station) and were evaluated in 2019B season. Fe/Zn is not yet determined. Best leads will be selected for 2020 crossing blocs and further evaluations. Most of introduced lines showed BCMNV which led to destruction of the majority of introduced lines. The survived lines may be used in common bean improvement.

On Farm trials: Evaluation of soybean lines for yield performance
Best lines that performed very well on Stations were evaluated in different agro-ecological zones on farmer's fields in season 2019 B in Kiramuruzi, Rukomo, Kayonza, Mareba and Kamonyi. The results showed 5 lines with very high yield: S1207-1-6 (3553 kg ha^{-1}), S0108-1-4 (3298 kg ha^{-1}), S1008-7-2 (3190 kg ha^{-1}), S0302-4-2 (3111kg ha^{-1}), S1007-6-2 (3056 kg ha^{-1}) and other 5 lines with good yield as well ranging between 2427 - 2978 kg ha^{-1}. Their physiological maturity ranged between 88 – 110 days. These lines are tolerant to pest and diseases. 8 best lines are proposed for release in 2020A season (S1207-1-6; S0108-1-4; S1008-7-2; S1007-6-2; S0302-4-2; S2508-3-1; S2508-5-1; S0302-4-2).

Evaluation of the performance of indigenous rhizobia strains

This study aimed at evaluating the performance of indigenous rhizobium strains under different agro-ecological zones (AEZs), and assessing their interactions with soybean varieties. Field trials were established in three contrasting AEZs: Ntendezi, Rubona and Gashora, with one field at each AEZ. In the first season (2019A), ten (10) indigenous rhizobium strains were tested and compared with the commonly used USDA 110 (exotic strain). Data were collected on emergence percentage; physiological dates (days to flowering, podding, maturity), biomass, nodulation and grain yields. Preliminary data analysis allowed to select five (5) best strains used in the second season 2019B at Rubona and Gashora. Further research on the five strains will continue (e.g. characterization).

Technology transfer
Enhance the skills of farmers and seed producers through training on developed technologies: A total of 20 demo plots were established at Kiramuruzi, Rukomo, Kayonza, Mareba and Kamonyi where 500 soybean farmers across sites were trained on soybean best agronomic practices, pest and diseases management. At the same occasion extension materials were distributed to the trainees. Farmers expressed their interest in using rhizobia inoculants and requested the inclusion of rhizobia inoculants in the fertilizer package they receive at the beginning of the cropping season.

Dissemination, Promotion, and Consumer Acceptance of Beans: About 600 MT of certified seed of Beans were produced with seed companies. A total of 11077 kg of early generation sees of biofortified varieties were produced in RAB. Promotional materials such as poster, books, leaflets, t-shirts were developed and disseminated to promote beans in Rwanda. Bean varieties were displayed and promoted in the 14th Rwanda national agriculture show held at Mulindi show ground in Kigali from 18th to 26th June 2019. Many (5) more other agriculture shows were attended in order to promote beans products. Television communications, radio talks, workshops and meetings with stakeholders were performed to strengthen bean value chain. 500 leaf lets were distributed along with 500 booklets. 500 stakeholders were trained. Training of 200 District and sector agronomists from Southern province was performed on bean technologies. A total of 70 demonstration plots were established countrywide.

1.4   Roots and Tubers program

The Roots and Tubers Program includes potato, sweet potato and cassava sub-programs. The activities of Roots and Tubers Programme during the fiscal year 2018/2019 focused on (i) development of new varieties, (ii) development of new approaches of pest and disease

management, (iii) development of good agronomic practices, (iv) seed production, and (v) technology transfer.

Development of new varieties

Different trials aiming at selection of best performing among new developed potato clones were carried out across RAB stations. They are various generations including crossing block, clonal evaluation, preliminary yield trial, advanced yield trial, multiplication trials, and national performance trials. These trials fall within following research topics: (1) evaluation of Solynta hybrid potato in Rwanda, (2) local development of new potato varieties tolerant to biotic and abiotic stresses, with high yield and market led traits, (3) evaluation of yield performance of farmer's varieties (Rundarunda, Kuruseke, Peko, Rutuku, Nyiragatuku, Purugeri), (4) evaluation of performance of tetraploid biofortified potato clones in Rwanda. In January 2019, an official variety release day was held at Musanze RAB station, and five new potato varieties were named by farmers as Nkunganire (CIP393280.64), Ndeze (CIP398190.615), Twihaze (CIP393371.58), Kazeneza (CIP393077.159), and Izihirwe (CIP396018.241). These new potato varieties entered on the list of potato varieties in Rwanda and seeds multipliers can multiply them and sell seeds to farmers.

On cassava commodity, a crossing block (polycross) was established at Rubona station with 21 parental lines selected (11 improved lined and 10 local varieties) based mainly on their performance (resistant to pest and disease and high yielding). It is expected to produce 10,000 cassava true seeds of full and half-sib cassava families for nursery and seedling evaluation. More than 10,000 cassava true seed were harvested from crossing block at former Karama station, and a nursery of 3640 seedling was established at Mututu research site/ Muhanga station. The clonal selection from seedling trial of 5971 generated 542 clones which have been planted at two sites for clonal evaluation at Mututu and Rubona sites. Among the 542 clones, 60% are bio-fortified with Pro-vitamin A or beta Carotene enriched.

The Preliminary yield trial was planted in December 2018 at two sites (Rubona and Mututu). A total of 63 clones were selected from clonal trial of 444 clones. Currently phenotypical data at 3 and 6 months after planting were recorded and showed only CMD symptoms on some clones. Other clones demonstrated a post infection recovery of CMD, this mechanism should be explored more to confirm the CMD tolerance mechanism by post-infection recovery for plant viral diseases. The wide adaptability (GxE or multi-location trials) of eight selected elite clones (SEMAK 150149, SEMAK 150452, SEMAK150226, MH95/0091, Bulk 13, Bulk 35, NAROCASS1, 97/2205) was established at 5 research stations (Rubona, Mututu, Gashora, Mahama and Nyagatare) in 2019 A. On farm trials for participatory variety selection of five pre-release cassava clones (01/1206/75; MM 98/3567; Ndamirabana/7; RWACASS-016-01; Gahene/2) were planted in

farmer's fields in 8 cassava growing Districts (Nyamasheke, Nyanza, Ruhango, Kamonyi, Bugesera, Nyagatare, Gicumbi and Gakenke).

The sweet potato sub-program focused on producing new populations using accelerated breeding scheme. The objective of the current sweet potato breeding program is to develop varieties with high yield, tolerant to sweet potato pests (mostly weevils) and diseases (sweet potato virus disease in particular), rich in B-carotene content (orange-fleshed clones) for nutrition purposes, suitable for dual purpose use, with high dry matter content (DMC) and farmer-preferred. Variety development comprised a crossing block complemented with a serie of experimental trials in various selection stages. A crossing block of 12 selected parents was planted in a diallel mating design and true seeds are being harvested. In addition, two advanced yield trials of 18 and 45 clones were established in 2018 B season, where 10 and 18 clones were selected, respectively. Another trial of 40 genotypes and two checks was conducted and 19 performing genotypes were selected for the advanced selection stage. The 19 selected high yielding genotypes are currently being evaluated in Rubona prior on-farm trials. On farm trials were established in Huye, Muhanga and Gakenke District in 2019B with 10 best bet clones using 1 local check at each district. Besides the above mentioned genotypes under development, 26 performing varieties were submitted to the release committee for possible release. The sweet potato breeding program is currently using 158 accessions maintained in situ comprising the 13 exotic varieties introduced this year from Mozambique.

Development of new approaches of pests and diseases management
Pest and diseases are among major challenges of root and tuber cops. To counterattack these challenges various studies were carried out. On potato, it has been done research aiming at (1) identifying the role of women in production and management of Roots, Tubers, and Banana crops in Rwanda, (2) identifying Pesticide Use Practices in Root, Tuber, and Banana Crops by Smallholder Farmers in Rwanda, and (3) identifying Farmer Reported Pest and Disease Impacts on Root, Tuber, and Banana Crops and Livelihoods in Rwanda. The results and key recommendations from these studies were published in scientific journals and can be found on the internet.

Development of good agronomic practices
In potato cultivation, the fertilizer recommendation (mineral fertilizer: 300kg of $N_{17}P_{17}K_{17}$ and organic fertilizer: 20ton/ha) applied is common without considering the site and soil characteristics. By considering the number of plantlets per ha, this quantity of fertilizer, and time of its application highlighted in current potato cultivation guidelines, we suspect variation effects. With this regards, a study aiming at evaluation of effects of fertilizers on potato yields was designed. This study what to identify effects of once and twice application of the combined mineral and organic fertilizers at planting time, earthling time, and effects of randomly and

precision application of the combined mineral and organic fertilizers at planting time, earthling time on yields of potato. The results of the first season are available while the second season failed because of thieves who destroyed the trial. This trial will be repeated in season 2020A.

Trainings

The sweet potato sub-program has conducted various trainings under ICOPSEA-BioInnovate, SUSTAIN, Feed The Future and SASHA-2 projects for agri-promoters and Decentralised Vines Multipliers (DVMs). The purpose of these trainings was to ensure good agronomic practices in sweet potato production and conservation of availed clean seed using low-cost net tunnels for conservation of clean planting material. In total, 85 DVMs were trained.

Seed production

The potato sub-program is involved in activities aiming at availing Earlier Generation Seeds (in vitro plantlets, minitubers, and pre-basic seeds from direct transfer). These activities were carried out to prepare season 2019A and season 2019B. The quantity of potato plantlets and minitubers produced is shown in Table 6 below.

Table 6: Plantlets from micropropagation and minitubers produced

Seed category	Season 2019A	Season 2019B	Total
Plantlets	1,162,400	1,243,280	2,405,680
Minitubers (conventional/aeroponic)	474,328	568,351	1,042,679
Pre-basic seeds from direct transfer	793,459	1,206,045	1,999,504

On cassava commodity, a total of 137,370,800 QDS cuttings were assessed from cassava multipliers. In addition to QDS, 2,310,000 cuttings of cassava certified seeds were produced at RAB stations and distributed to cassava multipliers in 9 districts (Bugesera, Kirehe, Kayonza, Nyanza, Muhanga, Ruhanga, Rulindo, Kamonyi and Huye).

In the framework of producing clean sweet potato planting materials, pre-basic seed was produced through cleaning and tissue culture multiplication of participatory selected popular varieties. In total, 28,680 sweet potato clean plantlets were multiplied in vitro; among them, 12,038 sweet potato plantlets hardened for multiplication in screen house and open field. Hardened plantlets from tissue culture lab undergone multiplication using two screen houses and 2 mobile net tunnels. In total, 10,493,000 million of basic seed were multiplied and availed to Decentralized Vine Multipliers (DVMs) in the most sweet potato growing Districts of Muhanga, Kamonyi, Rulindo, Gakenke, Kayonza, Nyamagabe and Nyaruguru. This activity was done thanks to SASHA-2 and Feed the Future projects (phasing out) and ICOPSEA/ BioInnovate Project.

Technology transfer

Two new cassava varieties (RWACASS 016-02 (Ndamirabana/7) and RWACASS 016-03(Gahene/2) selected from 8 on-farm trials. The selected cassava clones are under multiplication, RWACASS016-02 multiplied on 2.52ha, RWACASS016-03 multiplied on 0.74 ha and the introduced variety named RWACASS016-01 (NAROCASS1) was multiplied on 13.17 ha and seed will be available in season A2020. A training of 24 of ToT on cassava seed multiplication conducted at Rubona. The participants were selected from 6 cassava growers' cooperatives in southern province. It is expected that each ToT will train approximately 100 famers or member of cooperatives and at village level.

On sweet potato commodity, a total of 28 demo plots have been established in 8 districts (Rulindo, Gakenke, Rubavu, Ngororero, Muhanga, Nyamagabe, Nyaruguru and Kayonza). Data were collected and analysed. The aim of these demonstration plots at farmer's level was to improve the agronomic practices, while increasing adoption. In order to ease technology transfer, a platform for vine multipliers (DVMs) was created, and 18 farmers have a common group WhatsApp, where information or any other technology can be easily shared. The platform elected a committee led by Mr. Serge Ganza. The representatives of the platform were invited to participate to the International African Potato Conference (APA) Conference, held in Kigali, August 25-29, 2019.

Other Achievements

The potato sub-program has contributed in preparation to host 11th triennial African Potato Association (APA) conference. About 250 delegates have visited RAB stations of Rubona and Musanze research activities and facilities. Through this conference the potato and sweet potato scientists have presented 6 posters and 3 oral presentations.

1.5   Horticulture program

Development of new approaches of pests and disease management

Assessment of mango fruit fly population dynamics and effective pheromone/male lures for their management in Rwanda: A study was conducted in 7 districts of Kirehe, Nyagatare, Bugesera, Kicukiro, Huye and Rusizi considered being key mango production district. The aim of the study was to monitor changes in population levels of fruit flies in key fruit and vegetable production areas, test different pheromones/male lures and baits for effectiveness in trapping fruit flies, to discover the abundance of fruit fly species present in Rwanda. 4 pheromone lures were placed in

traps boxes targeting male flies: trimedrule, methyl eugenol, fermirule and cuerule. Pheromones were replaced every 2.5 months to ensure the effectiveness of the dispenser guaranteed. Identification of fruit flies was conducted twice, once every 6 months. Methyl Eugenol targeting *Bactrocera zonata spp*. was the most dominant at all sites compared to the other 3 lures. Fruit fly population increased coinciding with mango picking seasons November to March, and May to July but did not drop to complete zero when mangoes were off pick signaling the polyphagous habit to be feeding on other fruit species present that time. This was more pronounced in Bugarama because of the numerous fruit grown there which highly provided an alternative source of food for the flies.

Farmer need to continuously have lured traps in their mango orchards even in off pick periods as flies are still present feeding on other fruit species. Methyl eugenol was the most effective lure in monitoring managing fruit flies in Rwanda. Collaboration of all farmers engaged in production of different fruit crops should be emphasized through sensitization on the management of the pest and fruit selling points / markets must also install lured traps as this was discovered to be hotspots. Farmers are encouraged to do weekly picking of all fallen fruits in the orchard and burying them to reduce habitats in which they hatch from.

Effect of different fungicides on Pseudocercopora leaf and fruit spot disease on existing orchard in Rwinkavu: Pseudocercospora leaf and fruit spot disease was ranked the first in all citrus orchards in 13 districts surveyed (RAB, 2013). The yield reduction due to this disease can reach 50%-100% when climatic conditions are favorable to the disease development, and a timely effective control measures are not taken. The objective of this study was to evaluate the efficacy of different fungicides sprays for management of *Pseudocercospora* leaf and fruit spot disease of citrus. Even to start the experiment, pruning was applied in all fruit trees established ten years ago. The experiment was carried out in farmer's field based in Rwinkwavu sector, Kayonza district, starting in season A 2017 (November 2016). This orchard was established in 2008. Data collection took two years. Two systemic (Ridomil and Benlate) and two contact (Daconil and Copper hydroxide) fungicides were evaluated for their management of the *Pseudocercospora* leaf and fruit spot disease of citrus in this mentioned orchard. The variety planted in this orchard is Washington Navel.

The result from the baseline, the farmer's field of Rwinkawu had the highest disease incidence with 65.6%. The highest disease control on leaves was observed with Daconil and Copper hydroxide which reduced the disease incidence to 19.88% and 25.05% respectively as compared to other treatments such as control with 56.11%. Field application of Daconil and Copper hydroxide significantly reduced the incidence of the disease and thereby, increased marketable fruit yield. Fungicide application should be done by alternating with different chemicals thereby avoiding development of resistance by the target pathogen. For efficient control, it is

recommended pesticides use should be combined with cultural practices like pruning, collection and burying of diseased plant parts, cover crop, fertilizer application and weeding. For efficient control, it is recommended pesticides use should be combined with cultural practices like pruning, collection and burying of diseased plant parts, cover crop, fertilizer application and weeding. To respect the spraying calendar program by our citrus growers.

