Foreword

By the Chairperson of the Board of Directors

Rwanda Agriculture and Animal Resources 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 the Annual Report for Rwanda Agriculture and Animal Resources Development Board for the Fiscal Year 2017-2018. 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), which target crop and livestock intensification through development of new varieties, production and dissemination of high quality seed, improved storage and postharvest infrastructures, increased fertilizers use, artificial insemination and embryo transfer, increased use of irrigation and mechanization.

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. Achievements presented herein for the Fiscal Year of 2017-2018 include research and extension for various crops, natural resource management, and animal resources in order to assist policy makers to to take informed decisions.

The Fiscal Year 2017-2018 correponded with a restructuring of RAB which aimed to (i) ensure full intergration of research and extension, as erstwhile institutions that merged into RAB had resulted into analogous compartmentalization into the new institution; (ii) effect decentralization to increase outreach and service delivery, by creating thirteen stations, with each station overseeing two or three districts; and (iii) stregthen key services in line with national priorities, including creation of a Seed Systems Division, creation of a Division in charge of Postharvest and Marketing, and strengthening the unit in charge of internal audit, from two to five staff.

The Board of Directors of RAB would like to thank the Government for the support and guidance through the line Ministry. 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 dedicated work and look forward to even higher performance ahead.

Dr. Magnifique Ndambe NZARAMBA

Chairperson of the Board of Directors of RAB

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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   – Caliphornia 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

The Fiscal Year 2017-2018 corresponded with the first year of the National Strategy for Transformation, NST-1, developed for 2017-2024, and the last year of the Strategic Plan for Transformation of Agriculture, PSTA-3, covering period from 2013 to 2018. Rwanda Agriculture and Animal Resources Development Board has done research and technology transfer for deliver on national priorities outlined in these key strategic documents, through crop and animal resources improvement, clean seed production, natural resource management and sustainable agriculture intensification including increase of irrigation and mechanization as well mineral fertilizer applications.

Under crop improvement, new varieties were developed for maize (5 resistant to Fall Armyworm; 5 resistant to MLN disease, 7 drought and low N tolerant; 2 low N tolerant inbred lines, 5 tolerant to Maize Streak Virus (MSV) disease, Turcicum Leaf Blight (TLB) disease and Grey Leaf Spot (GLS) disease, 5 Quality Protein Maize (QPM) varieties). Rice research is developing cold tolerant varieties, and wheat research has produced crosses where the last set of F7 progenies is at advanced yield evaluation step. Irish potato research developed 5 clones overpassing yield of local varieties and National Potato trials were established in different agro-ecological zones for official release and has started crossing of biofortified diploids with best CIP and local clones. Sweet potato research has developed two new varieties with yield and fortified with pro-vitamin A. Cassava research is evaluating 17 promising virus resistant clones. Bean research has developed 4 bush and 4 climbing beans and is evaluating introduced and local varieties as well as crossing progenies for high Fe and Zn content. Soybean has evaluated 59 introduced varieties which are at different trial steps with first set undergoing on farm evaluation. Coffee breeding produced six F1 hybrids resistant to coffee leaf rust, coffee berry disease and tolerant to low rainfall with yield over 2.5t/ha overpassing currently used coffee varieties (BM139 and Jackson). These hybrids were. Tea research evaluated newly introduced tea clones and fertilizer doses and their effect on nutrient content in tea leaves. Banana research has evaluated 29 new hybrids of cooking banana. Horticulture research focused on development of good agronomic practices and disease management for citrus, mango and tamarillo.

To accelerate the access to clean seed and keep high growth rate in agriculture sector, RAB has produced an important quantity of seeds of different categories – breeder and pre-basic seeds: 3,418 kg of pre-basic seeds of rice; 941,480 plantlets and 4,512,960 mini-tubers of Irish potato; 417,000 cuttings of sweet potato; 1,832 kg breeder seed and 6,284 kg pre-basic seed for beans; 295 kg breeder's seed; 2,167kg pre-basic and 15,291kg basic seeds for soybean; 50kg seed of tamarillo, 335,400 scions for avocado, 193,800 scions for citrus and 117,200 scions for mango for grafting; 600,000 seedlings of new coffee hybrids and 7,500,000 seedlings of BM 139 and Jackson 1257; 50,420 banana ; 62,409 sweet potato and 76,849 micropropagated plantlets of cassava. As

per NST-1 key intervention for agriculture intensification, the establishment of infrastructures for Horticulture Center of Excellence was done at RAB-Mulindi.

Increase in mineral fertilizer use by farmers is another key area for agriculture intensification under PSTA-3 and NST-1. To optimize fertilizer rates for the diversity of crops and soils, Natural Resource Management research developed blended fertilizer formula across major Rwandan soil types and demonstrated them countrywide on farm on key food security crops - maize, Irish potato and rice. Agroforestry research has developed and demonstrated successful stalk production for beans with agroforestry tree species, as well as Irish potato yield increase with green tree biomass applications.

For crop intensification : Seeds and fertilizers were distributed to farmers: 2,373,329 kg of maize, 437,091 kg of wheat and 723,639 kg of soybean; 9,616,640 kg of DAP; 6,337,988 kg of Urea; 13,969,029 kg of NPK; 112,100 kg of KCl and 487,603 kg of Yara products. RAB through Twigiremuhinzi model conducted seasonal training on maize planting in 2018A season in 307 sectors for 13,601 participants (10,376 males and 3,225 females) from 307 out of 415 sectors in the country. The 2018B seasonal training was done in 401 sectors to facilitate the use of Smart Nkunganire System (SNS): new system of ordering agriculture inputs using telephones.

For livestock intensification and improvement, a NST-1 and PSTA-3 planned improvement of different livestock species was undertaken. Livestock research started embryo transfer on cows using freshly received and frozen embryos. A total of 68,101 semen doses (58,101 doses of Jersey and 10,000 doses of Holstein-Friesian) have been imported for artificial insemination; 104,373 cows were inseminated and 41,873 calves born. For pigs, 318 sows were artificially inseminated and 1,062 piglets weaned. Girinka Program targets was to distribute 31,190 cows to poor households in the fiscal year of 2017-2018. By the end of June 2018, 32,973 cows had been distributed to the poor families. A total of 813.5 ha were established with improved forage varieties (forage seeds multipliers initiated). A total of 393 Farmer Field School groups have been formed and established forage plots, and 7,244 livestock farms were cleared and fenced in Nyagatare and Gatsibo. Goat research continued and showed the productivity potential of cross breed exotic goats and local race. For poultry, Kuroiler and its crossbreeds with local chicken were characterized. Aquaculture and fishery research introduced new fish species to enrich fish stock in Kigembe fish farm for rearing and conducted study on fish feed availability and new fish feed formulations.

These achievements have been realized with the support of our Government through our line Ministry and our Board of Directors. We also acknowledge the contributions of our Development Partners, farmers and stakeholders including Local Government entities, service providers and Non-Governmental Organizations engaged in agriculture development for the cordial and fruitful working relationships that enabled us to successfully round up the year. Together with my team

we remain committed to contribute substantially to the transformational growth our country's economic through through research and extension to increase agriculture and animal resources productivity and sustainability and minimize postharvest losses.

Patrick Karangwa (PhD)
Director General of RAB

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Part 1. Research and Technology Transfer

1.1 Crop and Horticulture Research

1.1.1 Cereals

1.1.1.1 Maize

Introduction of climate resilient germplasm

In the year 2017-2018, different germplasm tolerant and or resistant to various stresses were introduced from CIMMYT. The materials were increased for having enough seed for further investigation. This germplasm comprised eight inbred lines resistant to fall armyworm, five inbred lines resistant to Maize Lethal Necrosis (MLN), seven drought and low N tolerant inbred lines, two low N tolerant inbred lines, five inbred lines tolerant to Maize Streak Virus (MSV) disease, Turcicum Leaf Blight (TLB) disease and Grey Leaf Spot (GLS) disease, four inbred lines adapted to high altitudes and five Quality Protein Maize (QPM) Inbred lines adapted to high altitudes as well.

New maize hybrid varieties selected from advanced yield trials

Thirteen new maize hybrid varieties were selected for final verification from advanced yield trials conducted both in mid and high altitudes. They included eight hybrid varieties for mid altitudes, five varieties for high altitudes, one foliar diseases resistant, two drought tolerant, one drought tolerant and early maturity, four early maturing and five varieties with general adaptablity to high altitudes (Tables 1 and 2).

Table 1: Eight maize hybrid varieties for mid altitudes selected for final verification

No	Codes	Type	Specific traits
1	RHMM1701	Three Way Cross Hybrid	Resistant to foliar diseases
2	RHMM1702	Three Way Cross Hybrid	Drought tolerant
3	RHMM1703	Three Way Cross Hybrid	Drought tolerant, early maturity
4	RHMM1704	Three Way Cross Hybrid	Drought tolerant
5	RHMM1706	Three Way Cross Hybrid	Early maturity
6	RHMM1707	Three Way Cross Hybrid	Early maturity
7	RHMM1708	Three Way Cross Hybrid	Early maturity
8	RHMM1710	Three Way Cross Hybrid	Early maturity

Table 2: Five maize hybrid varieties for mid altitudes selected for final verification

No	Codes	Pedigrees	Specific trait
1	RHMH1707	Three Way Cross Hybrid	General adaptability to high altitudes
2	RHMH1705	Three Way Cross Hybrid	General adaptability to high altitudes
3	RHMH1604	Three Way Cross Hybrid	General adaptability to high altitudes
4	RHMH1605	Three Way Cross Hybrid	General adaptability to high altitudes
5	RHMH1708	Three Way Cross Hybrid	General adaptability to high altitudes

Increase access to maize hybrid varieties by farmers through

The increase access to maize hybrid varieties by farmers were done through breeder', pre-basic and basic seed production and distribution. In total, 150 kg of breeder's seeds, 1,200 kg of pre-basic seeds and 10,400 kg of basic seeds were produced. The hybrid varieties concerned are either at certified seed production or at basic seed production levels (Table 3).

Table 3: Hybrid varieties involved in seed production

No	Codes	National catalogue registration name	Specific trait	Seed production step	Ecology
1	RHM104	RW-MZE-014-01	Drought tolerant	Certified seed	Mid altitudes
2	RHM1402	RW-MZE-015-02	Drought tolerant	Certified seed	Mid altitudes
3	RHM1407	RW-MZE-015-03	MLN tolerant	Certified seed	Mid altitudes
4	RHM1409	RW-MZE-015-01	MLN tolerant	Basic seed	Mid altitudes
5	RHMH1601	RW-MZE-018-01	General adaptability	Basic seed	High altitudes
6	RHMH1611	RW-MZE-016-02	General adaptability	Basic seed	High altitudes
7	RHMH1520	RW-MZE-015-04	General adaptability	Basic seed	High altitudes
8	RHMH1521	RW-MZE-015-05	General adaptability	Basic seed	High altitudes

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 on field. The field training was performed specifically by visiting the seed production plots at major stages of development such as: planting, rogueing, detasseling and harvesting. Furthermore four 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) were backstopped for certified seed production.

Maize Lethal Necrosis country wide distribution

A country wide MLN disease detection was conducted in all 30 districts of Rwanda by using agristrips, a new quick, efficient and inexpensive method of MLN detection developed by CIMMYT. This MLN detection was conducted on 5th and 6th July 2018 and from 9th to 13th July 2018. Agristrips the presence of Maize Chlorortic Mottle Virus (MCMV) whose presence imply the presence of MLN. One hundred eight-two samples were analyzed. Only 21 samples (11.5 %) tested positive for the presence of MCMV. These results indicated that the MLN disease in Rwanda still present in Rwanda (Figure 1 left). However, its presence has significantly reduced as compared to the situation of 2015 (Figure 1 right).
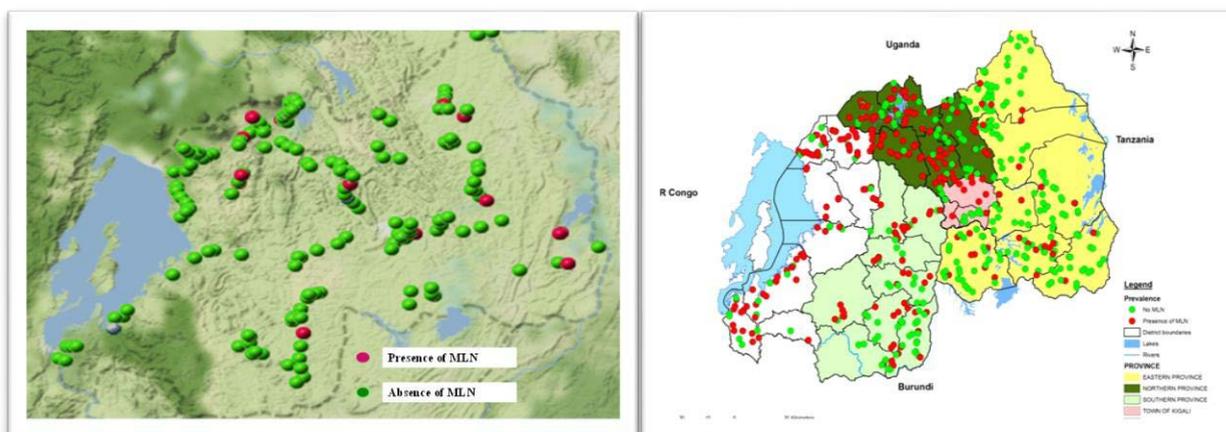
Figure 1: Prevalence of Maize Lethal Necrosis (MLN) disease in July 2018 (left) and July 2015 (right).

1.1.1.2 Rice

Rice is a staple food for half of the human population. Unlike other cereals such as wheat and barley, rice plants are susceptible to cold stress, which often results in decreased productivity, especially in regions where the type *indica* subspecies is cultivated. Low night temperatures is one of abiotic production constraints faced in rice cultivation in high elevation environments with the potential to affect growth and development from germination to grain filling. Cold temperature can be distinguished from freezing in terms of the range of temperatures that cause the related damages. Many species of tropical or subtropical origin are injured or killed by non-freezing low temperatures, and exhibit various symptoms of chilling injury such as chlorosis, necrosis, or growth retardation. In contrast, chilling-tolerant species are able to grow at such low temperatures. There is a wide range of genotypes based differences in cold tolerance among rice varieties, these differences often reflecting growth conditions and adaptability in different locations. To extend the innovative technologies to farmers, a technology transfer model was

initiated and known as FFS-Twigire Muhinzi and rice program staff used this approach successfully to reach farmers for good seeds, fertilizers and pesticides utilization.

Introgression of cold tolerance allele rymy 1-3 into three local varieties

Crosses were undertaken, where in breeding crossing block, crosses were produced using 08 Fan10, WAT 1395-B-24-2, and Supa varieties as female parents and Teta 57, a resistant variety to Rice Yellow Mottle Virus (RYMV) disease as donor. The F1 progenies evaluation results are are shown in Table 4 below.

Table 4: Data collected of first generation of three crosses made at Rubona

Parentage	Generation	Sowing date	Flowering date	Days to flowering	Number of F1 grains
WAT1395-B-24-2/Teta 57	F1	18/10/2017	11/2/2018	120	35
08 Fan 10/Teta 57	F1	16/11/2017	28/2/2018	105	135
Supa/Teta 57	F1	18/10/2016	4/2/2018	107	54

Adaptability trials of cold tolerant materials from different origin to local conditions

Seeds of 45 accessions were obtained from AfricaRice-Madagascar with 100 % of the seeds used in this test being tested for diseases control first in greenhouse at Rubona Station. Then, the lines were tested in Cyili, field research in Gisagara District. The experiment design used was an alpha lattice design composed by 9 blocks with 5 plots in each one. Two local checks were included namely Yun yin 4 as national check and Mbakungahaze as local check. The 45 treatments were replicated three times and the fields were evenly prepared and fertilizers used were 80 N-34 P-34 K with the nitrogen splitted 2 times. 50% of N were applied at early tillering stage whereas the second split was added at Panicle initiation. The traits recorded were plant height, plant acceptability, cold tolerance, lodging, sheath rot tolerance, Rice yellow mottle tolerance, Blast tolerance, total number of panicles, number of grains, grains fertility and yield. The analysis of data was done using breeding view VSNI product and three major parameters were evaluated: plant height, time of heading and yield. About half of the lines tested are early yielding and have short duration (<135 days). The second group of lines fitted in middle duration of 135-150] whereas the last group has a long duration. The acceptable varieties must have cycle duration between 135-150 days in order to be replace the current short grain varieties (Yun yin 4, Zhong geng , Yun er tian,...), which are late yielding with a cycle longer than 165 days. For height, the requirement is 90-110 cm. More than 50% of the tested varieties have similar height patterns. Moreover, all tested lines were tolerant cold night temperatures, rice yellow mottle virus and blast. Inoculation test will be conducted to confirm this tolerance. Despite the good results of

evaluation for abiotic and biotic stresses, most of the lines had poor phenotypic acceptability with moderate panicle exsertion. Yield and yield components are still under evaluation.

Technology transfer activities

Technology transfer (TT) group conducted various activities on paddy production, inputs used and marketing. The following tables below described the overall situation during 2017-2018.

1.1.1.3 Wheat

Wheat *(Triticum æstivum* L.) is one of the major cereal crop in Rwanda. The crop comes third after maize and rice in terms of food security and income generation and is among priority crops selected for crop intensification program (CIP). Figures indicate that wheat is grown on more than 50.000 hectares, scattered various highlands of the in Norther, Southern and Western Provinces of Rwanda. Despite the opportunities of wheat growing in Rwanda, the crop productivity still lags behind its expectations and national wheat production targets. For the recent decades wheat manufactory industry has been relying on wheat imports because of low production in terms of quantity and baking quality. Various constraints have been reported to hamper wheat productivity in Rwanda. These include: narrow genetic diversity of cultivars which reduces farmers' choices about the variety to grow; low yielding potential varieties with low baking quality; a number of various biotic and abiotic constraints which threatens wheat productivity. The major ones including wheat diseases among other stem, leaf and stripe rusts, insect pest and soil acidity that characterizes most of wheat growing reasons; post-harvest losses; poor agronomic practices technology transfer services; climate change hazards. Therefore, there is a need to increase crop productivity through adequate research and technology transfer initiatives. In these regards, research projects for the 2017/2018 fiscal year were centered on activities aiming at addressing the above mentioned wheat production related constraints.

Variety development

This breeding programme aims to develop new wheat varieties meeting farmers and market demand. This breeding programme is a result of bilateral partnership between RAB and CIMMYT. Hence some of the breeding lines were developed by RAB and others developed by CIMMYT.

CIMMYT Breeding lines: Breeding lines imported from various CIMMYT breeding nurseries were evaluated through : 1) Preliminary yield trials involving 300 breeding lines from the International Bread Wheat Screening Nursery (IBWSN); 2) Preliminary yield trial involving 275 breeding lines from the Semi-arid wheat screening nursery (SAWSN); 3) Preliminary yield trial involving 133 High

Rainfall Wheat Screening Nursery (HRWSN). From lines, ten accessions from each breeding nursery were selected to their yielding potential and multiple stress resistance (Table 5).

Table 5: Evaluation of 10 promising varrieties for selected traits from the 3 breeding nurseries

| Accession number | Days to Maturity | Plant height (cm) | Grain yield per plot (kg) | Estimated yield per ha (Kg) | Reaction to major diseases | | | |
					Yellow Rust	Stem Rust	Leaf rust	Powdery mildew
High Rainfall Wheat Screening Nursery (HRWSN)								
2070	113	93	430	7 166.7	20 MR	TR	TR	40 MR
2066	114	93	275.5	4 591.7	20 MR	TR	TR	TR
2054	105	88	251	4 183.3	20 MR	TR	TR	TR
2068	113	90	247.5	4 125.0	20 MR	TR	5 R	10 MR
2072	107	88	229	3 816.7	10 MR	TR	TR	40 MR
2137	113	86	227.5	3 791.7	20 MR	TR	TR	50 MS
2079	112	96	227	3 783.3	10 MR	TR	10 MR	10 MR
2112	104	90	227	3 783.3	10 MR	TR	TR	TR
2088	106	86	225	3 750.0	10 MR	TR	TR	TR
2080	115	90	223.5	3 725.0	10 MR	TR	TR	10 MR
International Bread Wheat Screening Nursery (IBWSN)								
1114	115	85	382	6 366.7	5 R	TR	TR	10 MR
1098	112	88	328	5 466.7	10 MR	TR	TR	TR
1266	111	90	316	5 266.7	20 MR	TR	TR	5 R
1241	111	90	302.5	5 041.7	10 MR	TR	TR	TR
1143	114	88	301.5	5 025.0	10 MR	TR	TR	TR
1039	113	90	301	5 016.7	TR	TR	TR	TR
1069	115	91	299	4 983.3	10 MR	TR	TR	TR
1012	116	90	296.5	4 941.7	10 MR	TR	TR	TR
1002	115	96	293	4 883.3	20 MR	TR	TR	TR
1167	114	93	291	4 850.0	20 MR	TR	TR	TR
Semi- Arid Wheat Screen Nusery (SAWSN)								
3010	110	90	356	5 933.3	20 MR	TR	TR	TR
3009	110	91	323.5	5 391.7	10 MR	TR	TR	TR
3001	118	86	307.5	5 125.0	20 MR	TR	TR	10 MR
3039	107	86	289.5	4 825.0	5 R	TR	TR	TR
3092	104	93	281.5	4 691.7	5 R	TR	TR	TR
3076	116	90	279.5	4 658.3	10 MR	TR	TR	TR
3152	112	91	271	4 516.7	20 MR	TR	TR	TR
3264	109	90	270.5	4 508.3	TR	TR	TR	10 MR
3095	112	95	270	4 500.0	10 MR	TR	TR	TR
3229	111	85	267	4 450.0	5 R	TR	TR	TR

Among the varieties tested, all the 30 genotypes from the three breeding nuserries have shown higher yield as compared to the national average yield (2 tones per ha). Consequently, for the next fiscal year (2018-2019), these lines will undergo advanced yield trials in multiple locations to evaluate their adaptation potential and yield and other core traits stability, prior to varietal release programs.

Photo 1: Wheat evaluation in RAB Rwerere (Leff) and Kinigi (right) Stations

RAB Breeding lines: Various parental materials from local germplasm have been submitted to diallel crossings to develop new genotypes (Photo 1). In these regards, a set of 15 F7 populations were evaluated for field performance of core breeding traits and superior genotypes selected. Best performing progenies will be evaluated through foreground selection (multiple stress resistance) and background selection (yield and quality characteristics). Another set of 51 F2 and 50 F3 populations were respectively advanced to generate F3 and F4 progenies. These populations will continue selfing and selection in a bid to develop higher generations during 2018/2019 fiscal year.

Strengthening wheat seed systems

In recent years, Rwanda has been importing more than 500 MT of seeds from Kenya. For the 2017/2018 fiscal year there efforts have been put in place to reduce the country's reliance on seeds imports through local seed production. In these efforts, all the aspects of seed production value chain are concerned, from early generation seed up to certified seed. Table 6 highlights quantities of pre-basic seed produced from newly released varieties.

Table 6: Pre-basic and basic seed production for released varieties (local names) and pre-released varieties (EN codes in italic)

Variety	Pre-basic seeds produced (Kg)	Basic seed produced (MT)
Nyaruka	1,199	
Gihundo	161	40 MT
Cyumba	238	
Majyambere	240	
Rengerabana	290	
Reberaho	454	
Mizero	474	
Keza	180	
EN 118	27	
EN 105	30	
EN 111	35	
EN 121	50	
EN 110	40	
Total	**3,418**	

EN codes in italic were pre-released varieties that were imported from Nigeria. *Pre-basic seeds from these varieties will be used for DUS trials prior to official varietal release.*

Wheat rust surveillance and monitoring

Wheat rust survey was done to track down the development of new wheat rust races and develop early warning systems. A total of 9 yellow (stripe) and 10 brown (leaf) rust samples were collected (Photo 2) in Nyabihu, Musanze, Burera, Gicumbi and Rulindo. The samples were sent to the Global Rust Reference Center (GRRC), Denmark, for identification. Results are expected within the second quarter of 2018/2019.

Photo 2: Rust sampling in Kinigi station

Technology transfer through Innovation platforms (IP)

Innovation platforms (IP) have been used as an agricultural extension tool to encourage easy adoption of agricultural innovation by farmers. Three wheat innovations platforms were established in Cyumba (Gicumbi), Butaro (Burera) and Gataraga (Musanze) (Table 7). A total of 13 demo plots were established in the IPs as follows: Cyumba IP (4), Butaro IP (5) and Gatara IP (4), while a total of five farmer field schools (FFS) were also established in Cyumba (3), Butaro (1) and Gataraga (1). Field visit was organized in Gataraga site in June 2018, assembling wheat farmers and other stakeholders from Butaro, Cyumba and Gataraga IPs for sharing experience and exchanging information on how to improve wheat value chain through innovation platform approach. In each IP a set of agronomic trials were evaluated in a participatory approach. These included planting either on beds or in farmers and 6 different fertilizer application rates.

Table 7: Composition of Innovation platforms in Northern Province of Rwanda

IP	Male	Female	Total
Mukura	11	5	16
Butaro	21	12	33
Cyumba	69	19	88
Total	**101**	**36**	**137**
Percent	73.72	26.28	100

This table indicates that IPs are dominated by men while more women are involved in various levels of wheat production. In each IP on field days were organized where participants shared experience and techniques on how to use appropriate varieties and other agricultural inputs, along with adequate crop management practices (planting time, seedbed preparation, planting densities, fertilizer types and rates, and right time to apply fertilizer, weeding frequencies, pest and disease management practices such as pesticides application, bird scaring, etc).

During field days, participants made rounds within and between fields, either established for demos or neighbouring (normal) farmers' fields to compare them and learn from the differences observed between the two types of fields (demonstration and normal fields), where in most of the normal fields of Gataraga wheat varieties showed numerous off-types difficult to rogue, with little fertilizer applied or applied unevenly while in demos the varieties were uniform/homogeneous with adequate amounts of fertilizers applied. This has a positive implication on plant health and grain yield increase.

Bean is major pulse crop in Rwanda providing important source of proteins. Bean research is currently focused on developing biofortified varieties and further screen them for pests and disease resistance for bush and climbing bean types.

High Iron Bean development for Improved Human Nutrition in Rwanda

The aim of this research was to develop bush and climbing bean populations with high mineral density (rich in Fe and Zn), combining resistance to diseases, drought tolerance, adapted to low soil fertility for priority market classes and accepted by farmers in different Rwanda AEZs.

Introduction: A total of 253 varieties were introduced from CIAT including 41 bush and 212 climbing types; evaluated and best varieties were selected. Superior lines were planted in 2019A for further evaluation along with locally bred genotypes. Among these, 41 entries were bush beans and only two genotypes including NCC 144 and NCC 145 were able to adapt to local conditions of Rubona station and able to accumulate Fe content ranging from 81 and 84 ppm, which was far from the target of 94ppm. The yield performance was poor (1700kg/ha) as compared to improved check. They will be tested along with locally developed lines in IYT in 2019 onwards. Among the 212 introduced climbing lines, only 9 were able to adapt and accumulate Fe content at the rate above 80ppm. The lines with Fe content >94ppm has low yield but selected for another chance for yield evaluation.

Local collection: 134 new locally collected germplasm were planted during 2018B. Evaluation is completed and identified leads have been planted for 2019A evaluation in IYT. 55 best lead entries have been planted in Rubona in 2019A and B seasons for Intermediate yield trial. Best leads will be evaluated in advanced/multilocation trials and superior accessions will be used as parents for Fe and other agronomic traits improvement. During evaluation, it was observed that all introduced lines were poorly adapted to test environment, and only 2 entries (CGA 56 and CGA 71) looked good in vigor. The heavy rains in 2018B destroyed many entries. Thus, the selection was based on the performance of the survived ones.

Breeding: A total of 790 crosses including 641 bush and 149 climbing were made and progenies were planted in F1 nursery to generate F2 seed in 2019A. From 420 F1 crosses, at total of 366 lines including a set of 277 lines and 89 lines respectively were planted in 2018B. Evaluation is

completed and 100 best lines including 16 bush and 84 climbing are planted in F2 nursery in 2019A to generate F3 seed. Among 1292F1s lines, 861 F2 lines were selected and planted in 2018B. Evaluation is completed and 243 best lines including 171 bush and 72 climbing are planted in F3 nursery in 2019A to generate F4 seed. 152 F3 lines of climbers were planted in 2018B. Evaluation is completed. The 157 individual plants are planted in F4 nursery in 2019A to generate F5 seed. Among 502 F3 lines, 432 F4 lines including 57 and 375 climbing and bush bean lines respectively were planted in 2018B. Evaluation is completed. The 421 best lines including 376 bush and 45 climbing are planted in F5 nursery in 2019A to generate F6 seed.

Among 303 F4 lines 238 F5 lines including 41 and 197 F5 climbing lines were selected and planted at Rubona and Rwerere in 2018B. Evaluation is is completed. Stable and best lead lines are being tested in PYT while the 31 best lead lines are planted in F6 nursery in 2019A to generate F7 seed. From 158 F5 lines, a total of 103 lines including 36 F6 and 67 F6 lines respectively were selected to be evaluated in 2018B. Evaluation is completed and 83 best lines are being advanced to the next generation (F7 nursery in 2019A to generate to F8 seed) while stable lines were selected and tested for preliminary yield trial in 2019A. From 32 F8, 13 best lines were selected as stable lines to be evaluated in preliminary yield trial in 2018B. The best lines were selected to be evaluated in IYT in 2019A.

A total of 121 entries including 19 climbing and 102 bush were mass selected from segregating lines and planted in Rubona for evaluation in preliminary yield trial in 2018B. Best leads were selected to be tested in intermediate yield trial in 2019A. From 261 lines, 140 including 181 climbing and 59 bush entries were selected and planted in Rubona in preliminary yield trial and 200 entries at Rwerere. The best lines were selected to be evaluated in intermediate yield trial in 2019A. In 2018B, a total of 112 climbing and bush bean lines were planted in 2018B as planned including 58 best bush entries, 25 climbers for validation of Fe content, 14 climbing entries for yield validation and 15 climbing entries for both yield and Fe validation analysis. The 54 best lines including 37 bush and 17 climbing are being evaluated in advanced yield trials in 2019A.

A total of 61 lines including 27 climbers and 34 bush bean lines were planted at Rubona and 25 climbing lines at Rwerere in 2018B in advanced yield trials. total of 26 best leads lines including 13 bush and 13 climbing are being evaluated in multilocational yield trials phase one in two sites of selection zone in 2019A. From 143 bush and climbing lines, 125 lines including 40 bush and 87 climbers of which 13 evaluated in Rwerere and 74 in Rubona of which 17 evaluated in 3 representative zones in multilocational yield trials phase one in 2018B. Evaluation is completed. A total of 28 best lines including 13 bush and 15 climbing are being advanced to multilocational yield trials phase two in 6 Stations in 2019A.

Performance evaluation of GxE Interactions

A total of 27 best leads climbing lines were planted for evaluation in multilocational yield trials phase two in different sites on station and on-farm in 2018B. Evaluation is completed. Eight (8) best lines were planted for adaptability and acceptability trials along with 7 other superior genotypes in 10 agro ecological zones in on farm trials in 2019A. Due to RAB restructuring, experiments were not followed up and are recommended to be replanted in the upcoming seasons. Differences in iron content were observed among tested genotypes and environments with strong GxE effects. It was observed that genotypes RWV 2425, RWV 3416 and RWV 2308-1 followed the RAB check in accumulating high iron content of 80, 82 and 83 ppm respectively. Differences in zinc content were observed among genotypes and environments at P<0.001. Thought tested genotypes accumulated low zinc content as compared to improved check, genotypes RWV 2308-1 and RWV 2425 were not significantly different from the check.

Table 8: The Mean iron content (in ppm) performance of another set of climbing entries selected in 2018 to be evaluated in adaptability and acceptability

Environment	1	2	3	4	5	6	7	8	Max	%	Min	%	Average	%
LOCAL CHECK	71	48	44	65	78	55	57	59	78	(16)	44	(42)	60	(30)
MAC 44 X RWV 1002 F4-1-2	89	73	63	91	91	76	80	78	91	(1)	63	(17)	80	(5)
MAC 44 X RWV 1129 F4-2-3	93	83	75	72	97	84	73	98	98	6	72	(4)	84	(0)
MAC 44 X RWV2872 F4-1-4	83	67	77	90	83	78	71	81	90	(2)	67	(11)	79	(7)
MAC 44 X RWV2872 F4-2-3	79	69	65	85	90	77	76	89	90	(2)	65	(14)	79	(7)
NGWIN X RWV 1129 F4-4-1	100	82	69	101	77	96	64	82	101	10	64	(15)	84	(1)
NGWIN X RWV 1129 F4-4-2	90	73	67	80	78	97	72	83	97	5	67	(11)	80	(6)
RAB CHECK	92	75	78	84	92	90	76	90	92	-	75	-	85	-
RWV 1129 X MAC 44 F4-1-1	83	74	60	72	85	69	66	90	90	(2)	60	(21)	75	(11)
RWV 1129 X MAC 44 F4-1-2	84	69	71	82	87	78	70	88	88	(5)	69	(9)	79	(7)
RWV 1129 X NGWIN X RWV 1129 F4-3-4	96	88	69	95	96	100	74	93	100	9	69	(8)	89	5
RWV1002XRWV 1129F4-1-2	89	72	67	79	95	76	80	79	95	3	67	(11)	80	(6)
RWV3006 X RWV 2872 F4-1-4	90	67	70	83	86	78	68	81	90	(2)	67	(11)	78	(8)
RWV3316 X GITANGA 4/1/22	83	79	69	74	92	68	70	83	92	0	68	(10)	77	(9)
RWV3316 X GITANGA 4/1/27	93	95	73	89	93	89	68	101	101	10	68	(10)	88	3
Season **		Genotype ns		Genotype/Seasonn ns				%cv 62						

(1) Muhanga 18A; (2) Muhanga 2018B; (3) Ngoma 2018A; (4) Ngoma 2018B; (5) Rubona 2018B; (6) Rubona 18A; (7) Rwerere 2018A; (8) Rwerere 2018B

The varieties RWV 3416, RWV3417, RWV 2425 and RWV 2380-1 yielded higher than RAB check used with 9 to 32% superior. It is therefore recommended that these genotypes be tested for adaptability and acceptability in on station and on farm trial for identification of superior genotypes to be grown by farmers.

Lines including MAC 44 X RWV 1129 F4-2-3; NGWIN X RWV 1129 F4-4-1; NGWIN X RWV 1129 F4-4-2; RWV 1129 X NGWIN X RWV 1129 F4-3-4; RWV1002XRWV 1129F4-1-2 and RWV3316 X GITANGA 4/1/27 showed high iron content than the RAB check (Table 8).

Table 9: Mean zinc content (in ppm) performance of another set of climbing entries selected in 2018 to be evaluated in adaptability and acceptability

Environment	1	2	3	4	5	6	7	8	Max	%	Min	%	Average	%
LOCAL CHECK	34	24	28	30	39	29	23	33	39	7	23	(15)	30	(9)
MAC 44 X RWV 1002 F4-1-2	35	33	32	38	39	31	35	29	39	8	29	8	34	4
MAC 44 X RWV 1129 F4-2-3	42	40	30	28	47	32	34	36	47	31	28	6	36	11
MAC 44 X RWV2872 F4-1-4	30	25	30	32	34	29	26	26	34	(6)	25	(7)	29	(11)
MAC 44 X RWV2872 F4-2-3	31	30	29	32	35	30	28	34	35	(4)	28	5	31	(5)
NGWIN X RWV 1129 F4-4-1	29	32	25	33	39	30	24	26	39	8	24	(12)	30	(9)
NGWIN X RWV 1129 F4-4-2	27	25	27	30	32	31	29	28	32	(13)	25	(9)	28	(13)
RAB CHECK	36	31	32	33	35	36	27	32	36	-	27	-	33	-
RWV 1129 X MAC 44 F4-1-1	30	30	27	30	31	27	24	32	32	(11)	24	(12)	29	(12)
RWV 1129 X MAC 44 F4-1-2	32	26	32	32	34	33	26	33	34	(5)	26	(5)	31	(5)
RWV 1129 X NGWIN X RWV 1129 F4-3-4	42	40	29	36	43	34	29	37	43	20	29	9	36	11
RWV1002XRWV 1129F4-1-2	39	37	34	38	45	35	34	41	45	25	34	27	38	15
RWV3006 X RWV 2872 F4-1-4	32	29	26	30	37	28	29	31	37	3	26	(4)	30	(8)
RWV3316 X GITANGA 4/1/22	29	30	31	31	39	28	26	30	39	8	26	(4)	31	(7)
RWV3316 X GITANGA 4/1/27	31	27	32	30	36	29	26	29	36	(1)	26	(2)	30	(8)
Season ***		Genotypes ***		Genotype/Season ***			%cv 11							

(1) Muhanga 18A; (2) Muhanga 2018B; (3) Ngoma 2018A; (4) Ngoma 2018B; (5) Rubona 2018B; (6) Rubona 18A; (7) Rwerere 2018A; (8) Rwerere 2018B

MAC 44 X RWV 1002 F4-1-2; MAC 44 X RWV 1129 F4-2-3; NGWIN X RWV 1129 F4-4-1; RWV 1129 X NGWIN X RWV 1129 F4-3-4; RWV1002XRWV 1129F4-1-2; RWV3006 X RWV 2872 F4-1-4 and RWV3316 X GITANGA 4/1/22 had high zinc content in seed (Table 9).

Table 10: Mean yield (in kg/ha) performance of another set of climbing entries selected in 2018 to be evaluated in adaptability and acceptability

Environment	1	2	3	4	5	6	7	8	Max	%	Min	%	Average	%
LOCAL CHECK	1,611	1,917	1,295	1,881	1,474	2,504	3,639	806	3,639	18	806	107	1,891	6
MAC 44 X RWV 1002 F4-1-2	1,472	2,250	1,715	2,196	1,829	2,392	2,667	500	2,667	(13)	500	29	1,878	5
MAC 44 X RWV 1129 F4-2-3	917	1,063	1,572	2,391	1,684	2,893	2,056	194	2,893	(6)	194	(50)	1,596	(10)
MAC 44 X RWV2872 F4-1-4	1,472	2,458	2,227	2,251	1,728	3,601	3,000	556	3,601	17	556	43	2,162	21
MAC 44 X RWV2872 F4-2-3	1,139	1,854	1,534	2,240	1,471	2,835	2,354	375	2,835	(8)	375	(4)	1,725	(3)
NGWIN X RWV 1129 F4-4-1	2,000	1,583	2,112	2,892	2,024	3,216	2,611	556	3,216	4	556	43	2,124	19
NGWIN X RWV 1129 F4-4-2	1,667	2,333	1,800	2,593	837	3,158	2,306	500	3,158	2	500	29	1,899	7
RAB CHECK	1,278	1,708	1,543	2,078	1,512	3,082	2,667	389	3,082	-	389	-	1,782	-
RWV 1129 X MAC 44 F4-1-1	1,639	2,042	1,474	1,470	1,709	3,584	3,528	444	3,584	16	444	14	1,986	11
RWV 1129 X MAC 44 F4-1-2	1,667	2,042	1,996	1,768	1,565	2,952	2,639	472	2,952	(4)	472	21	1,888	6
RWV 1129 X NGWIN X RWV 1129 F4-3-4	778	2,042	1,776	2,880	1,967	2,739	2,500	417	2,880	(7)	417	7	1,887	6
RWV1002XRWV 1129F4-1-2	944	1,083	760	764	1,219	1,840	2,139	1,111	2,139	(31)	760	95	1,233	(31)
RWV3006 X RWV 2872 F4-1-4	1,611	1,875	1,708	2,256	1,607	2,954	2,139	333	2,954	(4)	333	(14)	1,810	2
RWV3316 X GITANGA 4/1/22	1,083	1,833	947	1,308	1,667	2,923	3,194	722	3,194	4	722	86	1,710	(4)
RWV3316 X GITANGA 4/1/27	1,361	1,917	1,119	1,753	1,287	2,126	2,194	528	2,194	(29)	528	36	1,536	(14)
Season *		Genotypes ***	Genotype/Season *				%cv= 29							

(1) Muhanga 18A; (2) Muhanga 2018B; (3) Ngoma 2018A; (4) Ngoma 2018B; (5) Rubona 2018B; (6) Rubona 18A; (7) Rwerere 2018A; (8) Rwerere 2018B.

The varieties RWV3316 X GITANGA 4/1/22; MAC 44 X RWV 1002 F4-1-2; MAC 44 X RWV2872 F4-1-4; NGWIN X RWV 1129 F4-4-1; NGWIN X RWV 1129 F4-4-2; RWV 1129 X MAC 44 F4-1-1; RWV 1129 X MAC 44 F4-1-2; RWV 1129 X NGWIN X RWV 1129 F4-3-4 and RWV3006 X RWV 2872 F4-1-4 had high yield as compared to RAB check (Table 10).

Multilocational yield trials

A total of 27 best best bush lines were evaluated in multilocational yield trials on station and on-farm in 2018. The genotypes KAB 06F2-8-27 X RWR 2076-2, NUA 99 X RWR 2076, RWR 2076 X KAB 06F2-8-27 and KAB 06F2-8-27 X RWR 2076-1 accumulated between 15 and 17% higher iron than the RAB check used with the potential mean ranging between 105 and 116 ppm.

The varieties KAB 06F2-8-27 X RWR 2076-2, RWR 2076 X KAB 06F2-8-27, NUA 99 X RWR 2076 and RWR 1668 X SMC 21 F3-1-3-7 had higher zinc content perforemd better with the mean range of 5 to 8% higher zinc content than improved check with 43 to 48 ppm. The best yielders were RWR 1668 X SMC 21 F3-1-3-7, RWR 2154 X RWR 1668 F3-1-1-10, RWR 1668 X SMC 21 F3-1-3-1, KAB 06F2-8-27 X RWR 2154, RWR 1668 X SMC 21 F3-1-3-1 and RWR 2245 X RWR 2154 had 42 to 56% higher yield than the check. With reference to visual selection the varieties including RWR 1668 X SMC 21 F3-1-3-7, KAB 06F2-8-27 X RWR 2076-2, KAB 06F2-8-27 X RWR 2154, RWR 2154 X RWR 1668 F3-1-1-10, NUA 99 X RWR 2076, RWR 2154 X SMC 16 F3-2-1-18, RWR 2076 X KAB 06F2-8-27 were selected for adaptability and acceptability trials. The genotype RWR 2154 X RWR 1668 F3-1-1-3 had both high iron content and yield performance while the genotype BFS 32 had both high Zinc content and yield performance.

Six best climbing lines were evaluated for adaptability and acceptability at > 10 sites on station and on-farm in 2018B. Apart from RAB check, the varieties RWV 2387-3 and MEX 54 X TARS-UR 75 X G2333 X MLB 49-89 A F2-3-3 had high iron content of 86ppm (74-90ppm). Zinc content in seed varied among genotypes between 35 to 41ppm. Genotypes MEX 54 X TARS-UR 75 X G2333 X MLB 49-89 A F2-3-3, RWR 2076 X CAL 13F2-2-1 and RWV 2387-3 accumulated zinc content at almost the same level as RAB check used.

All tested genotypes were higher yielding than RAB check used except RWV 2387-3 with the potential yield ranging between 4750 to 6000kg/ha. The genotypes including RWR 2076 X CAL 13F2-2-1, RWV 2387-3 and 637 were recommended as high yielding and high Fe accumulation genotypes. the entry MEX 54 X TARS-UR 75 X G2333 X MLB 49-89 A F2-3-3 should be used for iron and yield improvement and stability.

Release of biofortified varieties

Elite climbing and bush bean lines were planted in 30 sites in 2018A in NPT trials. Fe/Zn was determined at Rubona. Validation at Adelaide University for elite lines was completed. Four varieties of bush and 4 of climbing lines were applied for registration and release.

Seed production

Seed of new varieties were multiplied in all RAB stations in 2018A and B. seasons. A total of 1.832MT of breeder seed were produced in 2018A in Rubona and Rwerere while a total of 6.284 MT of pre-basic seed were produced including 3.130MT produced in Ngoma, 0.140MT produced in Muhanga and 2.194MT produced in Rwerere, 0.820 MT from Musanze.

Conventional breeding to improve bean protein content and livelihoods in Rwanda

Bean is the main source of protein for rural poor. Having varieties with higher protein content would contribute to improve nutrition especially for those household who may not afford other sources of protein. Research aimed to develop new varieties with high protein content. A total of 146 local varieties were collected and evaluated for agronomic traits and protein content together with 117 F2 lines from breeding nurseries. Protein content varied between 7 and 25% of crude protein. During this experiment, it was observed that lines including 3 landraces 2584, 3036 and 4306 have got higher protein content of 24 for 2584 and 25 % respectively for 3036 and 4306 while crosses RWR 3194 XCAL 96 F2-2-1; RWR 3194 XCAL 96 F2-4-1 and MAC 42 X MAC 44 F2-2-1 had 23% and RWR 2245 X ALB 4 F2-4-1 and CAL 96 XRWR 2245 F2-2-1 had 24% which is higher in comparison to check (20% crude protein). All F3 seed lines were planted in F3 nursery to generate F4 seed while the landraces were planted in intermediate yield trial to identify genotypes that can be promoted for use and or used in bean protein improvement.

1.1.2.2 Soybean

Soybean (*Glycine max* .L) is an important food crop in Rwanda. It has an average protein content of 40% and 20% of oil. Soybean can fix atmospheric nitrogen, and thus contributes to soil fertility improvement. The crop was identified as one of the priority crops for the Crop Intensification Program (CIP) for Rwanda. However, the average annual production in the country is far below the increasing demand for local consumption and processing. Main constraints to soybean production include soil fertility, climatic variability characterized by unpredictable rainfall and drought, accessibility to improved seeds and poor germplasm. The soybean sub-program aims to address the above constraints through research and technology transfer activities. Research is focused to evaluate varieties that are high yielding, early maturing, resistant to pest and diseases,

with high protein and oil content, and development of best agronomic practices. Technology transfer activities focus on training farmers and seed producers on best agronomic practices, post harvest handling, development and distribution of extension materials. This report highlights the main activities done from July 2017 to June 2018 and has three components: (1) Variety evaluation, (2) seed and rhizobium production and (3) training of soybean farmers and seed producers.

Variety development

In 2018 A and B seasons, 6 F4; 12 F5 and 306 F6 segregating populations were under screening (Photo 3). From the 306 F6, 29 lines were selected for preliminary yield evaluation in 2019 A seasons. In 2017 B season, 354 individual plants that are homogeneous and stable were selected from F7 and F8 generations and planted in 2018 A season. Major traits based on for selection of a line were: early maturity, no lodging, no shattering, good health (no symptoms of any disease), good vigor (more branches, height and biomass), big number of pods on single plant, number of grains in a pod (at least 2 to 3 grains) and colour of the seed.

Photo 3: Screening of soybean lines for stability and performance at Rubona, 2018 A

Among the above 354 lines, 42 lines performed well and were selected for yield evaluation in 2018 B season. From these 42 lines, 25 best performing were selected for further evaluation in 2019 A season.

Evaluation of introduced lines

Germplasm exchange with partners has also been done with Makerere University. A total of 59 lines were introduced from Makerere and evaluated for adaptability. From these lines, 5 lines were confirmed for adaptability in RAB research Stations and are being evaluated in on-farm

trials in season 2019 A. In 2018, through a partnership with USAID Innovation Lab of Illinois University, 24 varieties have been introduced for adaptability test. In 2018, 2 varieties have also been introduced from Zambia Agricultural Research Institute and are being tested for adaptability in RAB research stations.

Evaluation of the performance of indigenous rhizobia strains

Rhizobium inoculum production takes place at RAB RUbona station. Recently, 50 indigenous rhizobia strains originating from major common bean and soybean growing areas in Rwanda have been isolated and characterized. Studies are going on evaluating their adaptability and interactions with legumes in three contrasting agro-ecological zones of Rwanda through field trials. Ten (10) indigenous rhizobia strains were first tested and compared with the commonly used USDA 110 (exotic strain).

Rhizobium inoculum production

Rhizobia inoculants for both common bean and soybean produced at Rubona are used in research by RAB and also sold to common bean and soybean growers. A total of 3,482 packs of rhizobia inoculants for both common bean and soybean were produced in this fiscal year 2017 - 2018 and used for research and sold to bean and soybean growers. Quality control is regularly checked by performing the Most Probable Number (MPN) test every 6 months to confirm the number of viable cells in the produced inoculants (Photo 4).

Photo 4: Rhizobia infectivity test using the most probable number (MPN) (left); Rhizobia inoculants ready for use at Rubona research center (right)

Seed production

Seed production for breeder, of the three categories of seeds was done in both 2018 A & B seasons at Rubona, Nyagatare and Ngoma RAB Research Stations (Table 11). The table below provides the quantity per category of seeds produced in seasons 2018 A & B. However, due to climatic variability characterized by heavy rains in 2018 B season; we did not get expected yields.

Table 11: Seed production in seasons 2018 A & B

Season	Variety	Breeder's seeds (kg)			Pre-basic seeds (kg)			Basic seeds (Kg)		
		Ngoma	Nyagatare	Rubona	Rubona	Nyagatare	Ngoma	Rubona	Ngoma	Nyagatare
2018 A	Peka 6	25	10	10	240		70	3040	2518	972
	SB 24	25	-	10	240		91	2640	-	252
	S0102	25	10	10	80		125	160	-	-
	S0103	25	10	10	80		120	480	-	-
2018 B	Peka 6	8	10	15	295	112	113	1520	950	1850
	SB 24	12	-	15	47	-	86	-	-	-
	S0102	10	10	10	-	106	127	-	-	394
	S0103	13	10	10	-	115	120	-	-	515

Farmer and seed producer training on developed technologies

A total of 100 soybean farmers and seed producers were trained on soybean best agronomic practices, pest and diseases management options and post harvest handling. The training was done in classes and on field at demonstration plots established in big consolidated sites at Kayonza, Gatsibo, Nyagatare and Ngoma in 2018A & B seasons (Photo 5).

Photo 5: Demonstration how to inoculate Soybean seeds with rhizobia at Rukara (left); Field training of soybean farmers and seed producers on best agronomic practices (right)

1.1.3.1 Irish Potato

In fiscal year 2017-2018, the potato sub-program has carried out various activities aiming at evaluation of new potato through On station, and National Potato Trials carry out various specific studies, establishment of crossing block for hand pollination to generate new potato clones, production of breeder seeds of new potato clones which are in the pipeline of release, Research on Potato Post harvest handling, Seed potato production for varieties under promotion in Rwanda.

On station trials

In collaboration with International Potato Center (CIP), Multilocation trial was established with eight potato clones of CIP398193.511, CIP398190.89, CIP388676.1, Shangi, CIP392797.22, CIP398190.200, CIP394611.112, CIP393079.4 and two local potato varieties of Kinigi and Kirundo as checks. These trials were established at Kinigi, Rwerere, Tamira, Gishwati, Gakuta, Sigira, Ngoma and Nyagatare RAB Research station. The objective of this trial was to evaluate the yield performance of these potato clones across a wide range of Rwanda agro ecological zones (Table 12).

Table 12: Potato tuber yield (t/ha) of 10 clones tested in multi-location trials - 2018

Clones	Sites								Clone mean
	Rwerere	Tamira	Nyagatare	Ngoma	Kinigi	Gishwati	Gakuta	Sigira	
CIP388676.1	33.52	26.94	23.78	23.24	21.93	13.72	12.56	0.00	20.48
CIP392797.22	24.98	10.06	30.70	27.96	12.63	23.43	19.80	3.31	19.80
CIP393079.4	16.97	23.00	19.09	39.38	31.90	13.10	14.98	7.71	19.64
CIP394611.112	28.93	0.60	30.71	24.88	29.57	16.45	11.88	6.40	19.46
CIP398190.200	11.70	24.20	28.96	24.63	28.60	16.80	7.69	11.59	19.19
CIP398190.89	20.86	16.41	23.65	37.00	25.79	0.00	11.71	9.28	18.98
CIP398193.511	23.32	10.79	21.63	34.02	36.64	9.21	3.27	8.14	18.97
Kinigi	15.27	27.05	9.97	22.93	24.45	18.52	10.11	7.47	17.16
Kirundo	19.94	10.42	4.20	34.91	31.76	7.51	19.47	5.61	16.61
Shangi	11.47	20.32	0.00	32.58	20.66	9.45	10.88	12.89	14.02
Site mean	20.82	18.53	19.27	29.28	26.21	13.04	12.10	7.76	18.38

Another on station trial was established with 18 biofortified potato clones (cycle II) at Kinigi, Rwerere and Tamira RAB Research stations. The trial consisted of the following clones: Trials composed by eighteen biofortified potato clones namely: CIP306155.68, CIP306513.57, CIP306087.72, CIP306140.78, CIP306087.132, CIP306143.65, CIP306143.122, CIP306018.4, CIP306143.62, CIP306018.66, CIP306418.53, CIP306154.126, CIP306416.68, CIP306417.79,

CIP306514.64, and CIP306022.69. The objective of this trial was to evaluate yield of the biofortified clones in the high land zones of Rwanda and select the outperforming clones to be recommended to farmer (Tables 13 and 14). The evaluated clones were bred for increased Iron and Zinc content but are known to present low yield due to their diploidy background compared to the normal cultivated potato varieties, which are tetraploids.

Table 13: Average yield of the evaluated biofortified potato clones

No	Variety	Rwerere	Kinigi	Tamira
1	CIP393371.58	13.0^a	NE	3.5^{ef}
2	Mabondo	9.5^a	13.6^a	11.6^{ab}
3	**CIP306018.4**	**7.9^a**	**9.7^a**	**6.2^{de}**
4	Gikungu	6.6$_{ab}$	NE	NE
5	CIP306416.68	4.8^{bc}	6.3^{abc}	NE
6	**CIP306087.72**	**4.6^{bc}**	**7.4^{ab}**	**12.7^a**
7	CIP306513.57	4.1^{bc}	3.4^c	5.2^{de}
8	CIP306140.78	3.6^{bc}	4.0^{bc}	5.9^{de}
9	CIP306018.66	3.6^{bc}	6.7^{abc}	8.2^{cd}
10	**CIP306087.132**	**3.5^{bc}**	**5.7^{bc}**	NE
11	CIP306155.68	3.3^{bc}	3.4^c	6.5^d
12	**CIP306143.62**	**3.1^c**	**3.8^{bc}**	**9.6^{bc}**
13	CIP306514.64	3.0^c	5.3^{bc}	NE
14	CIP306418.53	3.0^c	4.9^{bc}	6.8^d
15	**CIP306143.122**	2.6^c	**6.5^{abc}**	NE
16	**CIP306143.65**	2.2^c	6.9^{abc}	**7.2^{cd}**
17	CIP306154.126	2.1^c	4.5^{bc}	0.7^f
18	CIP306417.79	1.9^c	5.6^{bc}	11.5^{ab}
19	CIP306087.56	NE	5.2^{bc}	1.5^f
	Average	**4.6**	**6.1**	**6.9**

During harvesting of the above trials, yield data including: number of tubers harvested per plot, and weight of tubers per plot were collected. These data were used to calculate the total yield per hectare. Selection of performing clones based on yield and tuber appearance was conducted with farmer participatory variety selection approach.

National Potato Trials (NPTs) of the clones to be released

The first NPTs consisted of the following CIP clones: CIP393077.159, CIP393251.64, CIP396081.241, CIP 398190.615 and CIP393371.58 plus two checks checks (Kinigi and Kirundo). This NPTs were established at Musanze, Burera, Nyabihu, Rubavu, Rutsiro, Karongi, Nyamagabe, Nyaruguru and Rwamagana districts to identify the adaptability of tested potato clones.

Table 14: Iron and Zinc content of evaluated biofortified potato clones

No	Clone	Rwerere Fe	Rwerere Zn	Kinigi Fe	Kinigi Zn	Tamira Fe	Tamira Zn
1	CIP306143.65	26.7ab	41.7a	20.1bc	35.0abc	24.0a	26.4abc
2	CIP306417.79	27.8a	40.1a	20.5bc	32.1abc	23.7a	30.8a
3	CIP306140.78	25.0abc	39.0ab	NE	NE	19.6abc	26.1abc
4	CIP306143.122	27.7a	37.9ab	19.4bc	33.3abc	NE	NE
5	CIP306513.57	23.6abc	35.1abc	NE	NE	16.2bc	23.9bc
6	CIP306143.62	24.9abc	34.5abc	17.7bcd	27.4c	18.9abc	21.8c
7	CIP306154.126	25.3abc	34.1abc	27.8a	43.8a	19.4abc	25.0bc
8	CIP306416.68	23.7abc	33.5abc	NE	NE	NE	NE
9	CIP306155.68	21.2abc	32.4abc	19.6bc	33.8abc	22.0ab	26.3abc
10	CIP306087.72	19.6cd	30.6abc	16.8cd	29.2bc	19.2abc	26.4abc
11	CIP306087.132	23.6abc	28.2bc	19.1bc	28.7bc	NE	
12	CIP306018.66	26.0abc	27.5bc	20.3bc	32.2abc	19.2abc	21.7c
13	CIP393371.58	20.3bcd	24.7d	NE	NE	14.9c	22.9c
14	CIP306514.64	NE	NE	23.1ab	43.7a	NE	NE
15	CIP306018.4	NE	NE	21.0bc	31.3bc	30.0a	30.8a
16	CIP306418.53	NE	NE	20.4bc	30.3bc	21.2ab	21.0c
17	CIP306087.56	NE	NE	18.6bc	40.8ab	21.9ab	29.7ab
18	Mabondo	20.8abc	23.7d	13.0d	24.0c	17.4bc	24.5bc
19	Gikungu	14.0d	23.32d	NE	NE	NE	NE
	Average	**23**	**32.4**	**19.81**	**33.3**	**20.5**	**25.5**

The second NPTs consisted of potato varieties imported from Netherlands by BRAMIN Ltd. These varieties are namely FABULA, PANAMERA, VOYAGER, SAGITTA, CHALLENGER, SIFRA, HZD 02-1499, MEMPHIS, TAURUS and DERBY, and belong to HZPC Holland B.V, a Dutch breeder company in Netherlands. These trials were planted at three sites: Cyanika, Musanze and Jenda for 2017B season.

All these trials were established in a randomized complete block design with three replications of 30 hills per plot. Each plot consisted of three rows with ten plants each at the same spacing of 80cm and 30cm between rows, and plants, respectively. Mineral fertilizers N17P17K17 was applied at planting at a rate of 300kg/ha. Aphids (virus vectors) and other insects were controlled by applying Rocket 44 EC (Profenofos 40% + cypermethrin 4% EC) 30ml in 15 liters of water. Late blight was controlled by Ridomil gold at germination at a dose of 50g/15liters of water once in a week for two consecutive weeks. Late blight was controlled for the rest of the vegetative cycle using Dithane M45, a contact fungicide, wettable powder 80% Mancozeb; 2g/l sprayed before the appearance of symptoms of late blight infection and

by Ridomil gold, a systemic fungicide, wettable powder 64% Mancozeb; 4% Metalaxil; 2.5 g/l when symptoms appear. Weeding and soil ridging up were done manually during the growth of the crop. Trials were managed by farmers doing all crop husbandry activities. Late blight damage was assessed visually using the scale of 1-9, where 1 = no symptom, 5 = medium (20-50% damage) and 9 = very severe (75-100%) damage. The trials were harvested in July and August 2017. At harvesting, yield data including Number of tubers harvested per plot, and weight of tubers per plot were collected. These data were used to calculate the total yield per hectare (Tables 15 and 16).

Table 15: Mean of potato tuber yield (t/ha) of 7 CIP potato clones tested at 15 Rwanda locations in 2018

Sites	Clone							Site mean
	CIP393077.159	CIP393280.64	CIP393371.58	CIP396018.241	CIP398190.615	Kinigi	Kirundo	
Cyuve	51.90	48.98	40.13	24.87	17.67	40.43	46.23	38.60
Rwamagana	29.55	32.18	49.04	21.39	37.85	34.17	40.25	34.92
Kayonza	22.59	21.32	27.51	7.82	12.00	17.23	26.88	19.34
Jenda	21.30	16.75	28.32	9.76	5.42	22.23	25.76	18.51
Busasamana	17.40	4.43	25.61	2.47	3.36	21.11	40.62	16.43
Mukura	15.75	28.66	22.01	17.49	16.14	25.52	19.08	20.67
Nyabimata	13.98	15.64	18.62	15.01	11.19	24.22	26.62	17.90
Uwinkingi	13.30	13.96	18.87	9.68	11.29	22.29	28.65	16.86
Kigeme	12.07	8.62	14.11	10.64	10.14	19.29	18.24	13.30
Nyabirasi	11.37	10.09	18.35	8.01	8.98	20.50	19.03	13.76
Kisaro	10.46	13.28	18.07	5.09	12.17	16.52	17.33	13.27
Karongi	9.83	11.96	16.73	8.90	8.07	14.78	19.00	12.75
Ruhunde	9.81	12.41	13.02	7.78	6.77	13.24	10.25	10.47
Kinigi	8.26	4.16	13.00	4.99	5.20	17.55	15.45	9.80
Kabatwa	6.81	4.71	7.01	9.46	3.71	9.87	12.43	7.71
Clone mean	16.96	16.48	22.03	10.89	11.33	21.26	24.39	17.62

Crossing block for hand pollination to generate new potato clones

To develop new potato varieties with highly desirable market preferences using conventional breeding, a crossing block was established in RAB. Various parents with different traits were selected and used in crossing block. The description of the traits of selected parents is detailed in Table 17. Among the desirable market preferences are high yield, high dry matter content, shallow eyes.

Table 16: Average total yields of Dutch potato varieties tested for two growing seasons at three sites with two local checks, Kinigi and Kirundo

Varieties	Cyanika		Cyuve		Mudende		Average
	Season1	Season2	Season1	Season2	Season1	Season2	
Challenger	12.2	6.8	21.7	6.6	26.3	7.3	13.5[c]
Derby	16.6	8.2	18.3	7.8	27.0	6.2	14.0[c]
Fabula	16.4	5.7	12.1	4.4	21.6	9.3	11.6[c]
Kinigi	43.0	21.2	27.5	21.6	39.7	31.4	30.7[a]
Kirundo	37.1	23.9	39.8	25.1	51.4	27.8	34.2[a]
Memphis	16.7	8.0	15.2	8.6	25.5	10.5	14.1[c]
Panamela	22.2	15.2	22.7	11.9	30.7	18.4	20.2[b]
Rosi	14.2	10.8	22.5	8.1	33.2	9.8	16.4[bc]
Sagitta	19.6	9.5	30.9	6.6	19.7	8.7	15.8[bc]
Sifra	11.6	10.7	12.3	8.1	23.3	16.2	13.7[c]
Taurus	12.8	11.2	21.3	8.0	19.2	14.0	14.4[c]

Table 17: Selected potato varieties to generate new potato genotypes

Variety	Reaction to BW	Reaction to Lb	Traits	Origin
1.Kinigi	Tolerant	Tolerant	High productivity < 20t/ha, red skin, deep eyes, high dry matter, long dormancy (3months).	CIP
2.Gikungu	Tolerant	Tolerant	High productivity, long dormancy (2.5months), red skin, shallow eyes, high dry matter content	CIP
3.Peco	Tolerant	Susceptible	High productivity, white skin, long dormancy (2.5months), shallow eyes, low dry matter	Uganda
4.Sarpomela	Tolerant	Resistant	High productivity, red skin, long dormancy, shallow eyes, high dry matter content	Belgium
5.Rwangume	Tolerant	Resistant	High productivity, red skin, moderate dormancy (3months), shallow eyes, high dry matter content.	Uganda
6.Sangema	Tolerant	Susceptible	High productivity < 20t/ha, pink skin, deep eyes, high dry matter content, long dormancy (3.5months), tolerant to water stress.	Rwanda
7.CIP393371.58	Tolerant	Tolerant	High productivity < 20t/ha, white skin, shallow eyes, low dry matter content, moderate dormancy (3months), tolerant to water stress.	CIP
8.Cruza	Tolerant	Tolerant	High productivity < 20t/ha, white skin, shallow eyes, low dry matter content, moderate dormancy (4months), tolerant to water stress.	Mexico
9.CIP395112.6	Tolerant	Tolerant	High productivity < 20t/ha, white skin, shallow eyes, low dry matter content, moderate dormancy (3months), tolerant to water stress.	CIP

This crossing block was established at RAB Musanze Research Station. A manual cross-pollination program has been implemented for each pair of the selected parents. From the multiple crosses conducted, the following crosses have been successful: Gikungu x CIP395112.6, Kinigi x CIP395112.6, Peco x CIP395112.6, CIP393371.58 x Kinigi, CIP395112.6 x Kinigi, Gikungu x Kinigi, Peco x Kinigi, CIP395112.6 x Peco, Gikungu x Peco, CIP393371.58 x Rwangume, CIP395112.6 x Rwangume, Gikungu x Rwangume and Peco x Rwangume. The true Potato Seeds (TPS) have been extracted, collected and planted in the nursery. Plantlets from nursery will be transplanted in the open field for tubers generation of new genotypes in growing season 2019A.

Breeder seed production for potato clones which are in the pipeline of release

In the preparation of variety release the breeder seeds of new potato clones ready to be released were produced.Plantlets of the following clones: CIP393077.159, CIP393251.64, CIP396081.241, and CIP393371.58 were produced using tissue culture. Minitubers of these clones were also produced using direct transfer approach. There is a need of at least 20MT of Basic seed for each clone during the period of release. The seed increase of the following clones: CIP395112-6, CIP398193.511, CIP398190.89, CIP388676.1, Shangi, CIP392797.22, CIP398190.200, CIP394611.112, CIP393079.4, CIP392617-54, CIP392657.8, CIP393371.157, CIP393371.164, CIP396031.119, CIP398204.704, CIP399062.115, and CIP399073.18, was also carried out. The objective the seed increase of these potato clones was to avail seed which are needed for the establishment of multilocation trials. The above mentioned clones are also in the pipeline for release as new potato varieties. For each clones 320 plantlets were planted using the direct plant of in-vitro plantlets in the field and at harvesting the total number of tubers harvested was recorded. Each clone produced more than 800 tubers.

Another plot for seed increase for biofortified potato clones of cycle III, bred for high Iron and Zinc content was established at RAB Kinigi Research Station. The objective of this seed increase plot was to maintain twenty six (26) biofortified potato clones and to avail seed needed for trials establishment.

Development of new approaches of potato postharvest handling

With support from Post Harvest and Agribusiness Support Project (PASP), we evaluated with farmers the evaporative cooling system for potato storage in Nyabihu and Rubavu districts. The system aimed to help farmers to access a no-cost facility of potato storage. A new tool for potato storage was recommended - local basket for potato storage, which performed better than normal potato storage tools including white sacs, diffused light store and storage on soil inside the house. Two pilot sites of Busasamana in Nyabihu district with small holder farmers were selected to participate in this research. Although this study is still ongoing, some advantages of using local basket have been identified. Among them are quick sprouting and easy handling of big quantity in one basket e.g 100k/basket.

Seed production for varieties under promotion in Rwanda

Potato seeds are categorised into (1) In vitro plantlets, (2) Minitubers, (3) Pre-basic seeds, (4), Basic seeds, and (5) Certified seeds. Currently, tissue culture plantlets are produced by RAB Musanze and INES potato tissue culture laboratories (Table 18).

Table 18: Number of in vitro produced potato plantlets in Musanze and their destination

Seed category	Destination	Number of plantlets	Expected minitubers (January 2019)
Potato Tissue culture laboratory	RAB Musanze greenhouses	58,640	351,840
	RAB Gakuta&Ntendezi greenhouses	66,480	398,880
	RAB Sigira greenhouses	48,000	288,000
	Direct transfer Musanze Station	579,040	3,474,240
	Sold to private with greenhouses*	104,500	0
	Stock for 2019 **	84,820	0
	Total plantlets produced for 2019A	941,480	4,512,960

*RAB control on plantlets sold to private with screenhouse is limited, ** Stock for season B 2019 Preparation is not used for minitubers production.

Table 19: Pre-basic and basic potato seed production in 2018B

Station	Seed category	Season 2018B		Area (ha) for seed Production, Season 2019A
		Area (ha)	Yield (ton)	
Ruhunde&Masogwe	Pre-basic	9.4	0.0	6.0
	Basic	0	88.9	5.0
Kinigi	Pre-basic	12.5	118.3	20.0
	Basic	15.2	144.1	2.0
Rwerere	Pre-basic	0.0	0.0	1.5
	Basic	0.0	0.0	3.5
Tamira	Pre-basic	0.0	0.0	0.0
	Basic	10.0	80.0	11.0
Gishwati	Pre-basic	0.0	0.0	0.0
	Basic	3.5	30.0	0.0
Gakuta	Pre-basic	0.0	0.0	0.0
	Basic	10.0	43.0	10.0
Sigira	Pre-basic	2.0	10.0	2.0
	Basic	8.0	24.3	12.8
Total	Pre-basic	23.8	128.3	29.5
	Basic	56.0	410.3	44.3

Table 20: Minituber seed production in aeroponic and conventional screenhouses, direct transfer and area for pre-basic seed production

No	Varieties	Direct transfer	Aeroponic screenhouse	Conventional screenhouse	Total nber of mintubers	Pre-basic seed production (ha)
Varieties under promotion (40.4 ha)					
1	Victoria	12,344.0	0	195,317	207661	4.15322
2	Twihaze	135,945.0	68,385	38,035	242365	4.8473
3	Sangema	51,366.0	0	10,364	61730	1.2346
4	Ngunda	4,500.0	0	0	4500	0.09
5	Nderera	6,400.0	0	0	6400	0.128
6	Mizero	6,280.0	0	0	6280	0.1256
7	Mabondo	36,700.0	0	0	36700	0.734
8	Kirundo	93,183.0	86,168	23,779	203130	4.0626
9	Kinigi	138,056.0	156,034	23,156	317246	6.34492
10	Kigega	189,006.0	0	153,433	342439	6.84878
11	Gikungu	197,132.0	82,603	298,584	578319	11.56638
12	Cruza	12,108.0	0	0	12108	0.24216
New varieties under evaluation (6.6ha)					
13	-34	15,500.0	0	0	15500	0.31
14	-54	8,500.0	0	0	8500	0.17
15	-64	66,320.0	0	0	66320	1.3264
16	-102	2,847.0	0	0	2847	0.05694
17	-159	82,331.0	0	0	82331	1.64662
18	-241	6,830.0	0	0	6830	0.1366
19	398190-615	140,697.0	0	5,288	145985	2.9197
20	CIP 398190.200	1,347	0	0	0	0
21	CIP 394611.112	1,180	0	0	0	0
22	CIP 392797.22	1,376	0	0	0	0
23	SHANGI	1,396	0	0	0	0
	Total	1,211,344	393,190	747,956	2,347,191	47

Minitubers are produced by RAB, INES, and privates seed multipliers hosting using conventional or aeroponicscreenhouses, and by RAB using direct transfer approach. Basic and pre-basic seeds are produced by RAB and private seed multipliers. The potato certified seeds are only produced by private seed multipliers. In every growing season a number of seed multipliers involved in each seed category declare their field for inspection and certification. The estimation of seeds for pre-basic, basic and certified should be based on data from Seed Unit of inspection and certification. The quantity of potato seeds produced (In vitro plantlets, Minitubers, Pre-basic seeds, and Basic seeds is given in Tables 19-21.

Certified potato seeds were produced by seed potato Fund (SPF) Ikigega, which is a seed company buying and handling potato certified seeds and selling them to farmers of ware potato.

Table 21: Certified and Quality Declared seed harvested in season 2018B*

Districts	Seed produced in 2018B (ha)	Certified seed (tons)	Quality Declared seed (tons)	Total Harvested and stored seed (tons)
Rubavu	137.0	518.2	1,529.6	2,047.8
Nyabihu	442.4	640.5	6,080.8	6,721.3
Rutsiro	5.9	10.5	81.9	92.4
Karongi	12.5	16.4	167.0	183.4
Musanze	199.0	359.0	2,630.3	2,989.3
Burera	62.9	178.9	768.2	947.0
Rulindo	16.5	64.1	213.9	278.0
Gicumbi	31.8	84.3	382.7	467.0
Nyamagabe	82.3	134.0	181.5	315.5
Nyaruguru	123.7	538.4	1,453.6	1,992.0
Total	1,113.9	2,544.2	13,489.5	16,033.7

*Data from SPF Ikigega

Comparison of different multiplication methods for plant survival and multiplication rate

We compared survival of plantlets under different multiplication methods (Table 22). Aeroponic method produced the highest number of minitubers but the survival rate was lower than for direct transfer and conventional screenhouse.

Table 22: Minituber output and plant survival rates for different multiplication methods

Approach	% of plantlets at transfer time	% of plantlets at harvesting time	Number of tubers per plant
Conventional screenhouse	100[a]	76.9[b]	11.3[b]
Direct transfer	96.1[a]	96.1[a]	22.5[a]
Aeroponic screenhouse	89.2[ab]	89.2[ab]	25.7[a]

1.1.3.2 Sweet Potato

During 2017-2018, the program has focused on breeding; conducting advanced and multi-location trials; maintenance of 152 accessions in germplasm collection; improving the availability of clean planting material of new varieties; seed production. New populations were generated using Rubona crossing block. Many controlled and opened pollination crosses

were initiated from 12 families, from which 314 clones were generated. A total of 45 clones were selected from them and evaluated in preliminary yield trial. The other 15 OFSP genotypes from Mozambique were planted in Multilocation Yield Trials (MYT). Four out of 15 Mozambique varieties named Jane, Cecelia, Melinda and Ester had high yields of 30.34, 26.28, 24.44 and 23.57 ton/ha, respectively. In total, 152 accessions have been maintained. A set of 15 new OFSP varieties were introduced from Mozambique for evaluation and test tasting. The selected high yielding yellow and Orange Flesh Sweet potato varieties (OFSP) were also multiplied and maintained at TC Lab using different media. Advanced yield trials were conducted and two selected clones RW11-5091 and RW11-3736 are currently in pipeline for possible release after a series of uniformity and distinctness tests. Varieties UW-11906, Tacna, Maphuta, RW11-3736, RW11-17, RW11-5091, Ukerewe and Kakamega 7 were also maintained in TC via cryo-preservation. During season 2018A, 18 selected clones from the set of 314 clones were evaluated in Advanced Yield Trial (AYT) at Rubona research station (Table 23).

Table 23: Performance of 18 clones in AYT during season 2018A

	Accessions	Skin color	Flesh color*	Yield (t / ha)
1	Rw-2016-143	W	Y	13,43^{abcd}
2	Rw-2016-124	W	O	16,83^{abcde}
3	Rw-2016-118	W	W	19,36^{bcde}
4	Rw-2016-123	W	W	10,73^{ab}
5	Rw-2016-132	R	O	30,25^{f}
6	Rw-2016-144	R	O	22,4^{ef}
7	Rw-2016-117	W	W	8,34^{a}
8	Rw-2016-88	W	O	11,24^{ab}
9	Rw-2016-93	R	C	14,75^{abcde}
10	Rw-2016-102	R	Y	17,06^{abcde}
11	Rw-2016-109	R	W	12,48^{abc}
12	Rw-2016-87	R	C	15,9^{abcde}
13	Rw-2016-98	R	Y	11,78^{abc}
14	Rw-2016-84	R	O	21,54^{def}
15	Rw-2016-82	R	O	8,91^{a}
16	Melinda	W	W	18,18^{bcde}
17	X1	W	O	20,37^{cde}
18	X2	R	O	17,09^{abcde}
	Grand Mean			16.15

 * O: Orange Flesh; Y: Yellow Flesh Sweetpotato, W: White Flesh; C: Cream Flesh Sweet potato

The mean separation for yield showed that RW-2016-132, RW-2016-144 and RW-2016-84 were the high yielding clones with the yield of 30.25, 22.4 and 21.54 t/ha, respectively. All 3

high yielding genotypes are orange fleshed sweet potato. The White Fleshed Sweet Potato RW-2016-118 and Melinda were high yielding with 19.36 and 18.18 t/ha, respectively.

Seed multiplication and capacity building

Pre-basic see multiplication was done in RAB stations with 17 varieties, of which OFSP were Cacearpedo, Vita, Kabode, Terimbere (RW11-2560), Ndamirabana (RW11-2910) and Gihingumukungu. In total, 22,192 pre-basic seeds were hardened from Rubona tissue culture laboratory.

Sweet potato training was organized in collaboration with KEPHIS for RAB staff and aimed at increasing staff skills in virus indexing and grafting on setosa plants to test the level of contamination. The training was attended by 7 participants. In addition, 105 Decentralized Vine Multipliers (DVMs) were trained in agronomic practices and quality seed production. Another taining on sweet potato quality seed production and Quality Declared Seed (QDS) was organized for 6 seed inspectors and 9 lab technicians. DVMs across districts have been mapped and registered by RAB Seed Division. Together with Rwanda Standard Board (RSB), sweet potato standards were developed and regulations document was approved for use by DVMs. In partnership with Scaling Up Sweet potato Through Agriculture and Nutrition (SUSTAIN) and Feed the Future (FTF) projects, DVMs and agri-promoters were trained in Rapid Multiplication Techniques, agronomic practices, Integrated Pests Management and quality declared seed. 6 DVMs out of 95 registered were able to get their certificates as DVMs for year 2018.

Multiplication and promotion of Pre-basic basic seed of orange fleshed sweet potato

In total, 417,000 cuttings were produced for decentralized vines multiplied and 13 million of cuttings (in partnership with DVMs) were multiplied and availed to farmers in different districts. With army week support, 576.2 ha have planted with improved orange fresh sweet potato fortified with provitamine A. Sweet potato promotion and marketing have been initiated through sensitization on availability of new OFSP varieties different partners such as Union de Development integré, DERN-Catholic, YWCA, OSPEGA, TUBURA and Imbaraga syndicate. Contacts through phone calls, Umuganda and mini agri-show in Bugesera, Musanze and Bugesera were done to increase vines demand and increase marketing of vines. Fliers, brochures and leaflets, agri-shows, radio and TV talks were made in collaboration through Feed the Future and Sweetpotato Action for Security and Health in Africa (SASHA) Projects. RAB staff participated to 7th International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGFRA) conference. In a joint meeting with Feed The Future project, DVMs discussed how to share seed demand information to improve networking. Rwanda hosted the 9th Sweet potato for Profit and Health and Initiative (SPHI) Seed Systems and Crop Management Community of Practice consultation meeting in May 2018 with the theme

"Engaging youth for improved sweet potato seed and root production" where 55 participants from various countries participated.

1.1.3.3 Cassava

Introduction of climate resilient germplasm

Cassava (*Manihot esculenta* Crantz) is the second most important food crop in Rwanda and it plays a major role in food security and income generation. Cassava leaves are a protein rich vegetable while the carbohydrate rich tuberous roots are consumed in various dishes. It is the first most important root and tuber crop followed by sweet potato. In Rwanda, in terms of land area under crops, the main crops grown in season B 2014 were: Banana (23.6%), Cassava (23.3%), Beans (16.6%), Sorghum (8.5%) and Maize (5.2%) (NISR, 2015). Some attributes of cassava contributing to its fast adoption include its adaptability to marginal environments, relatively high yield of food energy (calories) per unit of labour input, fit to traditional farming systems and year round availability, thus providing insurance against crop failure. However, cassava production is currently constrained by cassava mosaic disease (CMD) and cassava brown streak disease (CBSD) which have devastated major growing areas in East, South and West Provinces. Among biotic factors, the cassava brown streak disease is the most important. It is caused by at least two ipomoviruses including: CBSV and UCBSV. The viruses are transmitted by whiteflies (*Bemisia tabci*) and perpetuated by use of infected cuttings. Recently, cassava brown streak disease (CBSD) has been reported in major cassava growing zones and its spread has increased year after year causing big losses to cassava production, mainly in Southern Province. The management of these virus diseases requires the development or breeding for resistant/ tolerant cassava varieties with high yield and preferred by farmers. The present report describes the main activities done during this fiscal year 2017 – 2018 which are: 1) Cassava disease and pest surveillance and management; 2) Increasing cassava genotypes diversity for breeding activities; 3) Development and dissemination of high yielding and disease tolerant cassava varieties and 4) Production of quality declared seed (QDS).

Cassava disease and pest surveillance

In partnership with MARI project, a country-wide survey was conducted in ten cassava growing districts of Rwanda: Kayonza, Kirehe, Nyagatare and Bugesera (East); Kamonyi, Ruhango, Nyanza and Gisagara (South), Rusizi and Nyamasheke (West). The survey aimed to track changes in the incidence and severity of CBSD and CMD across the country; and to identify the particular strains causing CBSD and CMD. In this survey, cassava fields were selected along major roads at interval of about 8-10 km.

Incidence and Severity of CBSD : The foliar incidence of CBSD was observed at different levels in six districts out of ten. The CBSD leaf symptoms were absent in four districts namely, Nyamasheke, Rusizi, Kayonza and Nyagatare. Similarly, the CBSD stem symptoms were absent in the same districts. The CBSD root necrotic symptoms were observed in all districts except Rusizi, Nyamasheke and Ruhango (Figure 2). The absence of root necrotic symptoms in Ruhango district could be linked to the distribution of improved variety (NASE14) with tolerance to CBSD, while in Nyamasheke and Rusizi districts, the CSBD pressure level is considerably low.

The CBSD severity was assessed on all parts of cassava plants (leaves, stems and roots). The severity was observed in all districts except Rusizi, Nyamasheke, Kayonza and Nyagatare. The severity on leaves was severe (> score 3) in Kirehe, Kamonyi and Ruhango districts, while the severity on stem were severe (> score 3) in all districts where it was present. For the CBSD root necrosis severity was highly severe (score 4.5) in Gisagara district and severe (score 3) in Bugesera district (Figure 3).
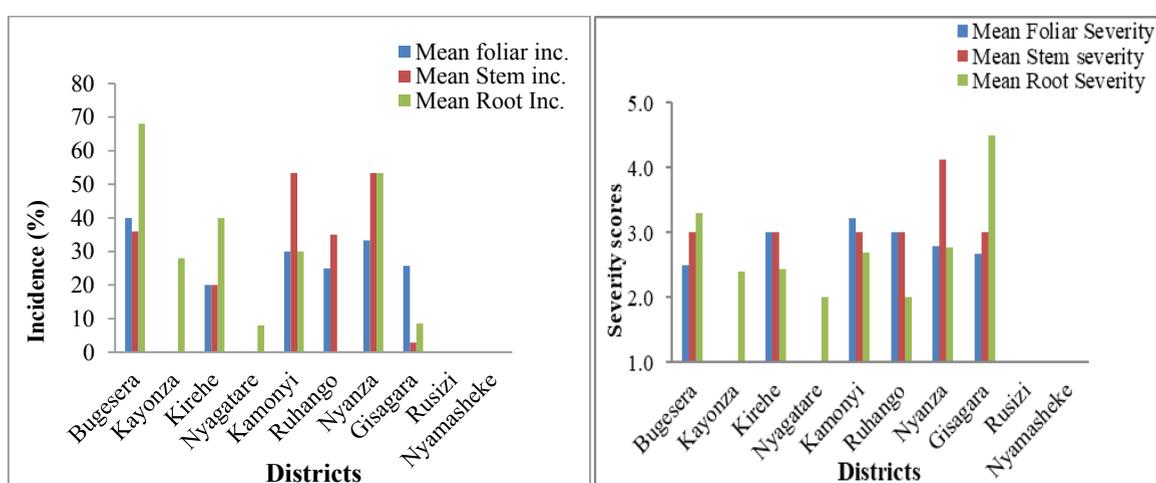
Figure 2: CBSD incidence (%) and severity

Incidence and Severity of CMD: The CMD incidence was high (>40%) in Kayonza and Kirehe districts of Eastern province, and moderate (20-40%) in Nyagatare, Rusizi and Nyamasheke districts. It was low (<20%) in the remaining five districts. The CMD severity was severe (>3) in all districts (Figure 3).

Characterization of emerging viruses: During the National survey, the decrease in percentage of both CBSV and UCBSV was observed as compared to previous surveys. For CMBs detection, results showed the decrease in percentage of both ACMV and EACMV, no co-infection was detected. This survey, ACMV was present in Gisagara district only while EACMV was present in Bugesera, Kayonza, Kirehe, Nyagatare and Nyanza districts.
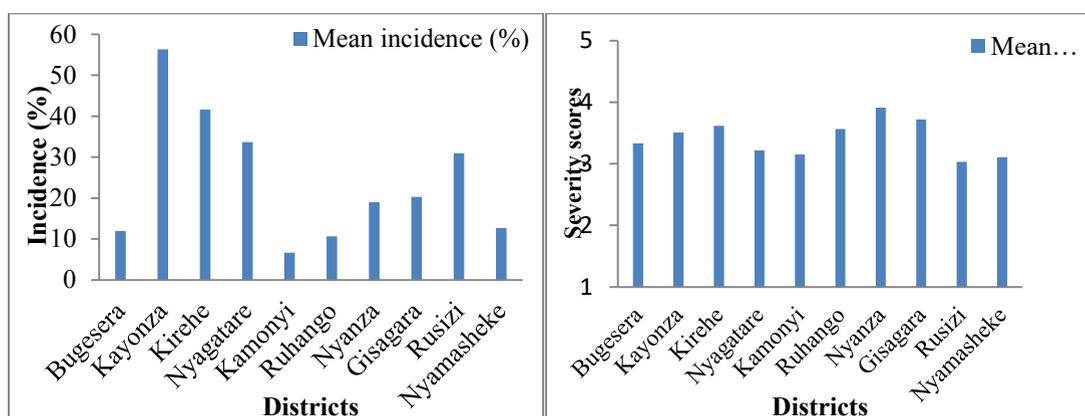
Figure 3: CMD incidence and severity

Increasing cassava genotypes diversity for breeding activities

Successful breeding requires the use of wide germplasm base with different traits. Introduction of new cassava clones, collecting and conserving local and improved cassava varieties are essential steps to expand germplasm base for future breeding. Using the IFAD-supported project entitled "Fight Cassava Brown Streak Disease and Cassava Mosaic Disease through the Deployment of New Resistant Germplasm and Clean Seed in Burundi and Rwanda", RAB has introduced and is testing new clones that will be evaluated and used for future breeding along with collection of local germplasm and seed multiplication.

Table 24: Introduced clones and their status

No	Clones	Received from GTIL	Infected/ Damaged	Planted plantlets	Hardened plantlets	Subculture	Infected plantlets	TC multiplication and conservation
1	Albert	200	95	62	39	172	6	362
2	KBH 2006/26	200	91	77	22	127	0	141
3	KBH/2002/066	200	51	82	47	269	30	393
4	Kiroba	200	24	140	94	144	7	240
5	EYOPE	200	0	168	61	129	18	188
6	Kibandameno	200	90	80	13	121	17	125
7	Kizimbani	200	80	84	52	143	25	84
8	TZ-130	200	117	48	38	140	12	149
9	Mkumba	200	137	42	35	84	0	118
10	NASE 1	200	101	72	49	107	0	102
11	NASE 14	200	91	56	7	212	6	796
12	NASE 3	200	137	6	0	229	0	351
13	Okhumelela	200	120	44	7	145	4	272
14	Orera	200	126	74	23	-	-	-
15	Pwani	200	112	64	13	97	0	277
16	Tajirika	200	121	54	39	100	6	156
17	F10-30-12	200	200	-	-	-	-	-
Total		3200	1692	1153	539	2219	131	3754

Among 1,153 plantlets planted only 539 were successfully hardened while 2,088 plantlets survived the subculture for multiplication and conservation of clean clones (Table 24, Photo 6). Till now, 3,754 plantlets were multiplied and conserved in Tissue Culture Laboratory at Rubona Research Center.

Photo 6: Hardened plantlets in screen house and TC conservation and subculture (multiplication) at Rubona

As we mentioned before, during transportation, the two clones (ORERA and F10_30_R2) were totally damaged. That's why we ordered other 20 plantlets for each for their replacement. The ordered plantlets were received and multiplied in tissue culture laboratory at Rubona. Currently, the total plantlets are 270 (170 of ORERA and 100 of F10_30_R2).

Introduction and selection of new breeding lines selected from true seed

The total of 8,765 true seeds was introduced, but 5,122 were viably planted and only 533 germinated (Table 25). The low rate of germination was attributed to the storage conditions of the seeds. The seeds were delivered in March and planted in July. The climate conditions of Rubona research center also could be the reason behind the poor germination.

In addition, 25 families of true seeds were received from IITA Tanzania and were planted in two sites (Mututu in South and Gashora in East) in season B (March 2018). In general, the total of 15,746 true seeds was received where 11,156 seeds were planted at Mututu sites while 1785 seeds were planted at Gashora site (Table 26). Currently, plantlets from nursery were transplanted to field in these two sites for further evaluations.

Table 25: Number of seeds for new breeding lines from true seeds

No	Families	Received seeds	Planted seeds	Empty seeds	Germinated seeds
1	Kibaha HS	246	149	97	17
2	Nziva HS	127	28	99	1
3	Kigoma Red Hs	134	38	96	1
4	Nase 14 HS	51	29	22	6
5	IITA-TMS-IBH 980505X Kaleso	50	31	19	3
6	F10-30-12 Hs	89	42	47	23
7	Colicanana HS	154	65	89	15
8	IITA-TMS-IBA 30572 HS	231	116	115	43
9	Pwani HS	97	52	45	5
10	Kaleso HS	211	128	83	16
11	KBH 02/066 HS (Kipusa)	2000	1386	614	65
12	Kiroba	328	216	112	7
13	Kizimbani HS	392	174	218	2
14	Orera HS	670	283	387	9
15	KBH 02/026 HS (Mkuranga 1	731	415	316	94
16	TZ 130 HS	341	307	34	49
17	Mkumba HS	540	310	230	36
18	Eyope HS	597	413	184	23
19	NASE 3 HS 2015	1776	940	836	118
	Total	8765	5122	3643	533

Photo 7 : Transplanted plantlets at Mututu site

Table 26: Introduced true seeds from Tanzania

Family	Introduced quatity	Planted at Mututu site	Transplanted at Mututu	Planted at Gashora site	Transplanted at Gashora
1. F-10-30-R2 HS	302	246	88	0	0
2. TZ 130 HS	680	600	199	80	26
3. Kizimbani HS	440	400	114	0	0
4. Kipusa HS	1113	1050	360	63	52
5. Mkuranga 1 HS	730	625	187	30	13
6. Albert HS	700	400	182	0	0
7. Mkombozi HS	721	500	160	75	25
8. Orera HS	1030	600	99	117	39
9. Tajirika HS	795	500	164	235	52
10. Shibe HS	1850	1125	378	450	156
11. Kiroba HS	350	300	76	0	0
12. Kibandameno HS	435	300	120	30	13
13. Sauti HS	415	300	76	30	0
14. Nase 3 HS	2250	1025	399	600	198
15. Colicanana HS	700	550	152	0	0
16. CH-05/203 HS	100	100	43	0	0
17. Eyope HS	300	200	57	0	0
18. MM06/0138 HS	200	150	59	0	0
19. N'ziva HS	700	600	114	0	0
20. Yizaso HS	400	400	76	0	0
21. Okhumelela HS	600	450	142	75	38
22. Sagonja HS	700	550	114	0	0
23. Kalawe HS	40	40	13	0	0
24. Nase 18 HS	150	100	38	0	0
25. LML2008/363 HS	45	45	13	0	0
TOTAL	15746	11156	3423	1785	612

Furthermore, 33 families of true seeds were received from IITA IBADAN/ Nigeria and were planted in two sites (Mututu in South and Gashora in East) in season B (March 2018) (Photo 7).

In general, the total of 16330 true seeds was received where 10100 seeds were planted at Mututu sites while 4350 seeds were planted at Gashora site (Table 27). One month after planting, seedlings were transplanted to field for further evaluations.

Table 27: Introduced true seeds from Nigeria (IITA, Ibadan)

No	Families	Number seeds	Planted at Mututu	Transplanted at Mututu	Planted at Gashora	Transplanted at Gashora
1	IBA000338	30	25	22	0	0
2	IBA011797	700	500	108	200	39
3	IBA061635	1000	500	57	500	288
4	IBA070337	1000	500	162	0	0
5	IBA070539	1000	500	81	500	162
6	IBA070593	2000	500	126	1500	360
7	IBA120008	1000	500	135	475	52
8	IBA141086	200	200	190	0	0
9	IBA141089	200	200	19	0	0
10	IBA141092	1000	500		175	39
11	IBA141096	200	200	72	0	0
12	IBA141097	200	200	72	0	0
13	IBA141099A	200	200	90	0	0
14	IBA141101	200	200	44	0	0
15	IBA141104	200	200	44	0	0
16	IBA160019	100	100	38	0	0
17	IBA160049	100	100	77	0	0
18	IBA160072	200	200	33	0	0
19	IBA160073	200	200	84	0	0
20	IBA160077	200	200	66	0	0
21	IBA160085	200	200	53	0	0
22	IBA160109	100	100	65	0	0
23	IBA160203	200	200	38	0	0
24	IBA961089A	500	75	22		
25	IBA961632	200	100	38		
26	IBA980505	1000	500	144	500	156
27	KALESO	600	600	144	0	
28	KIBAHA	600	600	209	0	0
29	KIGOMARED	400	200	57	0	0
30	KIROBA	600	600	95	0	0
31	TMEB419	400	200	52	0	0
32	TMEB693	1000	500	54	500	91
33	UBJ120003	600	500	144	0	0
Total		16330	10100	2635	4350	1187

Seedling transplantation, multiplication and clonal evaluation

Nineteen families of the first batch from IITA Tanzania, which were germinated in screen house were transplanted to the field in February 2018 for multiplication and further evaluations. Currently, 444 clones in total are under clonal evaluation at Rubona (Table 28).

Table 28: Seedling transplanted for clonal field multiplication and evaluation

No	Families	Germinated seeds in screen house	No. of clones transplanted
1	Kibaha HS	17	15
2	Nziva HS	1	1
3	Kigoma Red Hs	1	0
4	Nase 14 HS	6	17
5	IITA-TMS-IBH 980505X Kaleso	3	3
6	F10-30-12 Hs	23	45
7	Colicanana HS	15	12
8	IITA-TMS-IBA 30572 HS	43	35
9	Pwani HS	5	5
10	Kaleso HS	16	16
11	KBH 02/066 HS (Kipusa)	65	60
12	Kiroba	7	6
13	Kizimbani HS	2	2
14	Orera HS	9	8
15	KBH 02/026 HS (Mkuranga 1)	94	46
16	TZ 130 HS	49	38
17	Mkumba HS	36	38
18	Eyope HS	23	23
19	NASE 3 HS 2015	118	74
Total		533	444

Table 29: Transplanted clones for multiplication and evaluation at Rubona season 2018B

No	Clones	Hardened plantlets	Macro plantlet	Transplanted for field multiplication
1	Albert	39	134	76
2	KBH 2006/26	22	92	63
3	KBH/2002/066	47	121	105
4	Kiroba	94	256	31
5	EYOPE	61	136	109
6	Kizimbani	52	121	87
7	TZ-130	38	104	69
8	Mkumba	35	173	115
9	NASE 1	49	130	88
10	NASE 14	7	21	16
11	Tajirika	39	113	83
Total		483	1401	842

In addition, after hardening in screen house, 842 plantlets of 11 clones from tissue culture were transplanted in field for multiplication and evaluation at Rubona (Table 29, Photo 8).

Photo 8: Transplanted plantlets from screen house at Rubona Station

Collection, cleaning and conservation local and released improved cultivars

Following the collection procedure; germplasm collection was conducted in 15 districts of 4 provinces of the country. Up to 55 accessions were collected (Table 30, Photo 9).

Currently all the collected germplasm are established in field gene banks at Rubona and Gashora sites for morphological characterization and disease evaluation. Cassava leaf samples have been collected and submitted for DNA fingerprinting in collaboration with IITA. After that, Morphological data at 3&6MAP were recorded in the mentioned sites.

Table 30: Number of varieties collected and conserved at Rubona and Gashora

Province	District	No of collected germplasm
East	Bugesera	5
	Kayonza	1
	Kirehe	2
	Ngoma	2
North	Burera	1
	Gakenke	3
South	Kamonyi	2
	Muhanga	7
	Nyanza	4
	Ruhango	3
West	Karongi	1
	Ngororero	7
	Nyamasheke	7
	Rusizi	9
	Rutsiro	1
Total		55

Photo 9: Germplasm conservation at Rubona station

Development and dissemination of high yielding and disease tolerant cassava varieties

Cassava production in Rwanda is severely threatened by the current epidemic of cassava brown streak disease (CBSD) and cassava mosaic disease (CMD). Both diseases are propagated via infected planting material as well as being transmitted by the whitefly vector. Using clean and/or tolerant planting material with high yielding is one effective way to reduce CBSD and CMD yield losses in farmers' field. In this regards, the following stages of trials have been established.

Crossing block

For generating high yielding and tolerant varieties to diseases, it's necessary to create a genetic diversity through hybridization and conduction of multi-stage offspring selections. Thus, a crossing bloc was established at former Karama station with 13 Parental lines selected based mainly on their performance (Table 31).

Table 31: Parent lines planted in crossing bloc at former Karama station

No	Clones	No	Clones
1	MM 96/2134	8	NAROCAS 1
2	MM 96/0669	9	Ndamirabana/7
3	Gahene/2	10	Mushedire
4	MM 96/8299/1	11	Ndamirabana
5	05/0127/35	12	01/1206/75
6	MH 95/0414/1	13	Creolinha
7	TME 419/60		

Clonal evaluation trials

A total of 104 clones were planted in 2018 A and are under evaluation at Gashora site. Phenotypical data for 3&6 MAP have been collected and recorded. Field evaluations will be continuing up to harvesting.

Multi-locational (GxE) trials of elites clones

The aim of multi-locational trials is to test the wide adaptability of selected elite clones. In this regards, 6 cassava clones (MM 98/3567; MH95/0414/1; NASE 14; Ndamirabana/7; RWACASS-016-01; Gahene/2) from advanced trials are under evaluations at 6 research stations (Bugarama, Rubona, Mututu, Muhanga, Gashora and Nyagatare) in 2018 A. Currently, major cassava diseases ad pest incidence and severity at 3 and 6 MAP were recorded. Further evaluations will be done at 9 and 12 MAP.

Participatory variety selection (On-farm trials)

Before releasing variety, it's necessary to evaluate it in farmer's field conditions to involve farmers in selecting preferred clones based on their performance. Thus, 5 pre-release cassava clones (01/1206/75; MM 98/3567; Ndamirabana/7; RWACASS-016-01; Gahene/2) are planted in farmer's fields in 8 cassava growing districts (Nyamasheke, Nyanza, Ruhango, Kamonyi, Bugesera, Nyagatare, Gicumbi and Gakenke).

Production of quality certified and quality declared seed of cassava (cuttings)

The purpose of this activity is to ensure the availability of enough planting material of 5 varieties on 1.5 ha which are under evaluation at farmer's field level. The selected best varieties (2-3) will be released in season A 2019. In order to increase cassava planting materials, RWACASS-016-01 is in multiplication on 15 ha at Rubona and former Karama research stations while RWACASS-015-01 and RWACASS-016-01 are on 80 ha (800,000 cuttings) in mother gardens in different cassava multipliers in southern, 64 ha (640,000 cuttings) in Eastern and 19 ha (190,000 cuttings) in Western, 38 ha (380,000 cuttings) in Northern, provinces. The imported certified cassava cuttings from Uganda, were further multiplied to produce the QDS (declared quality seed) under fields of cassava farmers and multipliers. The total quantity of 89,690,000 cuttings were produced and distributed to farmers across the country.

1.1.3.4 Banana

Banana is one of the major staples and important cash crops in Rwanda, occupying 23% cultivated land. Banana yields and production are declining due to banana wilt and its current control, insufficient quantity of and access to quality plant material, low management

standards and increased nutrient removal from farms to cities. Dessert banana yields and cultivated are extent are limited by fusarium wilt affecting market preferred varieties (Gros Michel and Kamaramasenge). Thus, banana research and development activities focused on germplasm conservation, introduction of new varieties, seed production, banana rehabilitation and disease control.

Germplasm conservation

To keep local germplasm diversity for future breeding, banana research maintains two field germplasm collections with 111 and 117 varieties in Rubona and Ngoma, respectively. These collections are included in International Musa Global Information System and are being characterized and data shared with global database of banana varieties.

Introduction of new varieties

Twenty-nine new cooking banana varieties were introduced from the National Agricultural Research Organization, Uganda and IITA who had developed them from breeding using East African banana parents. Varieties included three PITA-s and 26 NARITA-s series that have good cooking quality attributes. A field experiment was established in Rubona to evaluate their yield potential. Currently, plants are completing first harvesting stage.

Seed production

RAB was involved in limited seed production of suckers. A total of 5,000 suckers was produced in Rubona and disseminated to farmers in the Southern Province. About 80 seed multipliers were involved in certified seed production, mostly in Eastern Province. They have capacity to provide about 140,000 suckers from their banana fields. Disseminated varieties included Injagi (cooking), Mpologoma (cooking), FHIA 17 (cooking and dessert) and FHIA 25 (juice).

Banana rehabilitation

District and sector agronomists were involved in site selection, farmer mobilization and follow up of the banana rehabilitation progress, while RAB staff performed technical support visits to the rehabilitation sites on quarterly basis. More than 5,000 ha were rehabilitated through district and sector support and organization of banana rehabilitation campaigns, mainly through Army week activities.

Banana disease control

Banana wilt, the most serious and epidemic banana disease, was controlled through organization of banana wilt control campaigns with support from districts and sectors. Banana research team has provided technical support to local authorities during campaigns, and during the Army Week in March-May 2018. A total of 21, 000 farmers were involved in banana wilt control campaigns.

Horticulture research aims to develop and disseminate appropriate technologies to improve the quantity and quality of the horticulture production. Efforts are more focused on selected fruits (avocado, citrus, tamarillo, passion fruit, mango, pineapple, water melon and apple), exotic vegetables (tomato, sweet and hot pepper), and indigenous vegetable such as amaranths (imbwija/dodo), spiderplant (isogi), nightshade (isogo) and African eggplant (intoryi). These crops were selected based on the commercial interest and the country's priorities as they have higher income generation potential to farmers. The horticulture research focused on some pests and disease studies.

Effect of fungicides on *Pseudocercospora* leaf and fruit spot in citrus orchards at Rwinkwavu

After avocado, banana amd mango, Citrus is one of the most economically important fruit crop grown by smallholders and commercial farmers. Its production of citrus is hampered by poor cultural practices, lack of clean planting material, insects, fungal diseases and drought. *Pseudocercospora* leaf and fruit spot disease was recently ranked as first constraint in all districts surveyed. The yield losses can reach 50-100% when climatic conditions are favourable to the disease development, and timely effective control measures are not taken (Photo 10). A fungicide trial was set in eight-year-old farmer's field aiming to assess the efficacy of different sprays for disease management. The experiment was done in farmer's field based in Rwinkwavu sector, Kayonza district, in November 2016 up to June 2018 with application of two systemic (Ridomil and Benlate) and two contact (Daconil and Copper hydroxide) fungicides.

A total of 9 treatments including control were considered during this trial (T1: Benlate; T2: Daconil; T3: Ridomil; T4: Copper Hydroxyde; T5: Benlate alternated with Daconil; T6: Benlate alternated with Copper Hydroxyde, T7: Ridomil alternated with Daconil; T8: Ridomil alternated with Copper Hydroxyde and a control with no fungicide (T9) at the following concentrations: Benlate, Copper Hydroxyde and Ridomil (37g/15l) and Daconil (65mg/15l). Spray interval used was 14 days. In addition, routine practices have been applied (weeding, collection of fallen and diseased fruits and burying them, pruning of old branches, planting of cover crop *Mimosa spp.* and application of inorganic fertilizer NPK (17-17-17)). The disease incidence was recorded by counting the number of diseased leaves per branches over total number of branches expressed in percentage. After two years, all fungicides significantly

(p<.0001) reduced disease incidence with Daconil and Copper Hydroxide having reduced the incidence to 19.88% and 25.05%, respectively, and the control with 56.11% (Figure 4 and 5).
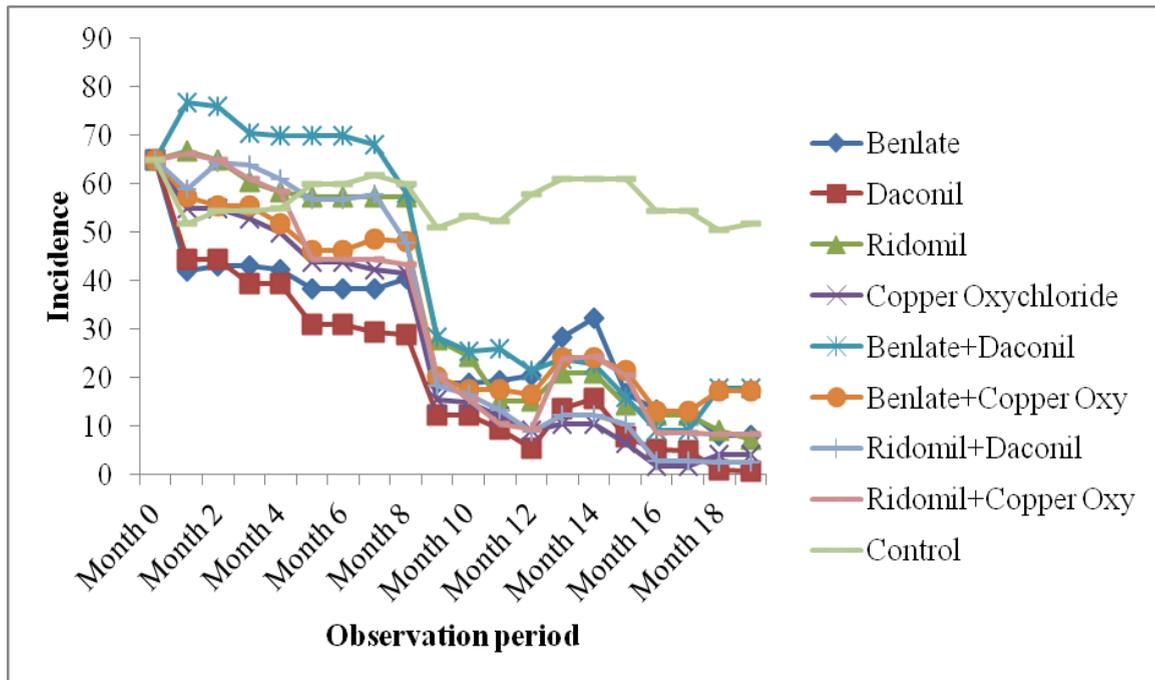
Figure 4: Reduction of incidence with continuous spraying
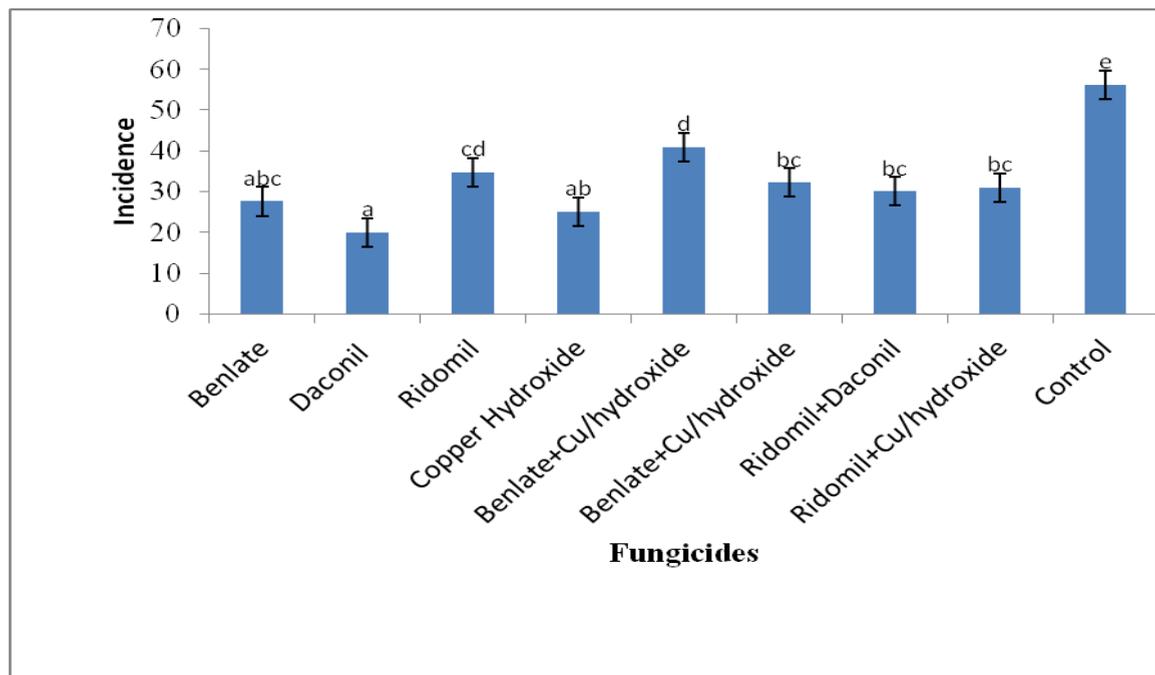
Figure 5: Disease incidence in different fungicides

Field application of Daconil and Copper Hydroxyde significantly reduced the incidence and increased marketable fruit yield. Combined fungicide application was recommended to prevent development of resistance to a single fungicide. For efficient control, cultural practices like pruning, collection and burying of diseased plant parts, cover crop, fertilizer application and weeding should be applied.