Development of IPM on mango, citrus and avocado and training of trainers (ToT): Integrated pest management extension packages in form of factsheet were developed for mango Powderly mildew, fruit fly and mango mealy bug management. A detailed fruit production booklet on avocado, citrus and mango containing detailed information of pests and diseases was also developed and validated by a team from RAB, RALIS and NAEB. These materials are to be used in training of trainers (ToT's). 63 ToT's from Busegera and Kayonya districts have been already trained in June 2019 and more are to be trained in the coming fiscal year 2019/2020 from out of 13 major fruit production districts

Detection of viruses in hot pepper varieties cultivated in Rwanda: Viral diseases are a major challenge to production of pepper worldwide, affecting yield and quality. About 68 viruses have been reported to infect pepper from various part of the world (Pernezny et al., 2003). In Rwanda, viral diseases have been reported to cause major yield loss in pepper for the past several years. Around 40 to 100% losses of marketable fruit due to viral diseases have been reported. Information on specific viral diseases responsible for the decline in yield and production of pepper is insufficient. Thus, the aim was to identify the viruses affecting pepper production. Such information is important for the successful management of these diseases leading to increase in productivity as well as famers' income. A total of 253 samples were collected from different districts of Nyanza, Rulindo, Kayonza, Gatsibo, Gakenke, Rwamagana, Nyagatare, Bugesera, and Rusizi. The presence of viruses was detected using enzyme-linked immunosorbent assay (ELISA) kits obtained from Bioreba, Switzerland and LOEWE Biochemica GmbH company, Germany following the manufacturer's protocol. The kits are specific to 5 viruses namely; _Potato virus Y_ (PVY), _Pepper veinal mottle virus_ (PVMV), _Pepper mild mottle virus_ (PMMoV), _Cucumber mosaic virus_ (CMV) and _Tobacco mosaic virus_ (TMV). Various symptoms of viral infection were observed in the fields sampled. However, visual symptoms alone were insufficient in virus identification since their expression may be influenced by other factors such as host cultivar, strain of virus, age of the host and environmental conditions. The suspected collected samples were then subjected to the ELISA tests were some proved positive to _Cucumber mosaic virus_ (CMV), _Pepper veinal mottle virus_ (PVMV), _Pepper mild mottle virus_ (PMMoV) and _Tobacco mosaic virus_ (TMV). These viruses have been reported in several other countries. ELISA test for PVY was negative.

In conclusion, viral diseases are considered to be a major limiting factor in pepper production in Rwanda, causing serious losses. In the present study, four viruses were identified i.e. _Cucumber_

mosaic virus (CMV) and *Pepper veinal mottle virus* (PVMV) transmitted by aphids and, *Pepper mild mottle virus* (PMMoV) and *Tobacco mosaic virus* (TMV) which are seed-transmitted. These findings reveal the need for more and repeated surveys to confirm the occurrence and significance of these viruses in the country. Information generated from this study will serve as a guide in management strategies to minimize crop losses and ensure sustainable production of pepper.

Development of good agriculture practices

<u>*Organic fertilization in Stevia production*</u>: This study was conducted at Rubona station with 4 treatments :(T1: compost, T2: cow dung, T3: Pig manure, T4: poultry manure, and check (soil without manure). It was concluded that poultry manure among the organic fertilizers performed best and hence recommended to stevia growers. It recommends repeating the study in different location in order to confirm the results.

<u>*Determination of the response of Stevia to different planting densities (Plant spacing)*</u>: This study was conducted in three location using 6 treatments (20x20, 20x25, 25x25, 20x30, 25x30, 30x30). Plant spacing of 20cm x 20cm is the best in stevia production according the result from three different locations.

Seed production

Horticulture center of excellence introduced 2 avocado varieties (Hass, Ettinger), 3 mango varieties (Tommy Atkins, Kent, Apple), 4 citrus varieties (Orange, Lemon, Lime, Pomelo); citrus rootstocks, and seeds of avocado and mango were introduced from Ethiopia and are being evaluated for their performance. A total of 34,419 vegetable seedlings of different varieties of tomato, eggplant, sweet pepper, watermelon, cabbage, onions were produced through the vegetable nursery and used in both, protected and outdoor production. The number of scions harvested and distributed is 353,660 for avocado, 193,400 for citrus and 240,500 for mango. A total of 50 kg of seeds was distributed in major production districts of tamarillo, which can cover 1,650 ha when planted. The districts which received the seeds are: Nyaruguru, Nyamagabe, Kamonyi and Nyanza in Southern province, Gakenke, Gicumbi, Rulindo, Burera and Musanze in Northern Province and Rusizi, Nyamasheke, Ngororero and Rutsiro in Western province.

Technology transfer

Horticulture center of excellence hosted and trained 185 students including Primary school, secondary and Universities, 154 farmers both individual and cooperatives paid visit to the Center. An intensive training was given to 67 extension workers (Master trainers) on irrigation, Plant protection and Vegetable production which received a certificate after the course and 14 university students were hosted for internship programs. A total of 220 (ToT) farmers have been trained   in Market oriented vegetable production. 29 farmers have been trained on hot pepper

in crop management and pest and disease control in Nyanza district; 45 farmers trained in passion fruit in crop management and pest and disease control in Rusizi and Ngoma districts. 250 farmers have been trained on tamarillo in crop management and pest and disease control in Nyamagabe, Gicumbi, Musanze, Gakenke, Rulindo and Burera and those farmers have received the clean seed from RAB which was planted in 2019A.

1.6   Industrial Crops program

1.6.1 Coffee sub-program

Among coffee production constraints are low yielding varieties, limited access to healthy planting materials, diseases and pests (such as coffee leaf rust, coffee berry disease, antestia bug and coffee berry borer), low inputs use and climate change hazards. Other factors include sub-optimal plant populations, macroeconomic mismanagement, poor extension services, unfavorable land tenure systems, poor adoption of innovations, unfavorable policies.

For the 2018/2019 fiscal year, research activities under the coffee sub-programme focused on interventions that enhances coffee productivity through mainstreaming climate change adaptation practices into the coffee sector. Because coffee is a perennial crop a number of activities were completed and other projects initiated. Coffee research focused on: 1) Monitoring and surveillance of major coffee pests and diseases; 2) Development of IPM Package; 3) Development of marked-led and climate resilient coffee varieties; 4) Enhancing seed systems through production early generation (basic) coffee seeds; 5) Development of communication strategies for adoption of new coffee farming technologies.

Monitoring and surveillance of major coffee pests and diseases
The main objective of the field surveillance and monitoring was collecting information on the spread and occurrence of the main coffee pests and diseases, as well as crop management practices. The survey included main coffee areas and the survey covered 20 districts across the country (Figure 3). High prevalence of coffee leaf rust, coffee berry disease and antestia bug were observed in all the coffee growing regions of Rwanda. High prevalence of coffee berry borer was observed in Western Province whereas high occurrence of stem borer were observed in Eastern Province. These findings were shared with coffee value chain stakeholders and NAEB.
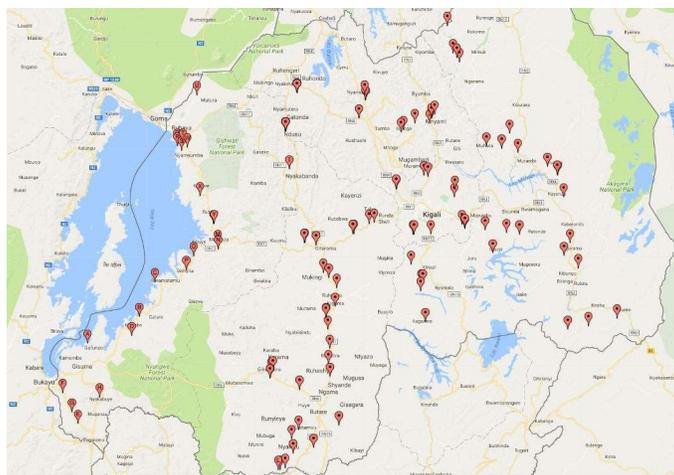
Figure 3: Major pests and diseases of coffee were assessed in various geographic locations of Rwanda

Development of IPM package for coffee growers

IPM guide was compiled in one document for existing practices. These include chemical management of coffee leaf rust, coffee berry disease, antestia bug, stem borer, leaf minors and coffee berry borer. The document will serve as a teaching/extension material for small-scale coffee farmers. New sustainable pest and disease management options were evaluated and will be included in the IPM package. These include systemic (tebuconazole) and biological fungicides (ProBlad) against major fungal diseases of coffee (leaf rust and anthracnose), use of a new class of insecticide (sulfoxaflor), which are less susceptible to insect resistance against antestia and coffee berry borer, the introduction of semiochemicals (trapping systems) against major insect pests. Another study was conducted to assess the effect of shade on coffee leaf rust. Promising results were obtained during 2018/2019. For 2019/2020 these IPM packages will be validated through 2nd scale up testing prior to large scale dissemination programmes.

Development of climate resilient and market-led new coffee varieties

<u>Coffee breeding</u> aims at developing new coffee varieties combining high yielding potential, good cup quality, and multiple stress resistance/tolerance. During 2017/2018 fiscal year six out of eleven F1 hybrids that were developed in 2012 have been evaluated for field performance. These hybrids revealed a yielding potential higher (>2.5t/ha) than existing commercial varieties (BM139 and Jackson). These hybrids are: BM139x6A, BM139XRUIRU11, BM139X5A, BM139XBATIAN, Jacksonx6A, Jackson x 5A. In addition, these hybrids are resistant to coffee leaf rust and coffee berry disease as well as low rainfall tolerance. During 2018/2019 The hybrids were evaluated for quality characteristics. All the hybrids revealed the overall quality higher than 85%. These are JacksonxRuiru (90%), BM139 x 5A (88%), BM139xRuiru (88%), BM139x6A (88%), BM139 x Batian (86%), Jacksonx6A (85%), Jacksonx5A (85%).

Best performing hybrids will undergo mass multiplication through clonal propagation for dissemination to farmers based on site-specific adaptation. Multi-locational evaluation of these hybrids is underway as well.

Variety introduction: In partnership with the World Coffee Research (WCR) new coffee genotypes were imported (Photo 3). In fact, WCR has gathered 35 top-performing coffee varieties from 11 suppliers around the world and developed 40 F1 hybrids. So far, 20 varieties were imported and submitted to multi-locational trials to assess adaptability and yield stability. These varieties are known as IPR 107 , SLn5B, BP 432A, H1, AB3, S.795, BATIAN, ORO AZTECA, PACAMARA, PARAINEMA, GEISHA, MUNDO NOVO, S 4808, COL1, MARSELLESA, BP432A, Paraiso, Col2, Sln 6, BLP10. In the same line 40 F1 hybrids have been imported from WCR as in vitro plantlets and submitted to acclimatization process. During the 201/2019 fiscal year field performance of these varieties for core traits were evaluated in multi-locational trials in Ngoma, Rubona (Huye) and Mwito (Nyamasheke) (Photo 3).

Photo 3: In vitro plantlets were received from World Coffee Research (1), acclimatized in Rubona (2) and put in multilocational trials

Enhancing seed systems through production early generation (basic) coffee seeds
For 2018/2019, seed gardens for released varieties were maintained. 1200 kg of a newly released RABC 15 variety were produced and supplied to farmers. This amount can produce 3,600,000 seedlings and plant around 1440 ha. On the other hand, 3,500 kg of clean seed from traditional varieties (BM139 and Jackson 1257) were produced and supplied to farmers. This amount of seeds can produce 10,500,000 seedlings and plant around 4,200 ha of land.

Trainings on new coffee farming technologies
During 2018/2019 a training program was organized and involved 60 sector agronomists from Western Province, 25 district cash crop officers and university students (Photo 4).

Photo 4: Trainings organized on coffee management

On the other hand, extension materials were produced distributed to farmers. These include leaflets, flyers and fact sheets of major pest and disease management techniques that were distributed to farmers.

1.6.2 Tea sub-program

The present report summarizes results from on-farm tea trials in relation to tea clone evaluation, fertilizer use and other agricultural practices including planting density. Both ongoing and new activities are here presented. The year 2018/2019 Tea sub-program continued the compilation of findings from long term trials in the same areas as above while validation and mainstreaming to end users was scheduled for 2019/2020.

Variety development

Yield data was collected from an ongoing tea clonal trial that was established during 2014/2015 FY at 4 sites of Mata (Nyaruguru), SORWATHE and ASSOPTHE (both sites of Rulindo) and Ntendezi (Nyamasheke). The 5th site of Pfunda (Rubavu) was stricken by Armillaria root rot disease and was under rehabilitation during 2018/2019 FY. The aim of the study was diversification of tea genetic resources in tea plantations. Clones under evaluation were TRFK 303/577, TRFK 301/4, TRFK 301/5, TRFK 54/40, TRFK 6/8, TRFK 31/8, TRFK 11/4, TRFK 7/3, TRFK 12/19, TRFK 12/12, TRFK 12/56, SFS 110, SFS 475, SFS 204, SFS 371, SFS 150, PC 81 and TRFK 6/8. Tea clones showed behavioral differences in terms of dried or made tea (m.t.) yield across sites whereas significant yield difference was observed at two sites of Mata and SORWATHE. At Mata site, best clones were SFS 150, TRFK 54/40 and TRFK 304/4. Respective yields were 2780, 2593 and 2508 kg m.t./ha/year. At SORWATHE clones TRFK 54/40 and SFS 475 were outstanding with respective yields 2796 and 2655 kg m.t./ha/year. A series of clones TRFK 303/577, TRFK 12/12, TRFK 301/5 and PC 81 followed yielding between 2300-2400 kg m.t./ha/year. Both sites are located on back slope of hills and experienced a severe dry season. Clone TRFK 6/8 yield was among the lowest at both sites. This clone is most grown in tea plantations of Rwanda because of its high quality. It

could have been more sensitive to dry season than others clones. At sites of ASSOPTHE and Ntendezi clones did not show significant yield differences, probably due to short time of data recording (6 months each). Trends showed for example that TRFK 12/12, TRFK 12/19 and SFS 150 yielded higher at ASSOPTHE while clone PC 81 yielded slightly higher at Ntendezi.

A new clonal trial was established in November 2018 at a new tea planting site in Kibeho Sector, Nyaruguru District to test adaptability and field performance of tea clones. End results will guide tea growers on best clones to plant in their fields. The trial comprised 4 new accessions, namely UTK 9710342, UTK 401658A, Martim 1 and UTK 900244B along with clones currently used in commercial production of Rwanda, including TRFK 31/8, TRFK 6/8, BB 10 and TRFK 11/4. The trial is conducted in collaboration with Unilever Tea Company LTD. Yield data collection is expected to start when tea is two year old while measurement of growth parameters will start at 9 months. Regular activities for conservation *in situ* of 33 tea clones at Ntendezi (2.5 ha) and 8 clones at Gakuta (5.5 ha) was performed through regular tea maintenance practices. The germplasm will help to provide tea growers with cuttings for seedling preparation and future breeding activities.

Agronomy

Yield data was collected from an ongoing trial that was evaluating effects of splitting fertilizer on soil nutrients and tea yield. It was established at Nshili-Kivu, Nyaruguru District in June 2015. Seven rates and frequency of application of NPKS 25-5-5-3 were as follows: T1: nil fertilizer application; T 2: 200 Kg /ha/year (i.e. 50 kg N/ha/year) in two splits; T 3: 400 Kg/ha/year (i.e. 100 kg N/ha/year) in two splits; T 4: 400 Kg/ha/year (i.e. 100 kg N/ha/year in two splits long with foliar application of urea (2 % i.e. 8kg of urea in 400l of water/ha) at month interval during July, August and September; T 5: 600 Kg/ha/year (i.e. 150 kg N /ha/year) in three splits T 6: 600 Kg/ha/year (i.e. 150 kg N /ha/year) in four splits; T 7: 800 Kg/ha/year (200 kg N/ha/years) in four splits. Yield of 7 fertilizer rates and splits from zero fertilizer application to 800 Kg of NPKS 25-5-5-3 /ha/year in four splits ranged from 2666 to 2984 kg made (dried) tea but yield was not significant (at 5% level). It would indicate that tea was not responding to fertilizer. The observed yield was more influenced by the year of tea in the pruning cycle (2nd year) than the fertilizer. Combining the actual result with the previous years' observation it was concluded that NPK 25-5-5-3 application at 400 Kg/ha/year (i.e. 100 kg N/ha/year in two splits (March/April and October) plus foliar application of urea (2 % i.e. 8kg of urea in 400l of water/ha) at month interval during July, August and September would be sufficient in the conditions of Nshili Kivu.

Another long term study testing different sources of fertilizers, namely Organomex" (a foliar plant feed), NPKS 25:5:5:3 at 150 kg N/ha/year, cattle manure and the control or nil fertilizer application. Yield data confirmed, as in previous years 'observations, that Organomex (leaf fertilizer) and cattle manure may be used as alternatives to NPKS without compromising yield at ASSOPTHE (Rulindo). A trial on tea plant spacing was established at Kibeho (Nyaruguru) in November 2018 to evaluate plant population effects on growth, development, yields and quality

of tea. It is testing five spacing or planting densities on clone UTK 9710342 and the local check TRFK 11/4. Spacing or plant densities under test were as follows: 1) 120cm x 80cm equivalent to 10,471 bushes ha^{-1}, 2) 120cm x 60cm or 13,889 bushes ha^{-1}, 3) 100cm x 70cm or 14,286 bushes ha^{-1}, 4) 80cm x 60cm or 20,800 bushes ha^{-1} and 5) 60cm x 60cm or 27,778 bushes ha^{-1}. Yield data collection is expected to start when tea is two year old while measurement of growth parameters will start at 9 months.