Photo 10: Fruits affected by *Pseudocercospora (left) and healthy plant after fungicide spraying (right)*

Determination of fertilizer rates for Tamarillo (RAB-Rubona)

Tamarillo or Tree tomato (*Cyphomandra betacea*) is among the most valuable horticultural crops in Rwanda. The growth of Tamarillo is constrained by certain cultural practices. This plant has difficulties to grow in heavy and infertile soil, in water-logged soil and cannot tolerate prolonged drought. Lack of information on adequate fertilizers is one of limiting factors for intensive production of Tamarillo.

The experiment was established in green house in Rubona in November 2016. The experimental design was Randomized Complete Block Design with three replications. In this experiment, the following fertilizers will be used: 1. Full theoretical rate (170kg N/ha, 45kg P/ha, 190kg K/ha); 2: 1/3 rate (226.6kg N/ha, 60kg P/ha, 253.3kg K/ha); 3. Full+ 1/2 rate (255kg N/ha, 67.5kg P/ha, 285kg K/ha); 4. ¾ rate (127.5kg N/ha, 33.7kg P/ha, 142.5kg K/ha); 5: Half rate (85kg N/ha, 22.5kg P/ha, 95kg K/ha); 6: NPK 17^3 200kg/ha; 7: Control (no fertilizer). Each treatment was allocated in its own plot of 6 plants with 2x3m plant spacing. Fertilizer application was done into two splits, first application was done two weeks after transplanting; the second application was done before flowering. Data were collected on plant height, leaf length, leaf width, number of days after transplanting to 50% flowering plants, number of days after transplanting to 50% fruiting plants, number of days after transplanting to 50 % maturity of the plants in a plot have green mature fruits ready to harvest for consumption, number of fruit per plant, fruit diameter, fruit length, yield per plant and

total yield per hectare. The data were analysed as RCBD by ANOVA using Genstat 14 edition. Mean separation was performed with turkey's test at P<0.005 level of significance

There was significant different between different fertilizers vis-a-vis plant height (Figure 6). The plants from NPK 173 (200kg/ha) are the highest. NPK 17-17-17 (200kg/ha) fertilizer gives the biggest stem diameter of 11.89cm. NPK 17-17-17 (200kg/ha), 226.6kg N/ha, 60kg P/ha, 253.3kg K/ha and 170kg N/ha, 45kg P/ha, 190kg K/ha give the highest yields: 14.62; 14.56 and 14.26 tons per hectare, respectively.
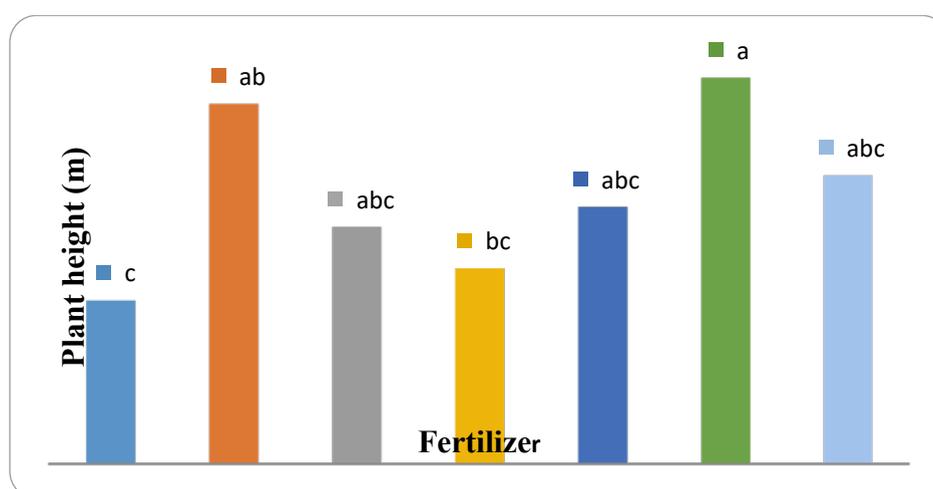
Figure 6: Plant height under different fertilizers

Thus, NPKP 17-17-17 (200kg/ha) gives good results comparing to other fertilizers.

Adaptability trial of new mango varieties at Karama

Mango varieties planted and evaluated at Karama Center in Bugesera with five improved grafted ones (Apple, Kent, Tommy, Bire and Zillate) and one local fibre filled mango (Dodo). They were planted in November 2011 and their yield evaluated in two growing seasons each year with the main season from flowering to harvesting running from August-March (harvesting November-March) and the sub season from January – July (harvesting June-August). Data were collected yearly and the average annual yield recorded (Figure 7).

Grafted varieties started producing in the 3rd year after establishment whereas the local dodo begun producing in the 4th year. Local dodo produces numerous very small fibred mangos every year. Tommy, Bire and Zillate bear twice a year on a regular basis whereas Kent and Apple have a tendency of bearing quite a lot in the major season and skipping the sub season. Tommy is quite superior in yield above all the five were as Kent is least.
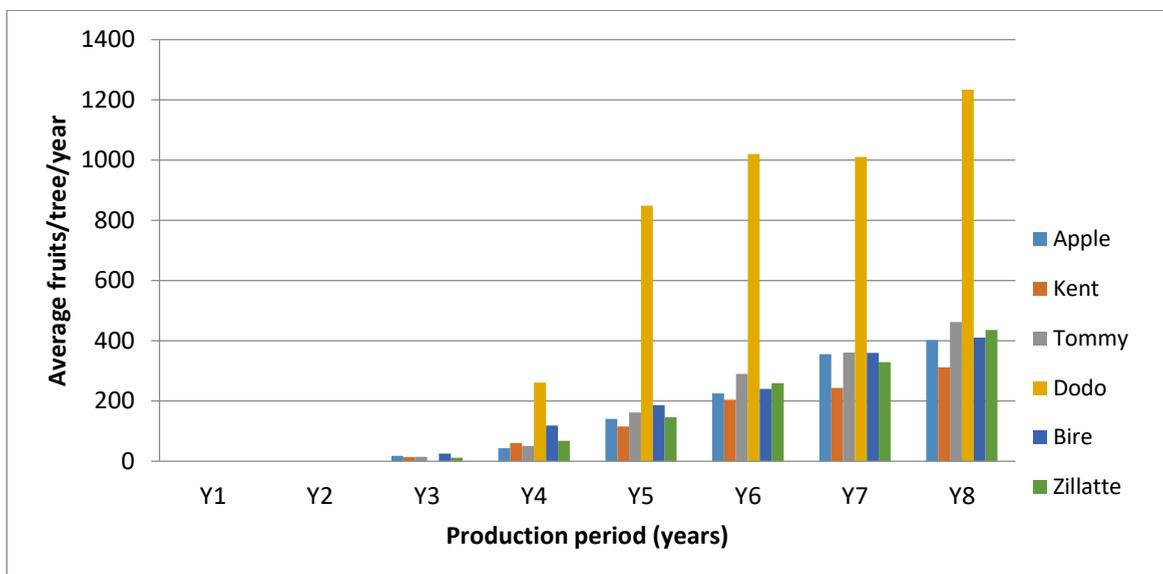
Figure 7: Mango production trend at Karama for six varieties

Molecular detection of viruses affecting chilli pepper (*Capsicum spp.*)

Chilli pepper is an important horticultural crop in Rwanda as a source of income to small-scale farmers, source of employment and foreign income earner. For instance, in 2017, 27 tones chilli pepper were exported, mainly to the UK, The Netherlands and Belgium, worth approximately US $54,000 (National Agricultural Export Development Board, Rwanda). Despite the importance of this crop in the country, low yields and poor quality are constantly recorded. This has been attributed to both abiotic and biotic factors, of which diseases caused by virus play a significant role. The aim of this study was to identify the viruses affecting chilli pepper production.

In January 2016, thirty-five (35) leaf samples of chilli pepper (*Capsicum sp*.) showing symptoms (distorted leaves, stunting and mosaic) of viral infection were collected from six districts: Ruhango, Nyanza, Rulindo, Kayonza, Nyagatare and Kirehe in Rwanda. Through the help of Plantwise program in Rwanda, these samples were submitted to Fera Science Ltd, for further analysis to identify the viruses present. Samples were analyzed using an Illumina MiSeq, Real time PCR assays and next generation sequencing. The sequences obtained were compared with the ones available in the Genbank using BLAST.

Viruses detected (Table 32) were: *Pepper veinal mottle virus* (PVMV, genus *Potyvirus*), *Pepper yellows virus* (PeYV, genus *Polerovirus*) and *Cucumber mosaic virus* (CMV, genus *Cucumovirus*) and a novel virus which is tentatively a member of the genus *Enamovirus*. Information generated is crucial for development of sustainable management strategies of viral diseases of chilli pepper. Further research needs to be carried out to determine the incidence, distribution and economic importance of these viruses in chilli pepper production in Rwanda.

Table 32: Viruses in chili pepper and the districts in chich they were located

Virus	Nyanza	Ruhango	Nyagatare	Kayonza	Rulindo	Kirehe
PVMV	√	√	√			
PeYV	√	√	√	√	√	√
CMV	√	√			√	

Production of clean seed of Tamarillo

Establishment of big plantations of tamarillo in RAB stations: Ntendezi and Gishwati in Western zone and Kinigi and Rwerere in Northern zone. Total area of 7 ha was planted. Those plantations have been used as source of clean seed in their respective zones in next seasons. Seed extraction was started in July 2017. 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.

Maintenance of existing mother gardens of avocado, mango and citrus

RAB mother gardens of avocado, mango and citrus have been used as source of scions distributed throughout the country which are used to develop new planting materials using the grafting method. Those mother gardens are established at Rubona, Karama, Nyagatare, Mahama, Kinigi, Bugarama RAB Research centers. Avocado (5ha), citrus (2ha) and mango (6ha). During the last fiscal year, the number of scions harvested is 335,400 for avocado, 193,800 for citrus and 117,200 for mango. The scions produced in those orchards were distributed to different beneficiaries including government projects like RSSP/LWH, NAEB through different private companies, NGOs (Caritas, Care International) and individual farmers.

Promotion of vegetable production in collaboration with SMAP project

The objective of RAB/SMAP project (Smallholder market oriented agriculture) was to improve the ability of technical implementation and management for related agricultural officers concerned, to realize the market oriented agriculture initiated by the smallholders through the extension services from the agricultural agencies, and eventually to contribute to improve smallholder farmers' income in Rwanda

During this fiscal year 2017/2018, this activity was conducted in two selected districts in each Province and City of Kigali. A total number of 50 cooperatives (five in each district) of vegetable growers got involved in theoretical and practical trainings through different Farmer

Field School (FFS) on market oriented vegetable production. Training of more than 250 trainers (TOT) attended these trainings who would later go and train their cooperative members. These FFS trainings were planned in the following manner:

FFS1: Market survey analysis, Crop selection, Crop planting calendar; FFS2: Nursery bed preparation& sowing; FFS 3: Transplanting & thinning (e.g.: carrot); FFS 4: Fertilizer application, first top dressing; FFS5: Fertilizer application (2nd top dressing) & Pests and diseases control and FFS 6: Harvesting.

Horticulture Center of Excellence

The Rwanda-Israel Horticulture Center of Excellence (HCoE) is a bilateral initiative between the Government of Rwanda and the State of Israel. The project is located at Mulindi Agricultural Show Grounds in Gasabo District, City of Kigali. The project activities were started in August 2016 in NAEB, and effective from 1st July 2017 the project and staffs are transferred RAB. The HCoE provides a suitable platform for a rapid transfer of knowhow on modern Israeli agro-technologies and agricultural best-practices to farmers namely the production of vegetables using improved varieties in greenhouses, walk-in-tunnels; net house and open areas, the use of modern irrigation systems and fertigation, and their adaptation to local conditions and the farmer's requirements.

For the last 12 months of implementation there has been, remarkable achievements in completion of the Center of Excellence infrastructures and strengthening an environment for demonstration of modern agro-technologies in Rwanda.

During this period, 3,000,000 liters of Water Reservoir and two water tanks were constructed and connected to Mulindi stream. Through the water pumps connected to the water reservoir, the clean water serving all sections for irrigation located in the center.

In order to increase the area of protected cultivation and also to ensure that farmers have access to modern technologies and agriculture innovation, the area of 0,7 ha are coved by 1 greenhouse and 8 tunnels for vegetable production. Both are equipped with drip irrigation systems and connected to the fertigation system for plant nutrition. Another area of 0.4 ha are coved by net houses for fruits nursery but while we waiting the fruits nursery trees the net is serving vegetable production. In additional of this, around 2ha of open field for Vegetables are full irrigated with high pressure irrigation and low pressure irrigation system (family unit system). This family drip irrigation system is affordable for small famers and also for urban farming where families' have a limited land for production.

From October 2017, the Center started the production and selling of different improved varieties of vegetables from Israel such as tomatoes, sweet and hot peppers, onions, cabbages , brocolli , cauliflower; eggplants, zucchini, cucumbers, watermelon, melon, basil and herb

varieties are the milestones so far achieved. As a result of these demonstration fields, more than 12 vegetables varieties are tested and 90 tonnes of vegetables harvested and sold to the local market.

In partnership with MASHAV with the aim of increasing capacity among center staff, 4 RAB/HCoE staff benefited intensive agriculture training and study tour in Israel. The training topics based on Israel experience and also specifically   vegetable production and efficient irrigation technologies. The project team and MASHAV experts provided training to 67 extension staff from different stakeholders. The training benefited the training on HCoE modern a horticulture technology includes vegetable production, soil, water, irrigation and plant nutrition and extension planning method. It's also in these context more than 300 farmers and investors received informal training through the study tours in the center of excellence and some of them are linked with irrigation kits suppliers and also with the seeds companies.

1.1.4.2 Tea

Tea research focused on (1) soil fertility and fertilizer use for improved tea productivity and (2) field performance evaluation of tea clones.

Effects of split fertilizer on tea yield and quality

Effect of splitting fertilizer applications on soil nutrients, tea yield and quality was evaluated at Mata and Nshili-Kivu in existing mature tea fields. Annual dose was 150 Kg N/ha/year in Mata and 200 kg N/year in Nshili-Kivu using NPKS 25:5:5:3. This was applied from one to 6 splits in Mata and 4 splits in Nshili-Kivu. Splitting fertilizers did not affect soil pH, available P (p>0.05) (data not shown).
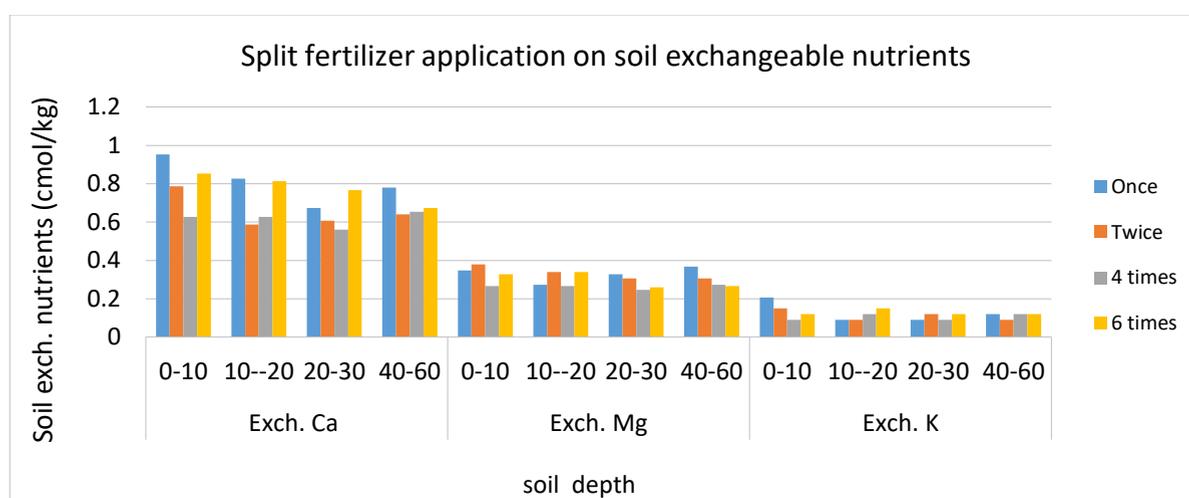
Figure 8: Effect of splitting N fertilizers on soil Ca, Mg and K at different depths (Mata)

Application of fertilizer in one single dose (T1) and two splits (T2) resulted in significantly (p<0.05) higher soil exchangeable magnesium (Mg) at 20-30 cm as compared to other

treatments. Nonetheless, mean exchangeable Mg was found in low range (< 1 cmol/kg) (Figure 8). These results would imply that soil pH and deficiency in exchangeable cations (K, Ca and Mg) need be improved for balanced tea nutrition and sustained production. Splitting fertilizer did not affect major nutrients in leaf. Splitting annual fertilizer in one, two, three, four six applications did not affect tea leaf yield (p>0.05) (data not shown).

In Nshili-Kivu, there was no significant difference of fertilizer splits on soil nutrients and pH (data not shown). Increased N application did not consistently affect leaf nutrients (Table 33) after one year of data collection. The experiment is still going on.

Table 33: Effects of fertilizer rates on mature leaf nutrients (Nshili-Kivu)

Treatment (kg N/ha/y)	Leaf total nutrients				
	N	P	K	Ca	Mg
T1 (no fertilizer)	2.74bc[L]	0.217	2.11	1.09	0.213
T2 (50kg N in 2 splits)	2.63ab	0.217	2.10	1.17	0.390
T3 (100kg N in 2 splits)	2.82bc	0.197	2.31	1.02	0.350
T4 (100kg N in 2 splits)	2.42a	0.220	2.13	1.18	0.333
T5 (150kg N in 3 splits)	2.55ab	0.223	2.15	1.16	0.300
T6 (150kg N in 4 splits)	2.58ab	0.230	2.15	1.18	0.180
T7 (200kg N in 4 splits)	2.90c	0.190	1.92	1.20	0.243
LSD (0.05)	0.23	NS	NS	NS	NS

NS: Not significant

Splitting annual fertilizer into two, three, four and six applications or once application did not lead to yield difference neither at Mata nor Nshili. Both sites Mata and Nshili have low pH (< 4). Problems of low K, Ca and Mg were observed in Mata soils. Dolomitic lime from 1-3 t ha^{-1} per pruning cycle is recommended to raise soil pH and supply of both Ca and Mg. Application of additional K fertilizers is particularly recommended at Mata to make a rate 80-120 kg K_2O/ha/year. Phosphorus was critical at Nshili in addition to Nitrogen. Application of manures would also be needed to improve soil microbial activity and subsequent fertilizer use efficiency in Nshili tea plantation.

Effect of N fertilizer on soil properties and tea yield and harvesting intervals on tea yield

The study evaluated the influence of N rates and harvesting intervals on tea yield of the clone TRFK 6/8) at Kitabi (Nyamagabe) and Mulindi (Gicumbi) from 2009. The site of Kitabi is on hilltop while Mulindi is located in marshland. Nitrogen rates of 0, 75, 150, 225 and 300kg N/ha were applied as NPKS 25:5:5:3. Plucking frequency at 7, 14 and 21 days interval was considered.

The N application and harvesting intervals did not affect significantly soil characteristics, except soil pH and phosphorus (Table 34). Higher rates of N application have significantly lowered soil pH. Althought tea is an acidophil crop, the pH observed was too low. The observed pH would lead not only to nutrient imbalance, but predisposes tea to health problems and ultimate low tea productivity.

Table 34: Effects of fertilizer rates on soil pH (2013 and 2015)

Treatment (kg N/ha/y)	Kitabi (2013)			Kitabi (2015)				Mulindi (2013)		
	Soil depth (cm)									
	0-10	10-20	20-30	0-10	10-20	20-30	40-60	0-10	10-20	20-30
	Soil pH									
0	4.16	4.18	4.16	3.91	4.03	4.15	4.26	3.92b [L]	3.99c	4.17
75	4.13	4.08	4.31	3.84	3.89	4.04	4.17	3.84ab	3.89bc	4.02
150	3.97	4.18	4.29	3.73	3.84	4	4.22	3.79ab	3.86abc	4.01
225	4.18	4.18	4.24	3.71	3.77	3.96	4.08	3.72ab	3.77ab	3.97
300	3.97	4.18	4.23	3.72	3.77	3.93	4.04	3.66a	3.67a	3.93
LSD (0.05)	NS	NS	NS	NS	0.181	NS	NS	0.15	0.15	NS

NS: Not significant; a,b – significantly different at p<0.05.

The pH steadily decreased with increase of nitrogenous fertilizer rates (Table 34), which would lead to soil degradation. Available phosphorus increased with increase of fertilizer rates. Available P was higher at Kitabi as compared to Mulindi (Table 35).

Table 35: Effects of fertilizer rates on soil available P

Treatment (kg N/ha/y)	Kitabi (2013)			Kitabi (2015)				Mulindi (2013)		
	Soil depth (cm)									
	0-10	10-20	20-30	0-10	10-20	20-30	40-60	0-10	10-20	20-30
	Soil available P									
0	49.9ab [L]	25.9	10.4	27.5	12.6	6.6	7.3	14.6a	11.4	14
75	43.9a	30.8	13.8	55.6	22.6	11.7	8.4	22.2a	14.1	12.3
150	68.3ab	37.4	21.5	56.6	19.9	10.9	9.5	23.6ab	16.7	15.3
225	84.5b	35.9	17.4	88.1	34.3	18.8	14.9	23.4ab	13	10.1
300	82.3b	40.1	17.9	103.2	36.2	15.8	11.8	61.8b	20	16.4
LSD (0.05)	26.1	NS	NS	42.7	12.8	7.48	4.4	27.8	NS	NS

NS – non significant; a, b – significantly different at P<0.05

Soil exchangeable potassium (K) tended to increase with higher fertilizer rates but not always significantly (Table 36). Soil exchangeable Mg did not change at Kitabi, but significantly decreased with higher fertilizers doses at Mulindi (data not shown). No significant change in soil exchangeable Ca was observed (data not shown).

Table 36: Effects of fertilizer rates on soil exchangeable K

Treatment (kg N/ha/y)	Kitabi (2013)			Kitabi (2015)				Mulindi (2013)		
	Soil depth (cm)									
	0-10	10-20	20-30	0-10	10-20	20-30	40-60	0-10	10-20	20-30
	Soil exchangeable K									
0	0.36	0.32ab[L]	0.24ab	0.26	0.19	0.14	0.11	0.23	0.22a	0.22
75	0.35	0.28a	0.21a	0.29	0.20	0.15	0.14	0.23	0.23a	0.25
150	0.42	0.36ab	0.36b	0.31	0.24	0.18	0.14	0.27	0.25ab	0.27
225	0.43	0.37ab	0.34ab	0.34	0.29	0.22	0.19	0.29	0.31b	0.28
300	0.49	0.39b	0.36b	0.36	0.31	0.22	0.12	0.30	0.25ab	0.32
LSD (0.05)	NS	0.072	0.098	NS	NS	NS	NS	NS	0.053	NS

NS – non significant; a, b – significantly different at P<0.05

The effect of N rates on the nutrients in mature tea leaf was similar to soil results where Ca and Mg decreased (P<0.05) with N rates increase (Table 37). It would denote antagonistic effect between N and Ca and Mg on one hand, and/or between K and Ca and Mg on the other hand. Continuous application of high N alone without balance with basic cations such as Ca and Mg would ultimately lead to soil depletion in both nutrients.

Table 37: Effects of fertilizer rates on mature leaf nutrients in tea

Treatment (kg N/ha/y)	Kitabi					Mulindi				
	Leaf total nutrients									
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
0	3.2	0.26	1.6	0.69	0.48	3.0	0.16	0.36a	1.75b	0.75b
75	3.2	0.27	1.6	0.69	0.67	3.1	0.16	0.45ab	1.75b	0.58ab
150	3.1	0.23	1.6	0.64	0.47	2.9	0.16	0.67c	1.60ab	0.76b
225	3.1	0.24	1.6	0.72	0.57	2.8	0.16	0.37a	1.60ab	0.50a
300	3.0	0.25	1.5	0.69	0.43	2.7	0.16	0.59bc	1.48a	0.53ab
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	0.132	0.170	0.174

NS – non significant; a, b – significantly different at P<0.05

In terms of soil fertility, soil pH and overall nutritional status were most critical. Continuous application of nitrogen led to further pH decrease. Therefore, concurrent application of 1.5-3 tons of agricultural lime or dolomitic limestone at rates 1.5-3 tons per pruning cycle would be necessary to offset soil degradation. Liming could eliminate not only excess of soil acidity and toxic amounts of Al, Fe, and Mn, but it would improve soil structure, gas exchange (oxygen supply), calcium supply, availability of P, K, Ca, Mg and Mo and active soil life. Application of KCl and $MgSO_4$ at rates of 80-120 of K_2O and 150-200 kg of $MgSO_4$ to improve soil K at Mulindi and Kitabi and Mg at Kitabi were recommended.

Significant (p < 0.05) tea yield response to rates of nitrogenous fertilizers was observed at Kitabi (Table 38). At this site, the highest mean annual yield (2,698 Kg made tea/ha/year) was obtained at 225 kg N ha^{-1} year^{-1}. At Mulindi, highest yield (920 Kg made tea/ha/year) was produced by 150 kg N ha^{-1} year^{-1} rate although not at significant level. Yield noticeably decreased at Mulindi due to pruning operation and resultant short period of harvesting.

The shortest harvesting interval (7 days) produced the highest yields (Table 38). The nitrogen rate 225 kg N ha^{-1} y^{-1} led to highest made tea yield at Kitabi. From the yield response to N fertilizer rates observed at Kitabi, the application of nitrogenous fertilizer rates ranging from 150 to 225 is recommended. At Mulindi, application of 75 to 150 kg N ha^{-1} y^{-1} is suggested to get positive response. Beyond this range no gain was observed.

Tea growers in both, Kitabi and Mulindi are not getting enough profits from applying N fertilizers alone as soil pH was below the required for tea. Thus, application of 1000-1500 kg lime in form of dolomite every two years or 1500-3000 kg per pruning cycle are suggested at Mulindi and Kitabi to raise soil pH to optimum levels (4.5-5.5).

At Mulindi, soil K was critically low and should be increased from the current 30 kg K$_2$O/ha/yr applied through NPK(S) 25-5-5-(3) fertilizers to 80-100 kg of K$_2$O/ha/yr). The same recommendation for K is valid for Kitabi in addition to Mg based fertilizers, which should also be supplemented to tea through fertilization.

Table 38: Tea yield (kg made tea/ha per yr) under various N and harvesting intervals (Kitabi)

HI (days)	Kitabi					
	Fertiliser rate (kg N/ha per year)					
	0	75	150	225	300	Mean
7	1975	2099	2381	3164	3147	2553
14	1378	1790	1886	2485	2700	2048
21	1343	1395	2185	2444	2190	1911
Mean	1565	1761	2151	2698	2679	
LSD (0.05)	HI: 174.2***	Rates: 224.9***		Interaction: NS		
	MULINDI^L					
7	1158	1116	1330	1057	1048	1142
14	863	833	845	717	795	811
21	595	652	583	518	845	639
Mean	872	867	920	764	896	
LSD (0.05)	HI: 138***	Rates: NS		Interaction: NS		

*** Significant at P < 0.001; NS: Not significant; ^{L}: Pruning year (7-month yield)

Evaluation of organic fertilizers on tea: productivity and value

Nowadays, some markets are willing to pay premium prices for food produced using natural products such as organic manures. Some tea producers, including Rwanda tea producers, have joined the organic food production and have ventured into organic tea production. However, it is not known if use of organic manures will reduce yields and quality of Rwanda tea. The main objective of this study was to compare yields and quality response of clonal tea to NPKS 25:5:5:5, Organomex and cattle manure and determine options that enhance most the tea productivity.

Trials were established in 2011 at two sites of Cyohoha-Rukeri, namely, Gatorwa and Rugando, with control, Organomex (at manufacturer recommended rates), cattle manure and NPKS 25:5:5:5 at 150 kg N/ha/year as treatments. The cattle manure and NPKS were applied once in January 2015 while Organomex was applied in the equal splits in January, April and November. Soil was sampled in January 2014 and January 2015 for both sites and November 2015 for Gatorwa. At this last time Rugando site was under pruning.
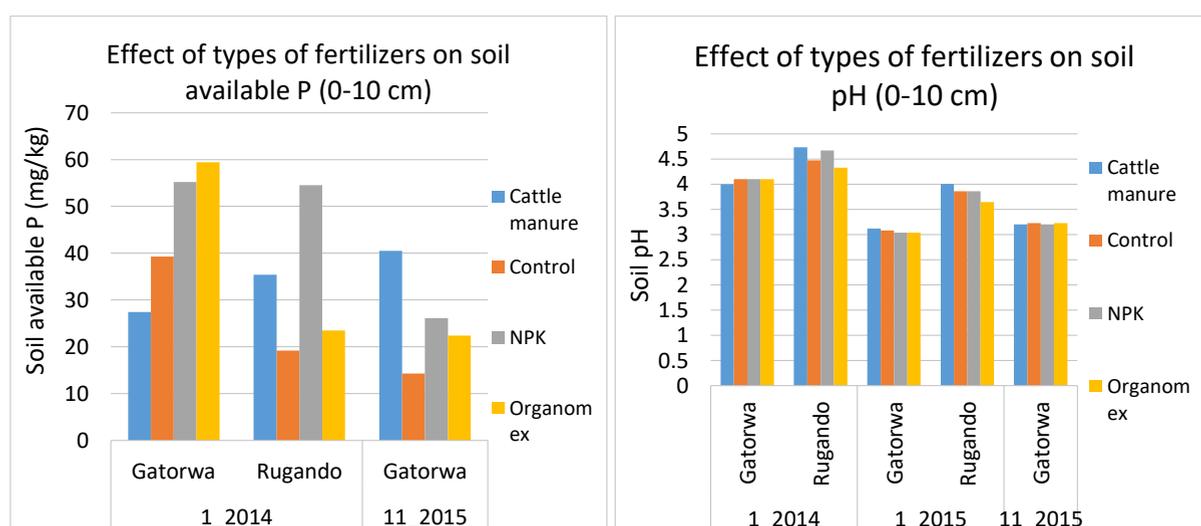
Figure 9: Effect of types of fertilizers on soil P and pH

Cattle manure, NPK and organomex treatments were not different (P>0.05) in soil pH and nutrients. Apart from the P which was in adequate range, other nutrients namely, K, Ca and Mg were low for balanced nutrition at both sites Rugando and Gatorwa (Figures 9 and 10).
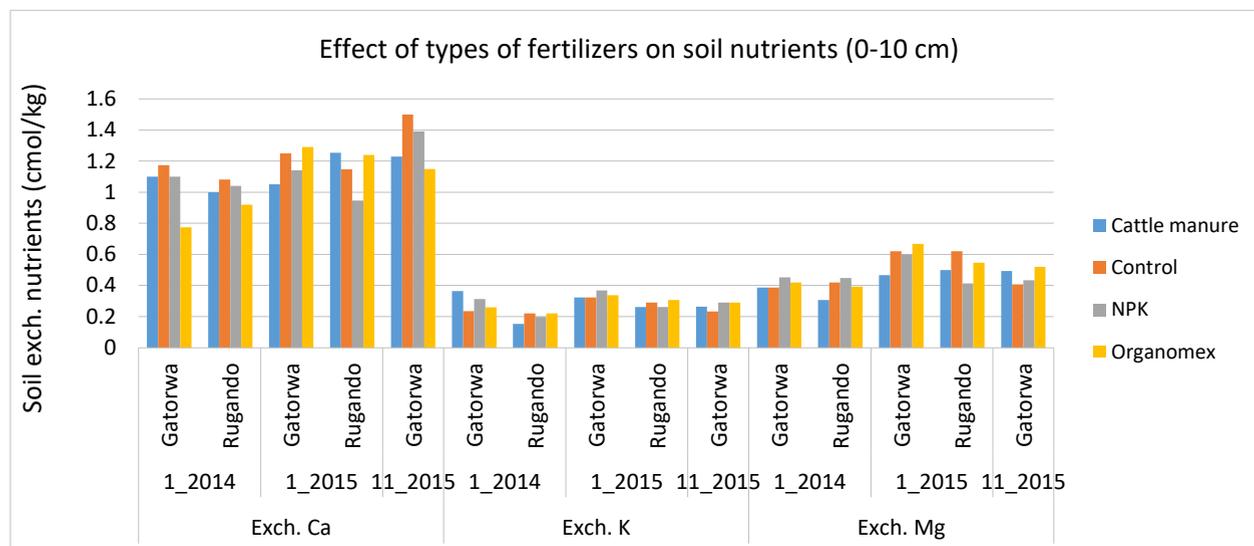
Figure 10: Effect of types of fertilizers on soil nutrients

Mature tea leaf nutrient analysis showed that Mg and Ca were adequate, N and P were medium to low while K was deficient (Table 39).

Table 39: Effect of types of fertilizers on mature leaf nutrients (Gatorwa 11/2015)

Treatment(kgN/ha/y)	%Ca	%K	%Mg	%Total_N	%Total_P
Cattle manure	1.7	0.61	0.56	3.1	0.19
Control	1.9	0.44	0.71	3.4	0.19
NPK	1.6	0.45	0.47	3.4	0.19
Organomex	1.6	0.47	0.68	3.3	0.21
Grand mean	1.7	0.49	0.61	3.3	0.20
LSD (0.05)#	NS	NS	NS	NS	NS

NS: Not significant

Observation of six years' made tea yield (Table 40) revealed that Organomex consistently yielded higher than other fertilizers at Gatorwa while at Rugando NPKS produced highest yield. The control yielded lower.

Table 40: Mean annual yield (6 years) due to types of fertilizers

Site	Fertilizer type				
	Organomex	Cattle manure	NPKS	Control	Mean
	Yield (kg made tea/ha/year)				
Gatorwa	3356	2852	2807	2642	2914
Rugando	2125	2179	2461	1952	2179
Average fertilizer	2740	2515	2634	2297	
LSD (0.05)	Site: 270.1	Fertilizer: NS			

NS: Not significant

At Gatorwa, yields in cattle manure and NPKS treatments were almost similar, 2852 and 2807 kg made tea/ha/year respectively; whereas at Rugando, yields from organomex and cattle manure were in the same range as well, 2125 and 2179 kg made tea/ha/year respectively. Tea yields in the organic fertilizer and manure treatments at both sites were not significantly different from as compared to inorganic fertilizers (NPKS) treatments. Thus, tea growing may be highly profitable as organic tea fetches premium price. As the soil pH was very critical, lime applications are recommended.

Effect of lime and fertilizer on soil properties, yield and quality of tea

High soil acidity results in soil nutrient imbalances that would making it difficult to profitably grow tea. To help farmers to grow tea on acidic soil, this study aimed to determine the optimal liming and fertilization regimes for tea. Field trial was established in February 2009 in existing mature tea field (clone TRFK 6/8) at Gisovu (Karongi) plantation. Lime treatments (dolomite) were nil; 1; 1.5 and 2 t ha^{-1} and were applied after each pruning. Nitrogen fertilizers were applied at following rates: nil; 150kg N/ha/yr (applied in two splits in March and October) as NPKS 25:5:5:3; 150kg N/ha/yr (in two doses at 75 kg N/ha/application in March and October) as NPKS 25:5:5:3 plus 50 kg K/ha/yr as Muriate of Potash (MOP 60% K$_2$O applied as a single dose 6 weeks after NPKS application); and 150kg N/ha/yr (in two doses at 75 kg N/ha/application in March and October) as NPK 20:10:10). Soil sampling was done after 4 years of the pruning cycle.

Tea yield did not differ in N fertilizer treatments, thus, soil samples were taken as combined sub-samples in all N-applied plots. Analysis of variance (Genstat 6) showed that application of lime at 2 t/ha slightly increased the pH of 0.37 unit although not at significant level (P > 0.05). The observation was similar at all sampled depths (Table 41).

Table 41: Soil pH in Lime and N fertilizer treatments at Gisovu

Soil depth (cm)	0-20			20-40			40-60		
Lime (t/ha)	N-fertilizer								
	Nil	N-applied	Mean	Nil	N-applied	Mean	Nil	N-applied	Mean
0	4.37	4.13	4.25	4.57	4.33	4.45	4.57	4.40	4.48
1	4.13	4.20	4.17	4.33	4.37	4.35	4.30	4.40	4.35
1.5	4.37	4.30	4.33	4.37	4.47	4.42	4.47	4.30	4.38
2	4.73	4.50	4.62	4.60	4.53	4.57	4.60	4.87	4.73
Mean	4.40	4.28		4.47	4.43		4.48	4.49	
LSD (0.05)	Fert: NS		L: NS	Fert: NS		L: NS	Fert: NS	Inter: NS	L: NS

Fert: Fertiilizer; L: Lime; Inter.: Interaction; NS: Not Significant

There was no significant effect of lime and fertilizers on soil P, Ca and Mg (data not shown).

in highly significant K content (0-20 and 40-60 cm) as compared to nil and 1 t/ha lime applications (Table 42). Fertilizer treatment also resulted in higher soil K as compared to the nil treatment. Analysis of mature leaf nutrients showed no significant effect of lime and NPK fertilizers on major nutrients namely N, P, K, Ca and Mg (results not presented). Consideration of site means revealed that mature leaf N was very low (2.83 %), Ca was medium to low (0.86 %) while K, P and Mg were from adequate to high ranges with 1.97, 0.34 and 0.63 % respectively. The trend of results presented here were not conclusive as effect of lime was not clearly shown. Unfortunately, the trial was not continued for various reasons. Restarting it is recommended.

Table 42: Effect of lime and N fertilizer on soil exchangeable K in Gisovu

Soil depth (cm)	0-20			20-40			40-60		
Lime (t/ha)	N-fertilizer								
	Nil	N-applied	Mean	Nil	N-applied	Mean	Nil	N-applied	Mean
0	0.453	0.487	0.470	0.370	0.343	0.357	0.257	0.257	0.257
1	0.340	0.457	0.398	0.343	0.313	0.328	0.343	0.257	0.300
1.5	0.483	0.570	0.527	0.343	0.400	0.372	0.287	0.340	0.313
2	0.653	0.797	0.725	0.457	0.513	0.485	0.427	0.370	0.398
Mean	0.482	0.577		0.378	0.392		0.328	0.306	
LSD (0.05)	Fert: NS		L: NS	Fert: NS		L: NS	Fert: NS		L: NS

Fert: Fertiilizer; L: Lime; NS: Not Significant

Performance evaluation of tea clones: ongoing trials of 2014/2015

The trial was established in 2014 and 2015 at Ntendezi (Nyamasheke), Mata (Nyaruguru), Cyohoha Rukeri (Rulindo) and Pfunda (Nyabirasi) (Photo 11).

Photo 11: Clonal trial of SORWATHE/Rugundu (Left) and ASSOPTHE (Right), on 25/1/2018

Data were collected including stem girth, height, crop cover and made tea yield (partially shown in Table 43, Photo 12). At Pfunda, some plots were destroyed by Armillaria root rot (Photo 12). Five best clones were from the highest: SFS 150, SFS 475, SFS 110, TRFK 301/4 and

TRFK 31/8. As compared with the preceding year, the most performing clones were TRFK 301/4, TRFK 301/5 and TRFK 31/8 followed by SFS 475.

Photo 12: View of the trial at Pfunda clean plot (left) and plot affected by Armillaria root rot (right), 11/1/2018

Table 43: Effect of tea clone on crop cover and made tea yield

Clone / Site	Crop cover (%)					Yield (kg made tea/ha)		
	Mata	Ntendezi	SORWATHE	ASSOPTHE	Mean	Mata	SORWATHE	Mean
TRFK 7/3	86.0	71.9	79.2	67.0	79.0	786	643	715
TRFK 12/19	92.4	69.4	95	77.0	85.6	1061	892	977
SFS 204	95.7	80.6	94.9	79.4	90.4	1047	897	972
SF S 371	97.3	71.3	75.8	62.8	81.5	927	804	866
Pc 81	89.8	66.3	87.8	80.5	81.3	918	797	858
SFS 150	**93.8**	**80.2**	**94.2**	**84.4**	**89.4**	**1238**	**910**	**1074**
SFS 110	**99.1**	**86.8**	**91.3**	**81.5**	**92.4**	**1070**	**920**	**995**
SFS 475	**96.4**	**78.9**	**96.9**	**77.9**	**90.7**	**1072**	**967**	**1020**
TRFK 11/4	95.2	72.7	92.0	79.9	86.6	971	801	886
TRFK 31/8	**96.4**	**79.8**	**95.5**	**76.1**	**90.6**	**980**	**840**	**910**
TRFK 6/8 (check)	90.4	75.7	92.9	74.7	86.3	882	747	815
TRFK 12/56	94.9	82.2	80.9	75.7	86.0	970	752	861
TRFK 12/12	82.9	70.4	99.3	83.5	84.2	795	776	786
TRFK 303/577	94.2	78.1	96	64.5	89.4	949	970	960
TRFK 301/5	89.9	81.5	88.8	62.8	86.7	1009	817	913
TRFK 301/4	**94.4**	**77.9**	**96.9**	**64.9**	**89.7**	**1057**	**835**	**946**
TRFK 54/40	94.1	76.6	90.4	70.1	87.0	1168	947	1058
LSD (0.05)	Clone: 4.73	Site: 1.99	Site x Clone: 8.20	ASSOPTHE: 12.9		NS	213	

[L]: ASSOPTHE was not included in the mean; NS - not significant at p=0.05.

Evaluation of newly introduced clones

New tea clones UTK 9710342, UTK 9400247 and UTK401658 were introduced by Unilever Tea Company in December 2016 and their adaptability was evaluated at Munini since October 2017 (Season 2018 A). The new clones were planted along with locally adapted clones, namely TRFK 31/8, TRFK 11/4 and TRFK 6/8 (Photo 13). Data were collected on plant height, stem

girth, branch and leaf development at 6 months after planting. Assessment showed that UTK 9710342 was most performing (well established and highly branching) of all evaluated clones.

Photo 13: Six-month old tea clones at Munini (Nyaruguru) site

UTK401658 performed similarly to check clones - TRFK 31/8, TRFK 11/4 and TRFK 6/8. Clone UTK 9400247 had not survived at nursery. Current observations confirm earlier year assessments whereby the clone UTK 9710342 performed better than locally adapted clones. The trial is still going on.

Advisory on white grubs infestation in some tea plantations

Following white grub infestation in tea fields in Nkora village, Mukondo cell, Nyundo sector (Photo 14) and request from Rubavu district, RAB has provided technical support to tea growers in the area. After floods (2012-2014), first observation of white grub was noted on tea roots in Nyamugari tea fields. The larvae caused tea leaf yellowing and drying of the whole plant. The highest incidence of pest was in July and October 2017. Rocket, Cypermetrine and Azadirachtin were applied locally for pest control. Thereafter pest severity went down and resurged in 2017 with high severity and new investation sites at SORWATHE-Kinihira (Rulindo), Kitabi (Nyamagabe) and Rugabano (Karongi). These sites were also visited early January 2018 by a conjoint team from RAB and NAEB. Yellowing of leaves, drying of the whole plants and subsequent death were observed. Larvae and adult insects were retrieved in samples. Ten samples of 1 m3 were collected where symptoms on aerial part of tea plants were visible and soil digging around the affected tea plant was done to inspect for insect presence. The mean number of larvae was 0.3 (ranging from 0 to 2 per sample) and 1 (ranging from 0 to 3 per sample for adult insects).

Photo 14: The team assessing the white grub at Nyundo – 9 Jan. (left); 27 Feb. 2018 (right)

The following recommendations were developed:

1. Tea farmers are advised to regularly monitor their tea plantations to find out when white grubs appear in tea plantation for timely management of this pest.
2. The most common practice to manage white grubs is hand picking. Therefore tea farmers are advised to handpick and destroy white grubs as soon as they appear in their tea farms.
3. For new tea planting areas, thorough check of white grubs at plough stage would be much easier than controlling them after tea planting when damage has occurred.
4. The use of light traps can help attract adult beetles and reduce white grub population.

1.1.4.3 Coffee

Coffee has been grown in Rwanda since the 1930's and has become the backbone of the country's agricultural foreign exchange earnings. It is grown by 350,000 households throughout the country, and contributes to the livelihoods of more than 1.5 million of Rwandans (NISR, 2012). Coffee annual production coffee has been ranging between 30,000-40,000 tonnes. Recent in-depth analysis of current trends in Rwanda's coffee sector has revealed that low and stagnating production has placed Rwanda's coffee sector in a vulnerable state. This led the coffee sector to still lag far behind the country's export targets. Despite this, official reports indicate that, for the last 5 years, coffee total export earnings rose from 54.9 to 64.12 Million USD, and the commodity recorded around 10 % of the all the export commodities. The low production is attributed to a number of factors including low yielding varieties, limited access to healthy planting material, diseases and pests (such as coffee leaf rust, coffee berry disease, antestia bug and coffee berry borer), as well as 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 2017/2018 fiscal year, research activities under the coffee sub-programme were centered on research projects aiming at enhancing coffee productivity through mainstreaming climate change adaptation practices into the coffee sector.

Baseline survey on pests, diseases and climate change adaptation practices in coffee

The baseline survey was carried out between December 2017 and January 2018 and covered all the coffee growing zones of Rwanda in all 4 provinces (Figure 11).
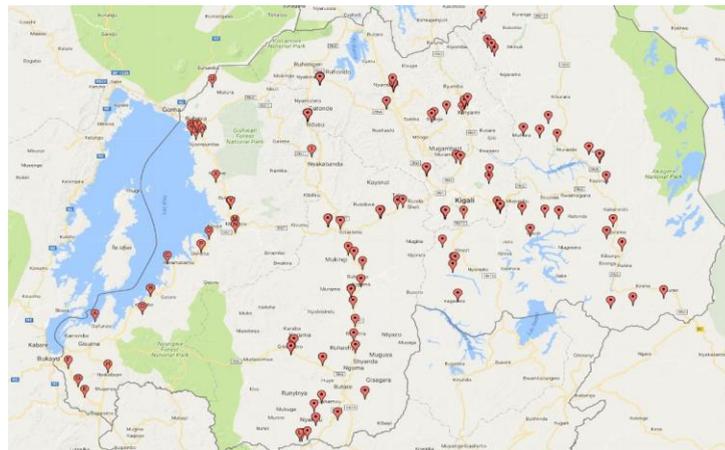
Figure 11: Surveyed sites across the country

Results from the survey (Figure 12) indicated severe cases of coffee leaf rust (CLR caused by *Hemileia vastatrix*) in all coffee growing regions of Rwanda. High coffee leaf rust severity scores were observed in Southern province, followed by Eastern Province. Least records were seen in Northern Province.
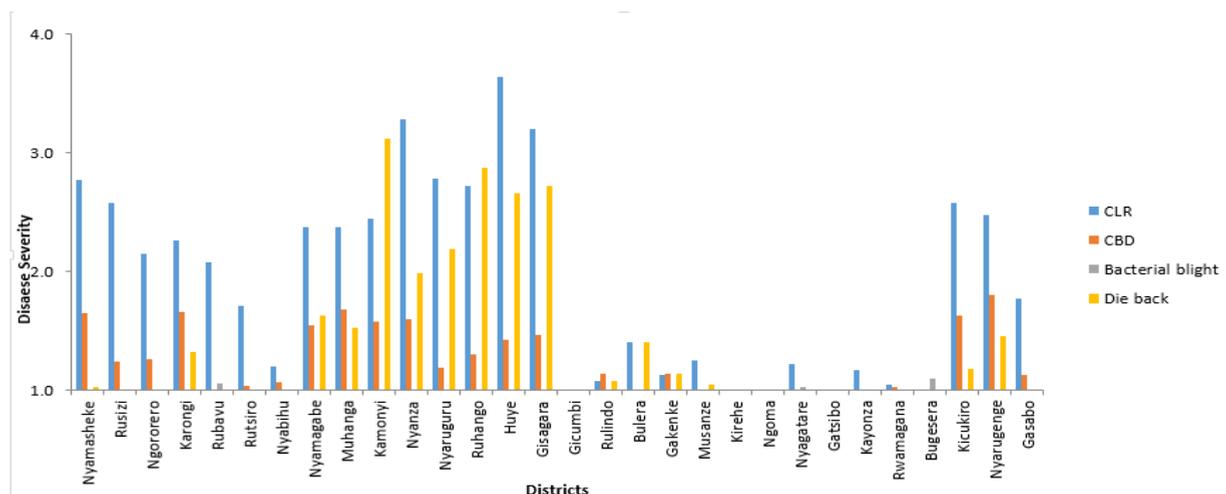
Figure 12: Major coffee disease severity of infection in surveyed sites

High records of die back are related to coffee leaf rust attacks as both diseases combined magnify the incidence. The results of higher coffee leaf rust infection in South, East and West can be linked to not only poor crop husbandry but also higher temperatures. Another major disease observed in all coffee growing districts is coffee berry disease (CBD caused by *Colletotrichum kahawae)* but its lowest incidence was recorded in North*.
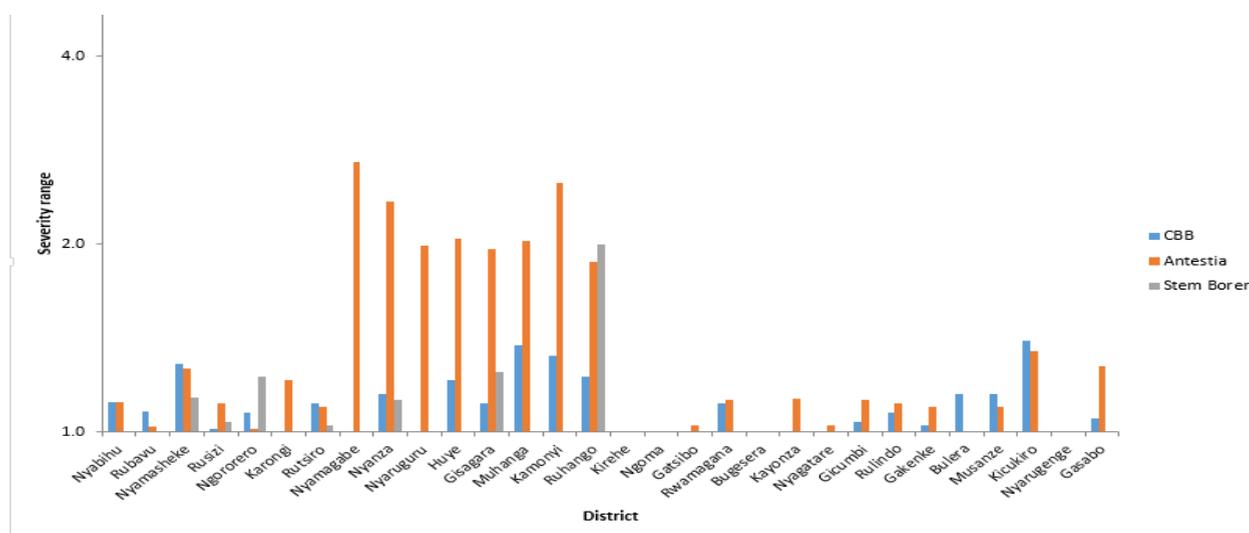
Figure 13: Major coffee pests severity of infestation in surveyed sites

Antestia bug and coffee berry borer are currently major prevalent coffee pests in all districts with higher populations in Southern Province (Figure 13). Stem borer was prevalent mainly in Southern Province. Climate change adaptation practices including, mulching, shading, pest and disease management, erosion control, and organic and inorganic fertilization were applied at a low level all across the country with least records in Southern province.

Development of IPM package for coffee growers

An IPM guide about agronomic practices was developed. It focused on 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 at the end of 2018/2019. These include systemic and biochemical fungicides against major fungal diseases of coffee (leaf rust and anthracnose), use of a new class of insecticide (sulfoxaflor) less susceptible to insect resistance against antestia and coffee berry borer, the introduction of semiochemicals against major insect pests. Another study was initiated to assess the coffee leaf rust mitigation under coffee-banana intercropping system. Preliminary results indicate reduction of leaf rust under banana shade.

Development of climate resilient and market-led new coffee varieties

Coffee breeding aims to develop new coffee varieties combining high yielding potential, good cup quality and multiple stress resistance or tolerance. Six out of eleven F1 hybrids developed in 2012 have been evaluated for field performance (Photo 15). These hybrids showed higher yield potential (>2.5t/ha) than the existing commercial varieties (BM139 and Jackson). These hybrids were: BM139x6A, BM139XRUIRU11, BM139X5A, BM139XBATIAN, Jacksonx6A, Jackson x5A. These hybrids were resistant to coffee leaf rust, coffee berry disease and were tolerant to low rainfall. Cup quality of these hybrids will be evaluated prior to pre-release. 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.

Photo 15: Coffee breeding crossing block (left) and one of mature crosses under field evaluation (right)

The World Coffee Research (WCR) has gathered 35 top-performing coffee varieties from 11 suppliers around the world and developed 40 F1 hybrids. In partnership with the WCR, 20 new coffee genotypes were imported and are being evaluated in multilocational trials to assess adaptability and yield stability (Photo 16).

Photo 16: *In vitro* plantlets received from World Coffee Research (1), acclimatized in Rubona (2) and evaluated in multilocational trials

These varieties are: 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. Another set of 40 F1 hybrids has been imported from WCR as in vitro plantlets and submitted to acclimatization process. During the 2017/2018 fiscal year field performance of these varieties for core traits were evaluated in multi-locational trials in Ngoma, Rubona (Huye) and Mwito (Nyamasheke).