1.7   Crop Protection program

Crop protection program aims to improve agricultural production through development and dissemination of pests and disease management technologies. Its main activities include collects and regularly update information on pests and diseases situation in the country and develop programs and technologies for their management; capacity building of extension agents and farmers; provide all information on the practices to control disease and pests in case of outbreaks and also make follow up for a better management of different pests in seed storage facilities. The following are main activities carried out in crop protection program during FY 2018/2019: (1) Monitoring and control of pests and diseases for priority crops and constitution of a strategic stock of pesticides to manage different identified pests, (2) Conduct Mobilization campaigns, meetings, radio talks on management of different pests, (3) Development and distribution of extension materials in area of crop protection for different crops, (4) Training of Extension agents (sector and district agronomists, CIP focal persons, farmer promoters, farmers) on management of different diseases & pests, and (5) Promote and strengthen plant clinic activities through Plantwise program.

Monitoring and control of pests and constitution of a strategic stock of pesticides
For pests and diseases management, farmers are advised to use non-chemical control practices (Cultural, physical, mechanical control, use of biological control, etc.) before chemical control options because they are inexpensive and safe to humans, farm animals and the environment. Farmers have been advised to do regular field monitoring to check if there are no pests in their field. Many interventions were done through field visits, meetings and community works in affected areas to manage identified pests especially FAW in Maize, White grub pest, bean disease and potato bacterial wilt in Irish potato and recommendations were given to farmers in order to manage those disease and pests. As strategic stock of pesticides, around 2,413 Litres of pesticides including Cypermethrin 5% EC, Cypermethrin 4% EC+Profenofos 40% EC, Lambdacyhalothrin 5% % EC, Pyrethrum EWC, and Imidachloprid 200g/L SL were distributed to farmers in different affected areas of the country and farmers have been shown the best way to apply those pesticides especially in managing maize stalk borer, fall armyworm and other pests.

Mobilization campaigns for pest management

Mobilization campaigns, meetings, field visit, radio talks (Radio Rwanda & Community Radio) on pest management were conducted especially on Fall army worm (FAW) pest, Maize Lethal Necrosis (MLN) disease and on Banana Xanthomonas Wilt (BXW) surveillance and control in collaboration with different stakeholders. About 410 new FFS Farmers were trained in Kayonza district on how to control BXW disease whereas in Ngoma District 490 farmers were trained on BXW control. Follow up on BXW control activities was done and during Army week and farmers who participated were 121 and 357 in Kamonyi and Muhanga districts respectively.

RAB in collaboration with FAO has organized training campaigns in the districts of Muhanga, Nyanza, Nyamagabe, Rwamagana and Nyagatare to enhance farmers' capacity in sustainable way of FAW control and management. 2800 farmers, 440 SEDOS and 79 sector agronomists were trained in FAW control strategies including use of pheromones traps. During this campaign, 250 FAW monitoring tools (pheromone traps, lures and insecticidal strips) were distributed.

Photo 5: Training of farmer promoters, Sedos and sector agronomists on FAW management in southern province

RAB in partnership with Feed the Future Rwanda Hinga Weze has organized and conducted an extension campaign through "Plant Health Rallies (PHR)" against FAW. This campaign was conducted in 6 districts of Hinga Weze zone of interventions: Ngororero, Nyabihu, Rutsiro, Nyamagabe, Nyamasheke and Karongi. In total 1,700 farmers have been reached, including 897 males, 714 females and 62 youth. The campaign focused on practices including: correct identification of FAW, Integrated Pest Management (IPM), the appropriate/safer application of pesticides and the promotion of the environmentally and sustainable use of less hazardous pesticides.

Photo 6: Participants during the FAW campaign in Ngororero. These include: Farmers, FPs, FFS facilitators, Agro-dealer, Local leaders, RAB staff and Hinga Weze staff (left); FAW campaign poster displayed at each site (right).

Development and distribution of extension materials in area of crop protection

Different Extension Materials on different pests have been developed. Leaflet and poster on Fall Armyworm identification, damage symptoms and its management; fact-sheet on mango mealybugs, Powderly Mildiou, fruit fly and Striga weed. More than 20,000 extension materials were distributed (leaflet, farmer's guides and fact-sheets) to farmers, farmer promoters and FFS facilitators during 19A &B seasons to help them to identify different pests and manage them. For 2020A season, other extension materials in collaboration with One Acre Fund have been developed on the following crops maize, Irish potato, wheat, tomato, cassava, soybean, banana, beans and horticultural crops to be used by farmers.

Training of Extension Agents on Pests and Disease Management

Due to outbreak of Fall Armyworm (FAW), training was focused on this pest. Around 14,000 Farmer Promoters were trained during 19A & B seasons on the management of the above mentioned pest in collaboration with other stakeholders like One-acre fund, Hinga Weze and FAO. With support of USAID & FAO, RAB has implemented 2 joint projects on fall army monitoring, early warning and management system in Nyagatare, Gatsibo, Kayonza, Rwamagana, Muhanga, Nyanza, Nyamagabe, Ngororero, Rubavu, Musanze and Gicumbi districts. Many Extension agents including sector and district agronomists, CIP focal persons, farmer promoters, farmers and SEDO'S have been trained on FAW biology and ecology, symptoms damage and its management. With support of the two projects 11 people trained on FAW management in Training of trainers (ToT), 226 technical personnel and experts involved in FAW monitoring and management, 220 community focal persons supporting on FAW monitoring and early warning system and 115 Farmer Field School Facilitators. Pheromone traps for FAW monitoring were also

installed on selected sites and people on these sites were taught how to collect data from those traps and how to do field scouting while checking FAW in the maize field. RAB in partnership with FAO and SOPYRWA have conducted a training on potato seed production techniques and Potato pest and disease management and pesticide handling for potato seed producers from Musanze and Nyabihu, Burera, Rwamagana, Kayonza, Nyamagabe, Gicumbi, districts. In total 136 participants were trained.

Validation of Push pull technology to manage Fall Armyworm (FAW) and stem borer

This study was conducted in Rubona, Rwerere & Mututu stations. Based on preliminary results of the first season of 2018B, the study shows the severity of the FAW in Rubona than Rwerere site. With the data of second seasons of 2019A, the results shown the reduction of infestation level caused by FAW in the push pull plots compared by damaged maize in the control plots. Unfortunately, yield was significantly decreased in second season 2019B due to the nutrient competition between maize and Desmodium in the push pull plots. However, Push pull practice seems to be a promising technology for maize stem borer management (Photo 7).

Photo 7: Push pull Plot at Mututu station

But the experiment will continue particular on appropriate spacing between rows of maize and desmodium in order to avoid crop competition.

Photo 8: FAW identification in Byumba sector, Nyiragasuruba site (left) Symptoms showing wilted plant with rotted potato (right)

Photo 9: Installation of trap in Nyanza District (left) and community focal persons during field day in Gatsibo district (right)

Technical support was provided to the communities on identification of the Fall Armyworm and use of traps (Photos 8 and 9).

Trials conducted on different potato varieties

The purpose of this trial was to screen up the varieties for identifying the ones which are more performant and accepted by farmers. The on farm trials were conducted in Rwamagana, Kayonza, Gicumbi, Nyamagabe districts (Table 7). As results, the varieties who have been performant more than others are Kirundo, CIP393371.58 (Twihaze), CIP393280.64 and CIP393077.159. This activity is still going on (not yet finished). On station trials were set in Nyagatare, Kibungo and Sigira site with the purpose of identifying new varieties to be promoted in Rwanda conditions. Some clones were more performant than others: Kirundo, Kinigi, CIP392797.22, Shangi and CIP393379.4.

Table 7: Description of potato genotypes to be evaluated in multiplication trials

No	Varieties	Other traits	Other traits	Other traits
1	Gikungu	Good for chips	Resist to LB	
2	Kinigi	Chipping	Resist to LB	
3	Kirundo	Good for chips	Resist to LB	
4	CIP393077.159	Good for chips	Resist to LB	Resist to virus
5	CIP393251.64	Good for chips	Resist to LB	Resist to virus
6	CIP396018.241	Good for chips	Resist to LB	
7	CIP393371.58		Resist to LB	Resist to virus
8	CIP398190.615	Good for chips	Resist to LB	Heat tolerant

Biocontrol lab

Research focused on development of optimization protocol for mass production of available EPNs and their maintenance in the biocontrol lab. Research on optimizing protocol for mass production (in vivo and in vitro) of all available Entomopathogenic nematodes (EPNs) was conducted and 43,191,655 infective juveniles (ijs) of local EPNs and 15,108,220 ijs from exotique EPNs isolates were produced (Table 8). Screening of local and international isolates of EPNs for management of target pests, cutworms (Agrotis spp), was conducted. The exotic EPNs exhibited good capability of killing cutworms. The local EPNs *Steinernema carpocapsae* showed promising results. However, this work needs to be completed with further repeated bioassays and field trials.

Table 8: Quantity of entomo-pathogenic nematodes (EPNs) produced at Rubona station

Scientific name	Code	Quantity of EPNs infective Juveniles (ijs)
Steinernema carpocapsae	RW-GR3a-2	283 280 IJs
Steinernema sp	RW-MC2b-1	18325 000 IJs (*Invivo* 867 145 ijs; *Invitro* 17 325 000 ijs)
Steinernema sp.	RW-MC2a-3	478 900 IJs
Heterorhabditis bacteriophora	RW-NC4a	2 015 400 IJs
Heterorhabditis sp.	RW18-M-1b	7 422 100 IJs
Heterorhabditis sp.	MD4S5Hr-1a	32 124 730 IJs
Steinernema carpocapsae	ALL	12 169 640 IJs
Heterorhabditis bacteriophora	HO6	1 296 900 IJs

Heterorhabditis indica	LN2	1 231 300 IJs
Steinernema Longidicum	X-7	410 380 IJs

Part 2. Livestock research and extension

Livestock is one of the key pillars for economic growth and poverty reduction. However, livestock makes a disproportionally low contribution to the income and welfare of the poorest smallholders (MINAGRI, 2012). Currently agriculture sector contributed 30% to the GDP and it generates over 60% of the foreign currency earnings. Livestock contributes 10% of the agricultural GDP and 3% to the national GDP (NISR, 2017). The national livestock populations as censed by the districts are given in the table below (Table 9).

Table 9: Livestock population in Rwanda, 2015-2018

Category	2015	2016	2017	2018
Cattle	1,138,799	1,149,749	1,165,835	1,293,768
Goats	2,706,382	2,605,780	2,923,706	2,731,795
Sheep	716,309	637,068	664,703	601,836
Pigs	1,492,506	1,684,709	**1,716,438**	1,330,461
Rabbits	1,354,703	1,387,669	1347860	1,264,734
Poultry	4,837,794	5,238,497	5,272,725	5,442,152

The distribution of livestock population is summarized in Table 10 below.

Table 10: Number of livestock per district in 2018.

District	Cattle	Goats	Sheep	Swine	Chicken	Rabbit	Dog	Cat
Bugesera	40,875	132,556	6,744	99,427	335,026	26,865	152	61
Gatsibo	82,836	102,765	6,688	57,919	185,894	24,127	1,222	861
Kayonza	60,066	117,351	8,008	29,178	119,263	18,437	708	125
Kirehe	52,278	114,966	11,253	33,316	126,891	14,698	574	82
Ngoma	38,596	99,022	16,172	39,840	109,127	16,728	493	129
Nyagatare	106,011	166,188	7,544	36,452	112,663	19,038	849	93
Rwamagana	33,096	93,165	9,828	56,706	221,082	18,396	769	100
Eastern Prov	413,758	826,013	66,237	352,838	1,209,946	138,289	4,767	1,451
Gicumbi	66,830	108,451	34,760	64,859	193,033	64,642	916	854
Bulera	2,216	91,176	38,361	29,454	126,464	38,818	261	170
Gakenke	56,413	97,335	45,268	57,899	197,532	76,103	751	605
Musanze	31,921	93,316	33,898	60,401	165,935	35,134	504	114
Rulindo	37,631	95,206	42,082	30,005	130,993	60,573	695	605
Northern Prov	235,011	485,484	194,369	242,618	813,957	275,270	3,127	2,348
Gisagara	32,835	132,696	4,591	89,768	155,996	28,375	603	240
Huye	36,334	47,033	5,514	27,588	56,423	35,033	1,059	663
Kamonyi	57,343	127,599	5,642	15,177	93,611	33,404	774	809

Muhanga	50,831	39,559	12,001	38,137	60,173	51,829	290	78
Nyamagabe	40,478	94,432	46,437	62,217	93,718	38,590	287	130
Nyanza	53,113	89,091	16,610	45,397	167,468	22,169	270	77
Nyaruguru	48,899	91,957	32,107	65,876	109,635	31,630	708	107
Ruhango	66,999	65,899	4,969	23,405	90,618	21,797	344	207
Southern Prov	386,832	688,266	127,871	367,565	827,642	262,827	4,335	2,311
Karongi	48,096	85,154	36,432	43,895	113,480	27,680	735	315
Ngororero	39,385	84,304	39,397	34,275	103,652	36,921	431	130
Nyabihu	27,057	84,121	30,792	20,158	160,510	14,578	464	179
Nyamasheke	31,859	86,667	19,158	59,995	214,597	14,105	417	248
Rubavu	15,846	81,634	25,424	57,353	167,355	46,694	944	348
Rusizi	19,971	83,123	15,891	65,838	134,522	5,884	469	535
Rutsiro	32,300	86,818	38,013	52,773	212,260	22,247	374	175
Western Prov	214,514	591,821	205,107	334,287	1,106,376	168,109	3,834	1,930
Gasabo	28,354	57,430	3,144	14,266	250,971	9,559	980	355
Kicukiro	10,413	48,127	2,578	10,098	110,113	5,853	856	190
Nyarugenge	4,886	34,654	2,530	8,789	123,147	4,827	426	202
Kigali City	43,653	140,211	8,252	33,153	484,231	20,239	2,262	747
TOTAL	1,293,768	2,731,795	601,836	1,330,461	4,442,152	864,734	18,325	8,787

The animal products are milk, meat, fish, eggs, honey, hides and skins, and the volumes are shown in Table 11.

Table 11: Animal products produced in Rwanda in 2015-2018.

Product	2015	2016	2017	2018
Milk	700,267	717,227	766,993	815,074
Meat	103,281	117,294	152,029	162,470
Fish	25,450	26,732	28,705	31,465
Eggs	6,973	7,347	7,475	7,936
Honey	4,585	4,738	5,105	5,200
Hides & skin	5,305	5,506	6,781	6,567

The Government of Rwanda has acknowledged livestock as an important part in achieving food security for Rwanda, especially in terms of the protein requirements and also its potential role in poverty alleviation. Livestock research focused on performance evaluation of cattle genotypes, conducting cattle embryo transfer and a baseline survey on genetic characterization of local chickens and pigs.

2.1 Cattle program

Evaluation of cattle growth

Growth performance of cattle at station level was collected individually for all categories of cattle. The evaluation of growth performance of different cattle genotypes was generated from first and second generation of Ankole (AA), crosses of Ankole and Jersey (AJ), crosses of Ankole and Friesian (AF), crosses of Ankole and Sahiwal (AS) and shown following results.
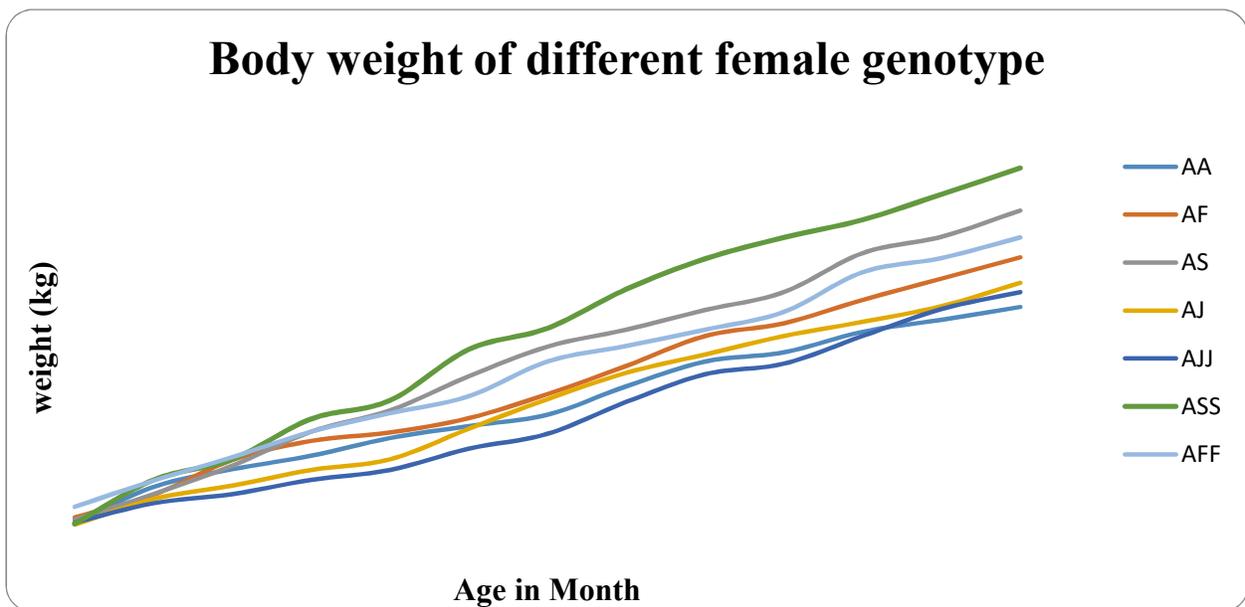
Figure 4: Monthly body weight for different cattle genotypes

The growth performance of cattle genotypes differs significantly (P>0.05) where ASS has the highest growth rate (Figure 5) as compared to other genotypes followed by AS this shows that Sahiwal breed has expressed their potentiality in meat production and this makes them to be more heavier than dairy (Friesian and Jersey) breed. However, the monthly body weight has shown different variations within and between breeds during a period of 12months.