Enhancing seed systems through early generation coffee seeds

Basic-seed seed multiplication. For 2017/2018, seed gardens for released varieties were maintained. A total of 200 kg of a newly released RABC 15 variety were produced and supplied to farmers. This amount can produce 600,000 seedlings and plant around 240 ha. On the other hand, 2,500 kg of clean seed from traditional varieties (BM139 and Jackson 1257) were produced and supplied to farmers. This amount of seeds can produce 7,500,000 seedlings and plant around 3,000 ha of land.

1.2 Natural Ressource Management

1.2.1 Soil and Water Management

Population growth, and limited cultivated land put imprint on food demand and the need to increase yields. Climate change and variability set additional challenge for increasing crop yields. One of the ways to sustainably increase yields is to provide optimal nutrients into soil in form of mineral and organic fertilizers. As Rwandan soils are very diverse, adequate site-specific recommendations are required. To date, mineral fertilizer recommendations in Rwanda were based on the macronutrients including N, P, and K. Secondary nutrients (Ca, Mg and S) and micronutrients such as Zn, B, Cu, Fe, B and Mo have not been considered, although soil studies showed extensive deficiencies of these elements in many areas of Rwanda (RSSP, 2012 and IFDC, 2014). To solve the problem, RAB and IFDC initiated a collaborative research since 2014, whereby N-P-K based fertilizers were tested in combination with secondary and micro-nutrients on Rice, Irish potato, Bean, soybean, Maize and wheat.

This work came up with promising site-specific fertilizer formulas recommended for the above-mentioned crops, taking into account macro and micronutrients. Based on these findings, RAB signed a cooperation agreement with OCP Africa in 2007 through which the new RAB-IFDC fertilizer formulas were blended and used for establishing demonstration trials in different sites of the country to serve as learning sites for scaling out. The purpose of the demonstration trials was to create awareness of the performance of balanced blended fertilizers against the commonly used fertilizer recommendations. In this line, a total of 200 demonstration trials were established in 2018A across the country on rice, maize and potato. The results obtained from these demonstration trials are shown below.

Strategy for promotion and scaling out the RAB blended fertilizer formulas

Office Cherifien des phosphates (OCP S.A.) in collaboration with Rwanda Agriculture and Animal Resources Development Board (RAB) implemented a collaborative activities in 2017B to 2018A to demonstrate RAB fertilizer formulas on Maize, Irish potato and Rice in Rwanda as to increase awareness and promoting new RAB fertilizer recommendations in line with the "memorandum of understanding signed between the Ministry of Agriculture and Animal Resources (MINAGRI) and OCP S.A, Africa's, regarding industrial investment in blending unit dedicated to the production of fertilizers adapted to soil and crop needs" in Rwanda.
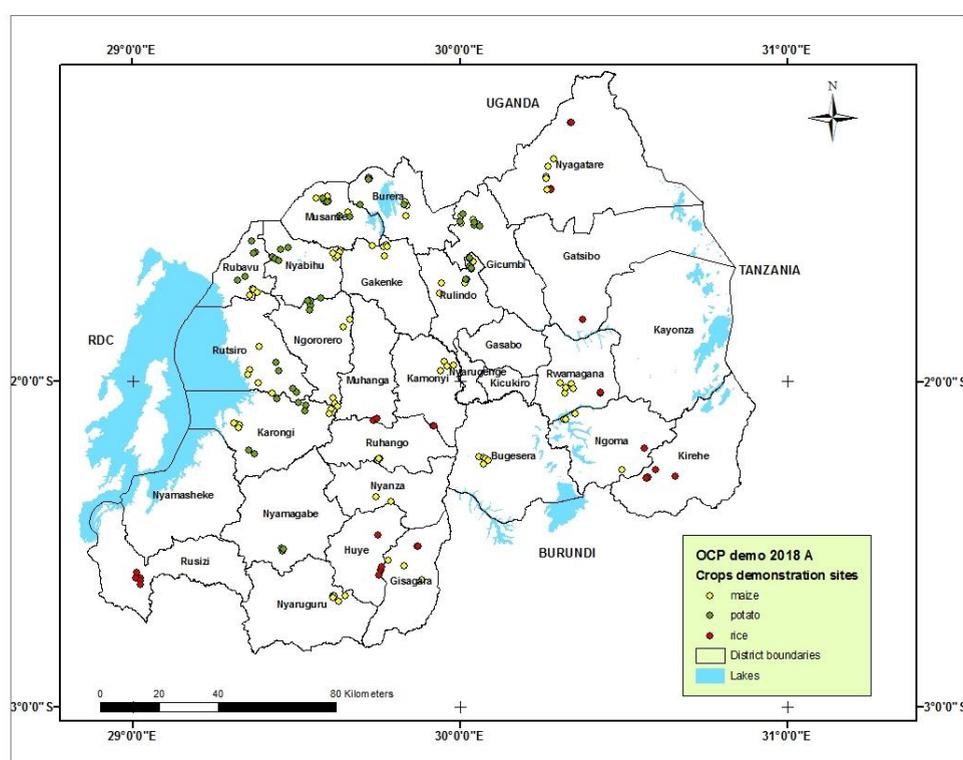
Figure 14: Distribution of demonstration trials in different districts of the country

The blending unit should use fertilizer formulas developed by RAB-IFDC, which showed high performance in increasing productivity and profitability of the tested crops. The study was carried out in Ngoma, Nyagatare, Gatsibo and Bugesera districts in the Eastern province; Kamonyi, Muhanga, Ruhango, Nyaza, Gisagara, Nyamagabe and Huye districts in the Southern province; Musanze, Burera, Rulindo and Gicumbi district in Northern zone; and Rusizi, Rutsiro, Karongi, Ngororero, Nyabihu and Rubavu district of Western province of Rwanda.

Developed Fertilizer Formulas used for demonstration trials

The new blended fertilizer formulas were developed by RAB-IFDC for maize, rice and Irish potato for major agro-ecological regions (Figure 14), which grow the big share of each of these crops (Table 47 below).

Table 44: New fertilizer formulas developed by RAB-IFDC blended for demo trials on maize, rice and Irish potato

Crops	Fertilizer formula	District
Maize	18.33.0.6S.0.4Zn.0.2B.0.2Cu	Volcanic soils of Rwanda
	18.33.0.6S.0.4Zn.0.2B.0.2Cu + dolomite	All districts of Eastern province, and Nyanza, Ruhango, Muhanga, Gisagara, and Kamonyi district of southern province
	13.24.16.4S.0.3Zn.0.2B.0.2Cu + dolomite	Western and northern non-volcanic soils and Nyaruguru district of southern province
Rice	12.20.20.5S.0.3Zn.0.2B.0.2Cu	Southern & Eastern marshlands
	12.20.20.5S.0.3Zn.0.2B	Bugarama marshland
Potatoes	13.26.18.3S.0.3Zn.0.1B.0.1Cu	Volcanic soils of western and northern province
	13.26.18.3S.0.3Zn.0.1B.0.1Cu + dolomite	Non-volcanic soils of western, southern and northern province

Sites selection, demonstration trials establishment and management

The selected sites for establishment of the demonstration trials were uniform in terms of soil type and fertility status (e.g., no localized gravel, anthill, rocky outcrop etc. in parts of the field) and field history of the previous crop. They were also in accessible area to allow easy accessibility during field days and farmer evaluation visits. The size of the field site plots was 400 square meters, which allowed the setup of two demos each measuring 20m by 10m and paths of 1m wide. After identification of the demo trial sites, GPS coordinates were captured and sites mapped. Demo plots were applied with basal fertilizers at the planting and top dress after germination.

Basal fertilizers were applied at a rate of 200 kg/ha for both current fertilizer recommendation and new fertilizer formula in rice. Plots under the new fertilizer formulas were top-dressed using urea briquettes at a rate of 112.5 kg /ha whereas plots under the current formula were top-dressed with granular urea at a rate of 100 kg /ha. In maize, basal fertilizers were applied at a rate of 135 k/ha for the new fertilizer formula 1 (18.33.0.6S.0.4Zn.0.2B.0.2Cu) and 180 kg/ha for the new fertilizer formula 2 (13.24.16.4S.0.3Zn.0.2B.0.2Cu) and 100 kg/ha for the current fertilizer recommendation. The top dress was applied at the same quantity of 50 kg/ha for the both formulas. Irish potato basal fertilizers were spot applied at the rate of 300kg/ha for current fertilizer recommendation and 275kg/ha for new fertilizer formula. Plots under the new fertilizer formula were top-dressed using 80kg of urea per hectare. At a

respective site, dolomite was applied through spot method two weeks before planting at the rate of 500kg per hectare as the source of magnesium and calcium nutrient. Regarding plant density, maize was planted at a spacing of 75 cm between rows and 30 cm between hills, rice was spaced at 20 cm between rows and 20 cm between hills whereas potatoes were spaced at 80 cm between rows and 30 cm between hills. For all crops, improved seed varieties suitable for each location were used. The demo plots received appropriate management practices during the crop growth, which include weeding, pesticides and fungicides treatments.

The data collection in demonstration plots focused on yield, while all crops were harvested at physiological maturity. For maize and rice, harvested grains were measured with the moisture content by use of moist meter and appropriate formulas were used to compute the yield at approximately 14% moisture content and weighed. For Irish potato, yields were obtained from fresh harvested potatoes weighed after cleaning and removal of soil. In all plots, the harvested area was determined after taking off two rows from each side of the perimeter of the plot.

Table 45: Fertilizer costs in Rwanda at the farm gate without subsidy (MINAGRI, 2015 & IFDC, 2016) at the rate of 1USD=856.5 USD

Fertilizer type	Cost per kg in USD
Urea	0.651
DAP	0.840
KCL	0.735
NPK 17:17:17	0.741
Ammonium sulfate	0.595
Magnesium sulfate 10% Mg	17.14
Dolomite	0.049
Solubor 20.9%Bok	3.20
Cu2O 75%Cu	12
ZnO75% Zn	2.8

The collected data were analyzed using analysis of variance with GenStat Statistical package, edition 4.Treatments means were compared with the least significant different (LSD) at the probability 0.05.

To determine the returns to fertilizer use, the value-cost ratio (VCR) was performed using the following formula:

$$VCR = \frac{Value\ of\ increased\ crop\ out\ put}{Cost\ of\ fertilizer\ applied}$$

Estimates of the marginal products of N multiplied by the output/input price ratio define the value-cost ratio (VCR). VCRs are commonly used in the literature in developing countries, especially when costs of labor and other inputs are not available to compute more detailed estimates such as gross margins or returns to labor. Generally, VCRs greater than 1 would imply profitability of fertilizer as long as other inputs were not altered as a result of using fertilizer. This is not likely be the case, and for this reason as well as the risks associated with fertilizer use. Experienced researchers have found that VCRs of two or more are generally required to find farmers using fertilizer in any appreciable amounts (Crawford and Kelly, 2002). This report adopts this convention and considers a VCR above 2 as an indicator that the use of fertilizer is profitable. The fertilizer prices used in the calculation of VCR were based on the fertilizer products presented in the Table 45.

The farm gate grain or tuber prices used in the value-cost ratio calculations were the average of prices in the farm gate local markets in Rwanda Francs averaging to 200frw per kg of grain maize, 180 frw per kg of potato tubers and 300 frw per kg of paddy rice. The VCR was calculated as a ratio of value of increased crop output to the cost of fertilizer applied.

Treatment effect on potato yield in Northern Province

Potato demonstration trials were conducted in Northern Province during the cropping season 2018A, in Musanze, Rulindo, Burera and Gicumbi Districts. Twenty demos were established in four districts where each district hosted 5 demos. Potato yields from the current blanket fertilizer recommendation NPK 17-17-17 was compared to the yields obtained from the RAB blend recommended formulas made of 13N-26P-18K+3S+0.3Zn+0.1 B +0.1 Cu in volcanic soils (Musanze), 13N13N-26P-18K+3S+0.3Zn+0.1 B + 0.1 Cu + dolomite in non-volcanic soils (Rulindo, Gicumbi and Burera).

The results in Figure 15 illustrate the performance of each treatment in the above districts. It appears from analysis of variance that there was highly significant difference (P< 0.001) between treatments. The treatment with blended primary, secondary and micronutrient yielded much better than the current blanket fertilizer recommendation (NPK 17-17-17) across all the districts of Northern Province. In Musanze District, the treatment 13N- 26P-18K+3S+0.3Zn+0.1 B +0.1 Cu yielded 29.38 t/ha, inducing a yield increase of 7.72 t/ha as compared to the current fertilizer recommendation (NPK 17-17-17), which yielded 21.66 t/ha. In Rulindo district, the highest yield of 30.68 t/ha was recorded from the treatment, which combined macro and micronutrients(13N-26P-18K+3S+0.3Zn+0.1 B +0.1 Cu + dolomite) with a yield increase of 8.92 as compared to the current recommendation (NPK 17-17-17). In Gicumbi and Burera districts, the treatment with blended fertilizer yielded 31.72 t/ha and

27.78 t/ha respectively, with a yield increase of 4.6 and 7.5 t/ha as compared to current fertilizer recommendation.
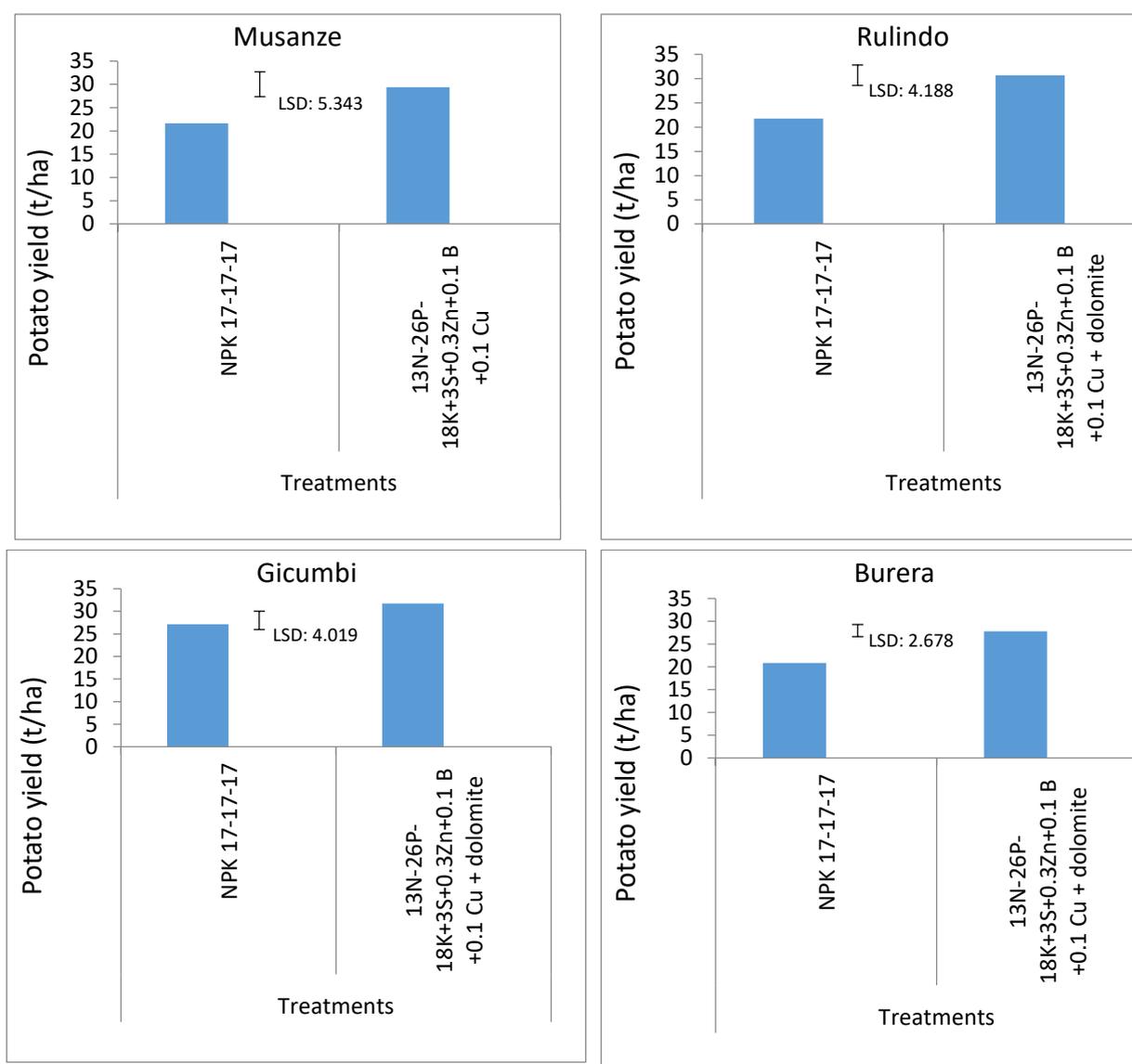
Figure 15: Potato yield of current fertilizer (NPK 17-17-17) and blend new fertilizer formula (13- 26-18+3S+0.3Zn+0.1 B +0.1 Cu; 13N13N-26P-18K+3S+0.3Zn+0.1 B + 0.1 Cu + dolomite) in Northern Province

Value cost ratio

The RAB blended fertilizer formula for potato increased VCR by 5.6, 6.0, 3.1, and 4.6 in Musanze, Rulindo, Gicumbi and Burera, respectively, as compared to the current recommendation (NPK 17.17.17). It is clearly shown that addition of secondary and micronutrients increased substantially fertilizer use return as the VCR is greater than 2 (Figure 16).
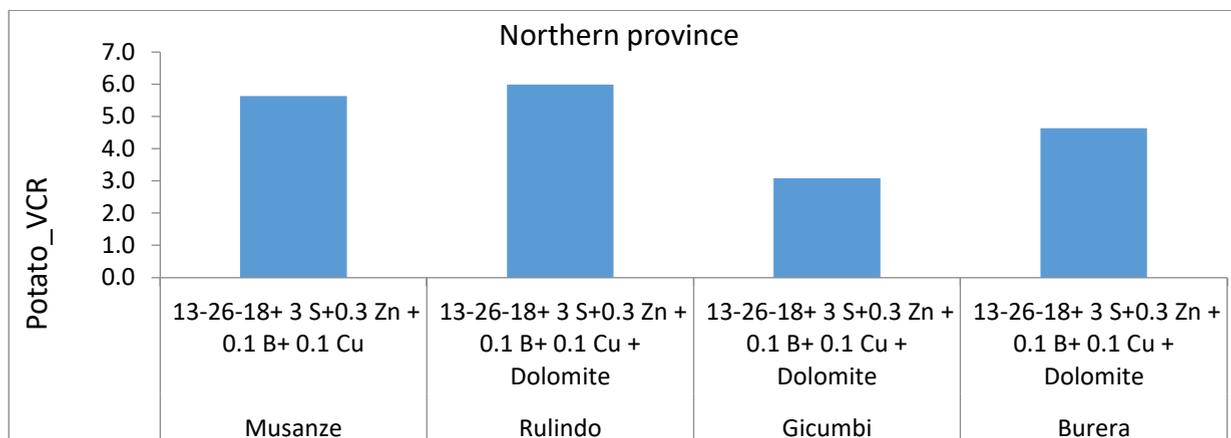
Figure 16: The VCR of RAB new fertilizer formulas on potato in Northern Province

Treatment effect on potato yield in Southern Province

The demonstration trials of new fertilizer formula (13N- 26P-18K+3S+0.3Zn+0.1 B +0.1 Cu + dolomite) and current blanket fertilizer recommended formula (NPK 17-17-17) on Potato were established in Southern province. The action sites were in Nyamagabe and Nyaruguru Districts. The analysis of variance has shown a significant difference between treatments (P<0.002). The results from Figure 17 indicated that the highest yield was obtained from RAB new fertilizer formula with 18.7 t/ha, 38.8 t/ha in Nyamagabe and Nyaruguru, respectively, as compared to 14.2 t/ha and 32.8 t/ha obtained from the current fertilizer recommendation. This is translated into yield increment of 4.5 and 6 t/ha respectively in Nyamagabe and Nyaruguru districts.
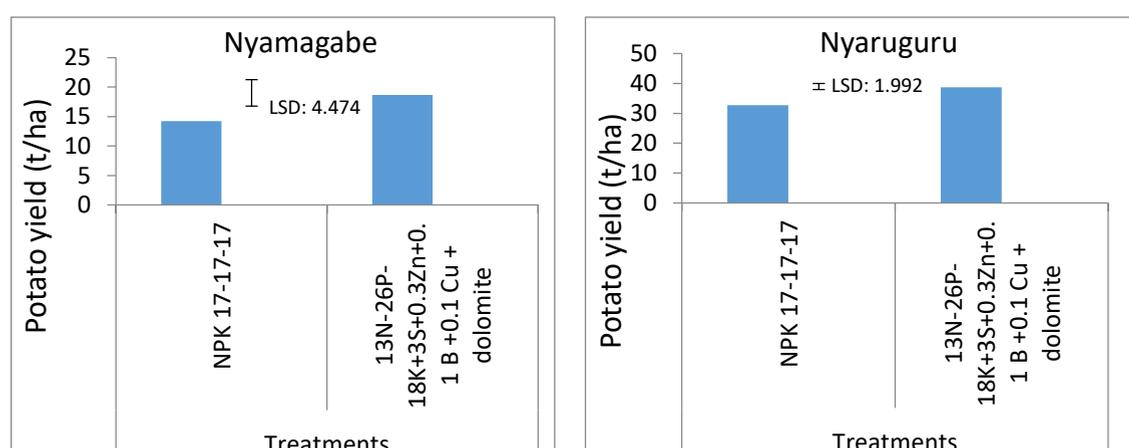
Figure 17: Potato yield of current fertilizer (NPK 17-17-17) and blended new fertilizer formula in Nyamagabe and Nyaruguru Districts

Value cost ratio

The RAB blended fertilizer formula for potato increased VCR by 3.0 and 4.0 in Nyamagabe and Nyaruguru, respectively, as compared to the current recommendation (NPK 17-17-17). It is

clearly shown that addition of secondary and micronutrients increased substantially fertilizer use return as the VCR is greater than 2 (Figure 18).
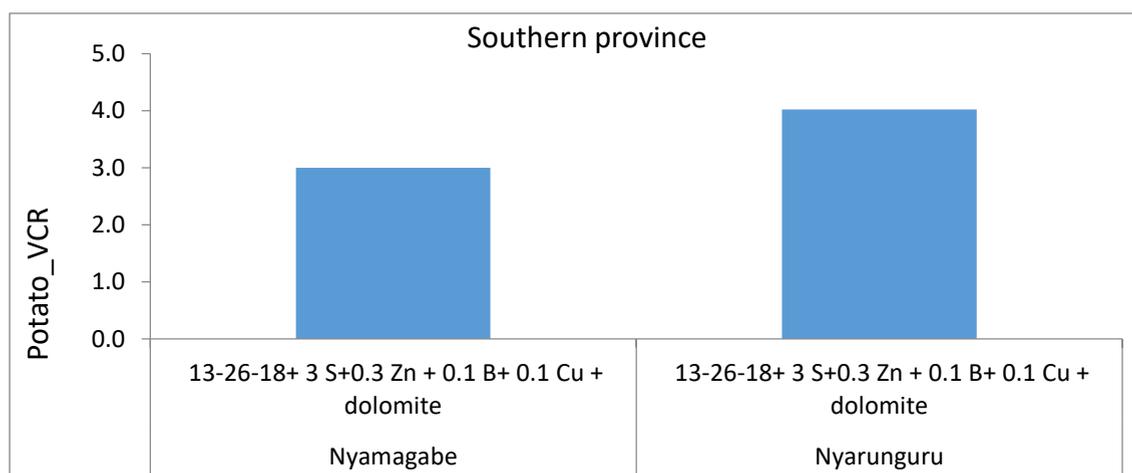
Figure 18: The VCR of blended new RAB fertilizer formula on Irish potato in Southern Province

Treatment effect on potato yield in Western province

In Western province, the demonstration trials were implemented in non-volcanic soils in Ngororero and Rutsiro Districts, in volcanic soils in Rubavu and Nyabihu Districts. The results of yield obtained from the current blanket recommendation and the new fertilizer formula are illustrated by the Figure 19.

In non-volcanic soils, the treatments were highly significantly different (p= 0.006) whereby 27.3 t/ha was obtained from the new developed fertilizer recommendation as compared to20.17 t/ha obtained from the current blanket fertilizer formula (NPK), which translates into yield increment of 6.1 t/ha. In volcanic soils (Rubavu and Nyabihu), the treatments were also highly significantly different (p< 0.001). The highest yield of potato tubers was observed in 13N- 26P-18K+3S+0.3Zn+0.1 B +0.1 Cu with 35.61 t/ha as compared to 30.41 t/ha from the current blanket fertilizer recommendation (NPK 17-17-17). This resulted in yield increase of 5.2 t/ha. Across all provinces, addition of secondary and micronutrient to NPK increased potato tuber yield significantly. These yield increases are due to the addition of secondary and micronutrients, which some of them were found deficient in Rwandan soils.

Value cost ratio

The RAB new fertilizer formula (13- 26-18+3S+0.3Zn+0.1 B +0.1 Cu + dolomite) recorded VCR of 4.8 (Figure 20) in non-volcanic soils and 3.8 in volcanic soils of western zone. In both soil types, the obtained VCR greater than 2 can suggest that the new RAB fertilizer formula is more profitable than current blanket recommendation where 1USD investment can generate 4.8 and 3.8 times the invested capital.
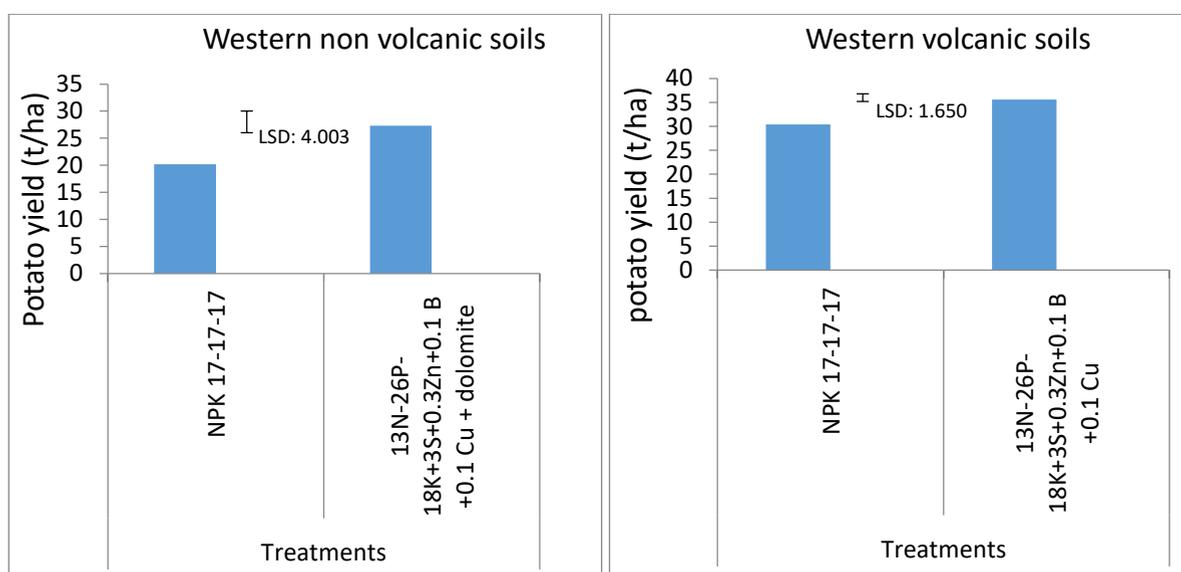
Figure 19: Potato yield of the current blanket fertilizer recommendation (NPK 17-17-17) and the new fertilizer formulas (13- 26-18+3S+0.3Zn+0.1 B +0.1 Cu + dolomite) in non-volcanic and (13- 26-18+3S+0.3Zn+0.1 B +0.1 Cu) in volcanic soils of Western Province
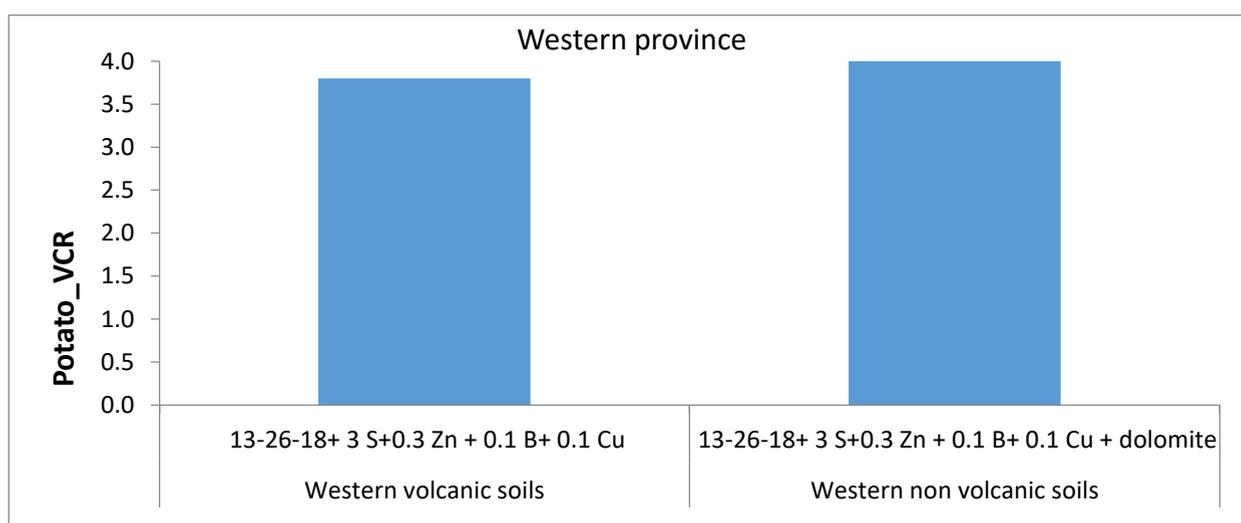
Figure 20: The VCR of RAB new fertilizer formulas on potato in Western Province

The response of Rice to blended and current blanket fertilizer recommendation (NPK)

The demonstration trials on rice were established in Rwandan marshlands namely Bugarama in Western province, Cyili, Rugeramigozi, Rwasave, Rusuli and Mukunguri in Southern province, Cyabayaga, Cyunuzi, Cyaruhogo and Kanyonyomba in Eastern Province. The new blended fertilizer formulas composed by primary, secondary and micronutrients (12N-20P-20K +5S + 0.3 Zn + 0.2B, 0.2 Cu) and (12N-20P-20K +5S + 0.3 Zn +0.2B) were evaluated against the current fertilizer recommendation (NPK) in Eastern, Southern and Western province,

respectively. The analysis of variance revealed highly significant difference ($p<0.0001$) between treatments.

The new fertilizer formula12N-20P-20P +5S + 0.3 Zn + 0.2B, 0.2 Cu used in Eastern and Southern provinces recorded the highest grain yield of 7.8 t/ha and 6.6 t/ha compared to 5.6 and 4.9 t/ha respectively (Figure 21). Similarly, the new formula 12N-20P-20K +5S + 0.3 Zn +0.2B used in Bugarama recorded the highest grain yield of 7.4 t/ha as compared to 5.5t/ha obtained in the current blanket fertilizer recommendation. Thus, the RAB new fertilizer formula increased rice grain yield by 1.7, 2.2, and 1.9 t/ha in Southern, Eastern and Western marshlands, respectively.
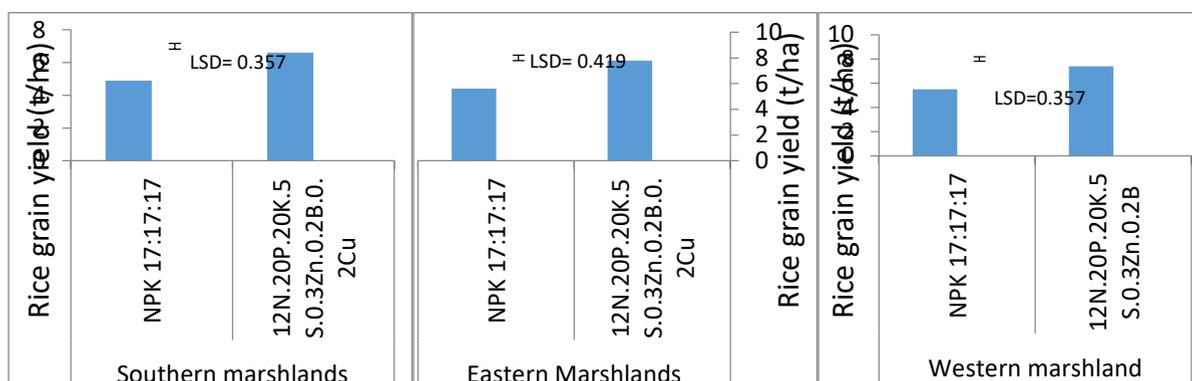
Figure 21: Rice grain yield of the current blanket fertilizer recommendation (NPK 17-17-17) and the new fertilizer formulas (12N-20P-20K +5S + 0.3 Zn + 0.2B, 0.2 Cu) in Eastern and Southern and (12N-20P-20K +5S + 0.3 Zn +0.2B) in Western Provinces

Value cost ratio

The blended RAB new fertilizer formula which included primary, secondary and micronutrients generated a VCR of 2.3, 3, and 2.9 in Southern, Eastern and Western marshlands of Rwanda, respectively (Figure 22). The obtained values of VCR greater than 2 imply that the new fertilizer formulas are economically profitable and thus worthy of being recommended for rice production.
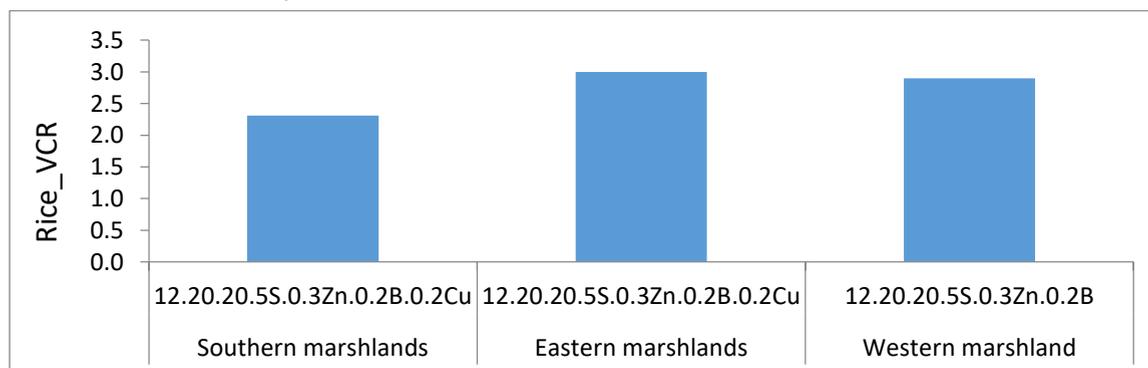
Figure 22: The VCR of RAB new fertilizer formulas on rice for Eastern, Southern and Western Provinces

The response of maize to new blended and current blanket fertilizers in Eastern province

The analysis of variance showed that treatments were very highly significant (P=0.001) but the interaction between treatments and sites was not significant (P=0.289). The current fertilizer recommendation (NP:18.46) recorded 5.1t/ha and the new developed fertilizer formula for maize which combines macro, secondary and micro nutrients (NPS Mg Ca Zn Cu B: 18-33-0-6S-0.4Zn-0.2B-0.2Cu + dolomite) yielded 6.7t/ha. Addition of secondary and micronutrients increased maize grain yield by 1.6 t/ha in eastern province (Figure 23).
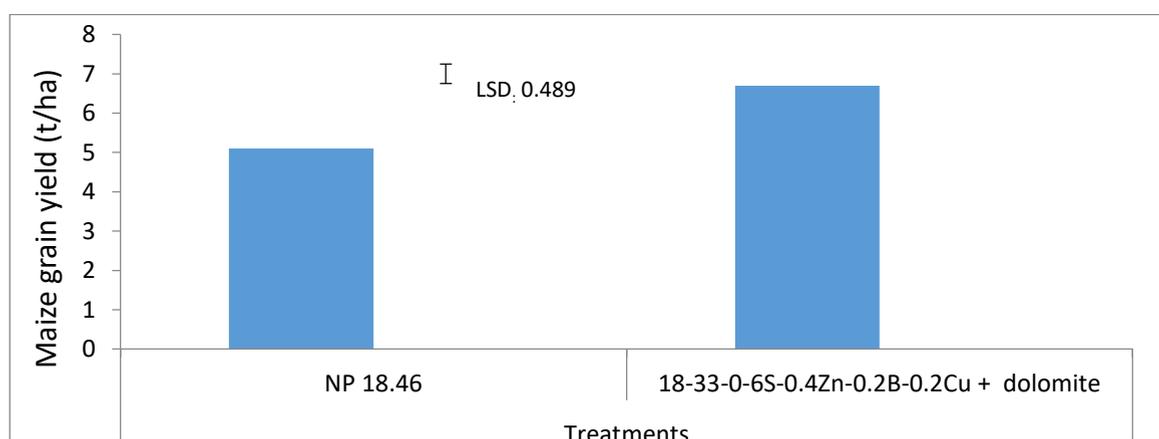
Figure 23: Maize grain yield of the current blanket fertilizer recommendation (NP) and the new blended fertilizer formula (NP S Mg Ca Zn B Cu) in Eastern province

The response of maize to new blended and current blanket fertilizers in Southern province

In the southern province, two formulas were evaluated against the current blanket fertilizer recommendation due to the site-specific characteristics. Formula 1:18-33-0-6S-0.4Zn-0.2B-0.2Cu + dolomite was evaluated in the district of Nyanza, Ruhango, Muhanga, Gisagara, and Kamonyi and formula 2:13-24-16-4S-0.3Zn-0.2B-0.2Cu + dolomite was tested in Nyaruguru district. The analysis of variance showed that treatments were highly significant (P= 0.001) and the interaction between treatments and site was not significant (P= 0.864). Current fertilizer recommendation (NP: 18.46) recorded 4.6 tha[-1] and the new developed fertilizer formula 1(NPS Mg Ca Zn Cu B: 18-33-0-6S-0.4Zn-0.2B-0.2Cu+ dolomite) yielded 6 t/ha. Addition of secondary and micronutrients in formula 1 increased maize grain yield by 1.4 t/ha compared to the current fertilizer recommendation. Similarly, formula 2, increased maize grain yield by 1.2 t/ha from 4.3 to 5.5 t/ha above the current fertilizer recommendation in Nyaruguru district (Figure 24).
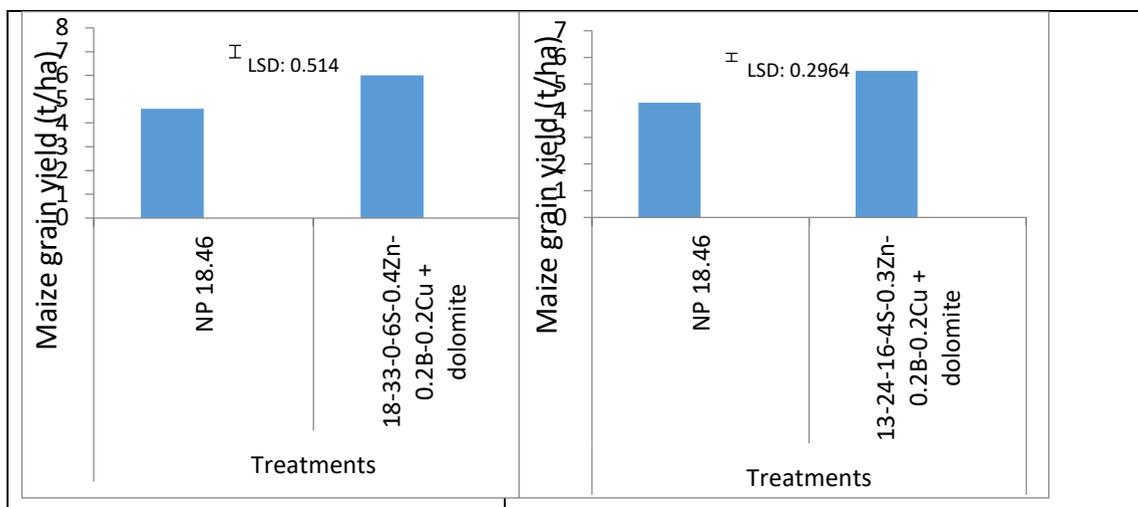
Figure 24: Maize grain yield of the current blanket fertilizer recommendation (NP) and the new blended fertilizer formulas (NP S Mg Ca Zn B Cu) and NPKS Mg Ca Zn B Cu in southern province

The analysis of variance showed that treatments were highly significant (P=0.006). The new developed formula NPS Zn Cu B (18-33-0-6S-0.4Zn-0.2B-0.2Cu) recorded 7.2 t/ha while the current fertilizer recommendation (NP18-46) yielded 5.6t/ha. Addition of Sulfur and micronutrients increased maize grain yield by 1.6t/ha (30%) in volcanic soils (Figure 25).
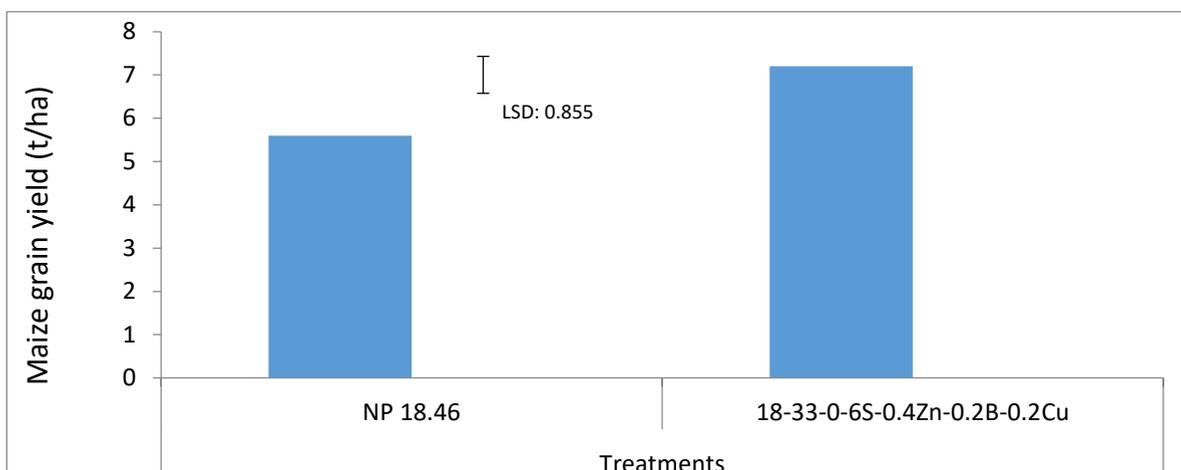
Figure 25: Maize grain yield of the current blanket fertilizer recommendation (NP) and the new blended fertilizer formula (NPS Zn B Cu) in volcanic soils of Rwanda

The response of maize to new blended RAB developed formula in non-volcanic soils of Northern Province

For non-volcanic soils of Northern Province, the new fertilizer formula was tested in the districts of Gakenke, Rulindo, Burera and Gicumbi. The analysis results showed that treatments are significant (P=0.005) and the interaction between treatments and sites are

not significant (P=0.915). The new developed formula (NPKS Mg Ca Zn Cu B: 13-24-16-4S-0.3Zn-0.2B-0.2Cu + dolomite) for non-volcanic soils of Northern Province yielded 5.3 t/ha while the current fertilizer recommendation (NP 18.46) registered 4.3t/ha (Figure 26). Addition of potassium, secondary and micronutrients increased maize grain yield by 1t/ha equivalent to 23%.
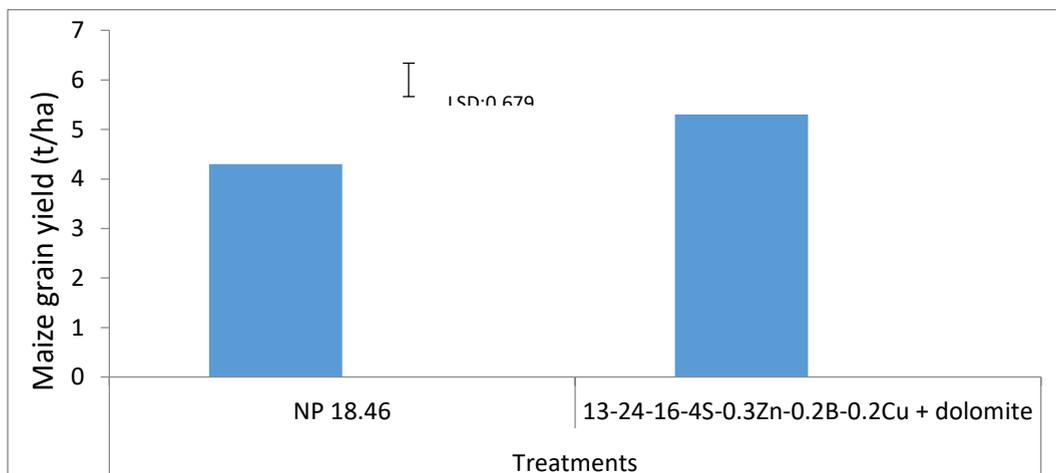
Figure 26: Maize grain yield of the current blanket fertilizer recommendation (NP) and the new blended fertilizer formula (NPK S Mg Ca Zn B Cu) in non-volcanic soils of Northern Province

The response of maize to new blended and current (NP) fertilizers in Western Province

The trials were established in non-volcanic soils of western province in Ngororero, Rutsiro, Karongi, Nyabihu, and Rusizi districts. The analysis results showed that treatments were highly significant (P=0.003) and the interaction between treatments and sites was not significant (P=0.921). The highest yield of 6.2 t/ha was obtained from the newly developed formula NPKS Mg Ca Zn Cu B (13-24-16-4S-0.3Zn-0.2B-0.2Cu + dolomite) as compared to 5t/ha recorded from the current recommendation (NP 18.46). An increase of 1.2t/ha (24%) above the current fertilizer recommendation was could be induced by addition of potassium, secondary and micronutrients (Figure 27).
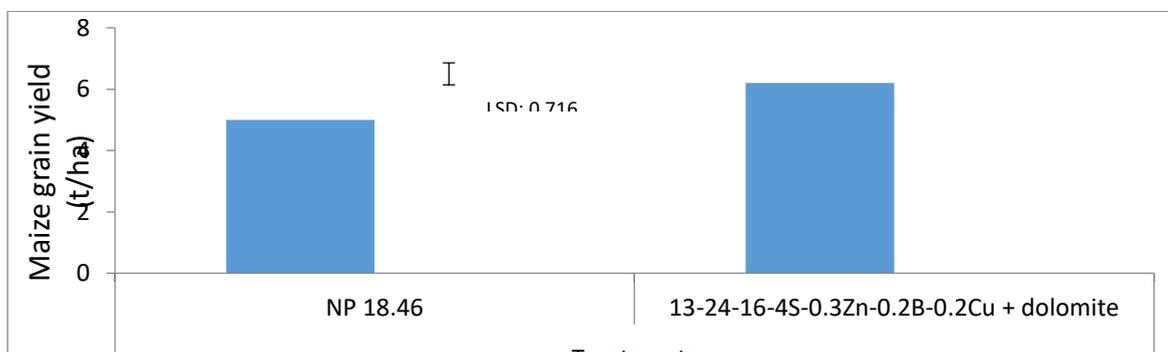
Figure 27: Maize yield with current blanket fertilizer recommendation (NP) and the new blended fertilizer formula (NPK S Mg Ca Zn B Cu) in non-volcanic soils of Western Province

Valu*e cost ratio for maize demonstration trials*

The blended RAB new fertilizer formulas, which included primary, secondary and micronutrients generated a VCR greater than 2 in Eastern province, volcanic soils of Rwanda and Southern Province. Thus, these new fertilizer formulas are more economically profitable. In non-volcanic soils of northern and western province the new fertilizer formulas are slightly economically profitable due to high price of dolomite yet the maize prices are low. In general, new fertilizer formulas are more profitable compared to the current blanket fertilizer recommendation (Figure 28).
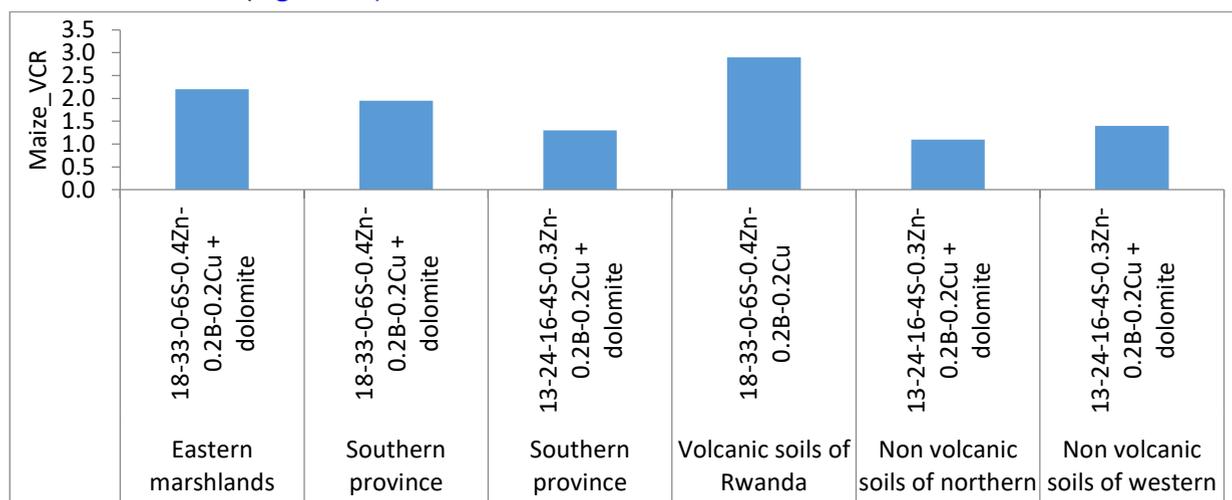
Figure 28: The VCR of RAB new fertilizer formulas on maize in Eastern, Southern, Northern and Western Provinces

Participatory evaluation of the fertilizer performance through Farmer Field Day (FFD) and awareness creation

Besides the collected agronomic data, a participatory evaluation of the performance of the RAB new fertilizer formula vs the current blanket fertilizer recommendation was conducted in demonstration plots through farmer field days. The objective of the demonstration trials was to serve as learning sites where farmers are trained on new adapted fertilizer formulas and agronomic practices for increasing crop productivity. They also serve for awareness creation on the performance of the new fertilizer products. The farmer field days were organized as to demonstrate to farmers the advantage of new blended RAB fertilizer formulas over currently used blanket fertilizer recommendation and discuss the benefit of new improved plant nutrient balance and share the successful stories from demo trials hosted by farmers (Photo 17). The event involved different stakeholders in agriculture including policy makers, researchers, representative of OCP Africa, local administration, extension agents, oversight input distributors (APTC), media, and farmer's organizations. Four main farmers field days event were officially launched in the four provinces for the three crops used for demonstration trials. In the Eastern Province, the event was organized on 31st October 2017 under rice demos in Cyunuzi marshland located in Gatore sector, Kirehe district. This event

on which about 200 persons from different institutions and farmers attended was officially launched by Dr Telephore Ndabamenye, the Head of Crop production and food security department (RAB), representing the Director General. Among other officials who participated in this event include the Mayor of Kirehe District in charge of Economic Development, the Business Developer and Proximity to farmers at APTC and the Head of Eastern Agricultural Zone Division in RAB. The overall observation of the participants was the high performance of the new fertilizer formula based on status of various rice growth parameters such plant height, tillers, panicle length.

Photo 17: Tour visit of participants on rice demos during farmer field day in Cyunuzi marshland, Kirehe District

In the Northern Province, the farmer field day was held on 29th November 2017 in Buyoga and Kisaro setors, Rulindo district around Irish potato demonstration trials. The event was attended by a total number of149 participants including RAB staff, representative of local administration at cell, sector and district levels, agronomists of sector and district, representative of OCP Africa, farmer cooperatives and farmers. The official launch of the event was done by Dr Patrick Karangwa, actual Ag. Director General of RAB who was leading the research department at that time and representing the former Director General. The Agronom of district was representing the Major in this event. The perception of participants from physical observations of the Irish potato demos was that the RAB new fertilizer formula was highly performing as compared to the current blanket fertilizer recommendation (Photo 18).

Photo 18: Tour visit of participants in the demo plots in Rulindo District (left - RAB new blended fertilizer plot, right – plot with currently used blanket fertilizer recommendation

In the Western Province, the farmer field day was held in Bigogwe sector of Nyabihu district on 30th November 2017 in Irish potato demonstration trials. The event was attended by about 250 participants including researchers and extensionists from RAB, local administration, farmer cooperatives and individual farmers. The officials who attended this event included the current Ag. Director General of RAB as Guest of honor, the Executive secretary of the district representing the Mayor, and the Head of western agricultural zone division. During the visit tour of participants around the Irish potato demo plots, the same observation was noticed whereby the RAB new fertilizer formula revealed better performance as compared to the current blanket fertilizer recommendation (Photo 19).

Photo 19: Tour visit of participants assessing Irish potato response on types of fertilizers in Nyabihu District

In the Southern Province, the farmer field day was officially launched on 4th January in Bweramana sector, Ruhango district by Dr Patrick Karangwa, actual Ag Director General of RAB. The event was organized around maize demonstration trials where the two types of fertilizers (RAB new fertilizer formula and the current blanket fertilizer recommendation) were evaluated. As in other sites, participants to this event totaling 210 were composed by

researchers and extensionists from RAB, sector and district agronomists, local administration representatives, farmer cooperatives and individual farmers. The event was also attended by the Vice Mayor in charge of Social Affairs of Ruhango District representing the Mayor. The higher performance of the RAB fertilizer formula against the current blanket fertilizer recommendation was also observed on maize demos during this field tour visit (Photo 20).

Photo 20: Tour visit of participants in maize demos during farmer field day in Ruhango District

Newly developed blended fertilizer formula with macro- and micro-nutrient combinationas developed by RAB have demonstrated superior yields on Irish potato, maize and rice across the whole country. The Value Cost Ratio analysis of these fertilizer formulas has shown that they can generate much higher profits. The next step will be availing the blended fertilizers on the local market widely.

1.2.2 Forestry and Agroforestry

Use of agroforestry stakes to increase bean yields

Climbing beans have shown a high potential of about twice the yield of bush bean on a small area as the crop allows exploitation of the aerial surface. However, adoption of climbing bean production in Rwanda is faced with the challenge of finding suitable staking materials which is prerequisite for high yield potential. Farmers use locally collected low quality stakes materials such as pennisetum and maize stalks. Adoption of agroforestry stakes such as alnus, grevillea, calliandra and leucaena can reverse the traditional practice by providing long durability stakes that can be used several times and in several seasons. The objective of this study was to determine whether the use of tree stakes increases climbing bean yields compared to conventional staking methods.

On farm trials experiments with agroforestry climbing bean stakes have been set up in Bugesera, Nyabihu and Rubavu districts. The designs comprised different options to compare under boundary conditions of household characteristics (gender, land size). These options were (i) planting of beans without stakes, (ii) farmers practice of supporting beans with *Pennisetum purpureum* (elephant grass), and (iii) supporting climbing beans with wood material from agroforestry such as *Alnus acuminata*, *Acacia angustissima* and *Arundinaria alpina*. Data were collected using Open Data Kit (ODK) Tool on bean yields, stake length and resistance, number of stakes harvested per tree, circumference of the stakes, coppicing/ sprouting rate ability, duration of use and number of seasons, for which the same stakes were used. In Bugesera, Rubavu and Nyabihu districts, 122 participatory trials involving the use of tree stakes for climbing bean have been established as follows: 53 trials in Rubavu and Nyabihu and 69 trials in Bugesera.

In various Bugesera sites, the yield of climbing beans varied among the farmers, sites and types of wood stakes used. In general the yield of climbing bean supported by agroforestry stakes was nearly double that of bush beans (Figure 29), especially, in Mareba, Musenyi and Rweru, suggesting more favourable soil conditions for growing beans and improvement of climbing bean yields when wood stakes are used.
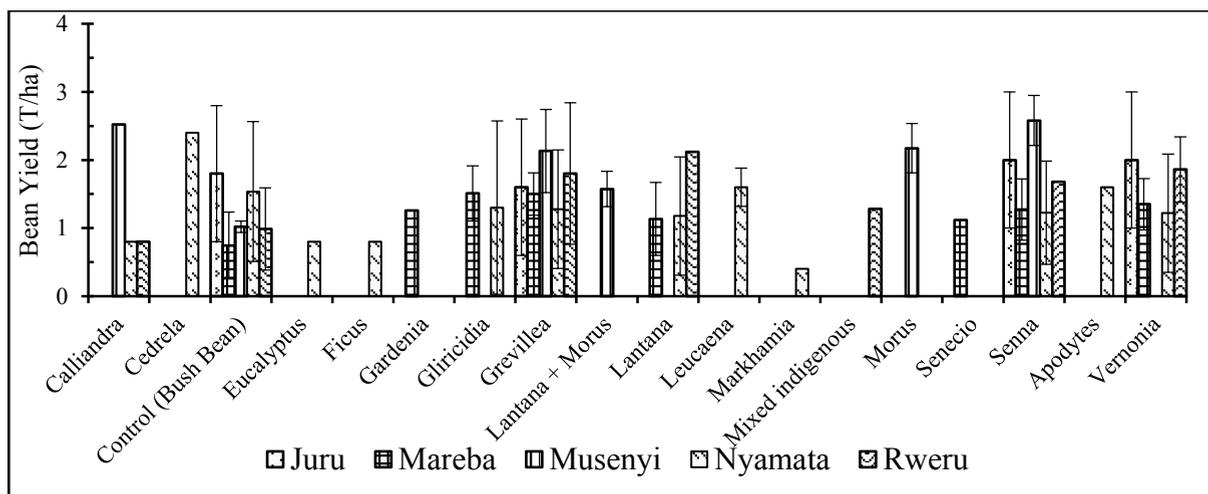
Figure 29: Yield of climbing bean staked by different types of agroforestry stakes in the sectors of Juru, Mareba, Musenyi, Nyamata and Rweru. Error bars are standard deviation of bean yields in t/ha.

In Rubavu district, especially at Nyundo sector, the bean crop was damaged by heavy rain during season 2017B and lower yields were recorded. Irrespective of stake types, the average yields was about 172 kg/ha, well below the national average of 0.9MT/ha. Figure 30 indicates that climbing bean yield was the highest when *Acacia angustissima* stakes were used in four on-farm trials but alnus and pennisetum stakes led to the same yield of climbing bean.
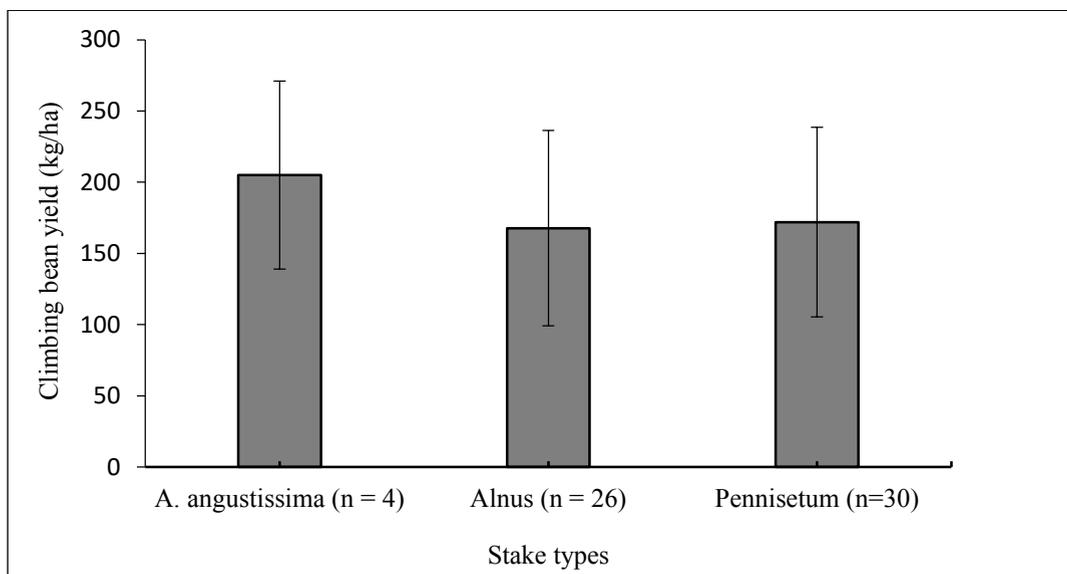
Figure 30: Average yield of climbing bean recorded in 60 on-farm participatory trials involving stakes of Acacia, Alnus and Pennisetum spp. at Nyundo Sector.

The yield of climbing bean did not seem to be affected by the different types of agroforestry stakes being used by the farmers but in general, the yields of climbing beans were higher than those of bush bean. Differences in yields were evident among the sites reflecting the influence of biophysical conditions and land management practices by the farmers. These differences among sites and inconsistent relationships between bean yields and types of agroforestry stakes complicate the prediction of the effect of stake types on crop yields. This warrants the development of a basket of options, from which farmers may select the options that they consider most relevant for their particular socio economic characteristics in their geographical locations. The next step of the research is to extend the network of agroforestry stakes across a range of options and contexts and to assess the durability and frequency of the use of wood stakes.

Green tree biomass incorporation for soil fertility improvement

The major agronomic constraint to crop production in Rwanda is soil fertility. Shifting cultivation and fallows are not practical to restore soil conditions as agriculture is continuously done on small farm sizes, which leads to depletion of soil nutrients, decreased organic matter, and increased risks of soil erosion. These factors combine to reduce crop yield. Inorganic fertilizers play an important role in maintaining and increasing soil fertility, but many farmers either do not obtain the necessary returns from fertilizer use to justify the costs or cannot afford to use inorganic fertilizer if government subsidies on fertilizer are not provided. The improvement of soil organic matter is critical for smallholder farmers. Agroforestry has the potential to produce sufficient high quality biomass to increase soil organic matter and improve crop yields. However, farm trials are needed to understand the

interactions between different agroforestry biomass and to describe the response to applied biomass. Results from farm trials needs to be interpreted with an understanding of the socio-economic circumstances faced by farmers so that adapted technologies developed. This research examine, through on-farm participatory trials, the way in which tree biomass incorporation improve soil fertility more effectively compared to use of mineral fertilizers.

Participatory tree biomass incorporation trials have been established in various sites across the districts of Bugesera, Nyabihu and Rubavu to determine how incorporation of biomass of different agroforestry species (*Alnus acuminata, Alnus nepalensis*) applied alone, mineral. Fertilizer applied alone and combination of tree biomass and mineral fertilizer improve soil fertility and consequently crop yield. The trials were established over a range of soil types and associated crops. In Nyabihu and Rubavu, yield response to fertilizer application was made for maize and Irish potato while in Bugesera, the crop test was bush bean during season 2017B. Data collection was made by using ODK tools and comprised initial data on farmer profiling/characterisation and crop yields.

At Bahimba, overall yields of maize was 5.8 T/ha. There was no significant different ($p < 0.05$) in the yields of maize across the application of different types of fertilizers but DAP alone produced relatively lower yields compared to the remaining fertilizer applications (Figure 31). Alnus biomass combined with DAP produced the same maize yield as in the control plots suggesting that farmers incorporate other sources of organic matter in their farms to improve soil fertility. It is worth to note important yield variations mainly due to differences in soil conditions across the range of farm trials.
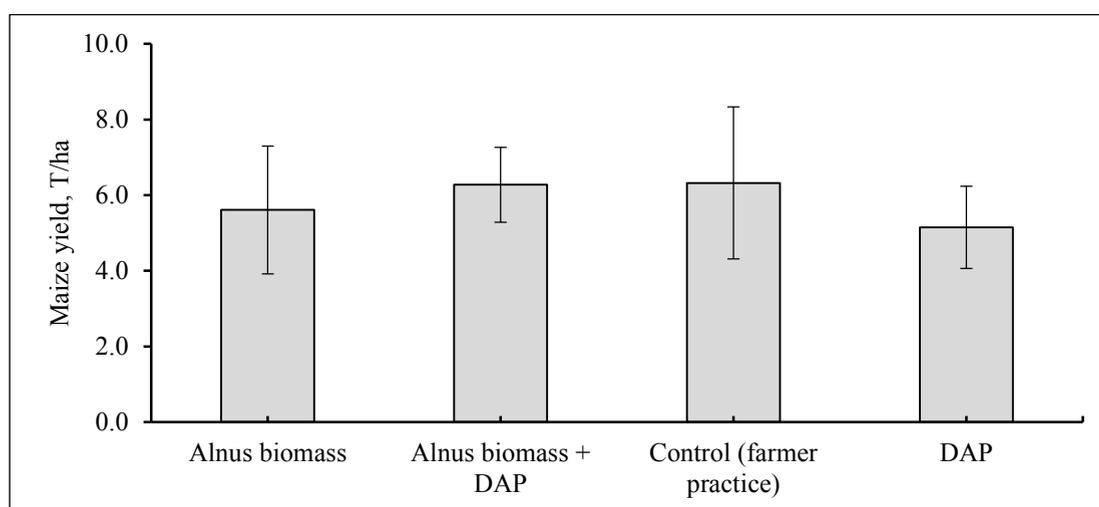
Figure 31: Maize yield response to application of different fertilizers at Bahimba

Irish potato yield response to application of different fertilizers at Kadahenda is shown in Figure 32. The average yields ranged from 3.7 T/ha to 5.2 T/ha, with the highest yield being

recorded in plots where application of alnus biomass combined with NPK was done. Alnus biomass alone did not significantly improve potato yield (3.7 T/ha) more than farmer practices of soil fertility improvement (3.9 T/ha) and application of mineral fertilizer alone (4.3 T/ha).
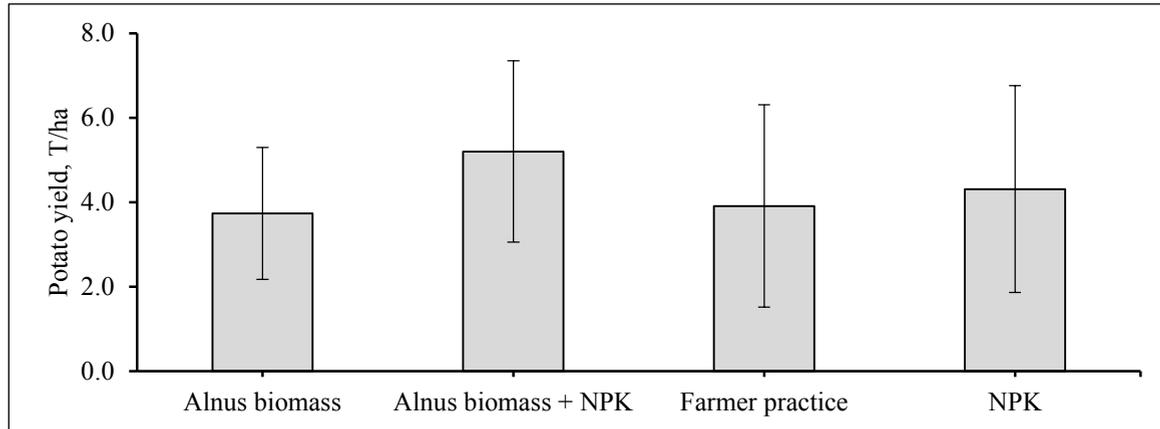
Figure 32: Irish potato yield response to application of different fertilizers at Kadahenda

At different sites in Bugesera, bush bean yield has been higher in fertilized plots than in the control plots (Figure 33). In general, bean yield response to the application of tree biomass alone and tree biomass combined with DAP and Urea was higher than yields under farmer practice and DAP combined with Urea. However, application of tree biomass alone and its combination with DAP and urea appear to produce similar effect on bean yield. Only significant differences in bean yields were obtained between the application of vernonia biomass and vernonia biomass combined with DAP and urea. Overall, the use of tree biomass and its combination with mineral fertilizer produce more bean yield than application of mineral fertilizer only.
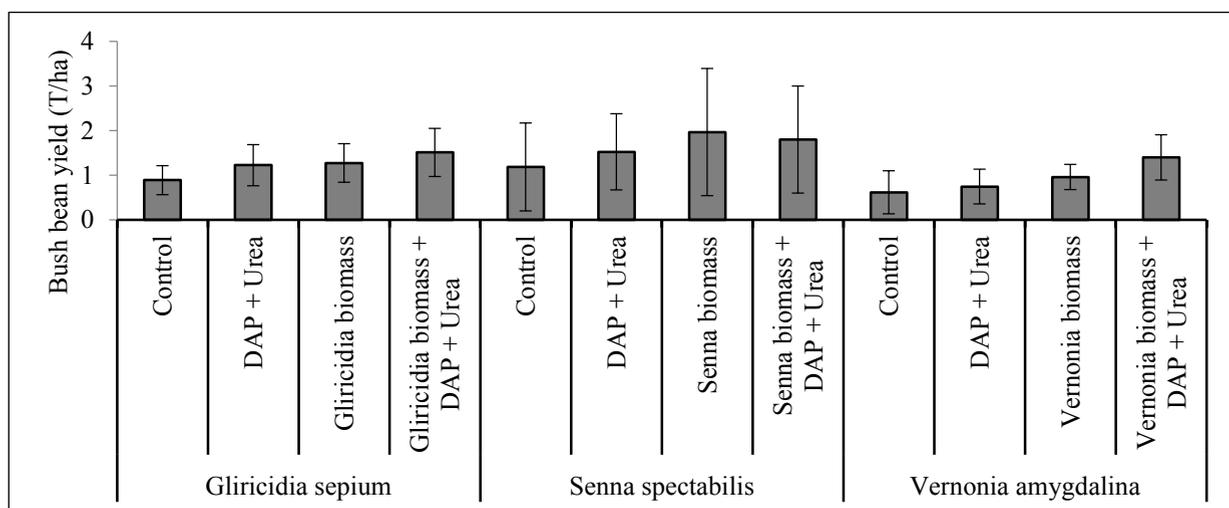
Figure 33: Bush bean yield response to application of tree biomass and mineral fertilizers in Bugesera

The preliminary results from on-farm participatory trials tend to indicate that application of tree biomass to soil improves crop yield compared to mineral fertilizer and more so when tree biomass is combined with mineral fertilizer. However, reliance on tree biomass could have limitations in areas where nutrients are limiting. If the potential of agroforestry tree biomass is to be realized, a strategy for addition of mineral fertilizer needs to be adopted to satisfy nutrient requirements from mineral fertilizer sources. Agroforestry tree biomass may therefore have its greatest impact on those farmers who can have afford some mineral fertilizer and this is possible through the input subsidy program in Rwanda. Future research will consist in the expansion of the network of tree biomass incorporation farm trials through a range of options by contexts so that results could be generalized at regional level (Agroecological zone, District, Sector, Cell) under the boundary conditions of household socio-economic characteristics.

Indigenous tree species screening trials for their agroforestry potential

In Rwanda, trees and shrubs are grown in association with crops by farmers to increase and diversify farm products. To date, the majority of agroforestry tree species are exotic with the indigenous ones being represented by few individuals in the agricultural landscape. The new initiatives in agroforestry are seeking to integrate indigenous tree species into farming systems. There is very little information about initiatives to domesticate indigenous tree species for use in agroforestry systems. The domestication of indigenous tree species for use in agroforestry must be carried out with the view of enhancing their capacity to provide services and products. At the same time, they should increase the social and economic benefits through improved profitability, reduced risks and diversified income sources, thereby serving for increased agricultural productivity. This research is carried out with the aim of assessing the potential of Rwanda indigenous tree species in agroforestry systems. The main objective of the research is to diversify the range of agroforestry species to incorporate in the farming systems by identifying indigenous tree species having an agroforestry potential. The specific objectives are to: (i) evaluate the performance of already well known indigenous MPTs outside their natural habitat (in open farmland) and (2) assess the compatibility of these MPTs with crops.

Experiments for screening of multipurpose indigenous tree species (MITs) were established in Ruhande and Rubona in 2009 to to test the suitability of indigenous tree species as upperstorey trees in croplands. The treatments consisted of nine indigenous tree species namely *Entandrophragma excelsum, Syzigium parvifolium, Markhamia platycalyx, Pterygota mildibraedii, Erythrina abysinica, Polyscias fulva, Maesopsis eminii, Croton megalocarpus* and *Ficus thonningii*. The design comprised also a control treatment, for which no tree species was present. These treatments were arranged in randomized complete block designs, replicated three times, both at Ruhande and Rubona. The indigenous trees species were

planted in blocks, spaced with 2.5 m apart, with a plot containing about 30 trees. Each season, crops were raised in each plot. Data on crop yields and growth of trees were collected each season. Each tree species occupied a plot of 12.5 m by 10 m or 125 m². During 2017B season and 2018A, bean and maize crops were established under these indigenous tree species. During these seasons, data on tree growth and crop yields were collected and analysed using MS Excel and Genstat 14.0 Software.

At Rubona, in season 2017B, bean yield in the tree-crop systems was very low and ranged from 0.8 tons per ha to 1.8 tons per ha. Higher yield greater than that in the control plot (1.4 tons/ha) was reached only in the bean-ficus agroforestry system (1.8 tons/ha), representing an increase of about 23.5% relative to the control (Figure 34). In the podocarpus plot, there was only a slight increase in bean yield of 1.2%. The presence of trees reduced bean yield by 18 to 42% in the remaining tree-crop systems. Higher decrease in bean yields, higher than 20% was found in the systems made up of *Croton megalocarpus* (42%), *Polyscias fulva* (42%), Pterygota *mildbraedii (32%)*, *Markhamia platycalyx* (25%) and *Erythrina abyssinica* (21%). The least decrease in yield was in plots of *Polyscias fulva* (19%) and *Syzygium parvifolium* (18%). These declines in bean yields could be linked with higher densities of trees and heavy branching of some tree species that reduces light interception by the crop on the ground layer.
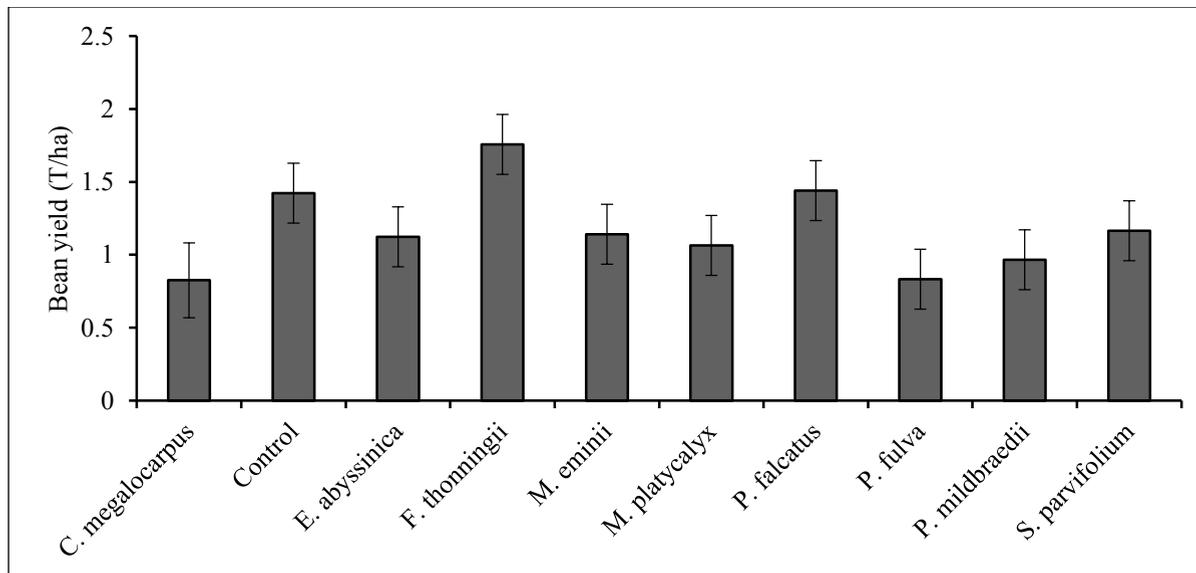
Figure 34: Bean yields in crop-tree systems at Rubona

At Rubona during season 2018B, maize was cropped in the plots composed of the nine indigenous tree species and in the control plot without trees. The average maize grain yield was 1.5 tons/ha (Figure 35). However, there were very significant differences in yields among the crop-indigenous tree systems. Pairwise comparison of means using Student-Newman-Keuls test revealed three groups of crop-tree systems having statistically similar maize grain

yields. The highest maize yield was recorded in Ficus plots but it was not significantly different from the yields in the control plot (without trees) and under the trees of *E. abyssinica*, *P. falcatus* and *M. platycalyx*. Being in the same group with the control, these four tree species appear to be less competitive to crops probably due to their development stage that does not cause below and underground competition for light, nutrient and water. Litter fall from Ficus has brought additional organic matter that improved soil nutrients and consequently more crop yield than in other crop-tree systems. Crop tree systems involving *P. fulva, S. parvifolium, M. eminii* and *C. megalocarpus* formed a group producing the lowest maize grain yields but not statistically different from the yield of *P. mildbraedii*. These species are fast growing to the extent that their heavy branching and rooting systems had induced competition on associated maize crop.
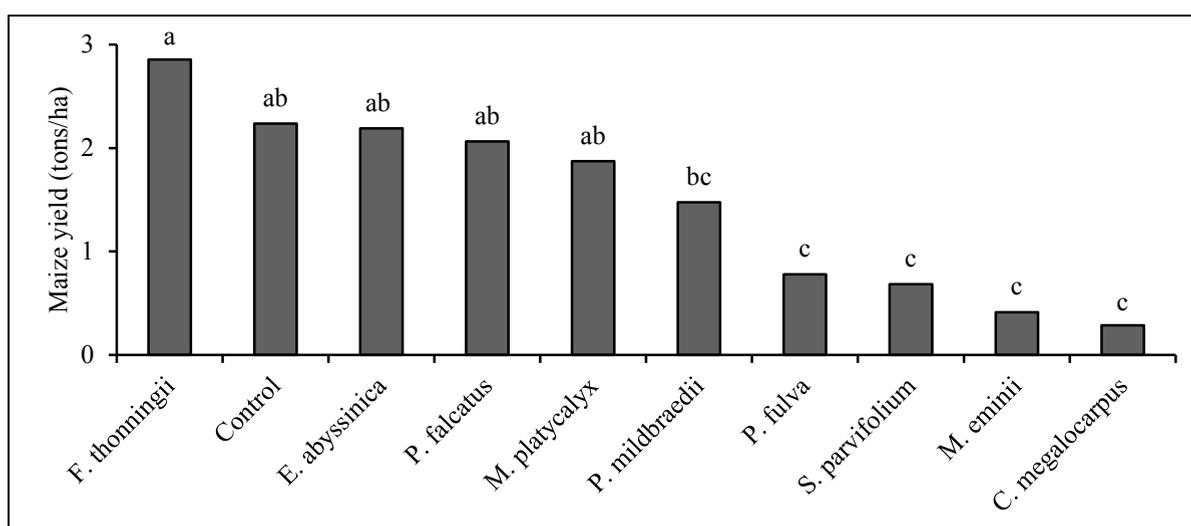
Figure 35: Maize yield in crop-tree systems at Rubona

Evaluation of adaptability of native tree species across different agro-ecological zones of Rwanda

In the Fiscal Year 2017-2018, adaptability of some highly valuable native tree species in three different altitudinal gradients of Rwanda was assessed. Underlying activities curried out were supported by the joint project between Rwanda Agriculture and Animal Resources Development Board (RAB) and the University of Gothenburg (UG) of Sweden since November 2016 through the Project entitled "*Tropical Montane Forest in a Worming World*". It is funded by Vetenskapsrådet (Swedish Research council). The project emphasises on native trees to reduce the knowledge gap regarding the potential impacts of global warming on tropical forests that is whether or not tropical tree species are close to an upper thermal limit above which they will experience heat stress and growth declines. The aim of the project is to assess the sensitivity of physiology, growth and competitiveness of tropical montane trees to increased temperature. The project aims to reduce a large uncertainty regarding the direct effects of high temperature due to lack of in situ warming experiments and co-variation of

temperature and drought in the field complicating causal interpretation inter-annual growth variability in monitoring plots or tree ring data.

Experimental plots of tropical tree species were established at three sites along an elevation gradient in Rwanda. These sites include Sigira site of Nyamagabe District (S 2° 30' 54"; E 29° 23' 44", Montane rain forest, 2400 m. a. s. l., 14.6 °C, 1750 mm), Rubona site of Huye District (S 2° 28' 30"; E 29° 46' 49", Transitional rain forest,1600 m. a. s. l., 19.1 °C, 1230 mm) and Ibanda Makera site of Kirehe District (S 2° 6'31"; E 30°51'16"E, Evergreen and semi-evergreen bushland and thicket, 1300 m. a. s. l., 21.0 °C, 850 mm). These sites are in elevation gradients because they offer the potential to study temperature responses of plants and ecosystems under ecologically realistic conditions.

Selection of tree species and trials establishment
Twenty native species were (10 climax and 10 pioneers) from Nyungwe National Park, refered here as "Afromontane rainforest species" (high elevation) and from Ruhande or Rubona Sites defined here as "Transitional rain forest species" (mid elevation) were selected ad propagated in the Rubona tree nursery (Table 46). The mix of climax and pioneer species was done in the trials because there are some indications that climax species are more sensitive to warming than pioneer species. In addition, in a temperature experiment with tropical seedlings, warming has a stronger negative effect on growth in climax species than in pioneer species.

Table 46. Selected native species from different ecological zones and successional groups

Afromontane rainforest species		Transitional rain forest species	
Pioneer	Climax	Pioneer	Climax
Bridelia brideliifolia	*Carapa grandiflora*	*Bridelia micrantha*	*Chrisophyllum gorungosanum*
Macaranga kilimandscharica	*Entandrophragma excelsum*	*Harungana madagascariensis*	*Markhamia platycalyx*
Harungana montana	*Faurea saligna*	*Dombeya torrida*	*Newtonia buchananii*
Maesa lanceolata	*Ficus thonningii*	*Croton megalocarpus*	*Podocarpus falcatus*
Polyscias fulva	*Syzygium guineense*	*Albizia gummifera*	*Prunus africana*

These species were collected from Nyungwe, Ruhande and Rubona, handled and propagated in Rubona nursery in 2016. The first plantation was done from December 2017 (at Sigira site) to March 2018 (Ibanda Makera and Rubona site). At each site, 1800 plants species were planted, making up 18 plots at each site (high, mid and low elevation sites). The size of each plot is 15 m by 15 m with plant spacing of 1.5 m over 1.5 m, allowing 100 plants per plot and thus six treatments in three replicates of each species.

Tree height (from top to the soil surface) was measured to the nearest cm with a measuring rod. Stem diameter was measured with calliper at 5 cm above the soil surface and recorded to the nearest 0.5 mm with a plastic manual calliper. The first measurements were taken two months after planting in March 2018. The second measuremts followed three months after the first measurement in July 2018. Dead trees were enumerated to calculate survival rate of each tree species in each site. Growth performance was calculated based on the ratio of tree height to stem diameter measured two times in December 2017 and July 2018. Survival rate was calculated from data taken at three months after planting.

After field planting, the survival rates of the 20 evaluated indigenous tree species were high, greater than 78% when all the data from the the sites of Sigira, Ibanda-Makera and Rubona are considered together. At Makere site, the survival rate of the majority of the tree species ranged from 94% to 100% with ecxception of Maesa lanceolata that recorded nearly 78%. At rubona the survival rate was also excellent for all the tree species, being in the range of 97% to 100%. At Sigira, the tree species survived at more than 98%. At the evaluation period, tree height was generally very high at Makera, followed by Rubona and least at Sigira (Figure 36).
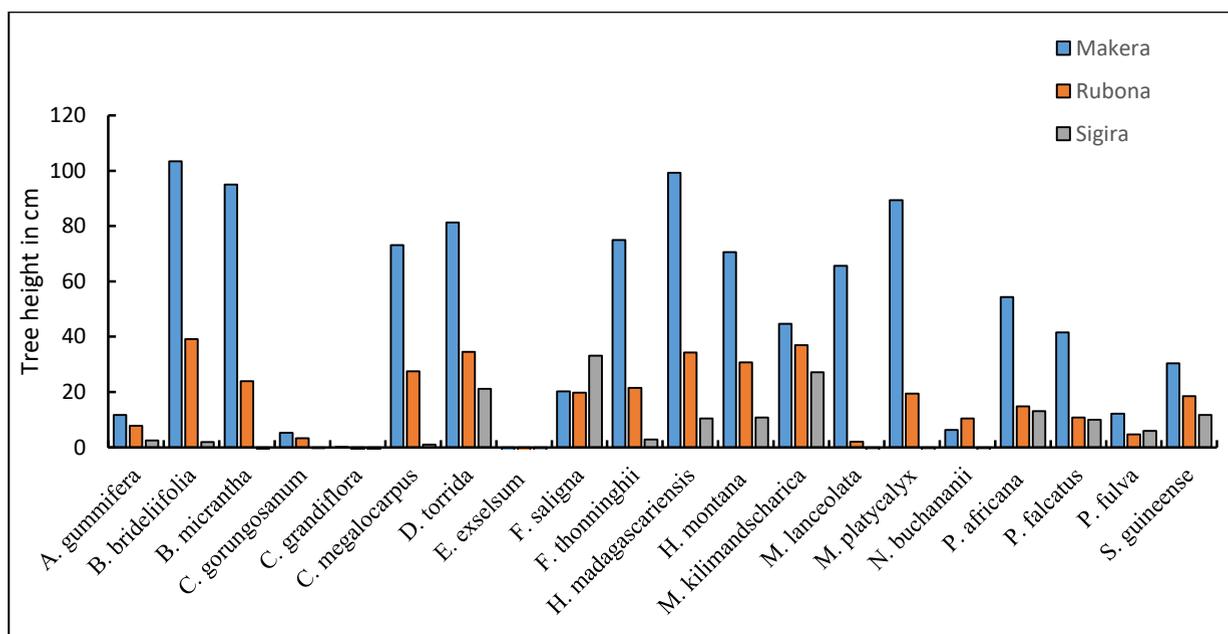
Figure 36: Tree height growth at Makera, Rubona and Sigira sites

Growth performance of the 20 native tree species, expressed as the ratio of stem diameter to tree total height is presented in Figures 37-39. Figure 37 shows that *Polyscias fulva* had significantly higher growth among species involved in the study at Makera site. In this site, *Albizia gummifera*, *Dombeya torrida, Entandrophragma excelsum and Chrisophyllum gorungosanum* performed well. The growth rate of *Dombeya torrida* and *Ficus thonningii* seems to decline because measurements were taken not on mother stems, but on coppices.
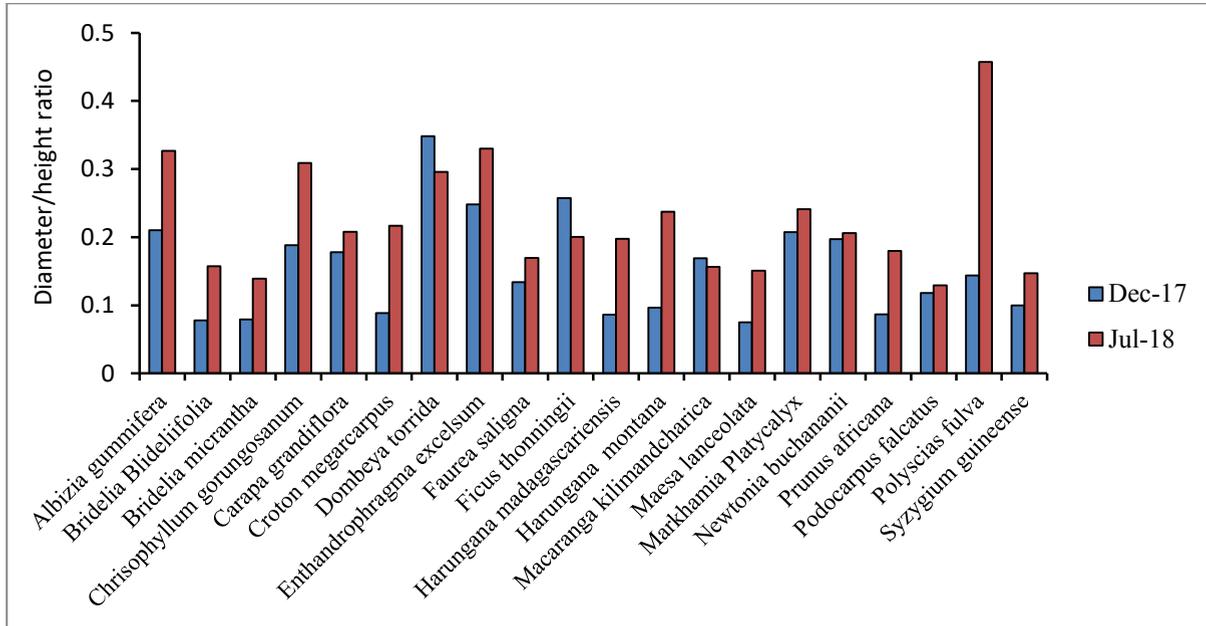
Figure 37: Tree growth performance at Makera site

The characteristics of planted trees in terms of the average diameter at breast height (DBH) and total height of trees at Rubona are provided in Figure 38. *Polyscias fulva* showed the highest growth at Rubona site. Also *Albizia gummifera*, *Entandrophragma excelsum, Chrisophyllum gorungosanum, Markhamia platycalyx* and *Dombeya torrida* had a good growth performance in Rubona site. The reason that *Macaranga kilimandscharica* and *Dombeya torrida* have the growth taken in 2017 higher than that recorded in 2018 is that their mother stems died and measurements were taken in coppices.
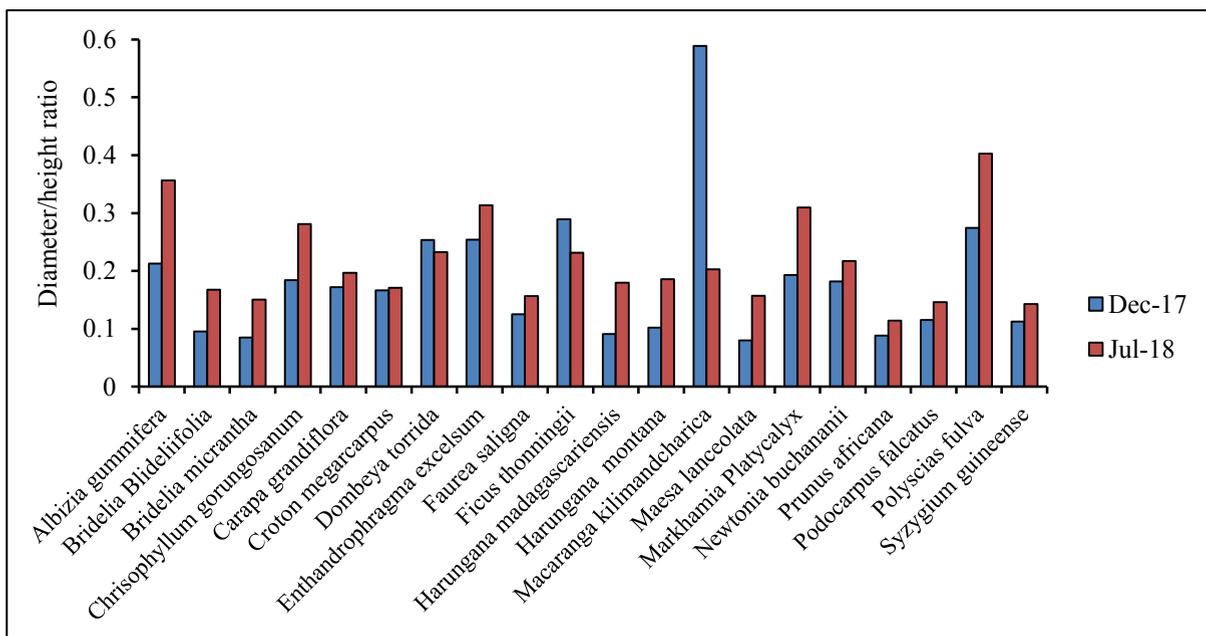
Figure 38: Tree growth at Rubona site

At Sigira site, *Polyscias fulva* and *Albizia gummifera* had the highest growth. Also, *Polyscias fulva*, *Ficus thonningii*, *Entandrophragma excelsum*, *Chrisophyllum gorungosanum*, *Markhamia platycalyx*, *Newtonia buchananii* and *Dombeya torrida* performed satisfactorily ([Figure 39]). Only *Dombeya torrida* had the growth taken in 2017 higher than the growth taken in 2018 because their mother stems died and measurements were taken on coppices.
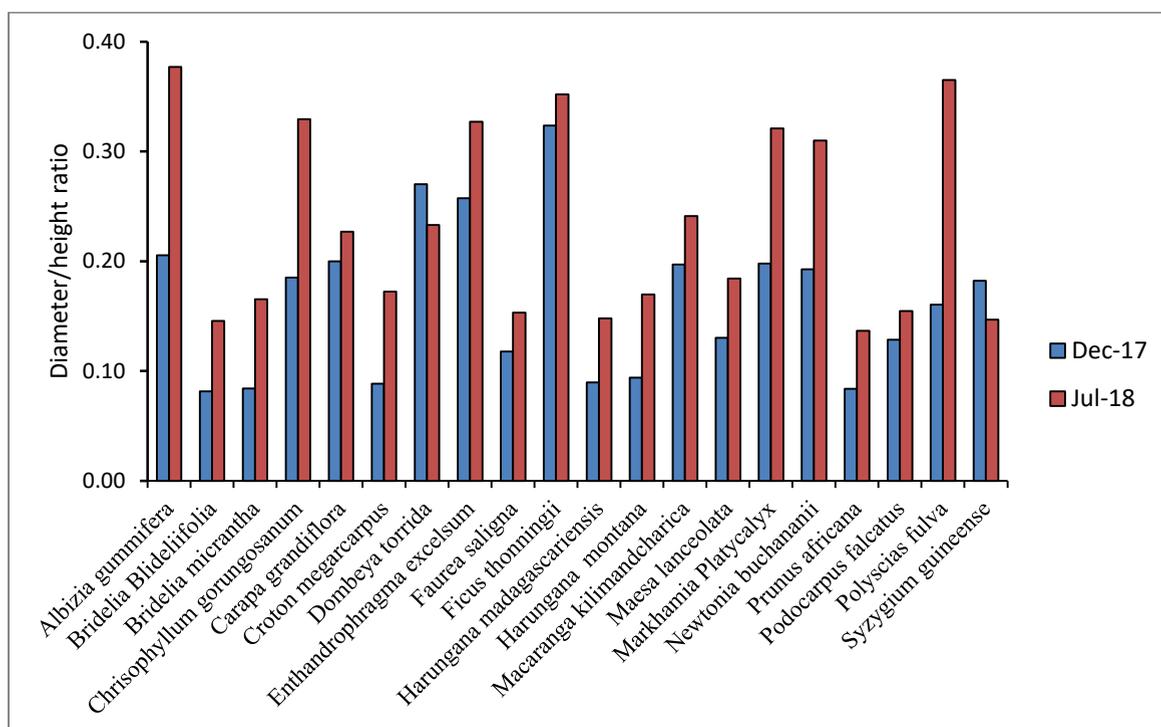
Figure 39: Growth of various tree species at Sigira

The status of planted seedlings is at interesting level and planted trees growth well. The key problem remains with *Carapa grandiflora* planted at Makera because they are vulnerable to termites attacks that seem to eliminate this species. Another problem was the inability to do beating up of *Faurea saligna* because of unavailability of seedlings in the tree nursery as the species germinates very low. Since the interest is in temperature responses, the study plots include experimental manipulations of water at Ibanda Makera and Rubona sites to mimic water condition at Sigira site.

The next step will be the application of fertilizer at Sigira and Rubona site to maintain these sites at the same fertility level as at Ibanda Makera and to evaluate the effect of nutrient on tree growth at all sites. Plastic rain exclusion shelters approximately 1 m above ground will be installed to channel a portion of the rain water to outside the plots at Sigira site to maintain water treatments lower than the site precipitation. In addition, the plot perimeters will be separated by trenches to avoid inflow of water from the sides.

1.3 Crosscutting Research

1.3.1 Biotechnology and plant pathology laboratories

Different crops were initiated into regeneration using tissue culture, sub-culture and/or multiplied in tissue culture laboratory. Furthermore, a number of protocols were developed and/or optimized.

Optimization of cassava and coffee tissue culture protocols

Cassava in vitro regeneration protocol was optimized via research trials on 35 cassava clones. Full MS both liquid and solid media were used. The liquid medium (without gellic) agent showed that clones did not respond well but they did well on solid medium. We optimized *in vitro* regeneration protocol of 14 hybrids F1 of Coffee. We optimized a coffee protocol aimed at reducing the time the crop spends in *in-vitro* system. The phytohormone 2, 4-D did not give any significant difference compared to other phytohormones as expected. The best phytohormone combination, therefore, was BAP, supplemented with IBA added at germination stage).

Plant disease diagnostics protocol development and optimization

Optimization of Maize chlorotic mottle virus (MCMV) RNA extraction using CTAB with some modifications protocol and one step RT-PCR were optimized. CTAB buffer was changed in concentrations of NaCl from 1.4M to 2M and 50μL to 30 μL of beta Mercaptoethanol. The results can be reliable for quick as a diagnostic tool. However, there must be a continuous optimization for better results. The newly optimized protocol was validated using 180 maize leaf samples collected from Eastern, Northern and Southern districts maize seed multiplication plots. Seed multiplication plots fields were scored using a scoring range of 25%, 50%, 75% and 100%. Samples collected and analyzed using RT-PCR one step from Gashora seed multiplication plot showed the infection of maize chlorotic mottle virus (MCMV). We recommended to reject the seeds from the infected plot.

Cassava viral disease diagnostics (cassava mosaic begomoviruses and cassava brown streak viruses) protocol was optimized. CTAB protocol, the organic extraction step whereby chloroform-Isoamylalcohol ratio 24:1 is used, we now use phenol-chloroform-Isoamylalcohol ratio 25:24:1 to remove all the polysaccharides and the time of precipitation stage whereby we use cold isopropanol (chilled on -20 degrees) was increased from 1 hour to overnight for get more nucleic acid (RNA) yield (pellet size increase). CTAB protocol was optimized on DNA extraction by adding to beta Mercaptoethanol with proteinase K. A total of 300 cassava leaf samples were analyzed of African and East African mosaic virus using PCR with JSP001/2 and EAB555F/R primer pair. The cassava leaf samples were collected at 3 months after planting (3MAP). Fields were scored using 1-5 scale (1-Healthy, 2-mild symptoms, 3-moderate

symptoms, 4-severe, 5-more severe: filiform) and 3 samples per field (one health, two with symptoms). Additionally, a total of 300 cassava leaf samples were analyzed of cassava brown streak viruses (CBSV and UCBSV) using two steps RT-PCR with $CBSDDF_2/R$ primer pair. The cassava leaf samples were collected from Eastern, Western, and Southern provinces from farmer's fields within 3 months after planting (3MAP). Fields were scored using 1-5 scale (1-Healthy, 2-mild symptoms, 3-moderate symptoms, 4-severe, 5-more severe: filiform) and 3 samples per field (one health, two with symptoms).

Production of clean planting material

A total of 50,420 banana plantlets were produced by micropropagation and disseminated to farmers in collaboration with Banana Program and partners. We produced 62,409 sweet potato plantlets of Sweet potato planting materials using tissue culture, and 76,849 plantlets of cassava planting materials using tissue culture and 24,843 Plantlets using macro-propagation.

1.3.2 Genebank

The mandate of the Rwanda National Genebank, RNGB is safeguarding National Genetic Resources (GRs) for sustainable food and nutrition security and development. The specific focus was put on Plant Genetic Resources (PGRs), Animal Genetic Resources (AnGR) and Forest Genetic Resources (FGRs).

Plant Genetic Resources (PGRs)

Plant genetic resources management includes collecting and storing passport data, field and laboratory conservation, collection of new species and field evaluation of species. Passport data for 43 collected plant species were entered into computer for better management. Thirty eight (38) accessions of different PGRs (2 accessions of rice; 2 for maize; 2 for wheat; 2 for sorghum; 20 for beans and 10 for taro) were explored and collected. Nineteen (19) identified plant genetic resources were planted in their appropriate chosen sites at Rubona, Karama and Rwerere for characterization, seeds increase and regeneration. Five hundred (500) accessions (banana, horticulture, sweet potato and coffee) were maintained as field genebanks. Four hundred and one (401) different plant genetic resources tested either for moisture content or for germination rate.

Animal Genetic Resources (AnGRs)

Management of animal genetic resources includes collection, characterization and conservation of animal species as well as their maintenance. Thirty seven (37) traditional cows without horns (inkungu) and 145 traditional cows with long horns (Inyambo) were kept for conserving traditional cow breeds and two young bulls of the latter were acquired, cared for

and trained for semen production in replacement of the previous old ones. Thirty five (35) passport data sheets were collected and recorded, 35 blood samples collected, treated and conserved in Rubilizi national laboratory and 35 Inyambo calves were characterized morphologically. Five new calves born in quarter one were recorded with their mothers and bull used and, 12 female pregnancy for the second generation were recorded

Forest Genetic Resources (FGRs)

The three main activities undertaken under Forest Genetic Resources (FGRs) in 2017-2018 fiscal year were: (1) seed collection of genetic resources of various indigenous and exotic tree species for their conservation, (2) assessment of conservation and adaptability trial of indigenous tree species in Rubona Centre and, (3) establishment of a botanical garden of indigenous tree species at RAB Rubona/ Genebank main office.

Table 47: List and seed quantity of tree germplasm collected in FY 2017-2018

Collection date	Tree species	Provenance	Quantity (kg)	Collection date	Tree species	Provenance	Quantity (kg)
Apr-18	*Chryisophillum gorungosanum*	Nyungwe	2.869	Jul-17	*Spathodea companulata*	Rubona	0.6
Apr-18	*Phoemix reclinata (umukindo)*	Kirehe	3.754	Jul-17	*Markhamia lutea*	Nyagatare	0.2
Apr-18	*Macaranga kilimandscharica*	Nyungwe	0.169	Jul-18	*Maesopsis eminii*	Ruhande	3
Apr-18	*Albizia gummifera*	Nyungwe	0.052	Jun-18	*Syzgium guineese*	Ruhande	3
Apr-18	*Faurea saligna*	Nyungwe	0.327	5/8/2018	*Parinari curatellifolia*	Kirehe	4
Apr-18	*Maesa lanceolata*	Nyungwe	1.5	6/7/2018	*Vitex keniensis*	Ruhande	6
Apr-18	*Carapa grandiflora*	Nyungwe	8.7	Apr-17	*Prunus africana*	Nyungwe	1
Apr-18	*Symphonia globurifera*	Nyungwe	10	Jul-17	*Carapa grandiflora*	Nyungwe	2
Aug-17	*Croton megalocarpus*	Nyungwe	12	May-18	*Strombozia schefflerii*	Nyungwe	7
Jul-17	*Hagenia obyssinica*	Nyungwe	0.5	Aug-17	*Faurea saligna*	Nyungwe	0.15
Jan-2018	*Maesopsis Eminii*	Rubona	50	Jun-18	Cambretum molle	Kirehe	1
Aug-17	*Maesopsis Eminii*	Nyungwe	9	Feb-17	*Harungana Montana*	Ruhande	3
Jul-17	*Markhamia platycalyx*	Nyagatare	0.3	Jul-17	*Maesa lanceolata*	Ruhande	0.2
Jul-17	*Erythrina abyssinica*	Huye	0.258	Jul-17	*Carapa grandiflora*	Nyungwe	30
Jul-17	*Zanthoxyllum gillettii*	Nyungwe	0.193	Jun-17	*Dovyolis caffera*	Rubona	2.7
Aug-17	*Albizia gummifera*	Rubona	0.2	Jun-17	*Markhamia platycalyx*	Rubona	3.5
Jul-17	*Vitex keniensi*	Rubona	2	Feb-18	*Peterygota Mildbraedii*	Bugesera	1.2
Jul-17	*Archontophoenix cunninghamiana*	Bugesera	0.293	Aug-17	*Acacia sieberiana*	Rubona	3.6
Jul-17	*Acrorcarpus fraxinifolius*	Rubona	1.5	Aug-17	*Entada obyssinica*	Rubona	1
Jul-17	*Olea europea spp. africana*	Rwimiyaga	0.1	Feb-17	*Grevillea robusta*	Rubona	0.2
Jun-18	*Harungana Madagascariensis*	Ruhande	3	Jun-18	*Senna didimobotrya*	Kirehe	0.15
Mar-17	*Hagenia obyssinica*	Nyungwe	1.284	Jun-18	*Acacia polycantha*	Kirehe	0.2
Jul-17	*Eucalyptus bortiyoide*	Rubona	0.29	Jun-18	*Entada obyssinica*	Kirehe	0.2
	Total		182.429				

The collection of genetic resources of various indigenous and exotic tree species for their conservation aimed at exploring, collecting, processing and conserving properly different forestry genetic resources available emphasizing on endangered and rare tree species across the country. In total, 182.429 kg of quality tree seeds comprising 32 indigenous pioneer and climax tree species and 5 exotic tree species were collected from Nyungwe National Park, Ruhande Arboretum, RAB Rubona, Kirehe and Bugesera districts (Table 47). The collected seeds were conserved, tested for germination and data recorded.

Table 48: Results on survival rate of indigenous species planted

Tree species	Local name	Provenance	Number of plots	Total of planted seedling/species	Survived seedling	dead seedling	survival rate %
Podocarpus falcatus	Umufu	Ruhande Arboretum	3	507	278	229	54.83
Markhamia Platycalyx	Umusave	Rubona	3	507	472	35	93.10
Maesa lanceolata	Umuhanga	Nyungwe NP	3	507	397	110	78.30
Polyscias fulva	Umwungo	Rubona	3	507	460	47	90.73
Croton megarcarpus	Umunege	Rubona	3	507	487	20	96.06
Bridelia micrantha	Umugimbu	Rubona	2	338	210	128	62.13
Syzygium palvifolium	Umugote	Nyungwe NP	3	507	457	50	90.14
Syzygium guineense	Umugote	Butare	1	169	161	8	95.27
Enthandrophragma excelicium	Umuyove	Nyungwe NP	3	507	47	460	9.27
Ficus thonningii	Umuvumu	Nyungwe NP	3	507	397	110	78.30
Albizia adianthfolia	Umusebeya	Rubona	3	507	188	319	37.08
Zanthoxylum gilletii	Umutulirwa	Nyungwe NP	3	507	264	243	52.07
Dombeya torrida	Umukore	Nyungwe NP	2	338	147	191	43.49
Maesopsis eminii	Umuhumuro	Rubona	3	507	284	223	56.02
Ptergota mildbraedii	Umuguruka	Ngoma District	1	169	0	169	0.00
Canthium schimperanum	Umukirage	Nyanza District	2	338	168	170	49.70
Hagenia abyssinica	Umugeti	Nyungwe NP	2	338	91	247	26.92
Erithrina abyssinica	Umuko	Ruhande Arboretum	2	507	271	236	53.45

Overall eighteen native and naturalized tree species from different agro ecological zones of Rwanda were proposed for domestication and conservation and performance assessment carried out in Gakera site located in RAB- Rubona Centre. Planted species include *Podocarpus falcatus, Markhamia Platycalyx, Maesa lanceolata, Polyscias fulva, Croton megarcarpus,*

Bridelia micrantha, Syzygium palyvifolium, Syzygium guineense, Enthandrophragma excelicium, Ficus thonningii, Albizia adiantifolia, Zanthoxylum gilletii, Dombeya torrida, Maesopsis eminii, Pterygota mildbraedii, erythrina abyssinica, Canthium schmperanum and Hagenia abyssinica.

Firstly raised in pots at Rubona nursery, the selected species were then transferred to the field and each tree species was replicated three times. Preliminary data collection on survival rate was done two months after tree planting and Table 48 presents the results from Gakera site in Rubona center. The survival rate of several species was above 50% including *Croton megarcarpus*, *Polyscias fulva, Bridelia micrantha* and 2 Syzygium species performed well with a survival rate greater than 90%. However, *Entandrophragma excelsum* and *Pterygota mildbraedii* recorded the lowest survival rate of 9% and 0% respectively.

A small botanical garden of afromontane and transitional indigenous tree species was established around RAB Genebank office. In total 40 climax and pioneer species from different agro ecological zones of Rwanda were planted randomly on an area equivalent to 900 m^2. Table 49 shows the list of planted species.