Embryo transfer

Embryo transfer in cattle has recently gained considerable popularity with dairy and beef producers. It is one step in the process of removing one or more embryos from the reproductive tract of a donor female and transferring them to one or more recipient females. Embryo transfer is a process by which an embryo is collected (flushed) from one female (the donor) and transferred to another female (the surrogate/recipient) to complete the gestation period (Hasler, 2004). Embryo transfer help to increase the number of offspring sired from superior females, results in faster genetic progress, increase the frequency of desired mating, capitalizing on

excellence of a mating, obtain offspring from old or injured animals incapable of breeding or calving naturally, increase farm income through embryo sales and exportation and importation of embryos are easier than with live animals (Sheetal et al., 2015).

Super-ovulatory responses, selecting the best dams Flushing and collecting the embryo established: Best dams used for super-ovulatory and embryo transfer were selected at RAB station and at farm level (Photo 10 and 11). In total 124 cows were selected including 57 from RAB station, 27 of Songa, 12 of Kinigi and 8 of Rubona Station and 67 from farmers of Muyira. Kinigi, and Muhoza sectors. Flushing and embryo collection were done on four selected and synchronized cows of Kinigi Station. Three of them had positive responses on hormones and AI, the ovaries status showed the presence of corpus luteum and embryo were collected through flushing process. After microscope checking of the flushing medium three embryos was collected from two cows and one cow had no embryo.

Photo 10: Selection of best dams by checking the status of ovaries using palpation method

Photo 11: Checking the status of pregnancy using ultrasound

Embryo transfer conducted and percentage of success rate increased: Embryo transfer was conducted on 51 cows in total 15 from Muyira, 17 from Kibilizi and 19 from Songa. Calf born from embryo transfer technology were four in Muyira, three in Kibilizi sector and six in Songa station (Photo 12), in total they were 13 calf out of 51 Embryo transferred. The success rate was reported at 26.6%, 17.64% and 31.57% in Muyira, Kibilizi and Songa, respectively. The general success rate was reported at 25.49%.

Photo 12: Calves born from embryo transfer, RAB – Songa station

2.2 Animal Nutrition program

Promotion of good forage species continued. A total of 274 farmers have established improved forages including *Chloris gayana*, *Brachiaria* spp. and *Panicum coloratum* on about 600ha area. A total of 1865 farmers and extension workers have been trained on feed and feeding management at RDDP operating areas. At station level, about 40.5 ha of forages as new seed production were established in Nyagatare, Songa, Gishwati, Musanze and Rubona stations. A total of 500 kg of seeds from Chloris and Panicum spp. have been collected. Under germplasm maintenance, at least 63 ha were maintained from the beginning of this fiscal year (2018-2019) (Photos 13 and 14), and different forage seed was produced, which have been distributed to different farmers in the aim of increasing milk production of their cattle.

Photo 13: *Cinhrus ciliaris* at Rubona (left) and *Macroptilium atropurpureum* (right)

Photo 14: *Brachiaria bazilisk* at Rubona (left) and *Desmodium incunatum* at Rubona (right)

Conservation of forage germplasm

At Nyagatare, Mirama station 20 tonnes of forages were conserved, both grasses and legumes on station. The total land used for seed multiplication is 60 Ha. Three species of forages were planted including *Chloris gayana, Panicum maximum, Desmodium* and *Pennisetum purpureum* (Photo 15 and 16). The following pictures show the different plots of forages cultivated at Songa.

Effect of adoption of cereal-legume forage integration system on GHG emissions and farm profitability in small land holder dairy farms in Rwanda

With a population density of 470.6 per km^2 for both human and cattle and an annual population growth rate of 2.7% and an increase in dairy cattle population due to the policy of one cow for every poor family in Rwanda, the land resource is continuously shortening in Rwanda for both human and cattle population and the productivity yield for both crop and livestock is relatively low. The average land holding capacity is of 0.2 ha per household. With the decreasing of land holding the area reserved for fodder production is narrowing, leading to insufficient feed production as compared to requirements for dairy cows. Daily dry matter intake in Rwanda is

estimated to 6kg for a cow of 300 kg body weight and this is far below the maintenance requirement, without considering milk production requirement of a cow yielding 12 liters per day. There is need to enhance forage production by efficiently using the limited available land resources without compromising the area reserved for crop production.

Photo 15: *Cenchrus ciliaris* **(left) and** *Chloris guyana* **(right) at RAB-Songa**

Photo 16: Pennisetum purpureum (left) and Desmodium intortum (right) at RAB-Songa

Study objectives were to (1) assess status in energy and protein feeds supply versus requirement to dairy cows in the study area; (2) determine the effect of integrated *Desmodium distortum* with maize on energy and protein supply; (3) determine the effect of feeding graded level of *Desmodium distortum* supplemented to maize stover harvested in improved soil on cost benefit and GHG emissions in lactating dairy cows; and (4) determine the effect of integrated *Desmodium distortum* with maize on farm profitability, soil nitrogen balance and greenhouse gas emissions.

Securing approval from and briefing local officials and vets about the study in three selected sectors of Rwamagana and visit of some sampled smallholder dairy cow's farmers in each sector were done. Farmers with cut and carry feeding system were identified and visited. This visit made us to have an insight on the difference of cattle management by wealth category in visited sectors. The visits made us to identify gaps which are existing in the system from which farmers need to build their capacity. Lastly, the vet officers were left a duty to identify groups of farmers which were supposed to receive some training in the next visit.

Photo 17: **Three farmers groups trained by a RAB researcher in Gahengeri**

Focus group discussion with livestock farmers groups were conducted at Gishali and Gahengeri (Photo 17). A total of four farmer groups were trained in a participative rural appraisal approach. Group discussions identified challenges, opportunities and solutions for good management of dairy cattle. The study will continue in the next financial year.

2.3 Monogastrics program

Baseline survey for characterization of local chicken

A study on local chickens production in Rwanda was conducted countrywide. Questionnaires, morphometric measures and blood samples were collected on pigs and local chickens. In each province three districts were selected, in each district two sectors were selected, in each sector three cells were selected and in each cell three villages were selected. A total of 12 districts, 24 sectors and 72 cells were randomly selected. A total of 1,560 household were interviewed

including 1080 rearing chickens and 480 rearing pigs. Morphometric measures and blood samples were collected on 120 chickens and 120 pigs.

Reproductive performance of indigenous chickens

Age at laying did not vary between provinces and was six months in Eastern and over seven months in Western, Northern, Southern and Kigali City provinces (Table 12). Sexual maturity for both males and females chickens varied a lot across the provinces, but it did no relate to age at laying hence data on age at sexual maturity should be handled with caution. Number of eggs laid per hen per year was available only for Eastern and Western provinces with a very wide variation. The biggest egg clutches were found in the Western province (14.7 eggs) while the lowest clutch size was 6.6 eggs in the Southern province. Egg hatchability was highest (85%) in the Western province and lowest (52%) in the Eastern province. Across the provinces, embryo mortality was low, at 30% or lower, except in the east where a staggeringly high 80% was reported. Again, the value of 80% should be handled cautiously considering that with that level of mortality, the flocks would be almost absent since chick mortality would wipe out the remainder.

Table 12: Reproductive traits of indigenous chickens from the survey

Variable	Province					
	East	West	North	South	Kigali	LSD
	(n = 200)	(n = 114)	(n = 67)	(n = 92)	(n = 47)	
Age at laying (months)	6.15[a]	7.46[a]	7.55[a]	7.6[a]	7.80[a]	1.97
Female maturity age (months)	4.88[a]	5.94[a]	6.47[a]	6.00[a]	9.08[b]	1.99
Male maturity age (months)	3.75[a]	8.00[b]	9.00[b]	7.40[b]	7.00[b]	2.00
Number of eggs per year	30.55[a]	62.66[b]	-	-	-	17.41
Number of eggs per clutch	11.10[a]	14.70[b]	13.40[c]	6.61[d]	14.44[e]	1.97
Egg Hatchability (%)	52.53[a]	85.03[b]	81.37[c]	61.93[d]	70.05[e]	1.98
Embryo mortality (%)	80.0[a]	30.0[b]	18.5[c]	18.5[c]	20.0[d]	2.10

Means within row with similar superscripts are not different (P>0.05)

Morphometric characteristics of indigenous chickens

Phenotypic data showed little variation across provinces in most traits. Four comb types were observed, with the strawberry type being the most dominant (51%). White ear lobes were most common (57%), round ear lobe shape was almost universal (92%) as was the curved beak structure (99.6%). Beak color varied between green, black, yellow and brown, the latter being was most prevalent (51%). Evenly distributed feathers was the most common phenotype (99.8%) whereas naked neck phenotype was rare (0.2%), other types such as frizzling and cresting were not recorded. Most chickens had brown eyes, though yellow, pearl and red eyes were also observed (Table 6). Thick skins were most common (88.4%), and yellow skin color was prevalent

(69%) among the sampled chickens. Most chickens (39%) had yellow colored shanks, though white (37%) steel blue (16%), black, green and pink colored shanks were also observed. Universality was observed on skeletal variation where the normal phenotype was recorded for all the chickens used in the study across the entire country (Table 13).

Table 13: Phenotypic characteristics of indigenous chickens of Rwanda

Variable (n= 520)	Level	Proportion (%)
Comb type	Single	42.4
	Strawberry	51.1
	Double	5.9
	Pea	0.6
Ear lobe colour	White	56.9
	Yellow	21.6
	Red	21.4
Ear lobe shape	Round	91.8
	Oval	8.2
Beak structure	Curved	99.6
	Straight	0.4
Beak colour	Brown	50.6
	Yellow	21.9
	Black	20.5
	Green	0.2
Feather distribution	Even	99.8
	Naked neck	0.2
Eye colour	Brown-orange	60.9
	Yellow	27.7
	Pearl	10.6
	Red	0.8
Skin thickness	Thick	88.4
	Thin	11.6
Skin Colour	White	31.0
	Yellow	69.0
Shank Colour	Yellow	38.6
	White	36.5
	Steel blue	15.6
	Black	6.0
	Green	3.1
	Pink	0.2
Skeletal variation	Normal	100.0

When data on body dimensions was analysed, an interesting trend emerged. Body weight ranged from one kilogram to five kilogram, and showed a mean of 1.4 kg. The rest of the traits considered are presented in Tables 14 and 15.

Table 14: Body dimensions of indigenous chickens of Rwanda

	n	Mean	Std. Error	Min	Max
Body Weight (kg)	501	1.44	0.02	1.0	5.0
Body Length (cm)	520	20.71	0.14	1.5	42.0
Wing Span (cm)	519	36.62	0.26	3.6	54.0
Neck Length (cm)	520	12.60	0.13	3.0	25.0
Skull Length (cm)	520	5.97	0.13	2.5	72.0
Skull Width (cm)	519	3.05	0.09	1.3	32.0
Comb Length (cm)	501	3.73	0.09	0.0	23.0
Comb Width (cm)	498	1.45	0.04	0.0	7.0
Beak Length (cm)	518	1.85	0.01	0.9	3.5
Beak Width (cm)	519	1.11	0.01	0.5	9.0
Ear Lobe Length (cm)	507	1.80	0.06	0.0	29.0
Ear Lobe Width (cm)	501	1.60	0.03	0.0	4.2
Wattle Width (cm)	481	1.56	0.06	0.0	13.0
Keel Length (cm)	519	10.14	0.09	0.0	18.0
Tail Length (cm)	515	14.66	0.15	5.0	38.0
Thigh Length (cm)	519	13.49	0.09	0.7	21.5
Tarsus Length (cm)	519	8.01	0.06	1.0	15.0
Tarsus Diameter (cm)	513	1.51	0.06	0.9	16.0
Centre Toe Length (cm)	517	5.02	0.04	1.2	14.0
Comb Size (cm)	490	1.68	0.04	1.0	3.0
Breast Circumference (cm)	462	24.21	0.37	1.0	38.0
Number of eggs laid	143	11.96	0.40	5.0	30.0
Number of clutches per year	131	9.86	0.73	2.0	60.0
Egg weight (g)	140	4.25	0.27	2.0	13.0
Egg Produced per year	112	38.58	5.29	14.0	80.0
Pulse Length (cm)	123	16.92	2.36	1.0	50.0

Table 15: Pearson Correlation Coefficients for various pairs of traits in indigenous Rwandan chickens

	BW	BL	WS	EP	NL	CL	CW	TL
Wingspan (WS)						0.443		
						0.001		
Eggs Produced/yr (EP)	-0.413	-0.526	0.595					
	0.18	**0.07**	**0.04**					
Neck Length (NL)			0.578	0.711				
			0.001	**0.009**				
Comb Length (CL)	0.250		0.443	0.605	0.370			
	0.001		**0.001**	**0.03**	**0.001**			
Comb Width (CW)	0.276				0.396	0.771		
	0.001				**0.001**	**0.001**		
Wattle Width (WW)						0.526	0.555	
						0.001	**0.001**	
Keel Length (KL)		0.494		0.401				
		0.001		**0.001**				
Thigh Length (TL)		0.414						
		0.001						
Comb Size (CS)						0.625		
						0.001		
Tarsus Length (TL)		0.427						0.635
		0.001						**0.001**
Age at Laying (AL)				-0.657				
				0.001				

Success drivers of pig artificial insemination based on imported fresh semen

The mean number of piglets born alive was significantly higher for crossbred sows as compared to pure Landrace sows (Table 16). However, the differences in number of piglets born live between boars of the two breed types were not significant; instead, it's the value for Pietrain boars that stood out. Parity of the sow did not influence the number of piglets born alive, but it did significantly influence the total litter size. Litter size clearly increased with parity, rising from 6.91 piglets for sows of first parity to 15.29 piglets for sows of parity 7. The number of piglets born alive did not differ between sows bred using artificial insemination and those that were bred using natural service. The number of stillborn piglets was not affected by sow breed, boar breed, and insemination method; but was influenced significantly ($P<0.05$) by parity of the sow.

Table 16: Number of piglets born alive for crossbreed and pure and litter size

Factor	Level	Litter size	Piglets born alive	Stillborn piglets	Inseminations per conception
Sow breed	Landrace × Pietrain (n = 37)	11.49[a]	10.81[a]	0.67	1.02
Boar breed	Landrace (n = 27)	9.04[b]	7.79[b]	1.25	1.11
	Landrace × Pietrain (n = 21)	7.99[a]	7.51[a]	0.47	1.09
	Landrace (n = 28)	9.43[a]	8.29[a]	1.14	1.10
	Pietrain (n = 15)	13.37[b]	12.09[b]	1.27	1.01
Parity	1st (n = 21)	6.91[a]	6.76	0.15[a]	1.06
	2nd (n = 15)	8.27[ab]	7.77	0.50[a]	1.12
	3rd (n = 9)	9.96[ab]	8.75	1.21[ab]	0.98
	4th (n = 6)	9.28[ab]	8.28	1.00[ab]	1.24
	5th (n = 5)	9.84[ab]	8.66	1.17[ab]	1.01
	6th (n = 4)	12.29[ab]	12.44	-0.14[a]	1.02
	7th (n = 4)	15.29[c]	12.44	2.85[b]	1.02
Insemination	AI[§] (n = 40)	8.06	7.45	0.61	1.17
	NS[ʃ] (n = 24)	12.47	11.15	1.31	0.97
SEM		0.429	0.404	0.164	0.025
LSD		1.48	1.32	0.60	0.10

In general, the number of stillborn piglets increased with parity (Figure 6), rising from 0.15 for primiparous (first parity) sows to 2.85 for 7th parity sows. Considering the number of inseminations per conception, all the factors namely sow breed, boar breed, sow parity, and insemination method did not show significant differences (P>0.05).
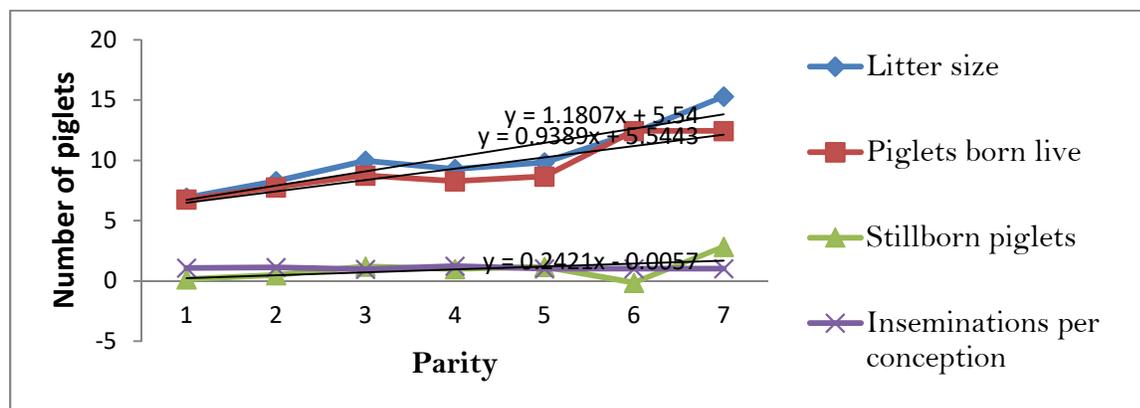

Figure 5: Effect of parity on litter size, piglets born alive and those born dead

2.4 National Artificial Insemination Center

Bovine genetic Improvement

The new livestock policy aims to increase the proportion of crossbreeds over local races. The best way to achieve this is increasing crossbreed is for the artificial insemination using semen from pure improved races to inseminate local cows. National Artificial Insemination Center (NAIC) plays a key role in semen import, storage and insemination countrywide. **Thus, the key functions of the NAIC division are:** Avail quality and genetically superior breeding germplasm; Manage and replace the bull stud at Masaka bull station; collect and process bovine semen;

Produce liquid nitrogen and facilitate access to artificial insemination (AI) inputs; build capacity of AI stakeholders in bovine artificial insemination, cattle reproductive management and AI inputs handling (especially, Liquid Nitrogen); facilitate and supervise cattle artificial insemination countrywide.

Management and replacement of bull stud

Masaka Bull station hosts a team of around 13 best bulls selected to produce semen in order to ensure fast dissemination of superior genetics and faster genetic improvement and conservation of local breeds (Photo 18). In the fiscal year 2018/2019, RAB, through RDDP project and in partnership with Heifer International Rwanda (HIR), acquired 4 high genetic merit bulls (2 Jersey and 2 Holstein-Friesian bulls) from Ireland. The new bulls replaced two old bulls and increased the semen producing bulls team at Masaka, which contributed to increased semen quantity. The usual work focused on management of bulls and training of new bulls on mounting to teaser bull or dummy cow and semen production. The new bulls adapted well to Rwanda environment and successfully started producing quality semen. Also, an existing Simmental bull which delayed to produce semen continued to receive training and has started to produce though the quantity and quality still low.

Photo 18:New Bulls acquired in 2018-2019; Jersey Bulls: Hudson (A), Guinan (B) and Holstein-Friesian bulls: Anton (C), Bruce (D)

Availability of Semen, Liquid Nitrogen and other inputs

Bovine semen and other inputs necessary to ensure good delivery of artificial insemination are availed by RAB and are accessible to all stakeholders. In FY 2018/2019 a total of 184,388 semen doses were produced and processed. To ensure accelerated genetic improvement, a proportion of bovine semen used in Rwanda is imported mainly for farmers to benefit from higher genetics of bulls of higher genetic merit "Super bulls" and to increase the genetic diversity of our breeding stock. Through RDDP project and partnerships between RAB, Jersey Island, Send a Cow, Bothar and MSAADA a total of 15,000 semen doses have been imported in 2018/2019. To ensure availability of Liquid Nitrogen (LN2) and increased access to AI inputs for improved service delivery, RAB has ensured good operation of the two Liquid Nitrogen plants installed at Rubilizi and Rubona Stations. All bovine artificial insemination inputs were availed to stakeholders.

Bovine artificial insemination and capacity building

Bovine Artificial insemination (AI) is the best and safe mean of cattle reproduction. With AI, the dissemination of superior genetics is faster; access of best bulls is ensured and reproductive diseases are prevented. Especially for Girinka beneficiaries and other smallholder cattle farmers, artificial insemination is the only option to breed their cows since they cannot afford to keep a good bull for breeding. To ensure that farmers benefits from this technology, RAB monitors the bovine AI and identification of AI born calves across the country.

In the 2018/2019 fiscal year, a total of 102,829 cows were inseminated and 38,504 calves born on AI identified (Figure 7). In this fiscal year we exceeded the targets planned. This commendable improvement was mainly due to significant efforts invested in availing liquid nitrogen; training of more inseminators; availing different inputs to technicians and training of farmers via RDDP project and other partners such other Send a Cow, Heifer International Rwanda, Jersey Island, Bothar, MSAADA, etc.
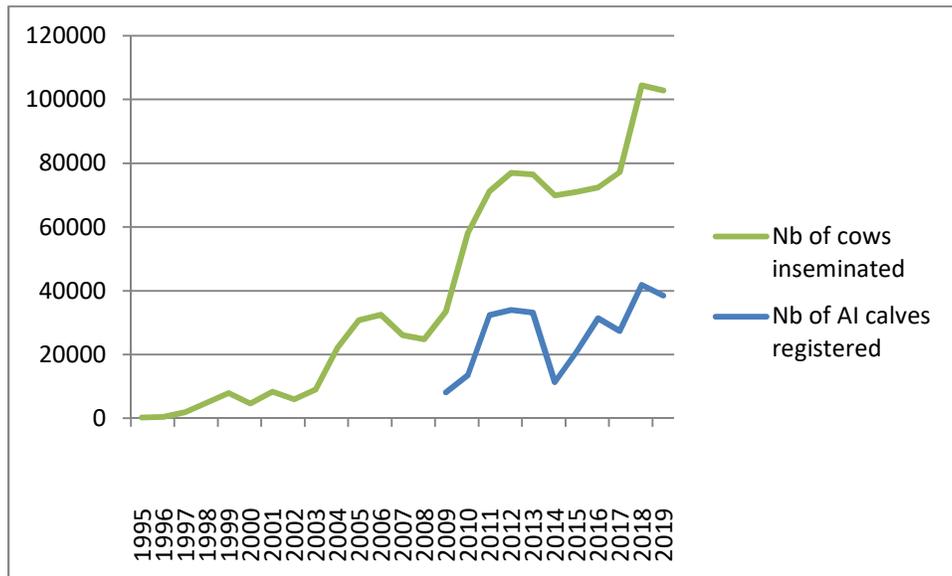

Figure 6: Annual achievements of Bovine artificial insemination since 1995

Every year, RAB and partners organized training for new AI technicians on cattle artificial insemination and reproductive management and refresher courses to improve the skills of existing inseminators (Photo 19). This is to address the challenges of low success rate of AI and low coverage which are known in cattle AI. In this fiscal year, a total of 303 animal sciences technicians have been trained on bovine artificial insemination technique, PD and best practices in bovine artificial insemination.

Photo 19: Capacity building of artificial insemination stakeholders

2.6 Aquaculture and fisheries program

Aquaculture and fishery activities were supported by Aquaculture and fisheries project targeted to achieve 35,000 MT of fish in FY 2018-2019. Summary on fish production is shown in Table 17.

Table 17: *Annual fish capture and aquaculture production 2018/2019 FY*

A. **Capture Fisheries**	Q1 (kg)	Q2 (kg)	Q3 (kg)	Q4 (kg)	Annual
Northern zone					
Northern zone	*157,523*	*229,432*	*213,202*	*270,521*	*870,678*
Eastern zone					
Gisaka-Bugesera	415,823	432,337	146,270	950,580	1,945,010
Nasho -Akagera	231,550	176,441	168,634	758,260	1,334,887
Muhazi	172,449	155,696	8,700	54,400	391,247
Total Eastern zone	*819,823*	*764,475*	*323,604*	*1,763,240*	*3,671,142*
Zone Kivu					
Kivu zone	*1,987,310*	*4,874,200*	*5,712,827*	*1,269,558*	*13,843,895*
Gasabo Capture fisheries	*0*	*-*	*5,850*	*4,741*	*10,591*

	Q1	Q2	Q3	Q4	Annual
Total Capture	**2,964,656**	**5,868,107**	**6,255,483**	**3,308,060**	**18,396,306**
B. Aquaculture	**Q1 (kg)**	**Q2 (kg)**	**Q3 (kg)**	**Q4 (kg)**	**Annual**
Eastern zone					
Easthern zone dams	62,583	62,653	56,231	116,815	
Gisaka - Bugesera	302,420	354,708	-	43,234	700,362
Nasho - Akagera	565,630	-	-	86,467	652,097
Total *Eastern zone*	*944,322*	*27,223*	*121,458*	*102,499*	*1,195,502*
Northern Zone					
S/tot Nothern Aquaculture	625	-	-	138,470	139,095
Total Northern zone	158,148	229,432	213,202	408,991	1,009,773
Western Zone					
Western Aquaculture	428,763	1,498,781	73,015	1,330,349	3,330,907
Total Western zone	2,416,073	6,372,981	1,342,573	2,599,906	12,731,532
Southern Zone					
Southern zone Dams	2,147	2,569	2,908	2,371	9,995
Ponds	19,192	6,539	21,905	14,894	62,530
Kigembe fish centre	159	15,989	317	502	16,967
Southern Aquaculture	21,498	25,097	25,130	17,767	89,492
Gasabo Aquaculture	18,431	21,431	25,578	9,454	74,894
Total Aquaculture	**2,344,271**	**1,989,893**	**301,412**	**1,845,054**	**6,480,630**
C. Total (A + B)	**5,308,928**	**7,858,000**	**6,556,896**	**5,153,114**	**24,876,938**

Project aims to increase national fish consumption to increase to above the Sub-Saharan Africa level, which is 6.7 kg per capita, from current 1.6 to 10.2 kg per year, and this is requiring 85,090 tons with significant increase in fish export in the next five years. This implies that 130,000 tons of fish to be produced per annum in 2020.

The project area is in nearly all the Districts of the country but more focus is on the Districts bordering Lake Kivu (Rubavu, Rutsiro, Karongi, Nyamasheke, Rusizi) in the Eastern Province that have Lakes (Bugesera, Ngoma, Kirehe, Rwamagana, Kayonza and Gatsibo) in the Northern Province that also have Lakes (Burera, Musanze and Gicumbi). The project, also cover districts with dams and ponds. Main project components include sustainable lake fisheries management; enhancement of aquaculture productivity and production; promotion of fish value chain; fisheries and aquaculture capacity building. A total of 24,877 MT of fish was produced in FY 2018-2019 (Table 17). The production of fingerlings was maximized, where a total of 9,390,740 fingerlings was produced against the targeted 8 million fingerlings (Table 18).

Table 18: Fingerlings produced during 2018/2019

Province	Q1	Q2	Q3	Q4
North	13,800	647,217	68,380	18,000
South	70,036	83,678	695,713	407,898
West	78,850	730,895	546,166	147,053
East	907,131	1,461,789	1,134,200	2,379,935
Total	1,069,817	2,923,578	2,444,459	2,952,886
Grand Total				9,390,740

Capture Fisheries

Fishing has traditionally been and remains an important socio-economic activity of communities living on lake shores. Haplochromis sp, Nile Tilapia, Catfish, Protopterus aethiopicus and Carpe are main fish of capture fishery. Fishing activities are undertaken through cooperatives of fishermen. The capture production in 2018/2019 FY was 18,396 MT.

Lake surveillance to control illegal fishing

Regular sensitization meetings and visits were carried out in different fishing zones for increased production in lakes. Lake surveillance was reinforced during the Biological rest order to control illegal fishers and guide fishing cooperatives in order to increase fish production from Rwandan. In all Rwandan Lakes 4,837 illegal fishing net and 424 illegal fishing boat were seized in collaboration with Police Marine, Army Marine, and Cooperative Union.

Inspection of Cooperatives

During the biological break fishing equipment were inspected in different cooperatives. A total of 36 cooperatives, 1753 fishermen, 298 fishing boats were inspected on Lake Kivu; 14 cooperatives on twin lakes with 128 fishermen, 111 fishing boats on Burera and 220 fishermen and 148 fishing boats on Ruhondo Lakes were inspected; and 27 Cooperatives, 2030 fishermen, and 1386 fishers were inspected on Eastern lakes. Fishing license were provided at the opening day of fishing activities (Table 19).

Table 19. Eastern lake inspection

Fishing zone	Lake	Number of cooperatives	Number of boats	Number of fishers
Muhazi	Muhazi	5	109	218
Gisaka	Mugesera	3	190	273
	Birira	1	78	82
	Sake	2	89	98
	Gashanga	2	56	98
Bugesera	Cyohoha Nord	1	264	316

	Rweru	1	66	69
	Mirayi	1	146	164
	Rumira	2	37	58
	Kidogo	1	45	90
	Kirimbi	1	40	76
	Gaharwa	1	46	92
Nasho	Cyambwe	1	47	81
	Rwakibare	1	32	58
	Kagese	1	12	24
	Rwampanga	1	75	139
	Nasho	2	54	94
Total		27	1386	2030

Aquaculture

The kind of aquaculture promoted until recently was subsistence fish farming characterized by low input and low output, primarily based on pond fertilization from livestock wastes with inherent managerial weakness of public sector dependent on hand-outs to subsistence farmers. Nile Tilapia, Catfish, and Carpe are mainly pond-cultured species in Rwanda. Pen culture and Cage culture system was introduced in Kivu, Muhazi and Ruhondo lake very recently. Aquaculture production in 2018/2019 FY reached 6,481 MT. For fingerlings production, a total of 14 farms with hatcheries have capacity to produce 3.2 million of fingerlings per month. In 2018/2019 FY fingerlings target was 10 Million but 9.3Million of fingerlings were produced.

New cage fish farming includes 6 farmers on Lake Muhazi with 164 cages, 11 farmers on Lake Kivu with 211 cages, and 3 farmers on Ruhondo Lake with 21 cages. A total of 286 ha in Rwanda are occupied by ponds, where 171 ha of ponds are not active and need rehabilitation.

Research study on Aquahort ltd Fish Feed

A feeding trial was conducted at Kigembe fish farming station to determine the effect of feeding formulations containing different protein levels on the growth performance of monosex Nile Tilapia fish, *Oreochromis niloticus.* The fish were fed four dietary protein levels (25%, 30%, 35% and 40%). The stocking density was 60 fish per hapa (5fish/m^3). Feed ration for each treatment was 6% of total fish biomass over the first 30 days, which was divided and offered at 10:00 and 16:00 daily. The amount was reduced up to 5% of the total fish biomass for the next 30 days while 4%, 3% and 3% of total fish biomass were provided during the last three months, respectively. The results showed a significant effect of dietary protein on growth performance of the reared fish. Weight gain and specific growth rate increased significantly with increasing dietary protein levels by 25 - 35%, but use of the diet with 40% crude protein showed insignificant increase in

growth parameters. The diet had no significant effect on survival rate of the fish. From the present results, diet containing 35% crude protein is considered as optimal for growth of monosex Nile tilapia, under the present experimental conditions and it is recommended for feeding monosex tilapia Fingerlings.

Assessment of fish farming and protection of buffer zone of lakes in Bugesera district

The study aimed to identify suitable sites for fish farming (cage culture, pen culture and ponds) in the eastern Lakes (Gaharwa, Kirimbi, Rweru, Rumira, Mirayi, Kidogo, Gashanga, Cyohoha north and Cyohoha south); Assess 50m buffer zone for protection; evaluate lake management, and understand socio-economic issues through group discussion with stakeholders. Among the nine visited lakes only five lakes (Mirayi, Rumira, Gashanga, Cyohoha South and Cyohoha North) are suitable for pen culture while four others (Kidogo, Gaharwa, Kirimbi, Rweru) could not hold either cage culture or pen culture because of the following reasons: very shallow (less than 5m) water depth for cage culture; abundance of waterweeds near the shoreline, limited site accessibility and dangerous animals for pen culture (crocodiles and hippos). However, Cyohoha North was the most recommended as pilot site because of the following reasons: ISANO Cooperative in charge of this lake is well-organized; fishermen from this cooperative got financial support from Rwanda Environmental Management Authority (REMA) to remove floating isles (amazinga) and water weeds; REMA agreed to support ISANO Cooperative to start fish farming (cage or pen culture) and the financial support will be availed after finishing the lake cleaning.