Table 49: List of indigenous tree species planted at Genebank, RAB - Rubona

Afromontane rainforest species (Pioneer / Climax)			Transitional rain forest species (Pioneer /Climax)		
Tree species	Provenance	Number	Tree species	Provenance	Number
Briidelia brideliifolia	Nyungwe	5	*Abizia gummifera*	RAB Rubona	5
Carapa grandiflora	Nyungwe	5	*Bridelia micrantha*	RAB Rubona	5
Harungana montana	Nyungwe	5	*Markhamia platycalyx*	RAB Rubona	5
Faurea saligna	Nyungwe	5	*Harungana madagascariensis*	Ruhande	5
Macaranga kilimandscharica	Busaga	5	*Ficus sycomorus spp. gnaphalocarpa*	RAB Rubona	5
Maesa lanceolata	Nyungwe	5	*Olea europea spp. Africana*	Nyagatare	5
Prunus africana	Nyungwe	5	*Zanthoxylum chalybeum*	Ibanda Makera	5
Polyscias fulva	Nyungwe	5	*Pterygota mildbraedii*	Ngoma	5
Syzygium parvifolium	Nyungwe	5	*Acacia polyacantha*	Nyanza	5
Zanthoxylum gilletii	Nyungwe	5	*Maesopsis eminii*	RAB Rubona	5
Croton macrostachys	Busaga	5	*Acacia sieberiana*	Nyanza	5
Hagenia abyssinica	Nyungwe	5	*Entada abyssinica*	RAB Rubona	5
Strombozia scheffleri	Nyungwe	5	*Erithryna abyssinica*	Ruhande	5
Chrisophyllum gorungosanum	Busaga	5	*Albizia adianthifolia*	RAB Rubona	5
Dombeya torrida	Busaga	5	*Vernonia amygdalina*	RAB Rubona	5
Podocarpus falcatus	Ruhande	5	*Ficus thonninghii*	RAB Rubona	5
Entandrophragma exselsum	Nyungwe	5	*Syzygium guineense*	Ruhande	5
Croton megalocarpus	Nyungwe	5	*Teclea nobilis*	Ibanda Makera	5
Newtonia buchananii	Nyungwe	5	*Ficus sur*	Ibanda Makera	5
Podocarpus latifolius	Nyungwe	5	*Ficus vallis -choudae*	Ruhande	5
Total		100	Total		100

1.3.3   Socio-economics and biometrics

The socio economic research includes baseline surveys, adoption of technologies, impact studies, gender, market and profitability studies. Other socio-ecomic activities focus on policy and value chain analysis, evaluation of new approaches for technology dissemination such as Twigire Muhinzi, FFS and Innovation platforms. In 2017-2018, the program focused mainly on up scaling innovation platform approaches, conducting different studies and contributing to the implementation of different projects.

Up scaling innovation platform (IP) approach

Through a four steps process (awareness creation, identification of potential IP stakeholders, shape wheat value chain and visioning as well as annual activity planning) Butaro wheat innovation platform was established under FARA project (Photo 21). Stakeholders were introduced to the Integrated Agriculture Research for Development (IAR4D) principles, IP approach and importance of wheat innovation platform in understanding roles and responsibility of each and every stakeholder in wheat value chain. Different approaches and techniques like SWOT analysis and pairwise ranking were used to identify and rank constraints and opportunities, finding solutions to the most pressing constraints, attributing roles and responsibilities to different stakeholders and establishing a participatory one year plan of activities.

Photo 21: Butaro wheat Innovation Platform elected committee

Under bean corridor project, beans IPs were initiated in three major productive zones of beans (Photo 22), namely Northern, Eastern, Southern provinces. An awareness creation and bean value chain analysis workshop was organized and the following information was gathered through group works: 1) the markets and needs in volumes of beans, (2) most liked bean varieties , (3) most bean productive area, (4) main producers, (5) main constraints, 6) Who has the solution to the constraints- and their names, 7) and how each platform will be composed, facilitated, monitored, financed and sustained, 8) tentative action plan for each Bean corridor (IP). The major stakeholders identified were: Farmers, Local government, Researchers, Agrodealers, Banks and microfinances, Insurance Company, Traders, Processors, MINICOM, MINAGRI and local radios.

Photo 22: Bean IP stakeholders workshop

Previously established IPs were strengthened through training and refresher workshop. The training on IP management was conducted in Gishwati IPs focusing on: the innovation system approach and its integration in the agriculture research for development; the concept of integrated agriculture research for development (IAR4D) and the IP management. Through two refresher workshops organized participants from both old and new established IPs were trained to the production technics of Passion fruits, tamarillo and wheat depending on their entry point. They shared also experience on the implementation and management of IPs.

Socio economic impact of Girinka program on poor rural households in Rwanda

This report presents results of an impact assessment study on Girinka Program, initiated by His Excellency President Paul Kagame in 2006 as part of poverty reduction strategy. The main objective of the study was to assess the socio-economic impact of Girinka Program on poor households' welfare in Rwanda.

A semi-structured questionnaire, was used to collect data 1106 households made of 343 Girinka Program beneficiaries and 763 non-beneficiaries randomly selected from 90 cells, 51 sectors and 10 districts. The focus group discussions and key informants' checklists for general

information and data sheets for anthropometric measurements were also used. The collected data were analysed using descriptive analysis, ANOVA, regression analysis and propensity score matching approach. In the 10 sampled districts, 23.1% of households that received a cow were headed by women and the average household size was 5.6 members. The average age of household members that were given cows was 52 years and most of them had completed part of their primary education (40.1%) or had completed primary education (28%). The average land size was 0.39 ha with beneficiaries having more land (on average 0.58 ha for beneficiaries against 0.31ha for non-beneficiaries

The cross breeds were the most common types of cow received with 52.8% of the total cow distributed to households and exotic breeds represent only 13.3%. The other types of livestock owned by surveyed households are goats, sheep, pigs, poultry and rabbits and they are owned by 53.0% of the sampled households. The important food crops grown were mainly beans and maize grown by 93.1% and 68.4% of total surveyed households respectively while others were grown by less than 20%. The highest yielding crops were respectively rice (6,608.3 kg/ha) and sweet potatoes (3,653.4 kg/ha) while the lowest yielding crop was peanut (416.8 kg/ha).

The majority of cows distributed by Girinka Program have given birth to between 1 to 4 calves and currently, the Program beneficiaries have in general one or two cows. About 89 percent (89%) of beneficiaries have a cowshed and only 32.1% of Girinka beneficiaries practiced artificial insemination (AI).

For the last three years (2015 – 2017), 91% of beneficiaries had a milking cow with an average of 4.5 litres of milk per day in 2015, 4.9 litres in 2016, and 4.2 litres in 2017and an average lactation period of 184 days per year. This provides average gross revenue from milk of Rwf 21, 529 per year. About eighty eight percent (87.9%) of respondents reported consuming milk in the household and only 42.2% sold milk to either neighbours (45.1%) or milk collection centres (35.3%). About 81.5% of the surveyed households were food insecure and the most commonly used coping strategies for food insecure households was to reduce the number of meals per day (16.1%), undertake food for work programs (13.9%), borrowed money to buy food or got food on credit (12.6%), generally mother eat less (12.4%) and substitute common purchased foods with cheaper kinds (11.3%). The top five benefits of Girinka Program encountered in the program's beneficiaries were: (i) health insurance (29.7%), (ii) house rehabilitation (27.7%), (iii) school fees (21.3%), (iv) land acquisition (15%) and (v) dowry (2.6%). Other quantifiable benefits were the acquisition of sewing machines, bicycles, agricultural inputs, other types of livestock, etc. (2.9%) The first four benefits were encountered in more than 90% of respondents suggesting that these items are really very important for rural poor households.

Results of this study revealed that receiving a Girinka Program cow was associated with higher crop yields, greater calorie intake, improved nutritional status of under-five children, and increased household income. More specifically, the distribution of Girinka Program from 2006 to 2017 contributed to an increased household maize yield by about 26%; to an improved household daily calorie intake per adult-equivalent (food security) by about 14%; to an improved household nutritional status of under-five children by about 58%   and 23% respectively for underweight and stunting; and to an increased household annual income by about 129%.

In fact, five out of the eight indicators considered in this study showed that there was a statistically significant positive benefit for beneficiaries as compared to non-beneficiaries. This shows that Girinka Program has had a definite constructive impact on beneficiaries.

Assessment of animal feed in Rwanda: case of existing processing factories

The objective of this assessment was to analyze animal feed production in Rwanda with focus on commercial concentrates in order to inform policy decisions to be taken for improved animal feed value chain in the country. Specifically, the assessment aimed at (1) identifying animal feed ingredients produced in Rwanda, the sources of raw materials and their associated costs; (2) assessing the constraints and opportunities for improving livestock feeding value chain and; (3) providing recommendations on options for overcoming identified constraints in order to increase feed production at affordable cost for increased animal productivity. This quick assessment used a structured questionnaire administered to all four feed processing units found in Rwanda. The data collected focused on types of animal feed produced, sources and types of ingredients and mechanisms of quality assurance. Collected data were analyzed using descriptive statistics.

Key findings of the assessment showed that high percentages of raw materials to produce commercial concentrates were purchased at the local market but some types of ingredients are not locally produced. Getting import permit was challenging and this has a negative impact on time for importing raw materials. This affects the feed production at the factory level, as well as all feed supply chains. The existing feed factories operate below their capacity due to shortage of feed market, especially for fish feed and dairy during the rainy season when pasture is plenty. This suggests that there is need to strength regional integration in trading and market to facilitate economic growth through livestock sub-sector development. Furthermore, average price for ingredients, except for fish feed, was higher than that of produced concentrates and this might negatively affect feed availability at the market, hence, low productivity of livestock enterprises in the country.   There is a need for synergy among stakeholders in animal feed production and setting up mechanisms to timely access import permit for animal feed.

The 13ᵗʰ agriculture show in Rwanda: Categories of participants and their perceptions

The main objective of the study was to find out whether the annual agriculture show meets the expectations of both exhibitors and the beneficiaries (Visitors). A semi structured questionnaire was used to collect feedback from 188 people (118 exhibitors and 70 visitors) and the collected data focused on (1) identification of respondents by gender and residence; (2) their primarily activities, targeted agricultural innovations and means of transport to reach Mulindi agrishow ground; (3) their appreciation of the innovations exhibited in 2018; (4) their business partnership and opportunities;(5) best extension approaches according to their own understanding and suggestions to MINAGRI.

The findings revealed that 61.5% of respondents were men; the time availability and low mobility known for women did not allow them to participate. Since the agri show took place in Kigali city, more respondents (64.4%) came from Kigali city and 67.7% of the total respondents have participated in the agriculture show at least for the second time. More exhibitors were either involved in food production (43%) or food processing (43.4%).

The first three innovations targeted by both exhibitors and visitors were irrigation technologies, new livestock and crop production technologies and chicken rearing technologies with 19.9%, 18.4% and 13.8% respectively. The majority of exhibitors and visitors reached the agri-show ground using public transport (56.2%) and private vehicle (23.9%) while only 3.5% of respondents reached the area by feet indicating how the accessibility was not easy for low income people. The agriculture show was found either very interesting (66.2%) or interesting (31.6%). Processing machines were the most appreciated with 30.3% followed by tractors and irrigation equipment with respectively 15.5% and 14% while in general, 86.7% find all products very good. More respondents (60.6%) were either working in partnership with different stakeholders or they were members of cooperatives and other platforms that strengthen their business capacity. The main lesson learned by 77.2% of respondents was the way of marketing their products. The registration fees seem to be a burden for majority of exhibitors (65.3%) and this is mainly because many exhibitors (60%) did not find sponsors. In general, the 2018 agriculture show was very interesting for both exhibitors and visitors and they have requested for more time and more advertisement.

Promoting crop-livestock integration technologies for food, nutrition and income security of smallholder women farmers in Muhanga District

A baseline study has been conducted to determine the current status of livelihoods among women in the project area and set the basis for measuring progress and impact of the project on the livelihoods of the Women Headed Households in the project area. Eighty nine women headed households (89) were randomly selected from 3 villages of the Shyogwe, Muhanga and Mushishiro sectors purposively selected to take part in this baseline survey. They were

interviewed using a structured questionnaire and the data collected focused on household characteristics, land and livestock ownership, agricultural technologies, access to inputs and other services, main occupation, important crops grown and food security. The descriptive statistics were used to analyze the collected data. The findings on household characteristics revealed that average age of household head was 50.93 years; most of the them were either widow (58.4%) or separated (24.7%) with an average of 15.8 years in heading the household; the average household size was 4.73 and 82% of household heads did not go beyond primary education. The average land owned was very small (0.37ha) and used mainly for crop cultivation (58%); the livestock population was also very small dominated by cows and pigs owned by 41% and 30% of households respectively; 42.6% of them keep animal for their neighbors (Kuragiza) and 13.5% did not own livestock.

Organic manure used the most common agricultural technology used by 91.4% of respondents while post-harvest control insect (6.7%) and improved fodder (14.6%) were the least used inputs. The main occupations were agriculture and livestock with 98.9% and 71.9% respectively and the most important crops grown include beans, cassava and sweet potatoes grown by 85.2%, 76.1% and 73.9% of respondents respectively and they were mainly grown for food security (71.4%) or both food security and cash (21.7%). The lack of membership contribution (with 76.5%) was the main reason for many respondents (59.6%) for belonging to any kind of groups/association and the majority of existing groups were involved in savings and credits (68.3%). The average level of trust for most people was at 72.5% with research institutions and NGOs being the most trusted institutions with respectively 69.3% and 60.5% of the respondents. The credits have been used by 74.2% but the amount of money borrowed was very small with an average ranging from 13036Frw to 22787Frw for about 95.7% of respondents who borrowed money. The extension in the area was very limited, only 27.6% of farmers visited an extension agent for seeking advice while 34.1% of them were visited by an extension agent once in the last 12 months. The main sources of income include the sale of crops, sale of livestock or livestock products and the casual employment related to agriculture with 33.9%, 22.2%, and 19.4% of respondents respectively. The amount of income gained from these sources annually was not much: 44,623Frw from sale of crops, 37,765Frw from sales of livestock or livestock products and 32,452Frw from casual employment related to agriculture. Nine out of ten farmers surveyed (91.0%) faced at least one month of food shortage and generally food was available in July (90.1%), January (87.7%), June (86.4%), February (82.7%) and December (75.3%) while food was unavailable in November (6.2%), October (9.9%), April (16.0%) and September (21.0%). Many of these baseline information data were far below the national average and this indicated to some extent a certain level of poverty among many households visited. It was recommended to focus on on-farm trainings at site level across all sectors to provide knowledge and skills in agricultural technologies to women farmers.

Introduction of crop-livestock integration technologies

Three innovation platforms and two farmer field schools were established in project areas and through these two approaches, different technologies were introduced after trainings. These include: (1) Improved feeds and feeding technologies for cattle and pigs, (2) Improved banana production technologies which encompassed diseases (BXW) and banana rehabilitation, (3) Integrated soil fertility management including compost techniques and soil erosion control using intercropping of crops with forage legumes and Napier grass on contour bands, (4) Improved sweet potatoes production technologies and (5) improved cassava production technologies. The combination of sweetpotatoes and livestock (cattle+ pigs), banana and Livestock (cattle+ pigs), Kitchen garden+fruits and Livestock (cattle+ pigs) have been adopted (Photo 23) and they are expected to bring some changes in farmers' attitudes about the enterprise choices for a better future.

Photo 23: Production of sweet potatoes and pig rearing in Muhanga and Mushishiro sectors

Mapping agriculture policies and institutions

The activity carried out under *Innovations for sustainability and food security in Africa project* (InnovAfrica) consist of identifying and analysing institutions involved in agriculture as wells as policies and strategies related to diffusion and establishment of agriculture innovations. Partner institutions in agriculture sector in Rwanda include government institutions, international donor agencies, international and local Non-Government Organizations (NGOs). The Ministry of Agriculture and Animal Resources (MINAGRI) is responsible for agriculture sector development including agricultural policies elaboration. Its affiliated institutions, namely Rwanda Agriculture and Animal Resources Development Board (RAB) and National Agricultural Export Board (NAEB) are responsible for policy implementation. MINAGRI collaborates with almost all ministries and their affiliated institutions but eight Ministries and four affiliated institutions were identified as the main partners of MINAGRI. These include for instance Ministry of Finance and Economic Planning (MINECOFIN), Ministry of Local

Government (MINALOC), Ministry of Natural Resources (MINIRENA) as well as its affiliated institution (REMA), etc. A long list of international donor agencies like World Bank, FAO, UNDP, USAID, SIDA, BTC, etc as well as international and local NGOs such as World Vision, Care International, ADR, Caritas, etc work closely with MINAGRI.

Agricultural policies related to the diffusion and establishment of agriculture innovations in Rwanda are imbedded in the National Agricultural Policy (NAP) elaborated in 2004 and revised in 2017. It sets the institutional, and policy framework for transformation of agriculture, economic development and poverty reduction in Rwanda. As a complementary to NAP, a list of ten policies were mapped and these include the National environment policy (2003), the National Land Policy (2004), the National Decentralization Policy (2004), the National Bioversity Policy (2011), etc. All of this polices are aligned with CADAAP, NEPAD, COMESA, EAC, AU, and recent SDGs. In addition, 12 strategies were also mapped and these include Crop Intensification Programme Strategy (2006), Agriculture Gender Strategy (2010), the national Post-Harvest for Staple Crop Strategy (2011–2016), etc. All these strategies converged to better implementation of Rwanda agricultural policies for improved agriculture production and at some extent, environment protection in Rwanda.

In practice, MINAGRI engages all stakeholders in the implementation of the policy through three mechanisms: the Agricultural Sector Working Group (ASWG) that is an essential forum for coordination; the Sector-Wide Approach (SWAp) Group that plays a key role in discussing issues related to budget support in the agriculture sector and the Sub Sector Working Groups (SSWGs) that seeks to enhance stakeholders' roles in the processes of planning, monitoring, advisory, coordination and financing for the sector.

Institutionalization of Innovation systems in Rwanda

The Agricultural Innovation Platforms (AIP) Institutionalization process has achieved some important results. The change management team was formed and through interactive and cross training (workshops), RAB programs leaders, projects leaders and change management team discussed the change implementation plan. From the discussions, the change management team developed the AIP process for inclusion in the Legal Framework and it was agreed that the fastest and easiest way of getting AIP's recognized in policy was if they were Cooperative led. Cooperatives are seen to be important as a driver of the success of agricultural innovation platforms as they were already legal and RAB just needed to define their role very clearly. The organizational culture survey was carried out and the findings showed that RAB was a very hierarchical organization that follows rules, policies and processes strictly and hence the need to ensure AIPs were backed by a legal framework. In addition, the change management team developed the AIP Structure at RAB which is presented in the AIP process booklet in English translated also in Kinyarwanda. This booklet

developed by the Change team has been discussed and benefited Heads of zones and Heads of Projects inputs which should increase the levels of buy in. The change management team has also been trained on change management and its role in the process of institutionalizing AIPs.

1.3.4   Postharvest

Information on postharvest losses in Rwanda is limited. The Reducing Postharvest Losses in Rwanda project (RPLR) was designed to identify post-harvest losses and provide tools and technologies to reduce post-harvest losses in fruits and vegetables.The project is three years (2017-2019) from the MoU between RAB and Agribusiness Associates Inc (ABA) signed and most of the project activities have started in July 2017 by launching of Postharvest Training and Service Centers (PTSCs) in the respective partner institutions (NAEB, UR, RAB). The project aimed to gain understanding of postharvest losses, constraints and opportunities in four identified horticultural crop value chains; to determine the benefits of introducing improved postharvest practices and technologies with RAB stakeholders; and to build entrepreneurial capacity in stakeholders across the value chain. The baseline survey was conducted in Southern Province on current practices for reducing post-harvest losses of the fresh commodities. The major findings are summarized in Table 50.

Table 50: The key findings of baseline survey on post-harvest practices and loss prevention methods

Domain	Finding
Farmer Knowledge	Harvesting practices are rough and cause damage to the produce. Only green chili is gently handled with sorting/grading practices for export
Farmer Organization	Farmers were found in individual farming (no cooperative formed to the focus crops). Tomato and Pineapple farmers are occasionally belonging to the cooperative for the crop.
Availability of priority crops	Tomato is dominant crop in all surveyed areas. Green banana is ranked at the second priority crop of the study. Chili, OFSP and Pineapple are localized in the area with support from partners (NGOs).
Postharvest treatment applications	No treatment is appropriated for tomato, green banana, pineapple and OFSP. The worse is application of pesticides on harvested tomato as treatment to improve shelf life of the produce during selling.
Temperature Management	All priority crops are exposed to the sun during harvesting, transport and marketing, and there are no cold chains or cool storage facilities for them everywhere in the area of the study. Charcoal cooler was found as standby facility for green chili in Nyanza and OFSP in Mihanga.

Transportation	Transport is handled roughly, leading to various losses along the chain especially for tomato whereby baskets and sacs are overloaded on Bicycles and trucks
Processing	There are limited processing options for all commodities of the study: banana beer in Gisagara district, pineapple wine in Ruhango and Muhanga Districts. None for tomato, OFSP and chilli pepper.
Access to finance for farming business	The access to loan for farming is promising despite that there is habit to use income saved (own means). There was not specific loan for investing in post-harvest solutions

Renovation of one of the RAB's apartments for PTSC

The MoU signed between RAB and ABA inc. included the support for renovation and improvement of the site for PTSC. Therefore, RAB as a hosting institution benefited the renovation of existing infrastructures of former cassava processing compound. The rehabilitation was done including Acquisition of equipment and material for PTSC.

Training manual for small scale postharvest handling

The main purpose of produced training manual was gain understanding of postharvest losses, constraints and opportunities of applying appropriate postharvest technologies by all actors of horticulture value chain. As an outcome from this training manual, 24 agronomists and 30 horticultures actors from Districts and sectors of southern province were trained (ToT) on small scale postharvest handling.

Photo 24: Zero Energy Cooling Chamber (ZECC) demo at Rubona Research Centre

The perspective of the project is to sustain the PTSC as center for postharvest consulting services (Photo 24) to meet with value chain actors (private companies and NGOs) and provide training to improve postharvest handling practices among operators.

Consumer sensory evaluation of cassava thick porridges in four regions of Rwanda

Two new varieties (NASE 14 and NAROCASS) and one local variety, Rwicabana also locally known as Gitamisi were collected from Nyanza District in the Southern Province to produce cassava flours. The flours were used to make cassava thick porridge (*Ugali*) that was used during the consumer sensory analysis in 4 districts of the southern province, known as the major cassava producing region of the country, notably Kamonyi, Muhanga, Ruhango and Nyanza Districts where 157 cassava farmers from 4 cooperatives participated in this exercise (the number of panelists may be increased to get more consumer responses).

Table 51: Consumer sensory analysis of ugali in southern province

Districts	Product	Colour	Aroma	Flavour	Texture	Overall acceptability
Kamonyi (n:40)	NAROCASS	6.6±1.4*	6.4±1.6	7.0±1.2	6.7±1.5	6.8±1.2
	NAES	7.6±1.1	7.5±1.4	7.8±1.2	7.6±1.2	7.8±1.1
	Rwica	6.9±1.7	6.5±1.9	6.6±1.8	6.7±1.7	6.9±1.6
Muhanga (n:39)	NAROCASS	6.9±1.5	6.6±1.6	7.0±1.6	7.2±1.3	7.0±1.5
	NAES	7.5±1.1	7.4±1.2	7.7±1.2	7.6±1.3	7.8±1.1
	Rwica	7.8±1.0	7.0±1.4	7. 4±1.1	7.6±0.9	7.5±1.0
Ruhango (n:39)	NAROCASS	6.8±1.2	6.8±1.3	6.9±1.2	7.2±1.2	7.0±1.2
	NAES	7.5±1.0	7.5±1.2	7.5±1.1	7.6±0.8	7.6±1.0
	R333	7.9±1.5	7.7±1.6	7.7±1.6	7.6±1.2	7.8±1.4
Nyanza (n:39)	NAROCASS	6.8±1.3	6.7±1.7	7.1±1.4	7.2±1.1	7.4±1.2
	NAES	7.4±1.1	7.4±1.6	7.6±1.4	7.7±1.4	7.5±1.7
	Rwica	7.5±1.4	7.6±1.3	7.8±1.1	7.7±1.1	7.9±1.1

* The scores are from 1 as lowest to 8 as highest

All *ugali* samples from the cassava varieties evaluated were acceptable (Table 51). The sensory acceptability of the products was determined by assessing various products attributes such as flavour, aroma, colour, texture and overall acceptability using a 9 points hedonic scale. The overall acceptability was above 6 suggesting that the samples were well perceived by the panelists. The sensory attributes of ugali sample were also acceptable. The new varieties can therefore be introduced in the food system in Rwanda since they were

found to be acceptable and the quality was also good. This work was conducted during June 2018, and we aim to conduct further consumer sensory analysis.

1.4 Animal, Fish and Insect Research

1.4.1 Large Stock

Large stock program focused on selective cattle breeding on exotic cattle for dairy with emphasis on crossbreeding at Songa, Rubona and pure breed at Kinigi Research Station. To date three experiments have been conducted to assess the reproductive performance of Ankole cattle and its crossbreds with Friesian (F), Jersey (J), and Sahiwal (S); the second study is on Milk production and lactation length of Ankole cattle and its crossbreds in Rwanda.

The following study was on evaluating the success rate of embryo transfer in recipient cows under field conditions; where the Identification and selection of the best dams for embryo transfer conducted at station and farm level, especially at Songa station, Kibirizi and Muyira sectors of Nyanza District.

Reproductive performance of Ankole cattle and its crossbreds in Rwanda

The aim of this study was to assess the reproductive performance of Ankole cattle and its crossbreds with Friesian (F), Jersey (J), and Sahiwal (S). The traits (number of records) studied were calving to first insemination, CFI (797); calving to last insemination, CLI (797); conception rate, CR (4354); number of inseminations, NINS (936); and calving interval, CI (259). The overall means of intervals CFI, CLI and CI, CR, and NINS were 192, 198 and 480 days, 67%, and 1.23 respectively. Breed group was significant ($P < 0.05$) for all traits except NINS, while season of calving was significant for CFI, CLI, and CI, and season of insemination was significant for CR. The breed group AF had better CR than the purebred Ankole and AS, and AS had lower CR than AJxS and AJ. On the other hand, Ankole (and to some extent AF) had longer CFI and CLI than AJ, AS, and FF. Ankole had 54 days longer CI than all other crossbreeds. The prolonged intervals CFI, CLI, and CI observed in this study call for proper postpartum anestrus management both in terms of nutrition and calf suckling management.

Conception rate

The overall mean CR was 0.67 (n = 4354, SD = 0.47). The factors' breed group (AA, AF, AJ, AJxS, AS, ASxJ), year of insemination, and technician were significant in the logistic model. There were too few FF to be included in the analysis. The genotype AF had better CR than the purebred Ankole and AS, and AS had lower CR than AJxS and AJ (Table 60). The difference between the lowest and highest technician was more than 20 percentage units. Despite an almost 5 percentage units lower CR for induced vs non-induced estrus, the results were not significant (P = 0.07). However, the interaction between breed group and estrus type was

significant (P < 0.01). Some breed groups followed the overall tendency of lower CR for induced estrus, whereas others had the opposite results (AJxS and ASxJ) compared to SDS (486 days) and SRS (495 days); however, SDS and SRS did not differ among each other (Table 52).

Calving interval

In total, there were 186 first parity cows with information on CI and 73 from second or later parities. Owing to the few number of records, it was not possible to have the same definition of breed groups. Instead, all crosses were grouped together and compared with purebred Ankole. After first fitting breed group (AA or cross), which was significant, season was significant but not time period, parity, or station. The overall mean calving interval observed was 479 days (n = 259, SD = 103). Ankole had about 54 days longer CI than the crossbreds (LSM 498 (SE 7.7) vs 445 (SE 10.8). The season of calving had significant effect on CI. Significantly lower CI were observed in LDS (442 days) deficiency by shortening number of days opens, leading to reduced calving intervals (Table 52).

Table 52: Calving interval (CI), intervals from calving to first or last insemination (CFI, CLI) and conception rate (CR) square means for different cow breeds during short and long rains

Variable[1]	Traits[2]						
	N	CFI	CLI	N	CI	N	CR [3]
Breed group							
AA	636	202±3.4[a]	208±3.5[a]			2480	0.71±0.016[bc]
AF	14	204±23[ab]	207±24[ab]			282	0.78±0.026 [a]
AJ	60	170±11[b]	176±11[b]			585	0.73±0.021 [ab]
AJxS						221	0.75±0.031 [ab]
AS	60	156±11[bc]	163±11[bc]			567	0.67±0.024 [c]
ASxJ		-	-			219	0.71±0.034 [bc]
FF	19	120±19[c]	131±19[c]				
Season							
SDS 3	127	189±8.4[b]	197±9.6[a]	48	486±14 [a]		
LRS 2	237	172±8.2 [ab]	179±8.4[ab]	84	462±11 [ab]		
LDS 4	200	190±9.4 [a]	170±8.8[bc]	62	442±13 [b]		
SRS 1	225	157±8.4 [a]	163±8.[c]	65	495±12 [a]		

AA=Pure Ankole, AF=Ankole x Holstein Friesian, AJ=Ankole x Jersey, AS=Ankole x Sahiwal, AJxS=AJ x Sahiwal, ASxJ=AS x Jersey, FF= Pure Holstein Friesian; SDS= Short Dry Season (Jan-Feb), LRS= Long Rainy Season (Mar-May), LDS= Long Dry Season (Jun-Aug), SRS=Short Rainy Season (Sep-Dec). 2N= Number of observations, CFI= Calving to first insemination, CLI= Calving to last insemination, CI= Calving interval, CR= Conception Rate; 3 Values transformed back to the original scale. [abc]=Mean values within breed group or season with different letters are significantly different (P<0.05)

The conception rate had progressively increased across years and was within acceptable levels, an indication of gradual improvement in the herd performance. Purebred Ankole had longer CFI, CLI, and CI than other breed groups; intervals for these traits were longer than

desirable for all breed groups, which is unfavorable for a profitable cattle production. Therefore, strategies aimed at improving the reproductive performance should be adopted. These should include early weaning, restricted suckling, and proper feeding, which aid in shortening of postpartum anestrus. Also, these extended intervals may be indicators of missed estrus signs and/or poor record keeping. Therefore, more focused studies are recommended to fully realize the genetic potential of these animals.

Milk production and lactation length of Ankole cattle and its crossbreds in Rwanda

The aim of this study was to assess the daily milk yield (DMY), 100-day (MY100) and 305-day (MY305) milk yields, and lactation length (LL) for purebred Ankole and their crossbreds, and influence of environmental factors on these traits. Milk yields were obtained from 865 cows and 1234 lactations. Data were analyzed using a fixed linear model. The overall least square means of DMY, MY100, and MY305 across breed groups were 2.7 (N=1234, SD=1.7), 262 (N=959, SD=176) and 759 (N=448 SD=439) litres, respectively, while the average lactation length was 291 days (N=814, SD=98). All sources of variation (breed group, season and year of calving, and parity) were significant except season of calving for MY305. First parity cows had lowest milk production, and highest production occurred in 4th parity for DMY and MY100. For all traits, the breed group AA significantly differed from all crossbreds with lowest average milk yield. Among the crossbreds there was no significant difference between AF, AJxS and ASxJ, nor between AS and ASxS. The overall averages for DMY, MY100, and MY305 across breed groups were 2.7 (N=1234, SD=1.7), 262 (N=959, SD=176) and 759 (N=448 SD=439) liters, respectively, while the average LL was 291 days (N=814, SD=98). The correlation between LL and DMY was close to zero (-0.08, p-value 0.01). The estimated effects of breed group, season, year of calving, and parity are shown in Table 53.

Breed group effect was significant for all four traits. Breed group AA had the lowest average milk yield; AA also tended to have longer lactation length. Among the crossbreds there was no significant difference in yield between AF, AJxS and ASxJ, nor between AS and ASxS. Calving season had significant effect on DMY, MY100 and LL. The pattern was similar for the three milk yield traits, with cows calving in SDS having the highest yield, albeit not always significantly different from all other seasons.

Breed group effect was significant for all four traits studied. The breed group AA significantly differed from all crossbreds with lowest milk yield and longer (albeit not significantly) lactation length. Among the crossbreds there was no significant difference between AF, AJxS and ASxJ, nor between AS and ASxS. The better performance of AF, AJxS and ASxJ is perhaps due the higher milk production potential of Holstein Friesian and Jersey, thus the crossbreds with Ankole excelled both due to heterotic effect and additive effect. From this study it can be concluded that, Ankole × Friesian and Ankole × Jersey crosses can be beneficial even under a management system of limited nutrition in Rwanda.

Table 53: Daily milk yield (DMY), milk yields for 100 and 305 days of lactation period (MY100, MY305) in litres, and lactation length (LL, days) for different breed group, season, year of calving, and parity

	DMY		MY100		MY305		LL	
Factor[1]	N	LSM	N	LSM	N	LSM	N	LSM
Breed Group								
AA	604	2.0^a	497	174^d	259	553^a	419	302^a
AF	144	4.7^b	99	468^a	34	1383^b	79	281^a
AJ	202	3.9^c	162	411^b	89	1182^c	138	278^a
AJxS	65	4.7^b	46	463^a	9	1486^b	38	230^b
AS	134	3.3^d	94	319^c	43	954^d	94	283^a
ASxJ	67	4.4^b	45	435^{ab}	9	1383^b	34	270^{ab}
ASxS	18	3.3^d	16	328^c	5	815^d	12	274^{ab}
Calving season								
LDS	308	3.7^b	248	361^a	93	1093^a	215	260^b
LRS	347	3.6^b	282	366^b	145	1102^a	251	277^{ab}
SDS	199	3.9^a	158	392^b	85	1128^a	147	294^a
SRS	380	3.8^{ab}	271	364^b	125	1108^a	201	264^b
Year of calving								
1998-2000	290	3.7^{ab}	237	360^{bc}	111	1092^b	176	275^a
2001-2003	91	4.0^a	79	402^a	44	1150^{ab}	65	297^a
2004-2006	349	3.7^{ab}	284	367^b	163	1053^b	291	291^a
2007-2009	123	3.5^b	88	338^c	25	1025^b	64	220^b
2014-2016	381	3.9^a	271	387^{ab}	105	1218^a	219	286^a
Parity								
1	658	3.2^d	477	324^d	216	989^c	403	267^b
2	113	3.5^c	94	340^{cd}	46	1083^{ab}	87	284^{ab}
3	113	3.7^{cb}	97	380^b	52	1061^b	84	301^a
4	91	4.0^b	74	385^b	30	1240^a	55	255^b
5+	180	3.5^c	164	355^{cb}	88	1074^b	185	263^b
Unknown	79	4.6^a	53	442^a	-	-	-	-

AA=Pure Ankole, AF=Ankole (50%) x Holstein Friesian (50%), AJ=Ankole (50%) x Jersey (50%), AS=Ankole (50%) x Sahiwal (50%), AJxS=Ankole (25%), Jersey (25%) x Sahiwal (50%), ASxJ=Ankole (25%), Sahiwal (25%) x Jersey (50%), ASS= Ankole (25%) x Sahiwal (75%); SDS= Short Dry Season (Jan-Feb), LRS= Long Rainy Season (Mar-May), LDS= Long Dry Season (Jun-Aug), SRS=Short Rainy Season (Sep-Dec). ^{abcd}=Mean values in a column with different superscripts differ significantly (P<0.05)

Embryo transfer evaluation

The success rates within the MOET industry, as measured by the mean number of embryos recovered per donor or by conception rates following embryo transfer, have changed very little over the years. In the present study, fresh embryos were non-surgically produced in the

cattle genetic improvement research farm at Songa station. Then, the imported Jersey frozen embryos were also used with the purpose of fresh and frozen-thawed embryo transfer in two different sites (RAB-Songa station and Nyanza small holder farms in the southern Province of Rwanda). The experiment was involving 88 recipient candidates, where 51 successfully received the embryos, on a period of 4 months. This time included the superovulation of donors, synchronization of recipients, insemination, embryo flashing and transfer. Results have suggested overall bovine ET pregnancy rates standing at 27.5% (n=51), with 50% (n=6) for fresh embryos and 24.4% (n=45) for frozen-thawed embryos. There was no significant difference between the pregnancy rates in RAB research farm [36.8 % (n=19)] and in Nyanza small holder farms [21.9% (n=32)] (P>0.05), on one hand. On the other hand, there was no influence of using fresh or frozen-thawed embryos on the success of the bovine ET pregnancy rate.

Despite a small number of transferred fresh embryos, its yielding ET pregnancy rate was found to be high (50%), which may support its choice over frozen-thawed embryos, under the present field conditions. The majority of studied recipient related factors (breed, body weight, body condition score, age, parity, shelter hygiene, pick milk quantity, postpartum interval, CL on PRID day, estrus intensity and quality of CL on ET day) did not show significant effect on bovine ET pregnancy rate (P>0.05). Only feed sufficiency (P=0.030) and watering system (P=0.037) showed a significant effect on bovine ET pregnancy rate (P<0.05). It was pointed out, during this study, that bovine MOET technology could be successfully applicable in the prevailing rearing conditions in Rwanda, where improved results are expected to be reached with appropriate training in MOET technology.
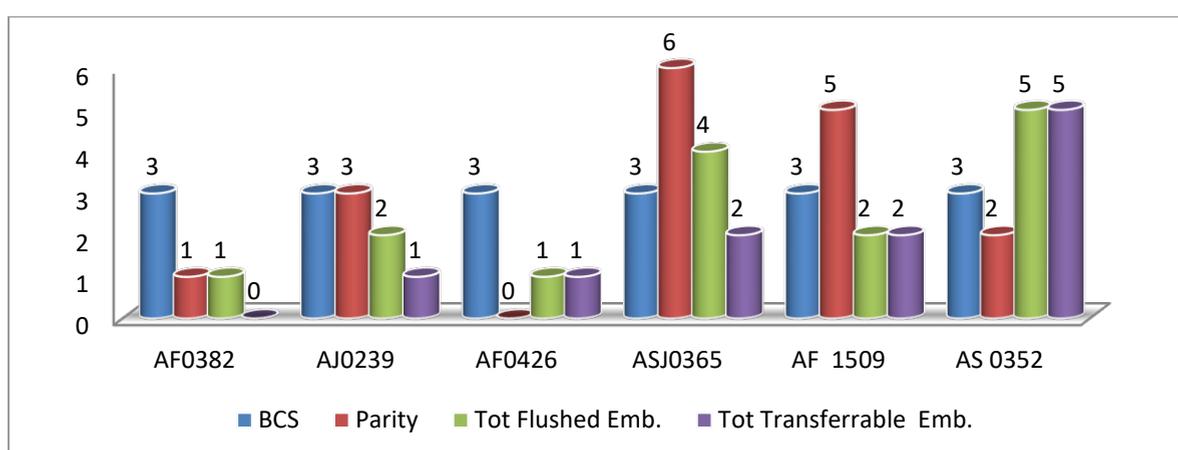
Figure 40: Number of total recovered and transferrable embryos produced in RAB- Farm from 6 cross breed donor cows with different BCS and parities

On-farm production of fresh embryos: Fifteen embryos were flushed from six donor cows and ten (66.7%) were transferable. One Sahiwal x Ankole crossbreed produced 50% of the total transferable embryos. The flushing average number of embryos recovered per one

donor was 2.5 embryos with 1.7 transferrable embryos per donor. The obtained results are presented in Figure 40.

Pregnancy rate of embryo transfer in recipient cows: Fifty one Embryos were transferred and the pregnancy rates were calculated for the recipient cows located in RAB-Songa and in Nyanza small holder farmers and the results were presented in the Figure 41.
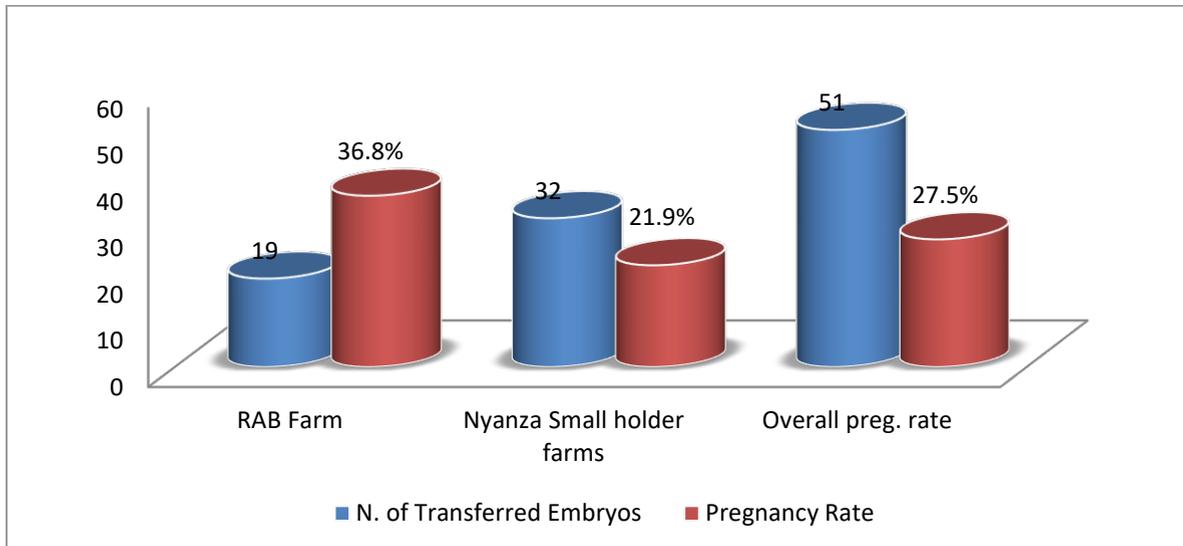
Figure 41: Bovine ET pregnancy rates for 19 recipient cows located in RAB-Songa and 32 recipients located in Nyanza small holder farms receiving 51 embryos

The results showing the association of considered 14 factors contributing to the bovine ET pregnancy rate were showed in Table 54. Bovine multiple ovulation and embryo transfer success rate was affected by different factors related to embryos and to the ET practitioner. In the present study, 66.7% (n=15) transferrable fresh embryos were produced and it was a reliable step to produce even more embryos for fresh and frozen-thawed embryo transfer for further cattle genetic improvement researches and future dairy cattle genetic improvement. According to the present study, the embryo recovery rate in Rwanda is now around 2 embryos per donor cow and it is probably possible to go forward and achieve the average mean standard of embryo recovery rate by increase of correct selection of donors.

Out of 6 on-farm produced embryos in RAB-songa farm, and transferred in the same research farm, 50% were pregnant. It is also not unreasonable to go from 36.7% of bovine pregnancy rate in the governmental farm (RAB) to very satisfactory results in ET if the Rwanda ET team if continuing searching and practice for further more self dependence in flushing, recovery and freezing-thawing of embryos.

Table 54: Effect of factors (breed, body weight , BCS, age, parity, shelter hygiene, feeding sufficiency, watering system, peak milk quantity, postpartum interval , CL on PRID day, estrus intensity, diameter of CL on ET day, transferred embryo type) on bovine ET pregnancy rate

Factors	df	F value	p-value
Breed	6	0.596	0.577
Body weight	2	0.161	0.674
Body Condition Score	3	3.998	0.115
Age group	3	0.254	0.495
Parity	2	1.053	0.286
Shelter Hygiene	1	3.711	0.058
Feed sufficiency	1	4.982	0.030
Watering system	1	4.575	0.037
Milk quantity at Peak	4	0.023	0.898
Postpartum interval	3	1.526	0.140
CL on PRID day	1	0.103	0.743
Estrus signs	1	0.013	0.909
Quality of CL on ET day	2	1.291	0.276
Transferred Embryo Type	1	1.727	0.188

The pregnancy rate of 27.5% obtained in this study is promizing for the future development of the field of embryo transfer in Rwanda because the present study will result in 14 calves (7 calves in RAB and 7 others in Nyanza small holder farms). Although the small number of animals used, the present study showed that the majority of selected recipient related factors like breed, body weight, body condition score, age, parity, shelter hygiene, feeding sufficiency, watering system, milk quantity, postpartum interval, CL on PRID day, estrus signs, quality of CL on ET day did not significantly affect the bovine ET pregnancy rate.

Only feeding sufficiency and watering system significantly affected the bovine ET pregnancy rate. Despite that most of those factors did not significantly affect the ET pregnancy rate, other studies related to the field of embryo transfer recommended to consider as many as possible of these recipient related factors during selection of suitable recipient cows for ET.

Training of Embryo transfer and embryo recovery and Pregnancy Diagnostics

Six RAB staff were benefited on capacity building for rapid multiplication improved animal breeds on multiple ovulation and embryo transfer (MOET) and pregnancy diagnostics by using Ultrasound machine, © BCF Technology Ltd. Theoretical training was attended at Songa by six staff and the practical was done at Songa, Kinigi and Nyanza on 51 cows (Photo 25).

Photo 25: Imaging PD in RAB Ankole Cow and in Small holder Farm on a Jersey heifer after 52 days of ET wth an Imaged 52 days Fetus though Ultrasound screen

1.4.2 Animal Nutrition

Biomass yield of tested grasses

Dry matter (DM) of tested Brachiaria grass showed that biomass from Nyamagabe was higher than from Kirehe site (Table 55). The discrepancies between the two sites in DM production could be attributed to the higher rainfall in the Nyamagabe. However, in both sites, *Panicum coloratum*, Basilisk, Cayman and Piata had higher DM content than other grasses. In addition, there was a significant difference (P<0.001) in DM production between grasses harvested at 60 days and at 90 days of planting. Grasses harvested at 90 days had higher DM content than the grasses harvested at 60 days (Table 55). Chemical composition of the samples is being determined for nutritional values characteristics.

Chemical composition of tested Brachiaria grass cultivars

Chemical composition of evaluated grasses significance differences among cultivars for most parameters except for Ca and P (Table 56). Also factor of harvesting showed significant difference among species across parameters except for NDF and Cellulose. Interaction site-species and Species-harvest time were not significant except for Na, as well as NDF for Species-harvest time interaction (Table 56). Additionally, there was significant different (P<0.05) for the interaction Site-Species-Harvest time for all parameters except for ADF and P.

Table 55: Dry matter content of tested forage grasses established on acidic soils and drought prone areas of Nyamagabe and Kirehe districts, Rwanda

Location	Cutting time	Grass cultivars	DM (g/kg)
Nyamagabe	60	Basilisk	182.7
		Cayman	194.8
		Coloratum	226.9
		MG4	188.0
		Piata	201.1
	90	Basilisk	365.5
		Cayman	350.7
		Coloratum	446.7
		MG4	350.1
		Piata	402.9
Kirehe	60	Basilisk	135.6
		Cayman	126.5
		Coloratum	166.5
		MG4	135.9
		Piata	154.1
	90	Basilisk	316.8
		Cayman	338.0
		Coloratum	383.4
		MG4	321.4
		Piata	353.9
Significance		Location	***
		Grass cultivars	***
		Cutting time	***
		Location*Grass cultivars	NS
		Grass cultivars*Cutting time	NS
		Location*Grass cultivars*Cutting time	NS

NS: Not significant (P>0.05); ***: Significant (P<0.001)

Table 56: Chemical composition of tested Brachiaria grass cultivars (organic in g/kg and inorganic mg/kg)

Harvesting time (days)	Species	CP	NDF	ADF	Cellulose	Ca	Mg	K	Na	P
					Kirehe					
60	Basilisk	182.7^{ab}	580.9^{abcd}	311.4^{a}	298.2^{ab}	4.55^{cd}	7.37^{bcd}	42.25^{abc}	1.375^{bc}	2.95^{ab}
	Cayman	145.7^{abcd}	617.1^{abc}	423.3^{ab}	324.7^{ab}	5.8^{bcd}	7.47^{bcd}	44.62^{ab}	1.475^{b}	3.525^{a}
	Coloratum	155.2^{abcd}	689.7^{a}	448^{ab}	370.1^{a}	3.25^{e}	5.32^{defg}	38.2^{abcd}	3.1^{a}	2.6^{abcd}
	MG4	146.6^{abcd}	629.7^{abc}	416.3^{ab}	345.8^{ab}	4.15^{cd}	6.58^{cdef}	47.8^{a}	1.475^{b}	3.225^{a}
	Piata	164.8^{abc}	605.1^{abc}	381.5^{ab}	299.6^{ab}	4.18^{cd}	6.05^{defg}	42.15^{abc}	1.275^{bcd}	3.175^{a}
90	Basilisk	152^{abcd}	565.2^{abcd}	399.4^{ab}	256.9^{ab}	8.07^{abc}	11.15^{a}	24.4^{de}	0.7f	1.425^{de}
	Cayman	146.2^{abcd}	549.2^{bcd}	374.2^{ab}	237.5^{b}	10.03^{a}	6.88^{bcde}	27.55^{cde}	0.725^{f}	1.425^{de}
	Coloratum	101.9 ^{de}	643.9^{abc}	500.9^{a}	334.8^{ab}	7.3^{abcd}	6.2^{defg}	19.98^{e}	4.15^{a}	1.05^{d}
	MG4	133.9^{bcd}	612^{abc}	454.9^{ab}	281.5^{ab}	8.95^{ab}	9.22^{abc}	29.05^{cde}	0.775^{ef}	1.475^{de}
	Piata	144.6^{abcd}	576^{abcd}	406.9^{ab}	263.7^{ab}	5.2^{cd}	9.57^{ab}	31.03^{bcde}	0.75^{f}	1.3^{de}
					Nyamagabe					
60	Basilisk	198.7^{a}	471.9^{d}	366.2 ^{ab}	255.6^{ab}	4.83^{cd}	4.95^{defg}	39.25^{abcd}	1.35^{bc}	3.125^{a}
	Cayman	174.5^{ab}	549.3^{bcd}	363.1^{ab}	273.9^{ab}	4.05^{cd}	3.3^{fg}	37.95^{abcd}	1.175^{bcdef}	2.925^{ab}
	Coloratum	161.9^{abc}	672.7^{ab}	390.4 ^{ab}	289.4^{ab}	3.97^{cd}	2.98^{g}	31.83^{bcde}	2.075^{a}	2.25^{abcde}
	MG4	191.2^{ab}	550.9^{bcd}	376.6 ^{ab}	221.8^{b}	4.67^{cd}	3.85^{efg}	39.67^{abcd}	1.25^{bcde}	2.825^{abc}
	Piata	177.2^{ab}	540.9^{cd}	364.5 ^{ab}	260.6^{ab}	4.9^{cd}	3.7^{efg}	35.55^{abcd}	1.175^{bcdef}	2.625^{abcd}
90	Basilisk	80.3^{d}	656.9^{abc}	346.1 ^{ab}	296.9^{ab}	5.95^{bcd}	5.18^{defg}	28.25^{cde}	1^{bcdef}	1.45^{de}
	Cayman	86^{d}	649.7^{abc}	358.8 ^{ab}	306.4^{ab}	3.77^{cd}	2.8^{g}	33.5^{abcde}	1.15^{bcdef}	1.725^{bcde}
	Coloratum	60.1^{d}	684.3^{a}	399.1 ^{ab}	337.3^{ab}	4.75^{cd}	3.35^{fg}	27.6^{cde}	1.05^{bcdef}	1.65^{cde}
	MG4	109.6^{cde}	659.9^{abc}	439.6^{ab}	270.1^{ab}	5.1^{cd}	3.52^{efg}	34.88^{abcde}	0.925^{cdef}	1.85^{bcde}
	Piata	82.6^{d}	674^{ab}	391.1^{ab}	300.6^{ab}	4.77^{cd}	4.1^{efg}	28.12^{cde}	0.825^{def}	1.575^{cde}
P-value	Site	*	NS	*	NS	**	***	NS	***	NS
	Species	*	***	*	*	NS	***	*	***	NS
	Harvest	***	**	NS	NS	***	**	***	***	***
	Site*Species	NS	NS	NS	NS	*	NS	NS	***	NS
	Species*Harvest	NS	*	NS	NS	NS	NS	NS	**	NS
	Site*Species*Harvest	***	***	NS	*	*	*	*	***	NS

*Numbers with the same letters in same column are not significantly different (P>0.05); ***: significance at P<0.001; **: Significance at P<0.01; *: Significance at P<0.05 and NS: Not significant (P>0.05).*

Integrated farm planning

Integrated farm plan approach was used to disseminate forage technologies among farmers in sustainable way. This is the planning of integrated activities related to crop, livestock, soil conservation, marketing, others activities generating revenues to the household. Farmerrs learnt that the plan should not be made by the household head only but also by each member of household in order to own the plan and its implementation. They also learnt planning, implementation and integration. Twenty-five (25) farmer innovators (PIs) were selected in Cyanika sector of Nyamagabe district and 25 PIs at Mpanga and Nasho sectors of Kirehe district. However, only 17 PIs in Kirehe and 15 PIs in Nyamagabe agreed to continue PIP activities. This is because these members have prepared vision and their action plan and they have started implementing.

During the on-farm Brachiaria evaluation, several lessons were learnt:
- Farmers were looking for good forages for quantity and quality feeds for their livestock, especially dairy cows;
- Use of vegetative material as planting materials was protracted and labour intensive, seeds could ease the work and help to reach to many farmers within a short time;
- Extension approaches like PIP could be an important approach for sustainable agricultural intensifications;
- For on-farm experiment, it is good to work with the receptive farmers;
- On-farm testing and evaluation, need a commitment of all stakeholders. It is therefore that next on-farm experiment will involve stakeholders and farmers willing to participate.

Brachiaria grass cultivars established at on-farm showed discrepancies in terms of dry matter production and chemical compositions and farmers' preferences. Farmer preference for palatability has led them to adopt some cultivars like *B. decumbens* cv. Basilisk, MG4, Cayman and Piata. Farmer preference of a given cultivar will be compared with quality and quantity data prior dissemination of the grass. In addition, some farmers have selected *Panicun coloratum* as drought tolerant grass. This is shown by the high dry matter content than other grasses evaluated in this study. However, its chemical composition was not better than other grasses. Training of farmers was also a key for on-farm forage evaluation. It is therefore capacity building of farmers is an imperative for sustainable agricultural intensification. The PIP approach was found to be an extension approach that could sustain the innovations that are being promoted for agricultural productivity.