There is a need to conduct a baseline study for the 9 lakes to achieve a better understanding of social and economic aspects of the lakes, coastline resources and how they are used and viewed by local population residing around that lake. This will help to deeply identify economic factors that affect the success of fishermen cooperatives and other challenges they are facing. It is important to choose one lake (with high environmental destruction/high rate of economic activities that affect the buffer zone) where the detailed feasibility study can be conducted to assess the cost effectiveness of the intensive conservation measures for restoration of the lake ecosystem. A joint coordination of better lakes management by all stakeholders (district, sectors, line ministries etc.) in providing public awareness programmes regarding proper use and management of the coastline of the lakes. Capacity building of the fishery cooperatives in resources management and conservation: Appropriate training in financial management and other resource monitoring to enable them to determine whether the state of exploited fish stocks is in imminent or progressive depletion. Pen culture project is recommended in Mirayi, Rumira, Gashanga, Cyohoha South and Cyohoha North as these lakes present suitable water parameters, less mobile islands, no dangerous animals and the shores are well shaped. Cyohoha North is the most recommended. If Cyohoha north is selected for pilot project, a dike should be constructed to control flooding in rainy seasons from Akanyaru River and to stop the outflow of lake water to the opposite direction especially during dry seasons.

Ponds are not recommended because all marshlands surrounding all lakes are easily flooded and they do not have natural sources, and construction of ponds on site surrounding the buffer zones are not effective (high costly). Cages also are not recommended due to the fact that the lakes are shallow (3m-4m) and depth change according to seasons; mobile island and presence of dangerous aquatic animals create constraint against cage culture.

Capacity building

In the framework of improving knowledge and skills in Aquaculture and Fisheries, RAB in collaboration with the Israeli Government organized a training in Kigali and at Kigembe Fish Center in Gisagara. The main purpose of this workshop was to strengthen knowledge and skills of different stakeholders on better management practices of fish farming to increase fish production. Israeli experts has trained RAB staff, farmers, fish factory on different subjects. Subject of training was on fish nutrition and fish feed formulation, diversification of fish species, polyculture system, introduction to stock assessment, treatment and prevention of fish diseases, water quality assessment, hatchery operation. A total of 764 fishers and fishermen were trained on: good fishing practices, fish handling, fishing equipment hygiene, fish smoking, fish drying, fish salting, fish flying, and cage fish farming.

2.7 Small stock project

This project was initiated under the auspices of RAB/MINAGRI to harness the potential of small stock based on agro-ecological zones and species adaptability in Rwanda by creating and accelerating sustainable increase in the productivity and poverty reduction among the most vulnerable groups (for wealth categories 1&2, and unemployed youth in rural area). The project was implemented by districts through earmarked funds. RAB provided technical assistance required to design specification for procurement of small stock and also carry out monitoring and evaluation on the progress of the project.

Small stock has distinct economic, managerial, and biological advantages. They have a fast reproduction rate, occupy little housing space and have lower feed requirements. They require a low initial investment and correspondingly a small risk loss. Apart from food production for the families, their products will be marketed in the region earning the country foreign exchange as well as creating employment along the value chain.

Photo 20: Pigs and poultry supplied to youth cooperatives via district earmarked funds

A number of small stock was supplied to the identified unemployed youth cooperatives, (Photo 20) specifically, 47,991 poultry, including 44,806 via earmarked funds and 3,185 via partners). Pigs were supplied in number of 3,511 including 2,149 via earmarked funds and 1,362 via partners).

2.8 Girinka program

One Cow per Poor Family program initiated in 2006 by His Excellency Paul KAGAME, the President of Rwanda aims to reducing poverty through promotion of dairy cattle farming, promotion of community unity and reconciliation among Rwandans based on the cultural principle that if a cow is given from one person to another, it establishes trust and respect between the giver and the beneficiary. The Girinka program is managed by the Rwanda Agriculture and Animal Resources Board (RAB) under supervision of the Ministry of Agriculture and Animal Resources (MINAGRI). The program is funded through Government earmarked funds and donations. The beneficiaries of Girinka are poor households in the first and second categories of Ubudehe selected at the village level and these activities are chaired by Girinka committee members from village level to District level as its stipulated in the ministerial guidelines No 001/2018 of 13/07/2018, and then by MINAGRI/RAB

Girinka beneficiary selection criteria
As stipulated in Girinka program Guidelines N0 001/2018 of 13/07/2018 in its Article 4, the eligibility criteria for households to be Girinka Program are as follows: Must not be owning a cow

and vulnerable in the community; Be owning land earmarked for pastures or have the capacity for getting cow's feed; Construct an animal shed or willing to join others in community and construct communal cow shed (igikumbarusange); Be willing to attend the prescribe trainings in basic animal husbandry management practices (nutrition, breeding, housing, disease control and management practices); Socially well integrated in community development practices; Willing and enthusiastic to pass on the first female offspring animal to new selected beneficiary.

Source of heifers distributed under Girinka Program

Sources of heifers for Girinka program are various institutions (Government, NGOs both local and International ones, private institutions and individuals; Girinka decentralization district committees through Earmarked funds; RAB purchases; Local initiatives via donations as well as Pass on the Gift Scheme.

Major Girinka program components

Major project components include selection of beneficiaries at grassroots level by the farming community leaded by Girinka committees; training of beneficiaries before giving cows; heifers screened for diseases and healthy before they are given to vulnerable families; daily follow up of the program across the country; follow up of Girinka decentralization; accompanying measures (packages of artificial insemination inputs, feeds, health, training farmers, organization in cooperatives and linking beneficiaries to milk collection centers); encouraging/ mobilization different partners groups and local initiatives.

Cows distributed to poor families during FY 2018-2019

The general target of Girinka program was to distribute 350000 cows to poor families by the year of 2017 and then by 30 June, the total number of distributed cows is 354,713 with the achievement rate of 101%. Girinka Program targeted to distribute 27,680 cows to poor households in the fiscal year of 2018-2019. By 30 June 2019, a total of 27,749 cows have been distributed. Since Girinka program introduction, a total of 354,713 cows have been distributed countrywide.

Training of New Girinka Beneficiaries and Girinka Committees

Every year Girinka program provide the basic training to the new family who wish to be given a cow at the first time must be on the list provide from Village level till district level. In this training a beneficiary get the basic information on who to keep health a cow based on the life condition he/she is living. In these trainings together with the attended participants, it has been discussed and reviewed all achieved Girinka activities of previous year 2017-2018, challenges and observations in 2017-2018, planned activities FY 2018-2019, Implementations of Girinka activities and Girinka ministerial Guidelines Implementation FY 2018-2019 and How to improve

what did not go well in each specific district during the implementation of Girinka ministerial guidelines and resolution were made.

Follow up of Girinka beneficiaries and on Implementation of Girinka Ministerial Guidelines

The main objective of this follow up was to visit Girinka beneficiaries in their homes and observing how their cows are being managed, discussing with the visited beneficiaries aiming at understanding their opinions on the importance of the cow given to them under Girinka program and implementation of Girinka ministerial guidelines. During this session of three days, the following activities were done and detailed report in each district was compiled by each focal person in the visited district using agreed on follow up reporting template.

Follow up of Girinka beneficiaries was done in all districts where beneficiaries were visited at their homes (House to house visit). Generally, it was noticed that the farmers have benefited from the program through getting milk and manure but their cows are grazing from outside. Majority of the beneficiaries do not have cowsheds for their cows and shortage of forages for feeding.

The meeting/training with Girinka committees at Cell and Village level on implementation of Girinka Ministerial Guidelines was conducted. On implementation of Girinka Ministerial guidelines follow up, meetings with Girinka committee members at cell and sector level was done where Girinka committees were reminded of the DOS and DON'TS of these ministerial guidelines and their responsibilities as committee members.

Girinka awareness week

During Girinka week the following activities have been conducted in different districts: cowshed improvement and pasture management; appreciation of local initiatives supported the event; correction of poor management of heifers distributed to the beneficiaries; mobilizing the pass-on-gift of calves/heifers to new beneficiaries at the sector level; recognition of the identified local initiatives that supported Girinka; certificate delivery to the beneficiaries; identification and inseminated cow on the natural heat or oestrus; training of the Girinka committees; prevention and control measures of tick bones diseases by using acaricides;   pasture planting.

Girinka implementation impact

Girinka implementation has contributed to increase milk production, increase crop production. Improved soil fertility, enabled beneficiaries to access loans, improved nutrition access to the shelter and different equipment, strengthened social cohesion, created employment to individuals and created an opportunity to educate family members of program beneficiaries. The program has also contributed to the improvement of the mind set towards cattle as a status symbol (the more cows one had the better) to a source of income and livelihood, etc

From plenty of testimonies of Girinka program beneficiaries; this program reveals highly remarkable impacts in changing on day-to-day life of beneficiaries thus this report is prepared the structure of Girinka program during Fiscal Year 2018-2019 as well as from the beginning.

Girinka week led to the mobilization of taking care for cows, especially, Girinka cows and to motivating the beneficiaries in their daily care of livestock. Girinka recipients face a number of challenges, as limited access to veterinary services and drugs, delay in access to earmarked funds located in districts for cow purchase, Girinka package limitations.

2.9 Livestock Intensification program

Livestock intensification program aims to improve the competitiveness of the livestock subsector in regional and international markets through establishing economically viable, socially acceptable and environmentally sustainable dairy, meat, poultry and honey value chains. The Program targets to increase public-private partnerships in animal genetic resources improvement, multiplication and commercialization; to strengthen animal diseases' control systems for increased access to regional and international markets; to strengthen public-private sector partnerships in animal feed resource development, production and marketing; and to develop an economically viable honey production and marketing value chain.

Major project components include livestock productivity improvement and commercialization , animal disease control for regional and international market access; support and promotion of animal feed production and marketing, and strengthening the honey value chain. During 2018-2019, a total of 184,388 semen doses were produced; a total of 102,807 cows were inseminated; a total of 38,498 AI born calves were registered and 301 trained for semen production. The program supplied small stock to youth cooperatives with poultry: 47,991 (via earmarked funds: 44,806, and via partners: 3,185) and pigs: 3,511 (via earmarked funds: 2,149, and via partners: 1,362). Vaccination campaigns were conducted in high risk zones, and a total of 468,297 animals were vaccinated against Black Quarters; 659,151 cows were vaccinated against LSD; 334,433 cows were vaccinated against RVF; 58,169 were vaccinated against Brucellosis; and 75,220 animals were vaccinated against FMD.

2.9 Gako project

Gako beef project aims to establish a sustainable cattle production system for increasing beef meat production in the country and for export and reducing trade deficits. Gako project is

operating in Gako natural forest and aims to develop meat cattle keeping by providing primary infrastructures, as water access, piping, kraal construction etc. To date, project activities focused on drilling bore holes to provide water to the future beef farming at Gako. A total of 5 out of 9 boreholes contracted have been drilled and pumping tested. Only 3 out 5 pumping from the bore holes produced minimal contractual yield and 2 produced less water than was required by the project contract. Further drilling work is going on. For the planned Irrigation Work, approval of detailed piping and instrumentation diagram (P&D) and Piping layout was partially achieved (20%); Construction of water intake, Pumping Station, steel tanks concrete bases were partially completed (25%). Supply of HDPE Pipes started and not completed (15%). Mechanical work of water intake, pumping station and steel tanks were not completed (25%) and still go on.

Part 3. Land Husbandry, Irrigation and Mechanization

3.1 Soil conservation and land husbandry

Since 90% of domestic cropland is on slopes ranging from 5 to 55%, investing in land management structures is central to improving productivity. This makes radical terraces development, accompanied by soil fertility management and soil erosion control a priority for every fiscal year. For less steep slopes progressive terracing and agroforestry have proven successful in reducing erosion and increasing the economic returns from the land. During 2018-2019 FY, 4,063.5 ha of radical terraces and 12,161.6 ha of progressive terraces have been developed at national level, this led to a cumulative area of 94,443.6Ha under radical terraces and 122,455.5 hectares under progressive terraces.

3.2 Irrigation development

The irrigation development is a key priority for the Ministry of Agriculture. In order to increase the irrigated land different projects have been put in place including internally and externally financed. The irrigation projects implemented during 2018-2019 FY were Government Funded Irrigation (GFI), Export Targeted Irrigation (ETI), Rural Community Support (RSC), Rwamagana Rehabilitation and Small Scale Irrigation Technology (SSIT) Projects. The joint achievements were the followings: (i) 572 ha of marshland were developed with irrigation facility - these are 110 ha of Kanyonyomba and 462 ha of Rwinkwavu marshlands. (ii) 2,316 ha under SSIT Irrigation developed. These achievements gave the total of 37,093 Ha of Marshlands developed 8,780 ha of Hillside and 9,190 ha of SSIT developed. The total land under irrigation has reached 55,063 ha by end June 2019. Besides the development and maintenance of irrigation land, Different beneficiaries were trained and mobilized on irrigation technologies. A total of 1,924 Farmers and

Technicians were trained on the use of SSIT Equipment. A total of 205 demonstrations and awareness campaigns were conducted to adopt Small Scale Irrigation Technology.

3.3 Export Targeted Modern Irrigated Agricultural (ETI) Project

The Export Targeted Modern Irrigated Agricultural (ETI) Project, is financed by EXIM Bank of India through a Line of Credit of USD 120.05 Million, aiming to deliver on the following components: (1) Irrigation and integrated watershed development for Mpanga and Mahama sectors in Kirehe district for a potential area extended on 3390 Ha, (2) Construction Centre of excellence in farm mechanization to support research and development , (3) Tomato processing plant with a daily capacity to treat 80MT, as a valorization complement to the yield from the irrigated land, (4) Solar powered plant with a capacity to generate 3 MW and (5) capacity building program for sustainability and management purpose. Detailed Project Reports-DPR were completed and validated for each of the listed above component. The physical development of Mpanga irrigation and watershed development stands at 72%, at the end of June 2019, Mahama 1, the procurement processes were completed, detailed topographic survey was on going and Mahama 2 Procurement Processes were completed and the contract was at EXIM for approval, the construction Mechanization Center of Excellence was at 58% of Progress Level.

3.4 Agriculture Mechanization

Agriculture mechanization is among the key technological pillars to boost agricultural yields by minimizing the harvest and post-harvest losses while saving the human and investment capital in farm operation. In partnership with private mechanization service providers, the sub-sector has increased the land tilled using machine from 41,010 ha to 47,060 ha. Besides increasing the number of mechanized land, cumulatively 2,080 farmers were trained on use of machinery in various farm operation, 213 tractors operators and 180 agronomists were also trained through the conducted on farm demonstration campaigns. In order to enable the affordability of the on farm operation, 6 service provider companies (Voluntious Agricon Ltd, NAGRICO Ltd, KNU Agro-Mechanized Services Ltd, AGRESOL Ltd, SBTC Trading and Construction Ltd, AGRIMECH Ltd) were contracted to exclude VAT from the charges to be applied to the farmer.

In collaboration with the private service providers, new post-harvest technologies were developed, disseminated and adopted by rice cooperatives and maize growers' cooperatives. These consist of harvesters, threshers and winnowing machines for rice and wheat plantation.

3.5 Agroforestry program

A total of 154 participatory trials were established in Gishwati (Nyabihu and Rubavu districts) and 175 trials in Bugesera district during 2018-2019 FY for enhancing the role of Agroforestry in Crop Productivity. Crop yields were evaluated under and outside the Grevillea and Alnus canopies in

Bugesera and Gishwati, respectively. Sap flow data for pruned and unpruned Grevillea and Alnus trees were recorded and correlated with soil moisture changes and crop yields. A number of households adopted different agroforestry practices through distribution of tree and fruit seedlings 235,112 trees and fruit seedlings at Bugesera and 111,100 trees and fruit seedlings at Gishwati (Nyabihu and Rubavu). However, low survival of planted trees in Bugesera was observed due to unexpected drought.

Twenty native trees species were maintained in selected sites through beating up, weeding, irrigation and amendment (liming): at high (Sigira of Nyamagabe), middle (Rubona of Huye) and low elevation gradient (Ibanda Makera of Kirehe District). *Plastic rain water exclusion shelters were* installed at Sigira and Rubona to reduce precipitation while maintaining it the same as in Makera.

Genetic resources were collected on six tree species (*Maesopsis eminii, Tetrapleura tetraptera, Croton megalocarpus, Casuarina equisetifolia, Calliandra calothyrsus, Leucaena diversifolia, Acacia sieberiana* and *Markhamia platicalyx*) and conserved in the Rwanda National Genebank.

3.6 Export Targeted Modern Irrigated agriculture project (ETI)

The project started in 2015 and will end in 2020. The Export Targeting Modern Irrigated Agriculture Project (ETI) aims to develop modern agriculture facilities on 7,000 ha in Mahama, Mpanga, and Nyamugali Sectors of Kirehe District (Eastern Province). The establishment of Mechanization Centre of Excellence was undertaken and the process of procurement and shipment of equipment from India will be completed in few months. Mpanga and Mahanga sites were supported to promote Hillside Irrigation schemes. At Mpanga site, the establishment of hillside irrigation scheme, building of sedimentation tank, water pumping station, and storage tank, watershed development were mostly completed.

For Mahama 1 site, detailed topographic survey was prepared and is under way prior to establishment of hillside irrigation scheme. It is expected to be completed in few months. In Mahama 2 site, the work has just started. The draft contract agreement was sent to EXIM Bank for approval and the request to open the line of credit was sent by RAB to MINECOFIN. The contract is still pending at Indian Ministry of External Affairs**.**

Among the challenges for project implementation, the progress of civil work was affected by the rejection of steel construction materials by RSB due to the non-compliance of standard of labeling and making. Later on, the project has slowed down due to financial constraint of the contractor. The delay for Mpanga was caused by the design, which took longer. The planned civil work a at Mahama 1 was not done due to negotiation of relaxation on Indian Importation on 65%, which took longer, and the negotiation with the Indian Importation content has taken much time as it has to pass through different institutions. The relaxation of 65% to 35% has been accepted but

still pending for the approval. The contract for Mahama 2 is still pending waiting the approval of EXIM Bank of India.

3.7 Government Funded Irrigation Project (GFI)

This project started in 2010 and will end in 2020 with possible extension to 2024. The project aims to sustain food security and generate incomes for farmers through (i) development and management of soil and water resources; and (ii) promotion of intensive and sustainable irrigated agriculture. The project started as a hillside irrigation project targeting Nyagatare and Kirehe districts, but has been expanded to incorporate marshland Irrigation Activities; IWUOs (Operation and Maintenance) Activities in different districts. The project implements both Hillside and Marshland Irrigation Development Studies across the Country. For Ndego site, Feasibility study is in progress, and for Karangazi Feasibility study was prepared.

Operation, maintenance and management of 49 irrigation schemes under HoReCo was done. Cleaning and maintaining of irrigation infrastructures in these marshlands through community works were organized. Proximity technical support of farmers on agricultural practices for yield increase was provided. Farmer cooperatives and water user's association members were given field training through FFS Demo-plots, cooperative and WUO book keeping and recording. Field exchange visits between irrigation schemes were organized, and farmers were mobilized towards SSIT Program.

Among the challenges, there was a delay for Ndego feasibility study caused by the request of IFAD to revise TOR to add some other activities (Batimetric survey) to meet the requirement of IFAD. The development of these marshlands delayed with procurement process but there is a good progress and hope to finish in Agustin for Urwonjya, For Nzavu there was a challenge of crops in the marshland but works will be accelerated as soon as they are harvested. For Mwura - Gatare tender for supervision of works was re-advertised but now signed and the works will start the soonest.

3.8 Mechanization program

The program started in 2010 and will end in 2024. The aim of the program is to promote appropriate farm mechanization technology; to increase access of farm machinery to the farming community; to promote private sector investment in mechanization, and to develop broad-based skills and knowledge through capacity building on farm machineries and implements. Routine maintenance of the existing fleet of Farm Machineries was done at RAB: 30 tractors were maintained or repaired. Eighty machine operators, agro-technicians and farmers were trained on use of farm machineries. A total of 27 demonstrations were conducted for the use of post-harvest technologies. Mechanization services were provided on 883 ha, while a total of 6,050 ha were

cultivated using tractors. The project was implemented in Bugesera, Gasabo, Gatsibo, Kamonyi, Rwamagana, Nyagatare, and other districts on request.

Among the challenges, 10 out of 40 tractors and power tillers were very old and were auctioned to be purchased by Private Operators and now RAB remain with 30 tractors, which were maintained. Targets for VAT Exemption were not achieved due to the closure of some Private Companies (Agrimec Ltd, Renaissance Main Ltd), or regressive Performance of some Private Companies (SBTC Ltd, Volutnous Agricon Ltd).

3.9 Small Scale Irrigation Technology (SSIT)

The SSIT project started in 2014 and will end in 2024, and it is supported by the GoR. The project aims to promote wide use of demand-driven, affordable locally assembled SSIT in order to support Rwandan small scale farmers with simple and affordable irrigation technology; increase their crop productivity, thus improving the sustainability of irrigation development through farmer-based approach. The project operates in all districts. Several demonstrations and awareness campaigns were conducted. A total of 1,924 farmers and technicians were trained on how to use the SSIT equipment, while 1151 farmers have accessed SSIT equipment with help of the SSIT project. The project promoted the use of SSIT equipment and a total of 2,111 ha were irrigated with its support.

3.10 Rehabilitation of Irrigation facilities in Rwamagana District

The project started in 2017 and will end in 2020. It is funded by Jica. The project aims to increase area under irrigation in Rwamagana through rehabilitation of 3 dams and 23 Km of concrete canal. The starting date of the project was postponed due to technical discussion regarding the construction of Cyaruhogo Dam.

3.11 Rural Community Support Project (RCSP)

The Rural Community Support Project (RCSP) is linked to the strategic plan for Agriculture transformation (PSTA 4). It aims to increase the agricultural productivity of organized farmers in the marshlands and adjacent hillsides targeted for development in an environmentally sustainable manner; increase farmers' income in market-based value chains activities; and to strengthen the participation of beneficiary farmers (men and women) with ownership based on the Korean Saemaul Undong mindset approach, self-help, diligence, and cooperation.

Photo 21: Rice field (left), managed marchland (right).

The project started in 2015 and will end in 2019. It is supported by KOICA.

Photo 22: Maize field (left); roadside with newly built water way (right).

Major project activities are on infrastructure improvement for Marshland, Hillside and Commodity Chain Development - marshland rehabilitation and development, sustainable land management on hillsides, and rural investment boost for economic infrastructure; and capacity building for farmers' organizations and cooperatives, improved production technologies and value chain development (Photos 21 and 22).

A total of 16.1 km of access road was constructed in marshlands. Finalization of bridges in Ruzigambogo, Kajevuba and Ruterana, Finalization of culverts in Ruzigambogo, Kajevuba and Ruterana. Construction of 1 Road Dyke in Rwinkwavu marshland is in progress. Construction of 3 storages and 2 drying grounds are in progress. A total of 2,352 ha of land prepared and 2,264 ha are planted with different crops. Rufuha & Rujambari, 4 ha were prepared and farmers are trained on seeds multiplication. RCSP has initially targeted to rehabilitate and develop 630 ha of marshlands. With the extension of 1 year, the target was changed from 630 ha to 695 ha. As of June 2019, the project completed 710 ha of marshlands.

The Project was initially mandated to protect against soil erosion the adjacent hillsides to the above-mentioned marshlands on 1,260 ha. With the revised target, the new area to be developed is 2,150 ha and were completed at 100%. With aim of supporting beneficiary farmers to minimize post-harvest losses for their produces, 2 vegetable collection centers were constructed in Kajevuba, 2 drying grounds for rice constructed in Ruterana and 2 drying grounds for rice constructed in Ruzigambogo. There are ongoing works for the construction of 3 storages (1 in Rwinkwavu, 1 in Kanyonyomba and 1 in Rufuha-Rujambari) and 2 drying grounds for rice in Rwinkwavu.

3.12 Sustainable Agricultural Intensification and Food Security Project (SAIP)

The project aims to increase productivity, market access, and food security of the targeted beneficiaries in the project area. Project started in 2018 and will end in 2023. It operated in eight districts - Rulindo, Rwamagana, Karongi, Rutsiro, Kayonza, Nyanza, Gatsibo, and Nyabihu.

Photo 23: Land prepared in one of the project sites (left) and vegetable growing (right)

A total of 6,904 ha of land were prepared and planted with different crops across project site. Workshop on Agriculture Financing was organized in collaboration with KCB bank. Training on post-harvest handling techniques was organized in Kayonza site and a total of 437 metric tons were processed through post-harvest infrastructures. Community mobilization need assessment was conducted and 40 Special groups (including 23 women groups) were identified. 13,127 farmers (including 7,170 women) are reached with agricultural assets or services. A total of 480 farmers were trained on good agricultural practices, 100 farmers were trained on Irish potato seed multiplication. 6 ha of land were provided with irrigation equipment. Several farmers were linked with financial institutions and 2,045 USD were mobilized as loan.

The project was also able to provide grants to 15 Cooperatives totaling 121,542,500 Frw with contribution from the beneficiaries equal to 39,548,700 Frw (32.5%) for the establishment of demonstration plots (Photo 23), training on good agricultural practices, Irish potato seed multiplication, and awareness campaigns for nutrition practices for pregnant women, capacity building on post-harvest handling and orange flesh sweet potatoes cuttings for nutrition improvement. Grant agreements were also signed between the project and 7 Water Users Association totaling 9,390,000 Frw mainly to pay the recruited guards and operators/irrigators. The project provided 46.15 tons of Irish potato basic seeds to both Karongi and Nyabihu sites for seed multiplication within the sites. The project mobilized and sensitized beneficiary farmers to cultivate bio-fortified beans in Season 2019B across the project sites and distributed 2,100,000 cuttings of orange fleshed sweet potatoes.

3.12 Rural Sector Support Project (RSSP3)

Project aims to (i) Increase the agricultural productivity of organized farmers in the marshlands and hillsides of sub-watersheds targeted for development in an environmentally sustainable manner; and (ii) Strengthen the participation of women and men beneficiaries in market-based value chains. The project started in 2012 and ended in 2018. It was supported by IDA/World Bank. Project intervened in marshland rehabilitation and development; sustainable land management on surrounding hillsides; promotion of rural investments for economic infrastructure and capacity building for farmers' organizations and improved production technologies for value chain development.

Photo 24: Drainage canal in one of the marchlands (left) and rice field for certified seed production (right).

Areas of the project intervention: Kigali City marshlands (Gasabo-Nyarugenge) including Kabuye marshland and Rugende (Gasabo-Rwamagana-East); Rugeramigozi (Muhanga); Mukunguri (Kamonyi- Ruhango); Base (Ruhango); Nyarubogo (Nyanza); Agasasa (Nyanza); Cyili (Gisagara-

Huye-Nyanza); Mushaduka (Gisagara); Mirayi (Gisagara); Rwasave (Huye-Gisagara); Rusuli and Runukangoma (Huye); Migina (Gisagara-Huye-Nyaruguru); Bugarama (Rusizi); Kamiranzovu and Kirimbi (Nyamasheke); Muringa (Nyabihu); Sovu (Ngororero); Nyirabirande-Ndongozi and Cyungo (Burera); Muvumba-P4, P5 and P8, (Nyagatare); Rwangingo-Karangazi (Gatsibo-Nyagatare); Rwagitima-Ntende (Gatsibo); Kanyonyomba (Gatsibo); Gacaca (Kayonza); Rwinkwavu (Kayonza-Ngoma); Rugende (Rwamagana); (Gisagara-Huye-Nyaruguru); Nyaburiba and Ruvubu (Bugesera) and Rwamagana marshlands.

Photo 25: Harvest ground build by the project (left) and water storage reservoir (right)

The project completed the rehabilitation of Rwamagana rice schemes in FY2018-2019 totaling 585 ha and overall achievement of 7,297 ha (Photo 24). During this FY 2018-2019, the project completed 204.9 ha of land treated with comprehensive land husbandry technologies to make a general achievement of 18,030 ha (Photo 25). Independent consultant as well as the Donor (WB) carried out the Endline survey and Implementation Completion Report (ICR) and the project was rated as successful. The project completed marshland development and rehabilitation work in 16 marshlands with 7,297 Ha out of 7,000 Ha planned.

Kigali marshlands were used for horticulture purpose; Nyirabirande-Ndongozi for horticulture and other food crops such as Irish potatoes, Beans and Maize; parts of Karangazi-Rwangingo and Rwinkwavu were used for Maize and Leguminous; and Rugende was used for horticultural crops and fodder; and other bigger part for rice growing, the completed schemes are being used for rice growing a twice a year using water reservoirs; diversion weirs and water intakes with other irrigation and drainage networks were put in place by the project. In order to protect the hillsides adjacent to concerned marshlands against soil erosion; and mostly the critical areas to prevent siltation, the Project has so far implemented comprehensive land husbandry technologies in 15 hillside sites surrounding marshlands developed and/or under development as well as 3 new sites located in Gishwati (Nyabihu-Mulinga & Ngororero-Sovu) and Rulindo/Cyungo. The total area with established protective land structures achieved was 18,030 out of 17,200 ha planned. The

total number of the project beneficiaries reached was 101,774 (of whom 42.1% are women). The beneficiaries were grouped in 51 Cooperatives. During the project duration, a total of 42 Waters users associations were formed and are functional.

The economic benefit per unit land was assessed for all crops and marchlands where the project intervened. The achieved benefit   non-irrigated hillside areas. The Project has also supported beneficiary Cooperatives to become certified seed producers. A total of 28 Cooperatives (21 in marshlands, and 7 on hillsides); of which the majority is for rice growing do certified seeds production.

Part 4. Scientific publications of RAB staff

2018

1. **Bigirimana J**, Gerard A, Mota-Sanchez D & Gut LJ (**2018**) Options for managing *Antestiopsis thunbergii* (Hemiptera: Pentatomidae) and the relationship of bug density to the occurrence of potato taste defect in coffee. *Florida Entomologist*, *101*(4), 580-586.

2. Habiyaremye JD, Muthuri C, Matiru V, Nyaga J, Mukuralinda A, **Ruganzu V, Ngabonziza JD** & Sinclair F (**2018**) Indigenous arbuscular mycorrhizal fungi associated with tree species of the agroforestry systems of Rwanda and their potential to colonize maize roots. *African Journal of Microbiology Research* 12(36): 879-888. DOI: 10.5897/AJMR2017.8511

3. Iiyama M, Mukuralinda A, **Ndayambaje JD**, **Musana BS**, Ndoli A, Mowo JG, … & **Ruganzu V** (**2018**) Addressing the paradox–the divergence between smallholders' preference and actual adoption of agricultural innovations. *International Journal of Agricultural Sustainability* 16(6): 472-485.

4. Kalibwani RM, Kakuru M, Tenywa MM, **Mugabo J**, Nyamwaro SO & Buruchara R (**2018**) Innovation opportunities for milk production in Rwanda with lessons from the Mudende innovation platform. *African Journal of Rural Development 3*(1): 651-664.

5. Kalibwani R, Sospeter M, Nyamwaro O, Wimba B, Muke A, Kakuru M, Tenywa M, **Mugabo J** & and R. A. Buruchara RA (**2018**) Women's vulnerability in bean value chain development at the Maendeleo innovation platform, Eastern DRC. *African Journal of Rural Development* 3(1): 633-649.

6. **Mugabo J**, Nyamwaro S, Kalibwani R, Tenywa M, Buruchara R & Fatunbi A (**2018**) Innovation Opportunities in Potato Production in Rwanda. *FARA Research Reports*, *2*(16), 15.

7. **Mutimura M**, Ebong C, Rao IM & Nsahlai IV (**2018**) Effects of supplementation of Brachiaria brizantha cv. Piatá and Napier grass with Desmodium distortum on feed intake, digesta kinetics and milk production in crossbred dairy cows. *Animal nutrition* 4(2): 222-227.

8. **Mvuyekure SM**, Sibiya J, Derera J, Nzungize J & **Nkima G** (**2018**) Application of Principal Components Analysis for Selection of Parental Materials in Rice Breeding. *Journal of Genetics and Genomic Sci*ence 3(010).

9. **Niyibituronsa M**, Onyango AN, **Gaidashova S**, Imathiu SM, **Uwizerwa M**, Wanjuki I, Nganga F, **Muhutu JC**, Birungi J, Ghimire S, Raes K, De Boevre M, De Saeger S & Harvey J (**2018**) Evaluation of mycotoxin content in soybean (*Glycine max l.*) grown in Rwanda. *African Journal of Food, Agriculture, Nutrition and Development 18*(3): 13808-13824.

10. Rutikanga A, Ntawugayumugabo C, Rudasingwa J, Munyandamutsa F & **Urinzwenimana C** (**2018**) Performance and Yield Evaluation for Exotic Maize Hybrid Genotypes in Multi-Environment Trials in Rwanda. *Redaction Committee*.

11. **Rushemuka PN** (**2018**) SIMLESA end of project stakeholders & external review meeting.

12. **Urinzwenimana C** & Muhizi F (**2018**) Review on Assessment of Use and Efficiency of Mating Design in Plant Breeding. *Research & Reviews: Journal of Agricultural Science and Technology* 6(2): 40-57.