Growth of different cross steers rice straw based rations in Mirama feedlot

This study compared the growth performance of steers in term of body weight gain of the group fed on treated rice straws to the group fed on untreated rice straws and also to assess the

nutritional composition of the rice straws and integrate rice straws as a feed resource for utilization in beef production in Rwanda. We have first prepared the material to use during the experiment by gathering rice straws from three different rice scheme which are Muvumba, Kazaza, and Cyabayaga and treat them with urea 4% nitrogen. This was followed by sampling and assessing nutritional characteristics of rice straw. And the results of the chemical analysis were used to formulate rations fed to the control group of Ankole and 3 groups of different steer cows. This study used 14 steers with initial body weight ranging from 150kg to 200kg body weight, 7 Local breed steers(Ankole), 4 Friesian steers, 3 Fleckvieh steers; these steers were from Musanze District considered as cold area as compared to Nyagatare, which is considered as hot area, the study was conducted in the period of 13 weeks and 15 days of acclimatization, and they were grouped according to breed and different type of feeds, the first group fed on treated rice straw was composed with 4 Friesian steers, 3 Fleckvieh steers and 4 Ankole steers.

The second group fed on untreated rice straw was composed with 3 Ankole steers that were control group, all those two groups fed on concentrates as supplement and water supplied as ad libitum. Feeding trial of untreated rice straw with concentrates was significantly affected the growth performance of the Ankole steers as had higher final body weight, average daily body gain (1.35kg/day), the weekly body weight was higher compare to other group. The higher growth rate of Ankole steers was associated with good adaptation to feeds. Fleckvieh on treated rice straw has shown an increase in body weight where the average daily body weight gain was (1.13kg/day) and the weekly body gain of 7.94 kg ,this was associated with capacity of Fleckvieh to adapt in different environments and able to use feeds of poor quality (Fleckvieh World,2014/2015). The Friesian on treated rice straw has low performance compare to other breeds as they had weekly average body weight gain of 5.80kg/week and daily body weight gain of 0.82kg/day this was associated with that Friesian adapted slowly in hot area and to feeds. Not only that but also Friesian is a dairy cattle and they cannot grow quickly as Fleckvieh, which is a dual purpose for meat and milk production and Ankole also which is dual purpose in milk and meat production. The results from this study suggest that the use of untreated rice straw with concentrates on indigenous cattle is likely to be technical and economically possible in Rwanda. However, exotic breeds needs further research on adaptation as there is strong variation in adaptability in different area of the country to see whether this study for exotic breeds could be conducted in cold areas to ensure that they depend to environmental conditions for their growth performance.

The samples were collected in February 2017 and originated from Kazaza, Cyabayaga and Muvumba rice scheme in Nyagatare marshland. Significant variability in samples was observed

for crude protein, fat and mean energy (Table 57). These variations might due to the fertility of the soil of origin or rice variety used and should be further studied.

Table 57: Rice straws proximate feed analysis carried out at RAB Rubona lab

Sample	DM (%)	Fat (%)	CP (%)	CF (%)	Ash (%)	P (%)	Ca (%)	NFE (%)	ME (MJ/kg)
1	94.52	1.27	10.30	39.19	16.61	0.43	1.5	32.63	8.16
2	94.26	0.42	5.86	46.6	18.9	0.58	1.8	28.12	7.10
3	92.52	0.57	6.77	45.76	12.7	0.47	1.6	34.14	8.06

DM – dry matter, CP – crude protein, CF - , NFE – nitrogen free extract; ME – mean energy, megajoule/kg

The results showed that the relationship between ration and breeds on weekly average body weight from week one to week twelve there was no significance effect of rations on body weight gain of steers as (P>0.05) while on week 13th weeks there was significance effect of rations and breeds on bodyweight gain because was P<0.05 (Table 58).

Table 58: Weekly average body weight

Week	Ankole on URC	Ankole on TRC	Friesian on TRC	Fleckvieh on TRC	P-Value
1	240	203.25	165.25	239.66	0.3613
2	242	194.25	168.5	235	0.338
3	249.66	194.75	170.25	230.66	0.2701
4	256	199.5	175.75	252.33	0.2301
5	267.64	209.75	183	275	0.2300
6	282.33	215.25	191	277.33	0.2499
7	289.66	219.25	199	290	0.2881
8	297.66	231	204.5	307.33	0.2907
9	311	241.5	209.25	307.33	0.1784
10	313.66	241.25	221	323	0.1864
11	326	251.25	227.75	326.66	0.1903
12	354	254.75	236	335.66	0.1092
13	363.66	257.75	240.75	343	0.0904
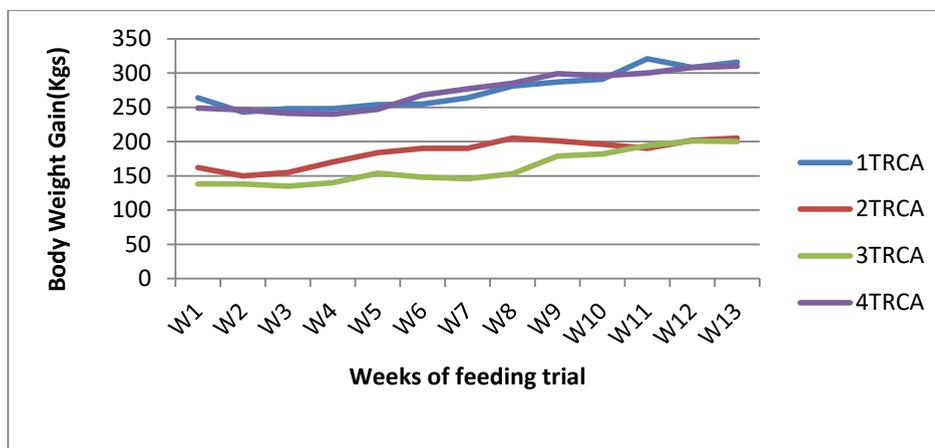
Figure 42: Weekly growth performance of each Ankole fed on treated rice straw and concentrates

Figure 42 shows the variation in body weight of four (4) Ankole steers fed on treated rice straw within 13 weeks where there was a significant increase in body weight gain on 13th week. While from week one to week 12 there is no significant difference in body weight gain. Exception to Ankole 2 the body weight has decreased a bit due to it has had disease during the feeding trial and after being treated and recovered, it has regained the weight. As those steers were in range of weight where Ankole 1 and Ankole 4 have showed higher increase in weight than Ankole 2and Ankole 3 and this increase was associated with that Ankole 1 and Ankole 4 had higher initial body weight compared to Ankole 2 and 3.
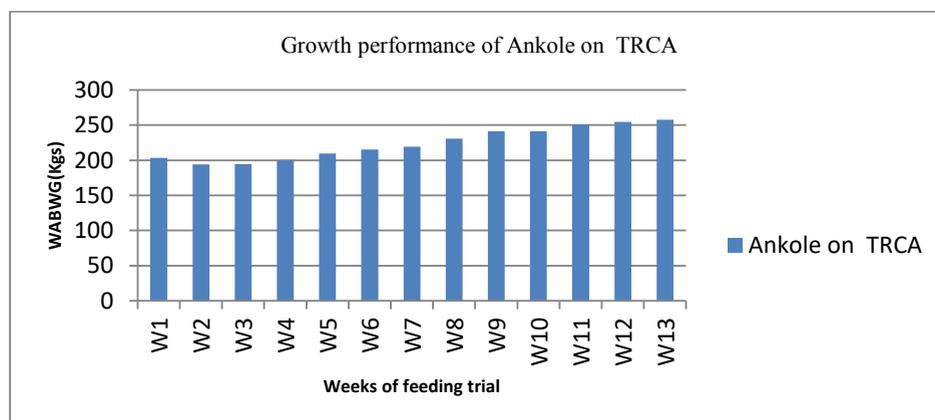
Figure 43: Weekly average body weight of Ankole fed on treated rice straw and concentrates

Ration I: Treated rice straw with concentrate, the average weekly body weight was 4.19 Kg and average Daily weight gain was 0.59 Kg. From week 1 to week 10 there was slight change in weekly average body weight gain (Figure 43), while from week 11 to week 13 there was significance in body weight increase.
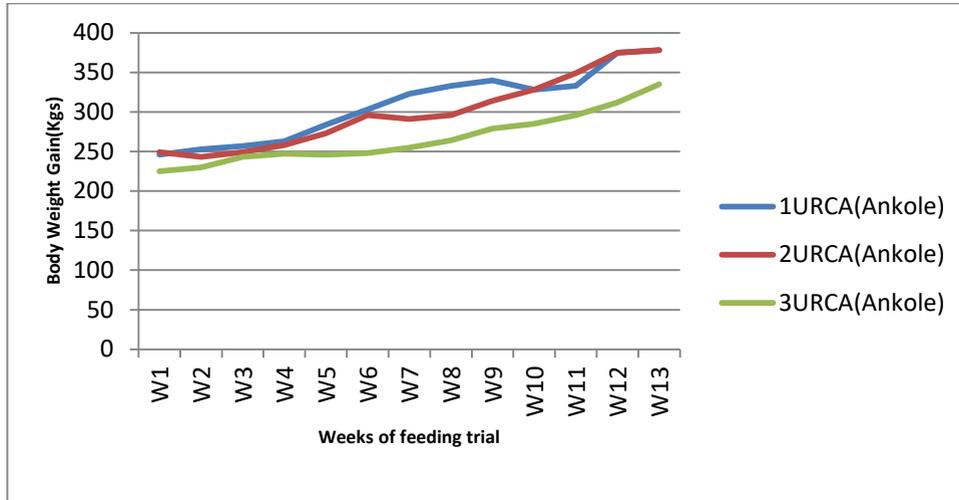
Figure 44: Weekly growth of each Ankole- control fed on untreated rice straws and concentrates

The Ankole 1 from W1 up toW9 there was slightly increase in body weight gain (Figure 44), but from W9 up to W11 he faced the decrease in the body weight due to disease, hence from W12 up to W13 he showed high increase in body weight gain after recovery.

The Ankole 2 from W1 up to W4 there was an increase in the body weight gain but from W5 up to W7 there was slightly decrease in body weight due disease and after recovery it has regained weight from W8 up to W13. The Ankole 3, from W1 up to W13 there was an increase in body weight gain.
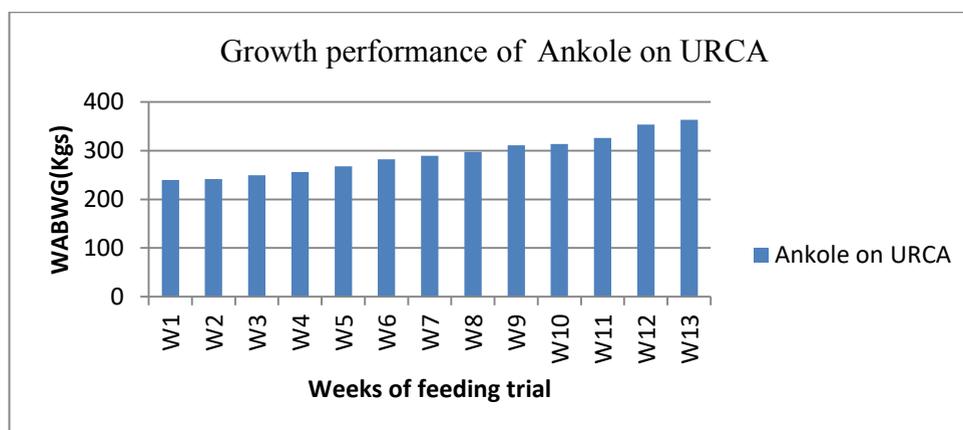
Figure 45: Weekly average body weight of Ankole- control fed with untreated rice straw and concentrates

Ration II: Untreated rice straw with concentrate to Ankole/Control, the average weekly body weight was 9.52 Kgs and average daily weight gain was 1.35 Kg (Figure 45). The average weekly body weight of Ankole-control fed on untreated rice straw in all feeding trial has shown that have

increased in body weight gain gradually as weeks pass on and the results shown above they indicate that Ankole-control steers have performed better than Ankole, Friesian and Fleckvieh steers that fed on treated rice straw, due to fact that our animals were not familiar of eating Urea in feeds.
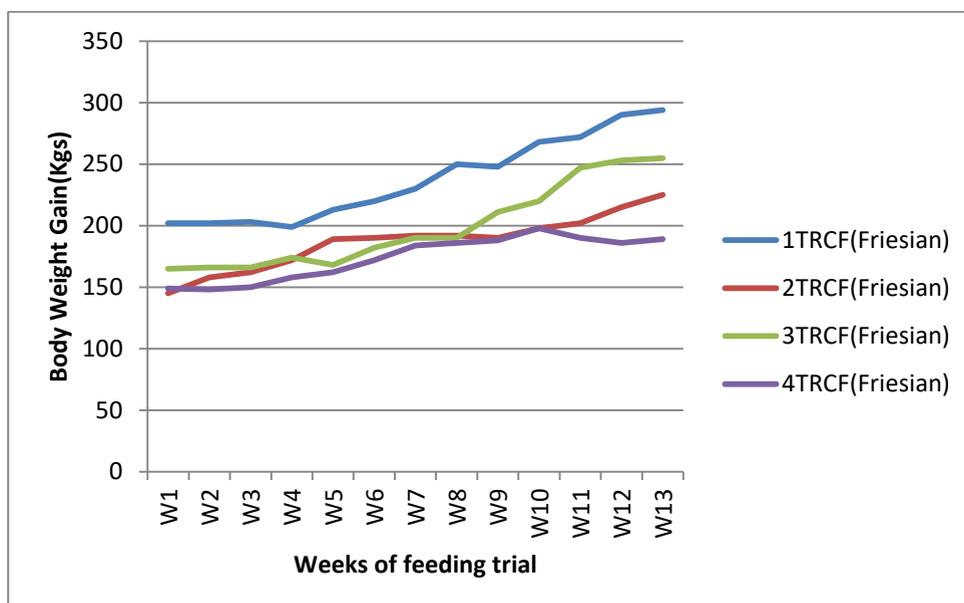
Figure 46: Weekly growth performance of each Friesian fed on treated rice straws and concentrates

Figure 46 shows the variation in body weight gain of four (4) Friesian fed on treated rice straw with concentrates. Where the Frisian 1 from W1 up to W4 showed a constant in the body weight that may be due to adaptation on feeds because from W4 up to W13 there was a significant increase in body weight gain. The Friesian 3 showed that from W1 up to W3 there was a constant in the body weight, which was associated with adaptation on feeds, after that adaptation from W4 it showed an increase in body weight gain up to W13. The Friesian 2 showed that from W1 there was an increase in body weight gain up to W13. The Friesian 4 showed that from W1 there was an increase in body weight gain up to W10 but from W11 there was a decrease in body weight gain up to W13 due to a decrease in feed intake related to disease.
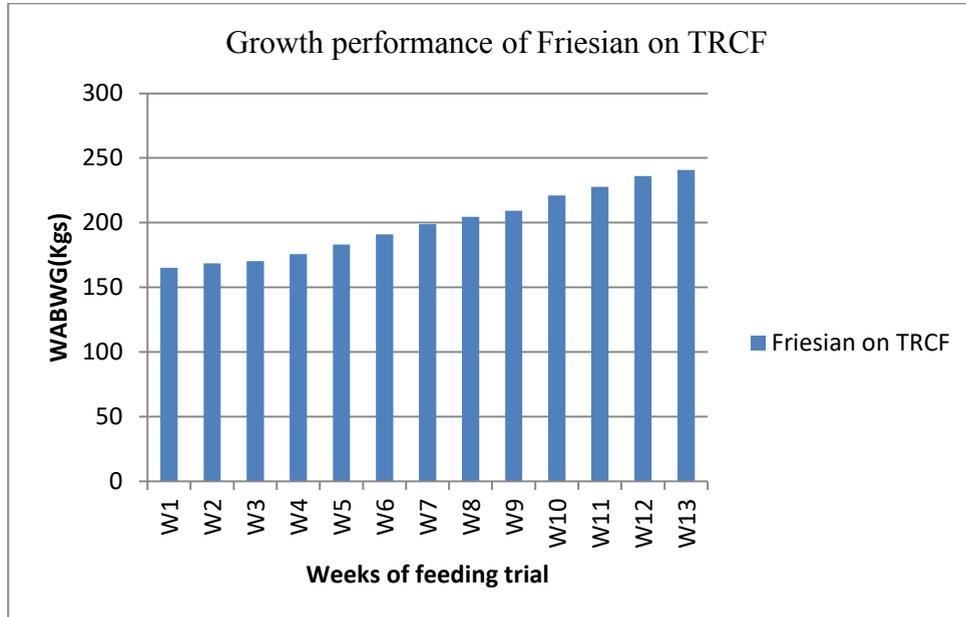
Figure 47: Weekly average body weight of Friesian fed with treated rice straw and concentrates

Ration III. Treated rice straw with concentrate to Friesian breed the average weekly body weight was 5.80Kgs and average daily weight gain was 0.82Kg (Figure 47).
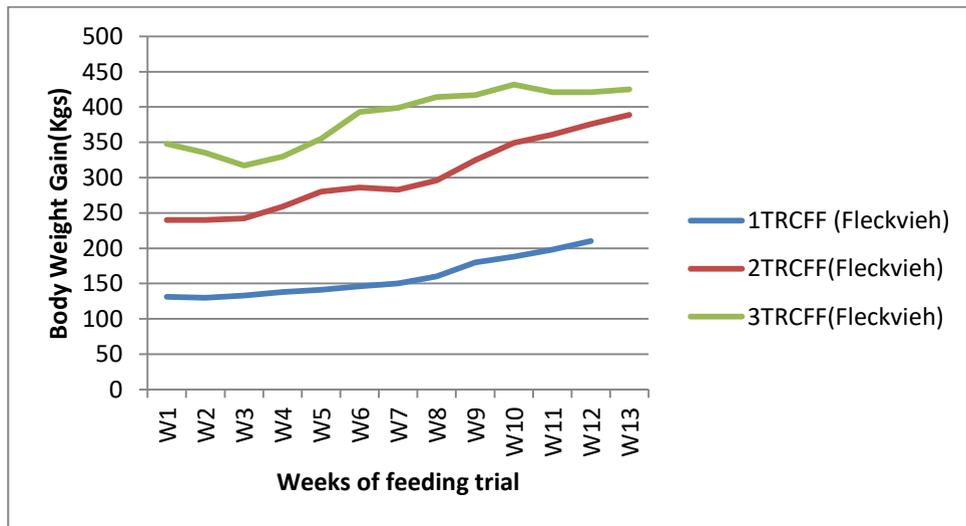
Figure 48: Weekly growth performance of Fleckvieh fed on treated rice straws and concentrates

Figure 48 shows Fleckvieh 1 and 2 from W1 had an increase in body weight gain up to W13 compared to the Fleckvieh 3 where from W1 up to W3 there was a decrease in body weight due to decrease in feed intake related to slow adaptability to feeds and environment,. Later from W4 up to W 13 showed that there was an increase in body weight gain.
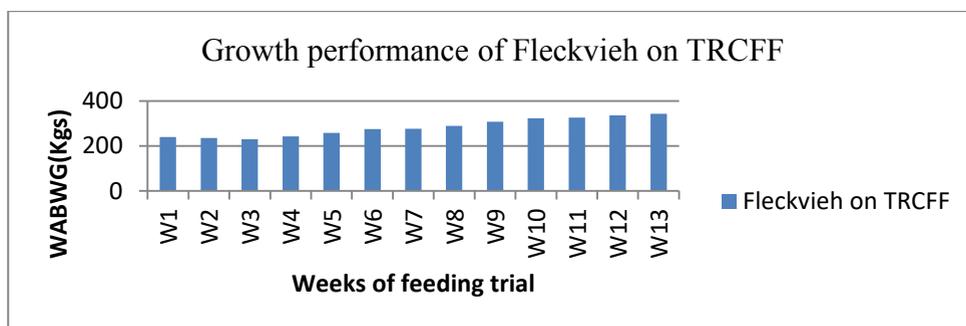
Figure 49: General growth performance of Fleckvieh fed on treated rice straws a/nd concentrates

Ration IV: Treated rice straws the results showed that the average weekly body weight was 7.94 kg and average daily weight gain was1.13 Kg (Figure 49).
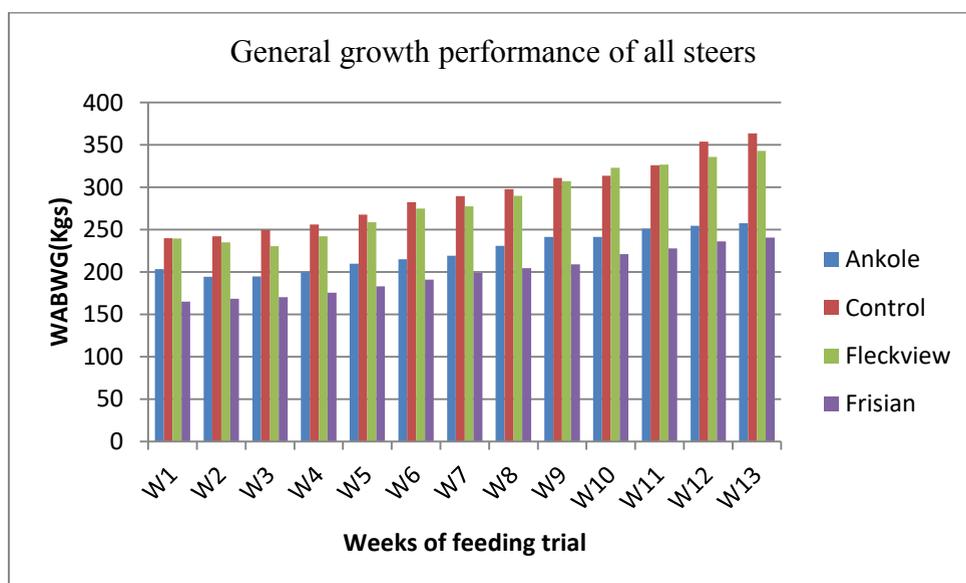
Figure 50: General growth performances in all different steers in a period of 13 weeks of feeding trial

Figure 50 shows in general the variation in body weight of all breeds in the period of 13 weeks. Here control group has increased a lot in body weight followed by Fleckvieh breeds than other breeds. The Friesian steer might not be well adapted to the rice straws, urea and to hot environment easily, but all breeds on 13th week have increased in body weight significantly, because Friesian is generally for milk production so it could not grow as fast as others.

The feeding of treated ammoniated rice straw with concentrates to Ankole, Fleckvieh and Friesian steers showed that they were able to maintain and gain body weight. The feeding of untreated rice straw with concentrates to Ankole steers showed that there were significantly increases of body weight compared to the steers that fed on treated ammoniated rice straw especially in Ankole steers. The results of our study on the effect of using untreated and treated rice straw on the animal performance can lead to a better use of local resources for cattle by farmers in the rice based farming systems, especially in Nyagatare and other region of the country where rice grown.

The adaptation of Fleckvieh and Frisian steers to rice straws feeding was low compared to Ankole steers that are familiar with poor quality feeds. The cost effectiveness of feeding rice straws in Ankole was successful compared to Friesian and Fleckvieh steers. So the use of rice straws in cattle feeding supplemented with concentrates is very economic to the farmers as verified in calculations due to its low cost, the more the cost of feeds reduces the more net profit of production increases .In addition the rice straws are available even in dry season. According to the results obtained the following recommendations can be provided to:

- To Rice farmers to do not burn rice straws as waste because they may contribute to degradation of the environment while those rice straws can be conserved so that they can be used as source of feeds to livestock during the shortage of feeds mainly in the dry season.
- To RAB to train rice farmers about how they increase rice production and how they should use rice straws as livestock feeds.

1.4.3 Goats

Following the government decision to close Karama station, goats were transferred from RAB Karama station in Bugesera to RAB Nyagatare station, where different breeds of goats are kept for maintenance and adaptability (Photo 26). Different goats breeds maintained are in different categoris as follow: 129 pure Galla, 13 pure Boer, 74 pure local, 146 cross Galla and 54 cross Boer.

Photo 26: Goat population in RAB Karama station transferred to RAB Nyagatare station

Evaluation of goat genotypes

The aim of this study was to evaluate the growth performances of goat genotypes at Karama and Nyagatare Research Centre in the fiscal year 2017-2018. The results shown that genotype significantly influenced birth weight, weaning weight and final age weight (p<0.0001). The second generation at weaning stage Boer cross local had 18.29kg while pure Galla goats had 17.6kg). The pure local goats had the lowest values at birth, weaning and final weight. The mean weight at weaning stage were 23.8kg (BB), 17.6 (GG), and 15.4 kg (LL) (Figure 51). It is concluded that pure Boer goats performed best during the study, management of the goats should be improved so as to sustain the performance, otherwise, local goats are hardy and always come handy under challenge of disease and lack of feed. Therefore, the best bet combination for eastern Rwanda would be crossbred of local goats to Boer or Galla, so as to take advantage of the two gene pools.
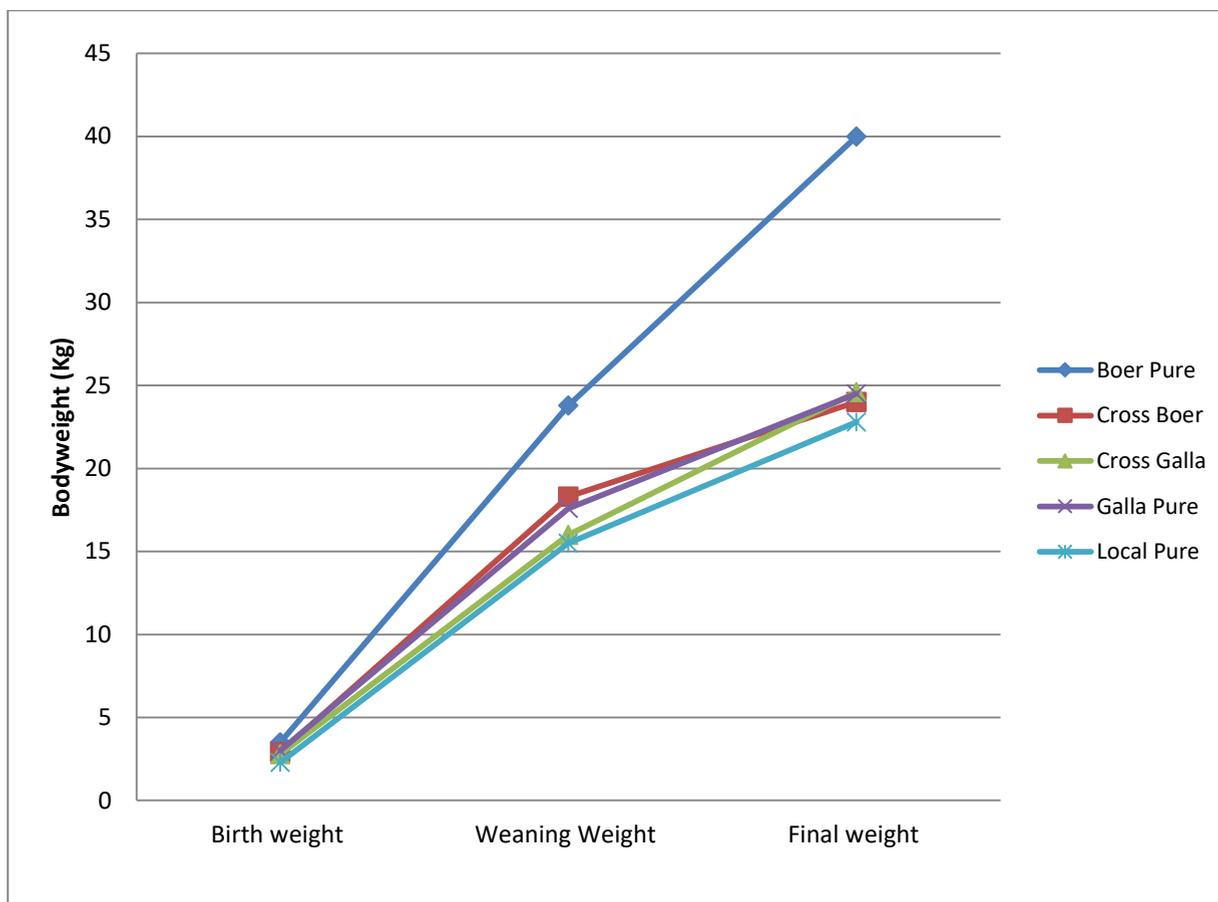
Figure 51: Effect of genotypes on body weight of goats: BB: Pure Boer; GG: Pure Galla and LL: Pure local

1.4.4 Pigs

This study was conducted to assess the factors that affect pig litter size, proportion of live pigs at birth, number of inseminations per conception, and efficiency of artificial insemination. The main factors assessed were sow breed (n = 2), sire breed (n = 3), sow parity (n = 7) and insemination method (n = 2).

The sow breeds used were Landrace, LL (n = 27) and Landrace × Pietran crossbreds, LP (n=37); boar breeds used were Landrace (LL), Pietran (PP) and Landrace × Pietran crossbreds (LP) (Table 59). Sows were randomly inseminated either by boar or artificially, with semen freshly imported from Belgium.

Table 59: Pig litter, piglets born alive or stillborn piglets, inseminators per conception

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
	Landrace (n = 27)	9.04[b]	7.79[b]	1.25	1.11
Boar breed	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 method	AI[§] (n = 40)	8.06	7.45	0.61	1.17
	NS[∫] (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

[§] AI = artificial insemination; [∫] NS = natural service

Landrace (LL) sows had significantly smaller (P<0.05) litter sizes at birth (9.04±0.72) compared to LP sows (11.49±0.45). On the other hand, the litter size for LL (±0.58) and LP (±0.67) sires did not differ, while PP sires had the highest (P<0.05) litter size (13.37±1.43). Interestingly, the method of insemination, whether use of a boar or artificially did not (P>0.05) affect the number of inseminations per conception, litter size, and proportion of piglets born live. Sow parity was found to have a linear relationship with a mean litter size at birth of 6.9±0.43 piglets for primiparous sows and 15.2±1.12 piglets for a sow of parity 7. However, the number of piglets born dead increased with parity, peaking at 3.0±0.66 (parity 7), while it was only 0.2±0.2 for parity 1 (Figure 52).
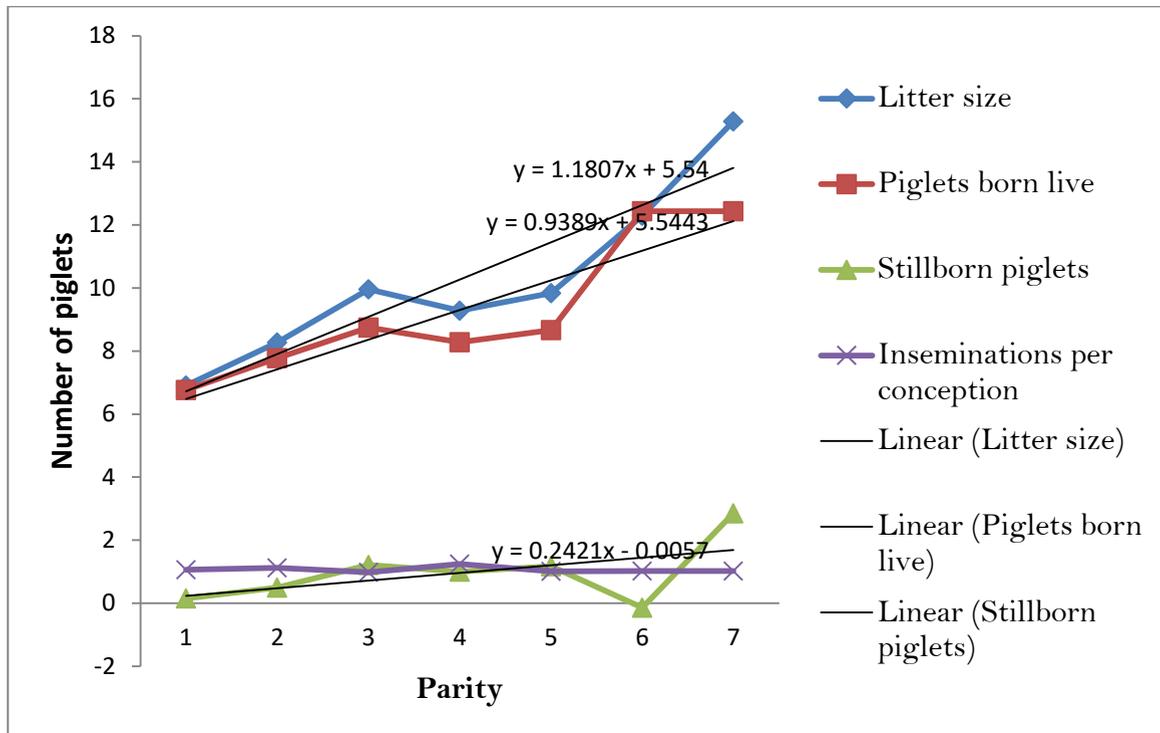
Figure 52: Effect of parity on litter size, piglets born alive and those born dead

Therefore, the LP crossbred sows and Pietran sires were recommended. Artificial insemination should be promoted since it performed as well as natural insemination but provides other advantages such as disease and inbreeding prevention, and avoids boar management costs.

1.4.5 Poultry

The research focused on growth and egg production performances of Kuroiler and local chickens at station and farm level. The data on growth performance and egg production of three genotypes Kuroiler, Kuroiler x Local and Local chickens were collected and evaluated. The average live body weight was significantly (P < 0.05) affected by the genotypes from day- old up to 20 weeks of age. The Kuroiler genotype has a high growth rate compared to their counterpart (local and crosses from kuroiler with local (Figure 53). However, the crossbreed Chickens had a better growth performance than local breed. The crossbreed expressed the traits of fast growth rate from kuroiler chickens.
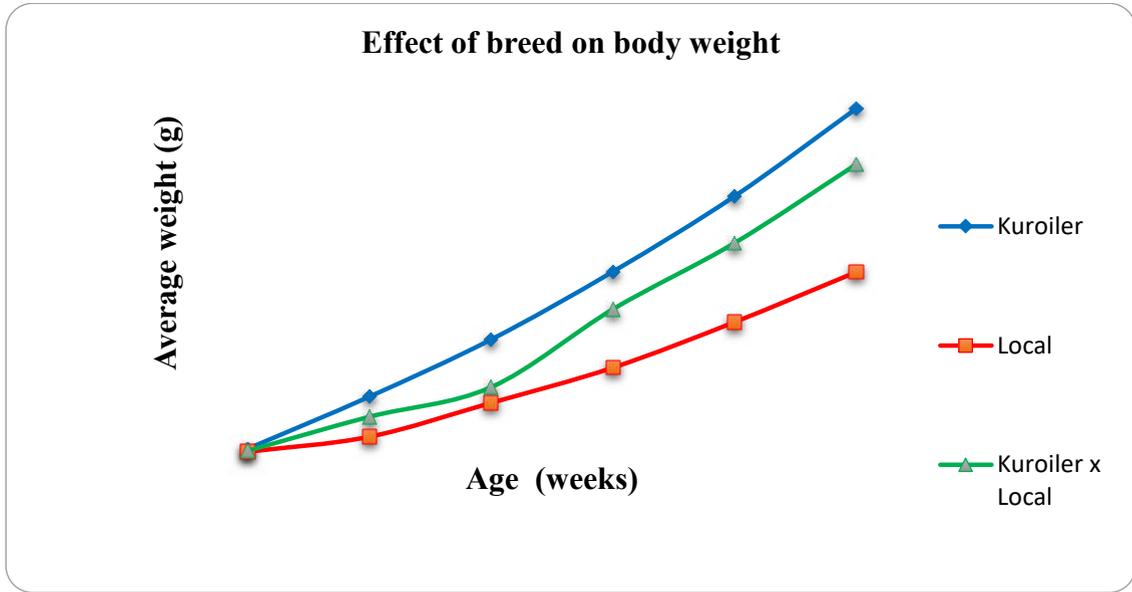
Figure 53: Effect of breed on body weight

The chicken body weight was significantly (P<0.05) affected by sex at all levels of age. Where males have high growth rate compared to females. However, from day-old to week three, the difference of the growth rate was not significantly (P>0.05) observed (Figure 54).
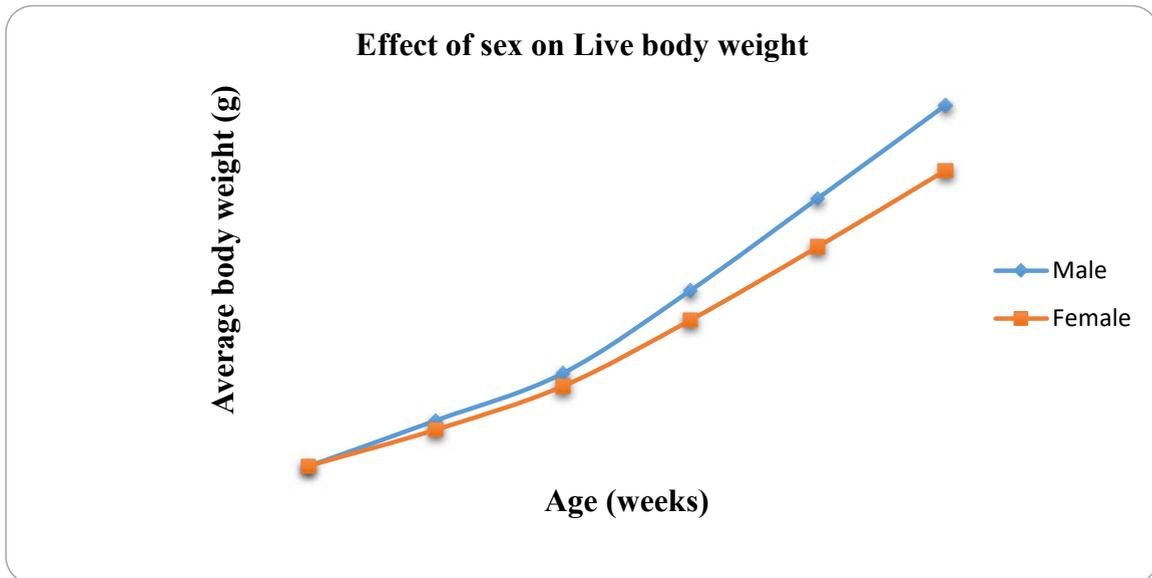
Figure 54: Effect of sex on live body weight

The average egg weight was significantly affected by the chicken genotypes, where the highest average weight was reported for kuroiler eggs and the lowest average egg weight was reported for local chickens **(**Figure 55**).**
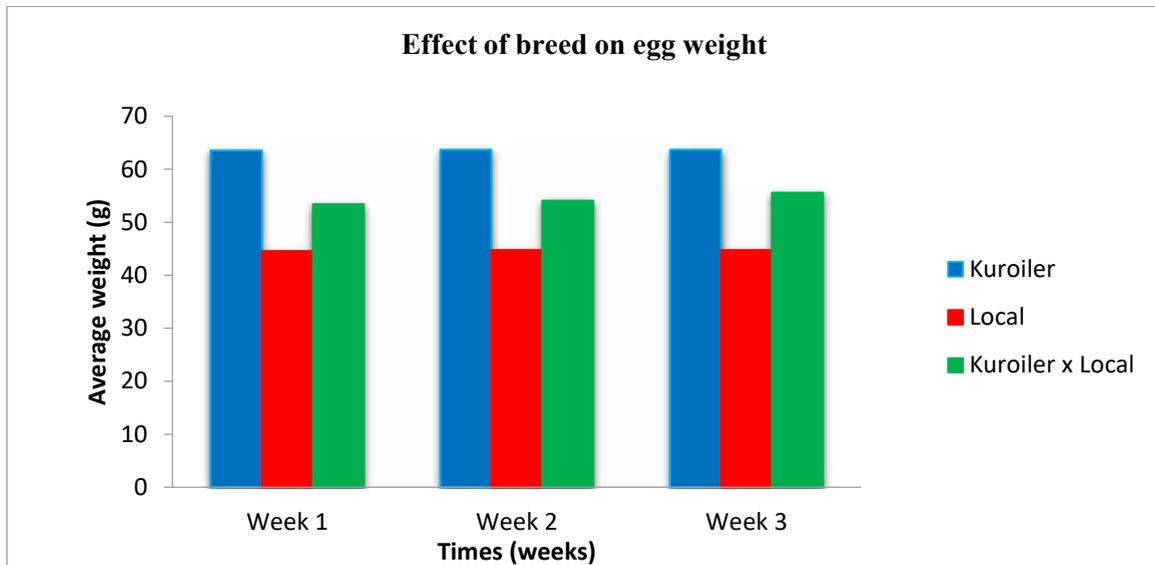
Figure 55: Effect of breed on egg weight

The research in aquaculture and fisheries focused on Diversification of fish species to increase production and exploit different ecological niches in water bodies; effect of stocking density on growth performance of Nile tilapia (*Oreochromis niloticus*) fed with locally produced fish feed in pond culture; Characterization of Kirimbi and Gaharwa lakes for better management under limnological study; assessing fish feed ingredients availability and technology dissemination by training.

Diversification of fish species to increase production and exploit different ecological niches in water bodies

Different fish species (90 carps, 10 *Clarias gariepinus*) were captured in Nasho fishing zone lakes (Rwampanga and Nasho) and brought to Kamisave fish farming station for adaptation. Some of identified fish transferred to Kigembe ponds for further research activities while being evaluated at Northern Agricultural Zone Division (NAZD) in collaboration with the identified fish farmers. Fish collected for adaptation are growing well and have to be artificially reproduced in warm seasons of the year (Photo 27).

Photo 27: Carps under adaptation at Kamisave fish farm

Effect of stocking density on the growth performance of Nile tilapia (Oreochromis niloticus) fed with locally produced fish feed in pond culture

The objective of this study was to verify the effects of stocking density on the growth performances of Oreochromis niloticus in pond culture system. The fish was stocked in ponds when they had attained an average weight of 2.6±0.1g at a density of 3fish/m^3 and 13fish/m^3 for LD and HD respectively both in triplicates. A total of six happas were installed in earthen pond. Fish were fed on locally feed (30% CP) made. The feed was administered to fish at 5% body weight fed three times a day (at 9.00, 13.00) for about 5 months. Feeding rate were adjusted every 2 weeks based on the average weight of fish. Three water quality parameters (pH, temperature and dissolved were recorded weekly based on their major influence on fish growth.

The growth parameters like: Average Daily Gain (ADG), Weight Gain (WG), and Specific Growth Rate of Oreochromis niloticus fed with locally made fish feeds under Low and High stocking densities and their results are shown in Table 60. It showed that specific growth rate/day (SGR), ADG and WG were significantly (p<0.05) different. The fish stocked under high density of 13 fish/m^3 had higher values than fish reared under low density of 3 fish/m. SGR was 2.71±0.02 2 and 3.47±0.03%, ADG was 0.27±0.007 and 0.57±0.017g while WG was 40.8±1.1 and 83.5±2.5g for fish reared in high stocking density and for fish reared in low density, respectively. However, the biomass for fish reared in high stocking density was significantly higher than those in Low stocking Density. The food conversion ratio (FCR) were no significant differences (p>0.05), although in High stocking density the FCR were low at 2.46 as compared to Low Density fish cultured with 2.71. Food conversion ratio was therefore not significantly affected by stocking density. Fish survival was good for the fish reared in High stocking density (96%) as well as for the reared in low stocking density (98%).

Table 60: Growth parameters, Food Conversion Ratio and Survival Rate of Nile Tilapia grown under Low Density and High Density for five months

	Culture system	
Parameters	LD	HD
Specific growth rate (%)	2.71 ± 0.02^{a}	3.47 ± 0.03^{a}
Weight gain (g)	40.8 ± 1.1^{a}	83.5 ± 2.5^{b}
Average Daily gain (g)	0.27 ± 0.007^{a}	0.57 ± 0.017^{b}
Biomass (g)	565.3 ± 14.2^{a}	258.3 ± 7.6^{b}
Survival rate (%)	96	98

Values in the same row sharing the same superscript are not significantly different (p>0.05. Data are represented as means ± standard error.

Although from the first up to fifth month the fish reared in Low stocking Density had a significantly faster growth trend values (p<0.05) (Table 61).

Table 61: Weight and Length of fish under high & low stocking density over 5 months

		Culture period (months)					
	System	0	1	2	3	4	5
Weight (g)	HD	2.6 ± 0.1^{a}	3.3 ± 0.1^{a}	9.8 ± 0.4^{a}	17.9 ± 0.7^{a}	30.6 ± 1.2^{a}	43.5 ± 1.01^{a}
	LD	2.6 ± 0.1^{a}	13.5 ± 0.6^{b}	26.5 ± 1.4^{b}	44.8 ± 1.5^{b}	56.2 ± 1.9^{b}	86.1 ± 2.5^{b}
Length (mm)	HD	51.2 ± 1.0^{a}	57.1 ± 0.5^{a}	77 ± 1.0^{a}	95.5 ± 1.3^{a}	117.9 ± 1.6^{a}	133.4 ± 1.2^{a}
	LD	51.2 ± 0.1^{a}	89.8 ± 1.3^{b}	111.8 ± 1.6^{b}	132.4 ± 1.4^{b}	146.7 ± 1.5^{b}	166.7 ± 1.4^{b}

Values in the same column sharing the same superscript under a parameter are not significantly different (p>0.05). Data are represented as means ± standard error

The values of dissolved oxygen and pH were in low density and in High density, 6.7±0.3 and 5.7±0.3, 7.4±0.2 and 6.5±0.3 for LD and HD, respectively (Table 62). The temperatures values were (25.4±0.7 and 25.0±0.4) in Low stocking density and in high stocking density, respectively. Thus, fish reared in low stocking density had good growth performance than the fish reared in high stocking density. But for the biomass, the results showed that the fish in high stocking density system give high biomass yield per area than fish stocked at low densities. However, in this study there was no significant effect on the survival and FCR of the fish in the two systems.

Table 62: Physicochemical parameters of water in High Stocking Density and in Low stocking Density

	Culture system	
Parameters	HD	LD
Temperature (°C)	25.0±0.4 [a]	25.4±0.7 [a]
PH	6.5±0.3 [b]	7.4±0.2 [b]
DO (mg/l)	5.7±0.3 [a]	6.7±0.3 [b]

Values in the same row sharing the same superscript under a parameter are not significantly different (p>0.05).

Data are represented as means ± standard error.

Characterization of Kirimbi and Gaharwa lakes

The objective of the limnological study is to assess the trophic status and characterize lakes Kirimbi and Gaharwa based on physical and chemical parameters as well as of their plankton composition, macro invertebrates and variations (primary and secondary production) (Photo 28).

Photo 28: Field work on lake characterization for Kirimbi and Gaharwa lakes

Field data were collected on water quality, temperature, pH, transparency, chlorofylle and dissolved nutrients from water samples collected in both lakes. The CTD device and conductivity and pH-meters were used to determine the temperature, Dissolved oxygen, pH, turbidity and conductivity. Nutrients and other chemical parameters such as

ammonia, nitrogen, nitrite, alkalinity, C02, hardness, chloride, chlorofyll, dissolved oxygen were measured with a fresh water aquaculture kit. Ammonia concentration was quantified. The NH4 JBL test was also used to confirm the ammonia concentration in water. Water samples at different depth were collected using Van Dorn bottle. Plankton net was used to collect water for further analysis in the laboratory. The data obtained are being analysed.

The water column is practically not stratified in term of temperature but this stratification may occur to the concentration in dissolved oxygen. It is due to the small size of Kirimbi and Gaharwa especially from their shallow depth. More details will be given at the end of this study. Physical and chemical water parameters are still being collected. Analysis to quantity and to qualify zooplanktons composition and biomass will be done the next fiscal year in collaboration with Lake Kivu Monitoring Program (LKMP).

Farmer survey to assess fish feed availability

About 32.7% fish farmers surveyed did not use any type of fish feed. They reported high cost of fish feed and their inaccessibility nearby as the reasons of none feeding. Only 30% fish farmers supplied either own formulated feed or bought fish feed from commecial establishments nearby. However, they mentioned high cost and difficulty in finding fish meal.

Fish meal is mostly available in western province. Similarly, the development of commercial aquafeeds has been traditionally based on fishmeal as the main protein source due to its high protein content and balanced amino acid profile. About 13% fish farmers used leaves of different crops as fish feed (Table 63). These were cassava, sweet potato or cabbage leaves. About 25% of farmers used by-products to feed their fish (Table 63), consisting mainly of maize, rice or wheat bran. These were generally cheap and available across the country.

The majority of fish farmers surveyed do not supply complete feed to their fish, and this has direct impact on keeping low fish yields. Rice, wheat and maize bran are the ingredients, which are mostly available in different sites of the country while fish meal can be found in Western Province.

Table 63: Feed type used by fish farmers

Location/ District	Number of farmers surveyed	No feeding for fish	Farmers using formulated feed	Farmers using by-products	Farmers using crop leaves
Muhanga	6	2	2	1	1
Ruhango	3	1	1	0	1
Huye	4	2	0	1	1
Nyamagabe	4	1	1	1	1
S/T	22	8	5	4	5
Musanze	5	2	1	1	1
Gicumbi	4	2	1	1	0
S/T	9	4	2	2	1
Gasabo	6	1	3	2	0
Rwamagana	4	2	1	1	0
Rusizi	5	1	2	2	0
Nyamasheke	6	1	2	2	1
S/T	11	2	4	4	1
Total	52	17	15	13	7
Percentage (%)	100	32.7	28.9	25	13.4

Ingredients preparation and feed formulation

After this survey, the sample of available ingredients considered as source of protein in fish feed (Sun flour, Cotton cake, fish meal and soya bean meal) was analyzed in laboratory of RAB at Rubona Centre to indicate the quantity of protein and lipid included. The ingredients used to formulate fish feed were locally purchased and grind to a small particle size. Thereafter, the ingredients were mixed thoroughly with added water to obtain approximately 30-40% of moisture. Then, diets were passed through mincer with diameter of 2mm and were put to sun dried for 2days. The composition of diets (Table 64) was formulated to be 35% CP and approximately 8% of crude lipid.

After this formulation, the feed was used for trials of Nile Tilapia fingerlings in order to evaluate the growth performance or to compare those feed with other feed (RAANAN feed and PAFI feed) from different factories. Fish feed from local factories must be utilized by Tilapia Farmers safely and efficiently when those local factories will be regulating the quality of inclusion rate of plant protein sources in the diets, balance of essential amino-acids, as well as the mineral contents.

Table 64: Ingredients used for experimental diets (100Kg)

Ingredients	Crude Protein (%)	Crude Lipids (%)	Quantity in diet formulation (100Kg)
Fish meal	50.04	7.8	38
Soybean meal	36	5.8	20
Sunflower cake	19.58	8.90	10
Cotton cake	28.92	6.8	20
Maize bran	8.3	6.2	10
Fish oil	0.00	100	1
Vitamins	13.50	3.90	0.25
Mineral premix	5.00	0.50	1
Dicalcium phosphate	0.00	0.00	1
Anti-oxidant	0.00	0.00	0.2
Total	35	7.82	100

Technical support, capacity building and Production of fingerlings

Trainings focused on fish farming as well as better management of capture fisheries (Photo 29). More emphasis was given to modern farming technics in cages, pens and ponds. Farmers got trained on ponds preparation, design and construction; fish fingerlings stocking, sampling and harvesting; fish farm management; installation of tilapia incubation systems given by FAO and hatchery operations; monitoring and follow up of cages, legal fishing in lakes; etc.

Photo 29: Training of fishermen in CODEPOITA cooperative and fishermen group from Northern Province (right)

Photo 30: Visit to lake Muhazi cage farming project (left); fish processing at Kibare landing site (right)

Fishing cooperatives were inspected by checking the fishing boats, fishing nets, fishing licenses, life jackets to limit illegal fishing and to avoid overfishing (Photo 30, 31).

Photo 31: Inspection of fishing equipment

Fingerlings production was done at Kigembe Fish Center. The main purpose of this station is to support farmers by assisting them with extension services, fingerlings production, trainings and technical advices (Photo 32).

Photo 32: Supply of fingerlings at Nyamasheke (left); breeding happas for fingerling production at Kigember (right)

1.4.7 Apiary

The apiary research focused on queen rearing, technology dissemination and training. Identification of suitable method for queen rearing and investigating the introduction time and early performance success rates of queen bees. The objective of the study was to evaluate the effect of queen age on introduction, early performance and satisfactory performance success

and to develop an effective method for rearing queen honey bees in Rwanda. There was no significant difference for queen bee survival rates 15 weeks after introduction for each age group of queens supplied to Apiary A and Apiary B for 2017 and 2018 (Table 65).

Table 65: Number of queen bees present at the 15 weeks inspection and displaying satisfactory performance

Date of introduction	Age of queen when caught (days)	Number of queen bees 15 weeks after introduction and displaying satisfactory performance			% #
		Apiary A	Apiary B	Total/40	
10.06.2017	7n	1*	3	4**	10.3 a
17.06.2017	14n	2	7	5	12.5 a
24.06.2017	21n	7	15	22	55.0 b
17.06.2018	7n	1	2*	3*	7.7 a
23.06.2018	14n	14	10	24	60.0 b
30.06.2018	21n	14	13	27	67.5 bc

 # groups are significantly different, $P<0.05$; n = caught from mating nucleus; b = caught from queen bank, but the total number of queen introduced are 20 per group

For 2017, there was a significant difference, $P<0.05$, for queen bees introduced at 7 and 14 days of age compared to 21-day old queens. For 2018, there was a significant difference, $P<0.05$, in queen survival rates for queens introduced at 14 and 21 to queens introduced at 7 days. There was significant difference ($p<0.05$) between the two methods of raising queens, the number of queen raised without grafting (using cupularva or brood frames) was higher than those raised with grafting method.

It is recommended that queen bees must have at least 21 days of age when they are to be introduced into an established honey production colony. The data demonstrated that seven and fourteen days (21 percent and 59 percent introduction success, respectively) are not suitable ages for catching queen bees for introduction into established bee colonies immediately on arrival at their destination.

Apiary technologies dissemination

Two technologies in queen breeding were developed in Ruhande apiary (by using grafting equipment and without grafting materials) and disseminated to 6 cooperatives and 2 beekeeping unions (at Nyabihu and Rusizi) in collaboration with Dr Horn from Germany where queen breeding technologies were disseminated and experimented in farmers apiaries in " Ibisi bya Huye" and Rusizi apiaries (Photo 33).

Photo 33: Training on queen bee rearing at Nyabihu

The techniques of colony multiplication by using artificial swarm and queen breeding were developed and disseminated to 20 master beekeepers from Musanze, Rubavu and Rutsiro as nucleus of beekeeping in the communities.