13. **Urinzwenimana C**, Melis R & Sibiya J (**2018**) Participatory Evaluation of Bean Ascochyta Blight [*Phoma exigua* var. diversispora (Bubak) Boerema] and Constraints of Bean Production in Rwanda. *Research & Reviews: Journal of Crop Science and Technology* 6(2): 25-37.

14. **Urinzwenimana C**, Melis R & Sibiya J (**2018**) Review of Breeding for Ascochyta Blight [Phoma exigua var. diversispora (Bubak) Boerema] Resistance in Common Bean. *Research & Reviews: Journal of Crop Science and Technology 6*(2): 38-53.

15. **Waweru BW,** Kilalo DC, Kyalo M & Musembi MJ (**2018**) Molecular detection of Ugandan Passiflora Virus infecting passion fruit (*Passiflora edulis* Sims) in Rwanda. *Annual research & Review in Biology* 30 (2): 1-10.

2019

16. Asare-Marfo D, Herrington C, Alwang J, Birachi E, Birol E, Diressie MT, **Dusengemungu L, Musoni A,** Funes J, Katungi E, Labarta R & Larochelle C (**2019**) Assessing the adoption of high iron bean varieties and their impact on iron intakes and other livelihood outcomes in Rwanda. *Gates Open Research*, *3*.

17. Basset-Mens C, Rhino B, **Ndereyimana** A, Kleih U & Biard Y (**2019**) Eco-efficiency of tomato from Rwamagana district in Rwanda: From field constraints to statistical significance. *Journal of Cleaner Production 229*: 420-430. https://doi.org/10.1016/j.jclepro.2019.04.256.

18. Bagstad KJ, Ingram JC, Lange GM, Masozera M, Ancona ZH, Bana M, Kagabo D, **Musana B**, Nabahungu NL, Rukundo E, **Rutebuka E** (**2019**) Towards ecosystem accounts for Rwanda: Tracking 25 years of change in flows and potential supply of ecosystem services. *People and Nature*.

19. Basset-Mens C, Rhino B, **Ndereyimana A,** Kleih U & Biard Y (**2019**) Eco-efficiency of tomato from Rwamagana district in Rwanda: From field constraints to statistical significance. *Journal of Cleaner Production 229*: 420-430.

20. Baudron F, Ndoli A, **Habarurema I** & Silva JV (**2019**) How to increase the productivity and profitability of smallholder rainfed wheat in the Eastern African highlands? Northern Rwanda as a case study. *Field Crops Research 236*: 121-131.

21. **Bigirimana J**, Adams CG, Gatarayiha CM, **Muhutu JC** & Gut LJ (**2019**) Occurrence of potato taste defect in coffee and its relations with management practices in Rwanda. *Agriculture, ecosystems & environment 269*: 82-87.

22. **Bigirimana J, Uzayisenga B** & Gut LJ (**2019**) Population distribution and density of *Antestiopsis thunbergii* (Hemiptera: Pentatomidae) in the coffee growing regions of Rwanda in relation to climatic variables. *Crop Protection 122*: 136-141.

23. Raatz B, Mukankusi C, Lobaton JD, Male A, Chisale V, Amsalu B, Fourie D, **Mukamuhirwa F**, Muimui K, Mutari B, Nchimbi-Msolla S, Nkalubo S, Tumsa K, Chirwa R, Maredia MK & He C (2019) Analyses of African common bean (*Phaseolus vulgaris* L) germplasm using a SNP fingerprinting platform: diversity, quality control and molecular breeding. *Genetic Resources and Crop Evolution* 66: 707–722 (2019). https://doi.org/10.1007/s10722-019-00746-0

24. Echodu R, Edema H, Wokorach G, Zawedde C, Otim G, Luambano N, ... & **Asiimwe T** (**2019**) Farmers' practices and their knowledge of biotic constraints to sweet potato production in East Africa. *Physiological and molecular plant pathology* 105: 3-16.

25. Johnson JM, Rodenburg J, Tanaka A, Senthilkumar K, Ahouanton K, Dieng I, **Gasore ER**... & Gbakatchetche H (**2019**) Farmers perceptions on mechanical weeders for rice production in Sub-Saharan Africa. *Experimental Agriculture 55*(1): 117-131.

26. **Hirwa CA**, Kugonza DR, Kayitesi A, Murekezi T, Semahoro F, Uwimana G & Habimana R (**2019**) Phenotypes, production systems and reproductive performance of indigenous chickens in contemporary Rwanda. *International Journal of Livestock Production* 10(10): 213-231.

27. Katungi E, Larochelle C, **Mugabo J** & Buruchara R (**2019**) Climbing bean as a solution to increase productivity in land-constrained environments: Evidence from Rwanda. *Outlook on Agriculture 48*(1): 28-36.

28. Msangi S, Were K, **Musana B**, Mudiope J, **Dusengemungu L**, Tanui L, ... & Korutaro B (**2019**) Enhancing Productivity and Market Access for Key Staples in the EAC Region: An Economic Analysis of Biophysical and Market Potential. In: *Applied Methods for Agriculture and Natural Resource Management* (pp. 213-260). Springer, Cham.

29. Mukasa SB, **Nduwumuremyi A** & Alexandersson E (**2019**) *The importance of inspection and certification in sustainable production of cassava in East Africa*: A case for Uganda and Rwanda, Swedish University of Agricultural Sciences – Makerere University – Rwanda Agriculture Board, Final AgriFoSe2030 Report 18. ISBN: 978-91-5769683-0

30. **Mutabazi J**, Ebong C, **Mutimura M & Hirwa CA (2019)** Cost effectiveness of feeding cattle genotypes fed rice straw with graded levels of concentrate supplements. *International Journal of Livestock Production* 10(6): 166-174.https://doi.org/10.5897/IJLP2018.0531

31. **Mutimura M**, Ebong C, Rao IM & Nsahlai IV (**2019**) Seasonal variation of livestock feed resources in semi-arid and humid environments of Rwanda. *East African Agricultural and Forestry Journal*, *83*(2) 137-148.

32. **Mutimura M, Tuisenge J & Dusengemungu L (2019)** Rwanda: making innovations in agriculture work for women smallholder farmers See page 24. In: Report on strategies for mainstreaming gender, Deliverable 1.3 ''. Ref. Ares (2019)1683873 - 14/03/2019, [727201] [InnovAfrica] - D1.3 - i

33. **Musabyemungu A**, Wasswa P, Alajo A, Chelagat DM, Otema MA, Musana P, **Rukundo P** et al. (**2019**) Adaptability of a US purple-fleshed sweet potato breeding population in Uganda. *Australian Journal of Crop Science* 13 (1): 17.

34. Manirafasha E, Vangh AV, Murwanashyaka T, Rugabirwa B, Ndikubwimana T, Mukagatare G, **Ndayambaje JD** et al. (**2019**) Algal resources exploitation for green economy and sustainable development a review. *Advances in Biochemistry and Biotechnology* (2019).

35. Mukuralinda A, Iiyama M, **Ndayambaje JD**, Ndoli A, **Musana B**, Mowo JG, Garrity DP & Sinclair F (**2019**) Taking to scale tree-based ecosystem approaches that enhance food security, improve resilience to climate change and sequester carbon in Rwanda.

36. Nabahungu NL, **Cyamweshi AR, Kayumba J,** Kokou K, Mukuralinda A, Cirhuza JM, & Wortmann CS **(2019)** Lowland rice yield and profit response to fertilizer application in Rwanda. *Agronomy Journal*. https://doi.org/10.1002/agj2.20006.

37. **Ndayitegeye O,** Onyando JO, Okwany RO & Kwach JK (2019) Vegetative growth of banana as influenced by irrigation deficit and irrigation interval. *Fundamental and Applied Agriculture* 4(4): 1047-1053. DOI: 10.5455/faa.70723

38. **Ndereyimana A,** Nyalala S, Murerwa P & **Gaidashova S** (**2019**) Potential of ento-mopathogenic nematode isolates from Rwanda to control the tomato leaf miner, *Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae*). *Egyptian Journal of Biological Pest Control* 29(1): 57.

39. **Ndereyimana** A, Nyalala S, Murerwa P & **Gaidashova S (2019**) Pathogenicity of some commercial formulations of entomopathogenic fungi on the tomato leaf miner, *Tuta absoluta (Meyrick)(Lepidoptera: Gelechiidae*). *Egyptian Journal of Biological Pest Control* 29(1): 70.

40. **Ndereyimana A,** Nyalala S, Murerwa P & **Gaidashova S (2019)** Bioactivity of plant extracts against tomato leaf miner, Tuta absoluta (Meyrick)(Lepidoptera: Gelechiidae). *Journal of Applied Horticulture* 21(2): 146-150.

41. **Nduwumuremyi A** & Melis R (**2019**) Gene action and heterosis in F1 clonal progenies of cassava for β-Carotene and farmers' preferred traits. *Heliyon* 5(6): e01807.

42. **Niyibituronsa M**, Onyango A, **Gaidashova S**, Imathiu S, De Boevre M, Leenknecht D, ... & Raes K (**2019**) The growth of different probiotic microorganisms in soymilk from different soybean varieties and their effects on antioxidant activity and oligosaccharide content. *Journal of Food Research* 8: 41-51.

43. **Niyibituronsa M**, Onyango AN, **Gaidashova S**, Imathiu S, **Uwizerwa M**, Ochieng EP, ... & Harvey J (**2019**) The effect of different processing methods on nutrient and isoflavone content of soymilk obtained from six varieties of soybean grown in Rwanda. *Food Science & Nutrition* 7(2): 457-464.

44. **Niyibituronsa M**, Onyango AN, **Gaidashova S**, Imathiu S, De Boevre M, Leen-knecht D, Neirnck E, De Saeger S, Vermeir P & Raes K (**2019**) The growth of different probiotic microorganisms in soymilk from different soybean varieties and their effects on anti-oxidant activity and oligosaccharide content. Mendeley Data, v1. http://dx.doi.org/10.17632/zdwmsh5hz9.1

45. **Niyibituronsa M**, Onyango, AN, **Gaidashova S**, Imathiu S, **Uwizerwa M**, Ochieng EP, Ng'ang'a F, Birungi J, Ghimire S & Harvey J (**2019**) The effect of different processing methods on nutrient and isoflavone content of soymilk obtained from six varieties of soybean grown in Rwanda. *Food Science & Nutrition* 7(2): 457-464.

46. Ntawuhiganayo EB, Uwizeye FK, Zibera E, Dusenge ME, Ziegler C, **Ntirugulirwa B**, Nsabimana D, Wallin G & Uddling J (**2019**) Traits controlling shade tolerance in tropical montane trees. *Tree Physiology* 40(2): 183-197.

47. Okonya JS, Ocimati W, **Nduwayezu A,** Kantungeko D, Niko N, Blomme G, Legg JP & Kroschel J (**2019**) Farmer reported pest and disease impacts on root, tuber, and banana crops and livelihoods in Rwanda and Burundi. *Sustainability* 11(6): 1592.

48. Okonya JS, Petsakos A, Suarez V, **Nduwayezu A,** Kantungeko D, Blomme G, Legg JP & Kroschel J (**2019**) Pesticide Use Practices in Root, Tuber, and Banana Crops by Smallholder Farmers in Rwanda and Burundi. International Journal of Environmental Research. Public Health 16: 400; doi:10.3390/ijerph16030400

49. Okonya JS, Mudege NN, Rietveld AM, **Nduwayezu A,** Kantungeko D, Hakizimana BM, Nyaga JN, Blomme G, Legg JP & Kroschel J (**2019**) The role of women in production and management of RTB crops in Rwanda and Burundi: Do men decide, and women work? doi:10.20944/preprints201906.0018.v1.

50. **Rukundo P, Ndacyayisenga T, Ntizo S,** Kirimi S & Nshimiyimana JC (**2019**) Yield and yield components of CIP advanced potato clones under Rwandan agro-ecologies. *Journal of Applied Biosciences* 136: 13909-13920,

51. **Rukundo P, Ndacyayisenga T, Ntizo S,** Kirimi S, & Nshimiyimana JC (**2019**) Yield and yield components of CIP advanced potato clones under Rwandan agro-ecologies. *Journal of Applied Biosciences 136*(1): 13909-13920.

52. **Rukundo P, Ndacyayisenga T, Ntizo S,** Kirimi S, Nshimiyimana JC (**2019**) Performance of CIP and Dutch potato varieties under Rwanda climate conditions. *African Journal of Agriculture Research*, AJAR/19.02.19/13969.

53. **Rurangwa E (2019)** *Enhancing biological nitrogen fixation and yield of soybean and common bean in smallholder farming systems of Rwanda*. Doctoral dissertation, Wageningen University.

54. **Rutebuka J**, Kagabo DM, Verdoodt A (**2019**) Farmers' diagnosis of current soil erosion status and control within two contrasting agro-ecological zones of Rwanda. *Agriculture, Ecosystems and Environment Journal*. https://doi.org/10.1016/j.agee.2019.03.016

55. **Rutebuka J (2019**) Integrated multiscale assessment of soil erosion and its control in Rwanda. PhD Thesis, Ghent University, Belgium.https://biblio.ugent.be/publication/8620562

56. **Shumbusha D,** Shimelis H, Laing M & **Rukundo P** (**2019**) Gene action and heritability of yield components of dual-purpose sweet potato clones. *Euphytica* 215 (7): 1 - 16. https://doi.org/10.1007/s10681-019-2454-x

57. Silvestri S, Macharia M & **Uzayisenga B** (**2019**) Analyzing the potential of plant clinics to boost crop protection in Rwanda through adoption of IPM: the case of maize and maize stem borers. *Food Security*. https://doi.org/10.1007/s12571-019-00910-5

58. Tambo JA, **Uzayisenga B**, Mugambi I, Bundi M & Silvestri S (**2019**) Sending your sick crops to the doctor: the impact of plant clinics in Rwanda. In *2019 Sixth International Conference, September 23-26, 2019, Abuja, Nigeria* (No. 295740). African Association of Agricultural Economists (AAAE).

59. Thuijsman EC, Ronner E, Wolde-Meskel E, Kantengwa S, **Rurangwa E**, Chikowo R, Chekanai V, Baijukya F & Giller KE (**2019**) Responses to inoculation of *Phaseolus* beans on N2Africa trials in Ethiopia, Tanzania, Rwanda and Zimbabwe.

60. **Uzayisenga B**, **Mutimura M**, Muthomi JW, Mwang'ombe AW & Ghimire SR (**2019a**) Emerging disease challenges to sustainable production of *Brachiaria* grass in Rwanda. Paper presented at the Annual Congress of Grassland Society of Southern Africa, South Africa, 30 June -4 July 2019

61. **Uzayisenga B**, **Mutimura M**, Muthomi JW, Mwang'ombe AW & Ghimire SR (**2019b**) Identification and Characterization of *Bipolaris Secalis* Causing Leaf Spot on *Brachiaria* Grass

in Rwanda. Paper presented at the AGRO 2019 Conference & Exhibition, University of Nairobi, Kenya, 22 -24 October 2019.

62. **Uzayisenga B**, **Mutimura M**, Muthomi JW, Mwang'ombe AW & Ghimire SR (**2019c**) Fungi Associated with Diseased Leaves of *Brachiaria* Grass in Rwanda. Poster presented at the AGRO 2019 Conference & Exhibition, University of Nairobi, Kenya, 22 -24 October 2019

63. **Waweru BW**, Kilalo DC, Miano DW, Kimenju JW, **Rukundo P** (**2019**) Diversity and economic importance of viral diseases of pepper (Capsicum spp.) in Eastern Africa. *Journal of Applied Horticulture 21*(1): 70-76.

64. Wortmann CS, Kaizzi KC, Maman N, **Cyamweshi A**, Dicko M, Garba M, ... & Kibunja C (**2019**) Diagnosis of crop secondary and micro-nutrient deficiencies in sub-Saharan Africa. *Nutrient cycling in agroecosystems 113*(2): 127-140.

65. **Urinzwenimana C**, Marker S & Chaurasia AK (**2019**) Genetic Diversity of Wheat (*Triticum aestivum* L.) Germplasm. *Research & Reviews: Journal of Crop Science and Technology 2*(2): 26-36.

66. Uwizeyimana D, Mureithi SM, **Mvuyekure SM**, Karuku G & Kironchi G (**2019**) Modelling surface runoff using the soil conservation service-curve number method in a drought prone agro-ecological zone in Rwanda. *International Soil and Water Conservation Research 7*(1): 9-17.

67. **Uzayisenga B, Mutimura M**, Muthomi JW, Mwang'ombe AW & Ghimire SR (**2019**) Emerging disease challenges to sustainable production of Brachiaria grass in Rwanda. Paper presented at the Annual Congress of Grassland Society of Southern Africa, South Africa, 30 June-4 July 2019. https://hdl.handle.net/10568/106593