1.4.8 Sericulture

Sericulture research activities were mainly focused on characterization, selection and breeding of both mulberry and silkworms.

Characterization of mulberry varieties

The characterization of germplasm accessions is carried out using morphological, biochemical and physiological characters, rooting ability of stem cuttings, leaf yield, leaf moisture, protein and sugar contents, photosynthetic efficiency, physiological water use efficiency etc. These traits will help breeders to select parent varieties with desired traits for further breeding programs. In order to select mulberry varieties, which have water high retention capacity in their leaves a study on water loss of three mulberry varieties, were conducted. The moisture content of mulberry leaf is one of the key constituents determining the quality of the feed. It has a positive influence on the growth of silkworm larvae. It is in that context that three mulberry varieties were characterized. These mulberry varieties include Diamond, as control, Nong Sang-14, and Gui Sang You 62.

Leaf moisture content and moisture retention capacity were determined on fresh weight basis. For each maturity, 25 leaves/replicate/variety were harvested separately from a longest shoot, leaves were wiping to remove dust particles, and fresh weight was recorded immediately. Ten

leaves were kept in normal environmental conditions (26 ºC±1 ºC temperature; 70%±5% relative humidity) for 6 hours. After 6 hours, leaves were weighed for calculating water retention capacity. Then leaves were dried in hot air oven at 80 ºC for 48 hours until constant weight was attained and dry weight was recorded. Leaf moisture content of tender, medium, and coarse leaves was calculated separately by using following formula and expressed in percentage (%).

$$\text{Leaf moisture content (\%)} = \frac{Fresh\ weight\ of\ leaves - dry\ weight\ of\ leaves}{Fresh\ weight\ of\ leaves} x100$$

Leaf moisture retention capacity was calculated by using following formula and expressed in percentage (%).

$$\text{Leaf moisture loss (\%)} = \frac{Fresh\ weight\ of\ leaves - wt\ of\ leaves\ at\ 6\ hours\ after\ harvest}{Fresh\ weight\ of\ leaves} xLMC$$

Leaf moisture retention (%) = 100- Leaf moisture loss

Mulberry varieties revealed variations in moisture content and moisture retention capacity. Moisture content was significantly higher in tender (80.64%), medium (78.19%) and coarse (75.74%) leaves of Gui Sang You 62 and lower in leaves of Diamond (66.72%, 64.77%, and 63.16% respectively). Moisture retention capacity was the highest in leaves of mulberry variety Gui Sang You 62 (81.56%, 79.54%, 77.19%, respectively) and lowest was recorded in Diamond (68.26%, 66.84%, 64.78%) (Table 66).

Table 66: Moisture content and moisture retention capacity of different mulberry varieties

Mulberry variety	Leaf maturity	Moisture content (%)	Moisture retention after 6 hours (%)
Gui sang You-62	T	80.64	81.56
	M	78.19	79.54
	C	75.74	77.19
Nong Sang-14	T	78.10	80.16
	M	76.41	78.19
	C	74.03	75.61
Diamond	T	66.72	68.26
	M	64.77	66.84
	C	63.16	64.78

T: tender, M: medium, C: coarse

In mulberry leaves, moisture content plays a vital role in improving nutrition levels that in turn improve the palatability and digestibility of leaves by silkworms as well as normal growth and development of silkworms and cocoons quality. It is a genetic character and influenced by available soil moisture and root proliferation nature of mulberry variety. Availability of moisture content in leaves enhances feeding efficiency of silkworm larvae, which in turn increases growth rate. Moisture content and moisture retention capacity was superior in Gui Sang You-62 followed by Nong Sang-14 and Diamond.

Screening of mulberry varieties

The larval growth development was measured by taking into account fresh weight of worms. Since quantity of mulberry leaves fed in all treatments was homogeneous and only one silkworm breed used, the comparison was based on mulberry varieties. Larval weight records taken in different periods (Figure 56) showed non-significant difference among treatments in the period P1 and P4, whereas in other periods (P2, P3, P5, P6, P7 & P8) treatments were significantly different (P<0.01) in larval weight.
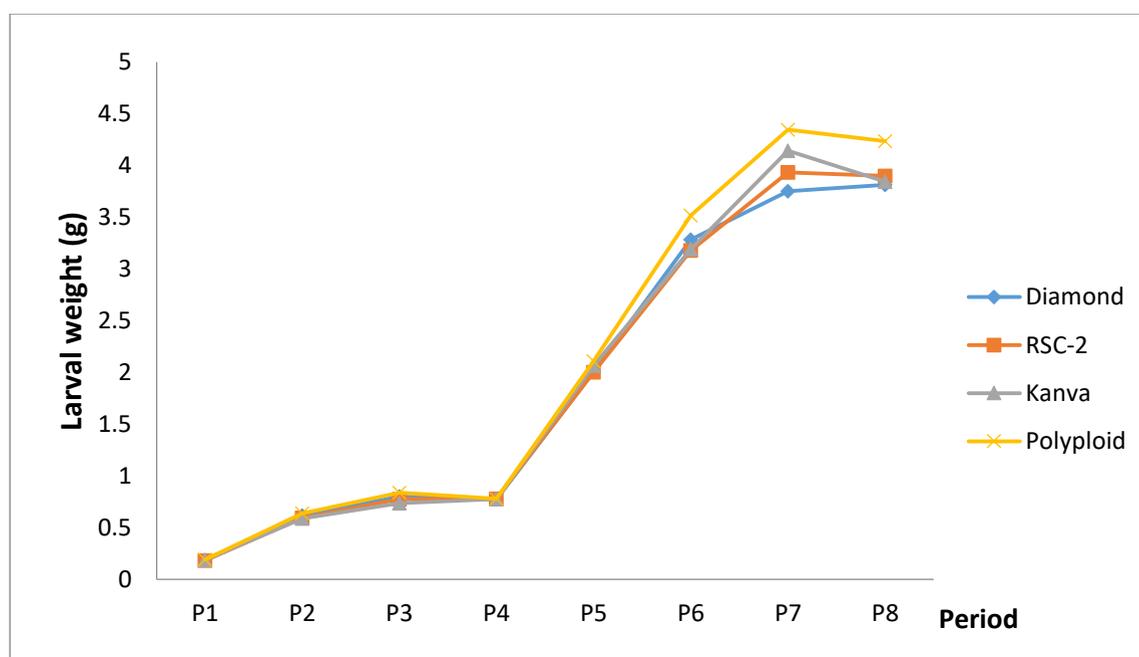
Figure 56: Larva weight of silkworm, recorded in different period, supplemented by different mulberry varieties

The mulberry worms feeding on leaves of polyploid variety (T3) were significantly better as compared to those feeding on other varieties.

Economic traits

Cocoon weight was the highest (p<0.05) in polyploid variety (1.74 ± 0.052 g), while the lowest was recorded in RSC-2 (1.55 ± 0.057 g). The highest (p<0.05) shell weight was also for polyploid variety (369.48 ± 10.95 mg), while the least was in Diamond (321.45 ± 11.83 mg). Higher (p<0.05) pupal weight was observed also for polyploid (1.378 ± 0.042 g) (Figure 57). No significant difference was noticed for shell ratio.

The performance of the silkworm breed SH was found to be superior by feeding the mulberry variety Polyploid over Diamond, Kanva-2 and RSC-2 varieties for larval weight and economic traits (cocoon weight, shell weight, pupal weight and shell ratio) (data not shown).
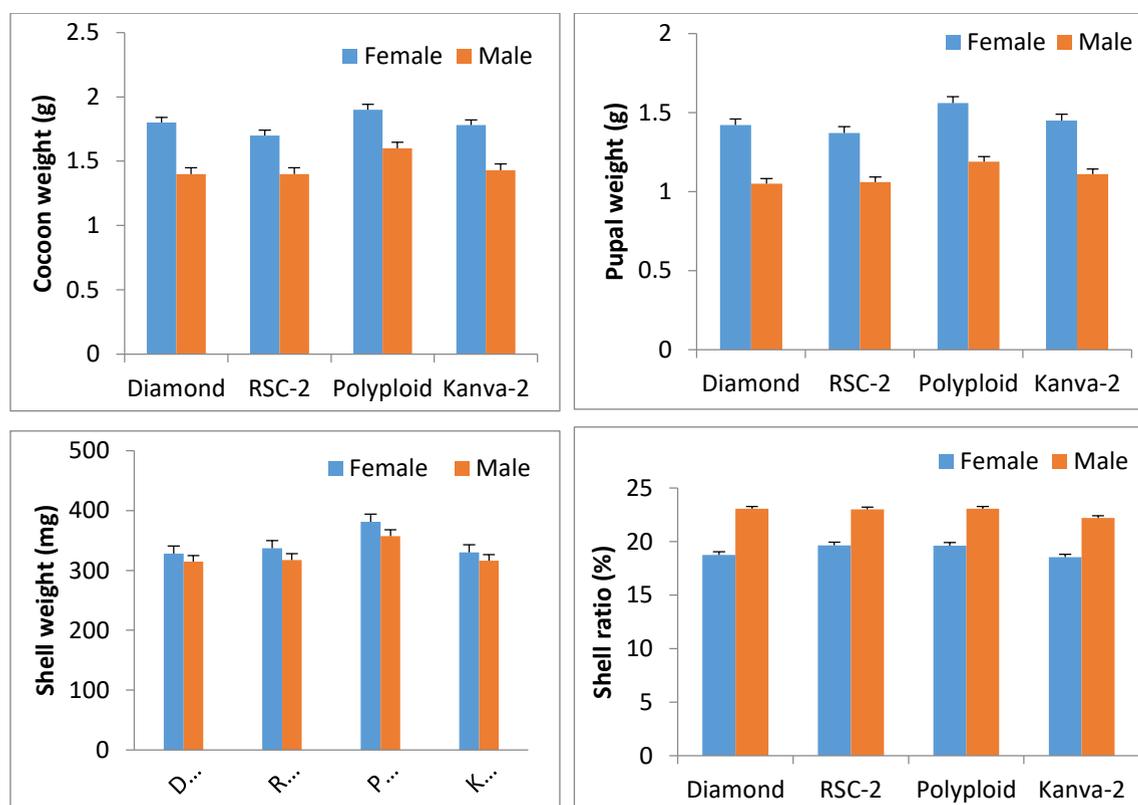
Figure 57: Cocoon weight, shell weight, pupal weight and shell ratio of silkworm hybrid SH fed on 4 mulberry varieties (Diamond, RSC-2, Kanva-2 and polyploid)

Training of technicians and farmers

Ninety farmers and agronomists were trained on mulberry cultivation, establishment of mulberry garden and saplings preparation, pruning of mulberry trees, harvesting methods of mulberry leaves, maintenance and fertilization of mulberry fields, mulberry pests and diseases,

preparation of silkworm rearing and rearing of silkworm, silkworm diseases and pests, harvesting and handling of cocoons, cocoon grading and pricing system (Photo 34).

Photo 34: Training of individual and cooperative farmers from Nyaruguru and Nyamagabe

Maintenance mother garden mulberry plantation

More than 700 000 mulberry cuttings were planted for the production of saplings. These saplings were distributed in different districts of the Southern province (Huye, Nyamagabe, Gisagara, and Nyaruguru) (Photo 35).

Part 2. Crop Production and Food Security

2.1 CIP

The Crop Intensification Program intends to increase the productivity of priority crops, increase the revenues among smallholder farmers and thereby ensure food security. The activities implemented under this program in 2017-2018 were around its four pillars: (1) distribution of inputs, (2) land use consolidation, (3) proximity extension services, and (4) post-harvest handling and storage.

Input distribution and use

The quantities of seed distributed in seasons 2018A & B were 2,373,329 kg of maize, 437,091 kg of Wheat and 723,639 kg of soybean while the mineral fertilizer distributed in these seasons were 9,616,640 kg of DAP; 6,337,988 kg of UREA; 13,969,029 kg of NPK; 112,100 kg of KCl and 487,603 kg of Yara products.

Land use consolidation

The targeted area under eight priority crops was estimated at 809,191ha and 577,880 ha in season 2018A & B respectively but 93% and 95% were planted in these two seasons. The table below presents the targeted and planted area by crop (Table 67).

Table 67: Annual targeted area Vs planted area by priority crop

Crop	Annual Target (ha)	Planted area (ha)	% of area planted vs target
Maize	321,514	314,179	97.7
Beans	705,130	707,711	100.4
Cassava	109,616	63,883	58.3
Soybean	24,720	15,980	64.6
Rice	29,505	28,790	97.6
Wheat	51,278	38,650	75.4
Irish Potatoes	134,344	123,063	91.6
Vegetables	10,965	8,970	81.8
TOTAL	**1,387,072**	**1,301,227**	**93.8**

Beans (100.4%), Maize (97.7%) and Rice (97.6%) achieved almost their targets while cassava has the lowest proportion of planted area vis-a-vis targeted area with only 58.3%.

2.2 Proximity extension services

Activities carried out through TWIGIRE MUHINZI Extension model focused mainly on the training of extension agents and farmer promoters as well as the distribution of extension materials and trainees incentives (Photo 36).

Photo 36: Training of Farmer promoters on Good Agriculture Practices

Training on Maize planting

During the training on maize planting, trainees got T-shirts, FPs training manual, Farmers' fliers, FPs inputs in 49 sectors and FPs cooperative inputs in 48 sectors as training incentives. As a results of the training and incentives received, it was observed that the number of farmers trained by farmer promoters has increased, the maize yield is increasing and more farmer promoters are applying good agriculture practices.

Training on good agriculture practices (GAP)

This training conducted in 2018B season aimed at making extension agents understand the benefits of using GAPs and how to use Smart Nkunganire System (SNS): new system of ordering agriculture inputs using telephones. The training was provided to farmer promoters, FFS

facilitators, Agro dealers, SEDOs and Sector agronomists from 401 sectors throughout the country and the focus was on four priority crops (Table 69).

Table 68: Trial variations used to train participants on maize planting

Trial description	Hypothesis
Active Learning Training (ALT) trial (in 210 sectors): combination of active learning theory and practical training sessions in fields using a trainer script	*Class based theory training results in limited knowledge transfer. Participatory, practical & shorter training will increase transfer and motivation*
Active Learning + individual FP Inputs for demo trial (in 49 sectors): Like ALT, but additional provision of fertilizers to FPs to be used in demonstration plots	*Inputs will ensure FPs will establish demonstration plots with improved input*
48 Active Learning + FP Cooperative (In 48 sectors): Like ALT, but additional provision of inputs (seed and fertilizer) to FP cooperatives	*Incentivizes encourage FP to improve R&R & strengthening or form cooperatives*

Table 69: The number of Sectors covered by province and by crop

	Soybean	Cassava	Beans	Irish Potato	Total
Kigali City	15	2	3	0	20
Southern Province	7	52	18	24	101
Western Province	4	4	73	15	96
Eastern Province	31	24	40	0	95
Northern Province	0	0	77	12	89
Total	**57**	**82**	**211**	**51**	**401**

During this training, different training materials were distributed to participants and these include: SNS guides, 18B booklets, FPs check lists, FPs and TM leader guides, FPs, FFs and SEDOs T-shirt, Hats and T-shirt for sector and district agronomists, Director of agriculture and Natural Resources, mayors and vice mayors.

Training on Fall Army Worm (FAW)

To respond to recent outbreak of fall army worm, The training on FAW was attended by 17,707 participants (13,539 males and 4,165 females) with a low rate of agro dealers especially because they were busy selling Agri-inputs to farmers. The incentives distributed in this training were FAW manual, Farmers' fliers, Gloves, Anti-gas mask, googles, a bottle of Cypermetrin 4% +Profenofo 40% (100ml) and Syringe

2.3 Crop Protection

The crop protection program's main activities carried out in 2017 – 2018 include:

➢ Monitoring and control of pests and diseases for priority crops as well as the constitution of a strategic stock of pesticides. In this line, strategic stock of pesticides of 4,950 litres of pesticides were purchased to manage pests especially maize stalk borer and fall army warm. During 18B season, on 6,234.5 ha of Maize affected by FAW, over 96% were managed and treated and affected crops were recovered. Over 1,616 litres of different pesticides including Cypermethrine, Cypermethrin+Profenofos, Pyrethrum, and Imidachloprid were distributed to farmers in affected areas to manage FAW and other insect pests.

➢ Mobilization campaigns, meetings, radio talks on management of different pests conducted especially on fall army worm pest. In collaboration with International Center for Insect Physiology and Ecology (ICIPE) RAB trained many Extension agents including sector and district agronomists, CIP focal persons, farmer promoters, farmers and SEDO'S on FAW biology and ecology, symptoms damage and its management. Pheromone traps for FAW monitoring were also installed on different sites in districts where the project will operate which are Gatsibo, Ngororero, Rubavu, Musanze and Gicumbi and people on the sites were taught how to collect data from the traps.

➢ Development of extension materials in area of crop protection: Extension materials on different pests for following crops; Maize, Soybean, Beans, Wheat, Banana, Rice, Irish potato were developed and these materials will be distributed to farmers, farmer promoters and FFS facilitators during 19A season to help them to identify different pests and manage them. On Fall Armyworm (FAW) and Maize Lethal Necrosis (MLN) disease, specific materials were developed. Especially on FAW, materials on pest identification, damage symptoms and Management were produced and 15,000 flyers were given to farmer promoters and farmers.

➢ Training of Extension agents: 13,090 farmer promoters, 1800 FFS facilitators, 392 sector agronomists, 1,900 SEDOs, 451 Agro-dealers were trained on management of Fall Armyworm.

- Capacity building of extension agents & agro-dealers in pesticides safe use and handling and self-protection. About 212 extension agents including sector and district agronomists, farmers and agro-dealers from Nyagatare, Kamonyi, Muhanga, Nyanza, Gisagara and Nyamagabe districts were trained on this issue.
- Promote and strengthen plant clinic approach.

2.4 Seed Inspection and Certification

The unit of seed inspection and laboratory services performed several activities of seed quality control during this fiscal year 2017/ 2018. It comprises of two seasons 18A and 18B: Seed field inspection for each seed category (Tables 70 and 71); Seed sampling; Potato seed control in stores; Field visit to the applicants to be seed multipliers, to verify eligibility to be accepted as seed producers; Seed testing in the Laboratory. All these activities were carried out to check and confirm the quality of seed from planting to storage.

Table 70: Certified and basic seed inspection in FY 2017/18

Crop	Certified seed			Basic seed		
	Inspected (Ha)	Complied to standards (Ha)	% complied to standards	Inspected (Ha)	Complied to standards (Ha)	% complied to standards
Maize	2390	2177.9	91.1	118.83	114.69	96.5
Irish potato	113.03	100.94	89.3	119.745	110.85	92.5
Bean	965.24	834.16	86.4	51.1	43.07	84.2
Wheat	115.58	105.38	91.1	165.12	149.97	90.8
Cassava	16	7.2	45	29.5	13.1	44.4
Soybean	23.5	14.3	60.8	29.42	29.35	100
Rice	174.33	126.5188	72.5	11.095	10.92	
Peas	14	14	100	4	4	100
Sorghum				2.12	2.12	100
Total	3811.69	3380.3988	88.68	530.93	478.07	90.04

The total area of inspected seed fields was 4,585.03 ha, where 4,059.5 ha (88.5%) were in compliance with seed field standards. Total area of the certified seed was 3,811.7ha, for basic seed it was 530.9 ha, for pre-basic seed production area was 116.7ha and quality declared seed was grown on 125.8 ha. This area reflects limited capacity and resources allocated to seed inspection and doesn't satisfy country needs in clean seeds. Thus the involvement of private sector into the seed industry would contribute to satisfying the national seed demand.

Table 71: Pre-basic and quality declared seed inspection in FY 2017/18

Crop	Pre-basic seed			Quality declared seed		
	Inspected (Ha)	Complied to standards (Ha)	% complied to standards	Inspected (Ha)	Complied to standards (Ha)	% complied to standards
Maize	9.69	9.49	97.9			
Irish potato	79.4	77.02	97.0	43.55	43.55	100
Bean	0.91	0.91	100			
Wheat	25.91	21.39	82.5			
Cassava				76.21	41.91	54.9
Soybean				6	6	
Rice	0.74	0.74	100			
Peas						
Sorghum						
Total	116.65	109.55	93.9	125.76	91.46	72.7

Table 72: Certified and basic seed samples analyzed in seed laboratory

Crop	Certified seed samples (number)			Basic seed samples (number)		
	Analyzed (Ha)	Complied to standards (Ha)	% complied to standards	Analyzed (Ha)	Complied to standards (Ha)	% complied to standards
Maize	532	488	91.7	53	41	77.3
Bean	230	198	86.08	34	28	82.3
Wheat	50	47	94	58	42	72.4
Soybean	19	18	94.7	38	25	65.7
Rice	65	63	96.9	34	31	91.1
Sorghum				4	4	100
Sunflower				3	1	33.3
Vegetables						
Fodder						
Total	896	804	89.7	224	172	76.7

Apart from inspection of seed fields, collection of seed samples for laboratory analysis was done for each seed category (Tables 72 and 73). The total number of samples received from Seed multipliers and RAB stations were 1261 Samples; within this 1258 samples were tested and 1098 samples (87%) have met the requirements standards of purity and germination.

Table 73: Pre-basic and quality declared seed samples analyzed in seed laboratory

Crop	Pre-basic seed samples (number)			Quality declared seed samples (number)		
	Analyzed (Ha)	Complied to standards (Ha)	% complied to standards	Analyzed (Ha)	Complied to standards (Ha)	% complied to standards

Crop					
Maize	3	3	100		
Bean	1	0	0	12	12	100
Wheat				8	8	100
Soybean	8	8	100	86	86	100
Rice						
Sorghum						
Sunflower						
Vegetable				16	11	68.75
Fodder				4	4	100
Total	12	11	91.6	126	111	88.09

Routine inspection of Irish potato seed stores was performed. Total quantity of seed inspected was 942.8 metric tonnes (Table 74).

Table 74: Quantity of Irish potato seed inspected in stores

Crop	Seed category	Quantity in metric tonnes
Irish potato	Basic	419.389
	Certified	313.745
	Pre Basic	140.437
	QDS	69.24
Total		942.811

Visits to applicants to be seed multipliers

A total of 191 applicants for seed production were visited, within these, 93 applicants met the requirements to be seed multiplier, and 98 applicants did not meet the requirements. A total of 1163 seed testing reports were prepared seed certificates were delivered.

Trainings

A number of trainings were delivered on seed production, requirements and standards, and management:: Training of IABM cooperative members on hybrid maize seed production; Trainings of 44 seed producers on potato seed production techniques; Seed inspectors and seed analysts were trained on hybrid maize seed production and on MLN disease.

2.5 Post-harvest

The key activities carried out include

(1) Meetings at national and local levels to prepare post-harvest season. Mobilization campaign to construct temporary shelter for drying was carried in Eastern province;

(2) Training of 104 farmer cooperatives and 744 farmer promoters on post – harvest handling;

(3) Distribution to farmers of 1400 sheetings, 3850 mechanical shellers, 80 Solar bubble dryers, 80 moisturemeters and 100,000 hermetic bags;

(4) Distribution of 20,000 Post harvest extension to farmer promoters, FFS facilitators and SEDOs. In collaboration with AIF Ltd maize cob model was introduced in order to minimize risks of contamination with afflatoxin.

Concerning agricultural marketing, sites with potential production were identified and linked to potential buyers of maize, beans, rice, soya beans and cassava. Irish potato collection centers managed by farmer cooperatives were established; minimum price for maize, beans, rice, Irish potato were calculated and fixed in collaboration with producers and buyers. The following are the identified markets as well as the quantities required: AIF Ldt (30,000 MT of maize); EAX (11,000MT of maize and 3000MT of beans); SARURA (10,000MT of maize and 3,000MT of beans); MINIMEX (20,000MT of maze); MINAGRI (10,000MT of maize and 50,00MT of beans) and BABUC (5,000MT of maize).

Part 3. Animal Resources Extension

3.1   Cattle Genetic Improvement

The animal genetic improvement aims avail quality and genetically superior breeding germplasm; management and replacement of the bull stud (Masaka bull station); bovine semen collection and processing; Liquid Nitrogen production and facilitating the availability of artificial insemination (AI) inputs; Capacity building of AI stakeholders on bovine artificial insemination, cattle reproductive management and AI inputs handling (especially, Liquid Nitrogen); Facilitating and supervising the cattle artificial insemination across the country, as well as strengthening pig genetic improvement.

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 37 and 38). In the fiscal year 2017/2018, we acquired 2 young Inyambo bulls to be trained on semen production to strengthen Inyambo germaplasm conservation. The

young bulls will replace 3 old bulls culled. The usual work focused on management of bulls and training of young bulls on mounting to teaser bull or dummy cow and semen production. Young bulls acquired in Ireland last year were trained and 2 of them have successfully started producing quality semen. The Simmental bull is still under intensive training.

Photo 37: Bull of dairy catte: Friesian (left) and Jersey (right)

Photo 38: Bull of Simmental cattle for meat (left) and Inyambo local breed (right)

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 2017/2018 a total of 69,715 semen doses were produced, processed and stored. 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 partnerships between RAB, Jersey Island, Send a Cow, Bothar and MSAADA a total of 68,101 semen doses (58,101 doses of Jersey and 10,000 doses of Holstein-Friesian) have been imported in 2017/2018.

Photo 39: A Second Liquid Nitrogen Plant installed at Rubona RAB Station

To ensure availability of Liquid Nitrogen (LN2) and increased access to AI inputs for improved service delivery, RAB through Rwanda Dairy Development Project has acquired and operationalized a second Liquid Nitrogen Plant and other laboratory equipment (Photo 39 and 40), which was installed in Rubona RAB station, Huye District. This plant has the capacity to produce 20 litres of LN2 per hour and will solve the issue of shortage of LN2 and improve its access, especially for Southern and Western Provinces.

Photo 40: New equipments acquired to improve semen collection and processing

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 2017/2018 fiscal year, a total of 104,373 cows were inseminated and 41,873 calves born on AI. In this fiscal year exceeded the targets planned and indeed an increase of 35% in insemination and 52% of calves when compared to last year achievements (Figure 58). This commendable improvement was mainly due to significant efforts invested in availing liquid nitrogen (a new plant installed); 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.
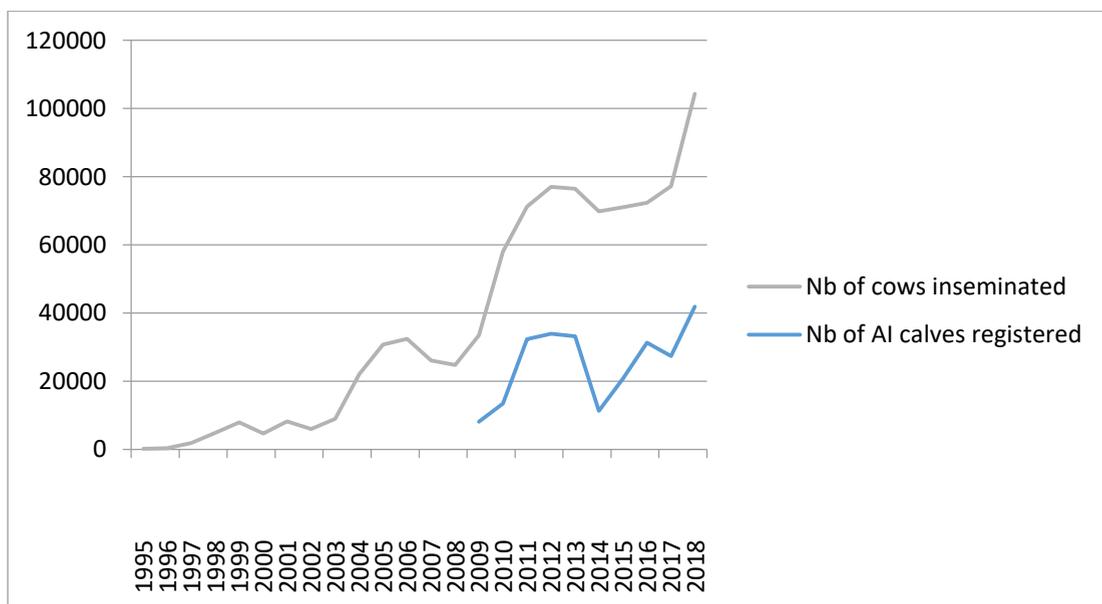
Figure 58: Annual achievements of Bovine artificial insemination since 1995

Every year, RAB and partners organizes training for new AI technicians on cattle artificial insemination and reproductive management and refresher courses to improve the skills of existing inseminators (Photo 41). 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, 206 animal science technicians have been trained on bovine artificial insemination technique and qualified as Inseminators. Also, existing 168 AI technicians have been given refresher courses on PD and best practices in bovine artificial insemination.

Photo 41: Capacity building of artificial insemination stakeholders

3.2 Pig Genetic Improvement

To strengthen pig industry, RAB supports pig breeders and farmers to acquire and disseminate the best pig genetic materials. In the 2017/2018 fiscal year RAB worked with farmers to improve pig husbandry and genetics through support to artificial insemination and recording of piglets born on AI.

Table 75: Recent achievements in pig artificial insemination

Year	Number of Sows & gilts inseminated	Number of Piglets recorded
2013-2014	72	648
2015/2016	201	576
2016/2017	224	1,416
2017/2018	318	1,062
Total	815	3,702

Through partnerships between RAB, CPPA Kisaro and UR-CAVM Busogo campus a total number of 318 sows were artificially inseminated and 1,062 piglets weaned in FY 2017-2018 (Table 75), which is higher than in preceding years. In this fiscal year MINAGRI and RAB continued to support and strengthen pig breeding centers (CPPA Kisaro, UR-CAVM Busogo campus and APTC Ltd) to improve availability and access of quality pig genetics and strengthening of Pig Farmers Association.

3.3 Animal Nutrition

Improved forage establishment

Forage cultivation is important to improve animal nutrition .Increase farm's forage productivity is also essential to cope with climate change challenges. During the 2017/2018 financial year, 813.5 hectares of improved forage varieties (forage seeds multipliers) were established. Farmers changed their mind-set and were willing to establish new plots to cope with fodder scarcity during the dry season. A total of 393 Farmer Field School groups have been formed and established forage plots as their main core activity for feeding trials and forage seeds pass on in between LFFS group members; and 7,244 livestock farms were cleared and fenced in Nyagatare and Gatsibo districts (Photo 42).

Photo 42: Forage multiplication FFS groups

Forage conservation

Forage conservation technology was promoted through trainings (Photo 43). In order to cope with prolonged drought during dry season farmers were trained on forage conservation techniques and supported with plastic silage tube to be used for silage making. A total of 933 Farmers were trained on hay and silage making, crop restudies treatment and conservation. The districts reached are Gatsibo, Kayonza, Ngoma, Kirehe, Rwamagana and Nyagatare. In total, 1,525.7 tons of hay were conserved**,** mainly *Chloris gayana*, bush hay, Sudan grass and bean straw.

Photo 43: Forage conservation

Water for livestock

During 2017/2018 financial year; 39 dam sheets were distributed and 3 boreholes were constructed for rain water harvesting and use of ground water to cope with the lack of drinking water for animals during the dry season (Photo 44)**.**

Photo 44: Dam sheets being put in a valley dam to be filled with water

In addition, 13 water tanks were constructed in Nyagatare (6), Gatsibo (1) and Kayonza (6) to provide water for livestock. Water tank construction was found to be a solution as when the dam fills up, they hold a lot of water that can assist livestock for a long. Another innovation to avail

water for livestock was getting it from the Akagera River where at Karushuga in Rwimiyaga sector, Nyagatare district water for was obtained through a trench passing under the RDB electric fence and collecting it in a small well that would be pumped into drinking troughs and this facility helped farmers to water over 1,200 heads of cattle per day during the dry season. A similar trench measuring 58 km and crossing Rwinkwavu, Gahini Mwiri and Murundi sectors of Kayonza District was constructed from Kadiridimba to Mucucu ku cya Musenyeri and this facility provided water for more than 3,000 heads of cattle.

3.4 Small stock development

Small stock development 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 (wealth categories 1&2 of Ubudehe, unemployed youth in rural area). The project aimed to distribute smallstock to the poor families. The Project was implemented by the selected districts through earmarked funds (Photo 45). RAB provided technical assistance as required to design specification for procurement of small stock and also carry out monitoring and evaluation on the progress of the project.

Photo 45: Eggs produced from the small stock distributed by the project in Rubavu district

.

The project distributed small stock in Rusizi, Nyamasheke, Rutsiro and Rubavu districts (Table 76).

Table 76: Number of small stock distributed per district in FY 2017-2018

District	Number of beneficiaries trained	Number of communal shed (**CS**) or Hen house constructed according to standard	Number of small stock distributed
	Target 2017/18	Target 2017/18	Target 2017/18
Rusizi	5 unemployed youth coop/hens+ 40 unemployed youth coop/ pigs	5 hen houses+40 CS	5000 Layers +440 pigs (10 female&1 male each coop.)
Nyamasheke	5 unemployed youth coop/hens+ 40 unemployed youth coop/ pigs	5 hen houses+40 CS	5000 Layers +440 pigs (10 femele&1 male each coop.)
Rutsiro	5 unemployed youth coop/hens+ 40 unemployed youth coop/ pigs	5 hen houses+40 CS	5000 Layers +440 pigs (10 femele&1 male each coop.)
Rubavu	5 unemployed youth coop/hens+ 40 unemployed youth coop/ pigs	5 hen houses+40 CS	5000 Layers +440 pigs (10 femele&1 male each coop.)
Total	-	20 hen house and 160 CS	20,000 Layers 1760 Pigs (1600 femele&160 males)

3.5 Veterinary and Laboratory Services

The Veterinary and Laboratory Services Unit is the Unit that is mandated by the law of Rwanda to provide quality services related to prevention, control, detection and response to animal diseases including zoonoses; and to provide information related to the status of animal diseases in the country at national and international standard. The V&LSU is divided into several section which include among them: Disease control section, Virology section, Bacteriology section, Serology section, Protozoology and entomology section, Helminthology section, and Pathology Section. The Unit also coordinates other sections including border post and quarantine plus satellite laboratories.

The main roles and responsibilities of Veterinary and Laboratory Service Unit are to:

- Provide leadership to the prevention, diagnosis and control of animal diseases; to coordinate activities aimed at diagnosing and monitoring animal diseases and providing early warning measures to farmers.

- Supervising activities of satellite laboratories so that they can carry out disease surveillance and control.
- Coordinate monitoring of animal diseases at border and other control posts.
- Coordinate interventions in liaison with local authorities before, during and after disease outbreaks.
- Compile disease status information for the country and report to the national, regional and international authorities.

The objectives of Veterinary and Laboratory Services Unit are to:
- To implement the national veterinary services development policy and animal health laws.
- To provide stockbreeders and consumers of animal products with technical information and services meant for improving their profession and supplying the market with increased produce and raising their incomes.
- To control animal diseases and implement appropriate strategies meant for ensuring prevention, protection, diagnosis and treatment of animal diseases and particularly zoonosis;
- To build the capacity of animal product consumers so as to allow them play their role in the food safety improvement and the country's development in regard to the sanitary and phytosanitary measures SPS- Animal health.
- To collect and publicize statistics and information linked with animal diseases at the national level; live animal movement and animal products by issuing permits for import /export of live animal, animal products and veterinary drugs;
- To participate and establish relations and collaboration with other regional and international organizations engaged in animal health network.

3.6 Veterinary Inspection

Animal Health status in Rwanda

Rwanda is a land locked country surrounded by different countries among them is Uganda, Tanzania, Burundi and Democratic Republic of Congo. The boundaries of Rwanda are very porous allowing easy movement of Animal in and out of the country and this predisposes the country to introduction of Transboundary animal diseases like FMD, CBPP, RVF, and Brucellosis among

others. The status of these transboundary animal diseases including Zoonotic diseases is as follows:

- The country was declared free from Rinderpest in 2006 by OIE and from then has the same status,
- in addition, there has been no clinical cases of CBPP, PPR, ASF and HPAI in the country since 2010,
- during this year, we note an upsurge of rift valley fever affecting cattle, sheep and goats in Kirehe, Ngoma, Kayonza and Rwamagana districts in the Eastern Province; Kamonyi and Muhanga in the southern province; Gakenke, Rulindo and Gicumbi in the Northern Province
- Although there have been no clinical cases of foot and mouth disease during this year, it did not prevent us to continue to enhance immunity by vaccination of cattle that had been exposed to the disease in 2017 in the districts of Nyagatare, Gatsibo, Kayonza and Kirehe in Eastern Province
- the sero-prevalence of bovine brucellosis on the whole national cattle herd is 0.7%, the highest prevalence is found in the Eastern Province and more particularly in Nyagatare District with a rate of 3.5% when the prevalence in goats, sheep and pigs is still zero
- The sero-prevalence for RVF was 7.9 % in cattle and there is a decline of prevalence in due to strengthening of Control measures,
- The prevalence of mastitis in cattle in Rwanda is 67,4%
- In 2016-2017 financial year, the prevalence of Theirelia parasites was 1.5%;
- Trypanosoma parasites prevalence of 0.0% was recorded in cattle around Akagera River, but 9% for canine
- Anaplasma and Babesia were not detected in any of the submitted samples and that making a prevalence of 0.01%;
- The prevalence of helminthes in cattle was 24.5% and 38.3% in small ruminant.

Control of transboundary animal diseases

The control of transboundary animal diseases (TADs) is an activity that was taken on from the financial year 2017/18, the country made significant progress in controlling TADs. Those of interest include lumpy skin disease (LSD), African swine fever (ASF), peste des petit ruminants (PPR) and contagious bovine pleuropneumonia (CBPP). World Animal Health Organization (OIE) progressive control pathway staging of FMD status in Rwanda is stage 3 on 5-stage pathway and the country is set to apply for certification to stage 4. During 2017/18, a total of 16,500 HC around FMD high risk areas were vaccinated, these areas include districts bordering Tanzania and Uganda; and among these are; Kirehe, Kayonza, Gatsibo and Nyagatare districts. Outbreaks of

LSD were reported in various districts and 655,713 cattle were vaccinated. There were no clinical and sero positif cases of ASF, PPR and CBPP. 510,550 heads of cattle were vaccinated against black quarter in endemic area.

Control of zoonotic diseases

Rwanda has had different zoonotic diseases incidences of which some have become endemic and pose a big threat to the public. These include Brucellosis, Rift Valley Fever, Rabies and cysticercosis. During this FY 2017-2018, we note an upsurge of rift valley fever affecting cattle, sheep and goats in Kirehe, Ngoma, Kayonza and Rwamagana districts in the Eastern Province; Kamonyi and Muhanga in the southern province; Gakenke, Rulindo and Gicumbi in the Northern Province. 163 HC death and 308 abortions due to RVF was registered. 295,220 cattle, sheep and goat was vaccinated and 457,853 sprayed using Permapy+ done in aim to control the spread of the disease in the all affected area. Since the disease is known to be transmitted by mosquitoes, livestock reared near large expanse swampy areas were considered to be at high risk. Along the Nyabarongo, Akanyaru, Akagera and Muvumba rivers in the all Nile bassin. In this FY 2017-2018, human dog bites were registered, vaccination of 10,705 dogs/cats and culling 2,792 stray dogs were done. In order to control the brucellosis, 101,630 young female cattle (4-11months) were vaccinated and the sero-prevalence of bovine brucellosis on the whole national cattle herd is 0.7%, the highest prevalence is found in the Eastern Province and more particularly in Nyagatare District with a rate of 3.5% when the prevalence in goats, sheep and pigs is still zero (Table 77).

Table 77: Reasons for Death registered during 2017-2018 FY

	Cows	Goats	Pigs	Poultry
Drought/ Heat	311	55	-	-
Flood	-			-
Road Accidents	44	107	-	-
Landslide	137	269	-	-
Dogbites	12	36	-	-
Disease				
Foot and Mouth Disease	-	-	-	
Rift Valley Fever	163	52	14	
Tick borne disease	2622	414		
Lumpy Skin Disease	14	-		
Newcastle, variole, salmonella	-	-	-	5,375

Control of animal movement for Animal and animal products

Control of animal movement is one of the control measures put in place by veterinary services to control transboundary animal diseases and is mandated to issue out permission to allow movement of animals.Imports and exports of animals and animal products are shown in Table 78.

Table 78: Import and export of animals and animal products in FY 2017-2018

Species/Item	Import	Export
Cats	73	60
Dogs	271	208
Cattle	2652	170,862
Goats and Sheep	1763	218,604
Pigs	-	154,572
Hides and Skin		12, 706 T
Eggs and Day old chick	987,560 DOC	3,175 T eggs
Fish	8,867 tones	10,000 T

In addition, 187,3050 cattle, 248,000 small ruminants and 183,692 pigs were identified for sale in the livestock markets; 3180 movement permits books for large and small animals were produced and distributed to different districts in the country. Furthermore, out of six border and quarantine posts in the country, only four are operational.

Issuing permit of importation of veterinary drugs, animal feeds and equipments

In order for the veterinary drugs to be regulated, the veterinary services issues out importation permits, to allow them to be imported into the country. In relation to this the veterinary services issued out 237 importation permits for importation of different veterinary drugs including among others; antibiotics, antiparasites, anti-inflammatory drugs, minerals, vitamins; hormones, vaccines; 35 importation permits for 2.750 tonnes of animal feeds and feed additives, 174 permits for fish farming materials and 5 permits for bee keeping equipments. Inventory of veterinary vaccines circulating in Rwanda was carried out and 24 different types of vaccines identified and recommended for registration. 162 vaccines and vet drug suppliers were identified.

Refresher Training courses for Community Animal Health workers

Community animal health workers were identified, trained and equiped with basic veterinary kits that helps them to execute their work. 223 CAHW were trained and monitored in Muhanga,

Ruhango, Nyanza and Huye District and also 975 were monitored and had a refresher training course in the management of animal diseases.

Laboratory diagnostic services

The National Veterinary Laboratory at Rubirizi provides confirmatory diagnostic services for different animal diseases in the country. Samples analyzed were collected by laboratory staff on request by animal owners. Samples were also submitted by field veterinarians. Additional samples were collected by laboratory staff during epidemiosurveillance of animal diseases aimed at estimating different disease burden. The laboratory is divided into sections namely Protozoology, Serology, Bacteriology, Virology, Helminthology and Gross pathology.

Protozoology section: Immunization against East Coast fever in Rwanda

East Coast Fever (ECF) is a cattle disease caused by a protozoan parasite, Theileria parva, and transmitted by the brown ear tick Rhipicephalus appendiculatus. Climatic conditions in Rwanda are favorable for a year round presence of the three major tick species (Amblyomma spp, Boophilus spp and Rhipicephalus spp) (FAO., 1982; Bazarusanga et al., 2008) recorded in Rwanda. Rhipicephalus appendiculatus accounts for more than 90% of the total tick species and is present on over 95.6% of the national territory (Lessard et al., 1990). The country wide presence of the vector mirrors the geographic distribution of diseases they transmit (Bazarusanga et al., 2007). ECF is prevalent in all regions of the country except in the mountainous volcanic regions. Although there is general paucity of quantified information on economic losses caused by ECF in Rwanda, ECF has the greatest impact on small scale resource poor farmers through animal morbidity and mortality and the huge costs incurred annually in the control of the disease through tick control and chemotherapy. In a study carried out in Zambia (Berkvens et al., 1987), ECF incidence rates of 70% to 80% were recorded in calves less than one year old with corresponding fatality rates of 30-40%. It is estimated that countries where the disease is prevalent spend up to $315 million a year in losses due to treatment, mortality and control costs (Minjauw and Macleod, 2003). This scenario makes it difficult for the herders to plan for the future, to improve their livestock enterprises and thus raise their standard of living.

Current status of control methods

In endemic areas, the disease is commonly controlled by different methods or a combination of tick vector control and curative treatment. However, the limitations associated with these control methods have prompted a search for safer and effective vaccination control strategy. This new method is based on tick derived *T.parva* sporozoites and simultaneous treatment with long acting oxytetracycline to reduce the rate of multiplication of parasites in the cattle host (Photo

46). This vaccination method commonly known as "Infection and Treatment Method (ITM)" is being used in several countries in Eastern, Central and Southern Africa. This method of immunization is very effective in any given area if properly administered (Paling and Geysen, 1981; Musisi et al., 1989; Mutugi et al., 1988). However, there has been a general belief that the immunity generated by one strain affords protection against itself and possibly a few strains that are genetically related to the immunizing strains (Cunningham et al., 1973; Irvin et al., 1983). Failure to provide full protection has been attributed to the existence of variability in the parasite population. A combination of three stocks referred to as "Muguga cocktail" was found to confer protection against most of strains circulating in the field in Eastern, Central and Southern Africa.

However, the extent of variability in parasite population under field conditions is not known. It is generally recommended that before any immunization program can take place in a new area, validation of the vaccine under field conditions is a prerequisite. It is against this background that immunization trials have been carried in Rwanda aiming at elucidating the levels of protection conferred by the Muguga cocktail vaccine under local epidemiological conditions. The protection conferred by the Muguga cocktail vaccine (MCL01) is slightly high, for that during 2017/2018, 3109 cows was immunized against East Cost Fever (ECF): 2374 in EP, 367 in SP, 258 in Kigali City and 110 in the NP.

Photo 46: Vaccination against East Cost Fever

Bacteriology section: Monitoring and control of mastitis disease in dairy cows

Mastitis, the inflammation of the mammary gland and udder tissue, is one of the most important diseases of dairy cattle worldwide as well as in Rwanda. It usually occurs as a result of chemical, mechanical or thermal injury to the cow's udder. It is often transmitted through contaminated hands or other materials in housing, bedding and other equipment. Other factors that predispose to occurrence of mastitis are poor milking procedures, teat injuries, teat sores and exposure to environmental pathogens and may present a subclinical, sub-acute, acute or chronic course.

Photo 47: Cow affected by mastitis

To monitor and supervise the control of subclinical mastitis disease, the following activities were done: 1) Public awareness of mastitis disease on prevention and control by disseminating information using radio talk, posters, pamphlets; Screening of subclinical mastitis disease in different districts: (Nyanza, Musanze and Rwamagana during an active surveillance; Nyabihu, Rutsiro and Rubavu during mastitis control campaign in Gishwati milk shed; and Milk sample analysis. 2) Organizing meetings between Gishwati farmers, RDDP, RALIS, Districts, Inyange Industries, Mukamira Dairy Processing Plant and RAB; 3) Training of farmers, cow handlers, milk collectors, RYAF technicians on good milk hygiene practices, CMT testing and milk sampling collection and handling.

Surveillance at Nyanza, Musanze and Rwamagana

During quarter I and II, the Bacteriology desk of RNVL organized an active surveillance against subclinical mastitis disease in 3 districts, Nyanza, Musanze and Rwamagana (Table 79). The surveillance aimed to study the epidemiology of mastitis disease and the evaluation of antimicrobial resistance in chosen districts and to increase availability and access of mastitis testing facilities to the farmers; to study the prevalence of sub-clinical mastitis disease. The exercise was screening with California Mastitis Test (CMT) at farm level, from cow to cow, teat to teat; collection of milk samples into sterile tubes, carrying them into laboratory for isolation

on blood agar medium; identification of pathogens causing that infection and finally evaluating the susceptibility of different antimicrobials against the isolates.

Table 79: Surveillance results on mastitis identification

N^O	Variables	NYANZA	MUSANZE	RWAMAGANA	TOTAL
1	Number of farms visited	41	11	27	79
2	Number of cows tested	84	60	42	186
3	Number of cows tested negative	22	9	17	48
4	Number of cows tested positive	62	50	25	137
5	Prevalence per cow	73. 8%	83.3%	59.5%	73.6%
6	Number of teats tested	335	238	167	740
7	Number of teats tested negative	205	95	117	417
8	Inactive teats	4	2	1	7
9	Number of teats tested positive	126	143	51	320
10	Prevalence per teat	37.6%	60%	30.3%	43.2%

Considering the number of animals tested (186) and the total number of positive cases on CMT (137), the prevalence ranges from 59.5% in Rwamagana, 73.8% in Nyanza and 83.3% in Musanze. This means that for a total number of hundred dairy cows in these 3 districts, 73.6 have at least 1 teat infected with subclinical mastitis disease. Considering the total number of teats screened by CMT (740), the prevalence is estimated at 43.2% ranges from 30.3% in Rwamagana, 37.6% in Nyanza and 60% in Musanze.
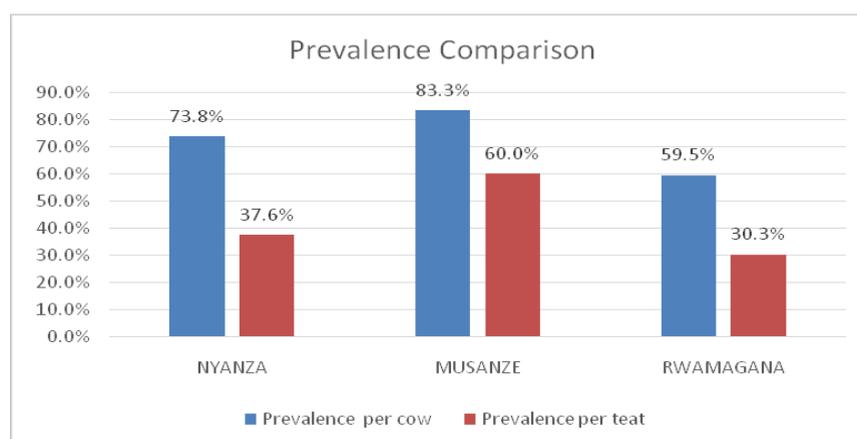
Figure 59: Prevalence of mastitis in Nyanza, Musanze and Rwamagana

Considering the positivity levels, Table 80 below shows how weak, medium or strong the infection is per District. In most cases the infection was weak to medium (Table 80).

Table 80: Severity of California mastitis in Nyanza, Musanze and Rwamagana districts

District	CMT (+) Weak positive	%	CMT(++) Intermediate positive	%	CMT(+++) Strong positive	%
Nyanza	69	54.7	36	28.5	21	16.6
Musanze	65	45.4	53	37	25	17.4
Rwamagana	29	56.8	22	43.1	22	15.3
Total	163	50.9	111	34.6	68	21.2
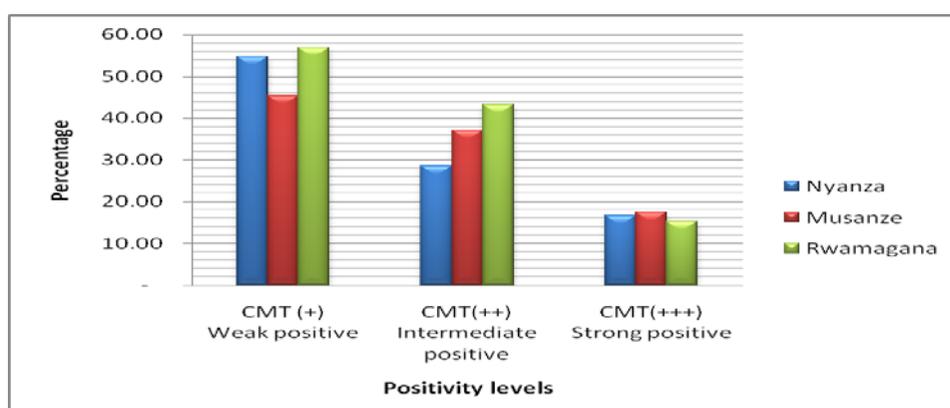
Figure 60: Percentage of cows infected by mastitis in Nyanza, Musanze and Rwamagana

The percentage of early infected cows (weak positive cases) was high than the medium or strong positive infections, which means that more dairy cows are getting infected by subclinical mastitis disease (Figure 62).

Isolates and Antimicrobial resistance (AMR) testing

The other isolates from the described above epidemiosurveillance held in Nyanza, Musanze and Rwamagana included: *Staphylococcus aureus* and CNS Staphylococcus species, Streptococcus species, Bacillus species and Coliform species.

Monitoring of antimicrobial resistance to the existing drugs was done in the bacteriology laboratory. It evaluated 8 antibiotics: Penicillin G (PG), Gentamycin (GT), Streptomycin (Str) and Tetracycline (TE) existing on the Rwanda market and Lincomycin (L), Cephalexin (Cz), Cloxacillin (Ck) and Ciprofloxacin (CIP) unavailable on our market.

Photo 48: Bacteriogogical evaluation of antibiotic resistance for currently marketed drugs

A total of 31, 22 and 23 isolates were tested for AMR from Nyanza, Musanze and Rwamagana Districts (Photo 48; Table 81).

Table 81: Length of inhibition zone showing the status of resistance or susceptibility to antibiotic by bacteria

N°	ATB	Average (mm)	Results	Average (mm)	Results	Average (mm)	Results
		Nyanza		Musanze		Rwamagana	
1	PG	11.50	Resistant	9,1	Resistant	13	Resistant
2	L	18.00	Susceptible	14,9	Intemediate	21	Susceptible
3	GT	26.30	Susceptible	28,7	Susceptible	25	Susceptible
4	Cz	26.50	Susceptible	22,3	Susceptible	25.5	Susceptible
5	Str	15.10	Susceptible	17,6	Susceptible	15.6	Susceptible
6	AMX	14.20	Intermediate	14,4	Intemediate	11.9	Resistant
7	TE	20.60	Susceptible	20,7	Susceptible	21	Susceptible
8	Ck	6.90	Resistant	4,8	Resistant	13.5	Intermediate
9	CIP	26.80	Susceptible	27,3	Susceptible	26.3	Susceptible

Penicillin G (PG), Gentamycin (GT), Streptomycin (Str) and Tetracycline (TE) existing on the Rwanda market and Lincomycin (L), Cephalexin (Cz), Cloxacillin (Ck) and Ciprofloxacin (CIP)

The test showed that the bacteria have built resistance to Penicillin G, which is still commonly used in the treatment of different bacteriological infections in the country. This was the case for all three districts. In two districts of of three, the bacteria were resistant to Cloxacillin, which is also commonly used.

Mastitis Control in Gishwati milkshed

Assessment the cause of milk rejection at MCCs

Field trip was organized to assessing the cause of milk rejected by Mukamira Dairy Processing Plant in Gishwati milkshed (Photo 49).

Photo 49: Visit of RAB team to Gishwati milkshed

In December 2017 a field trip was organized to identify farmers whose milk was not accepted at milk collection centers and assess the reason of that rejection. The technical team composed with 2 staff from RAB and 1 from RDDP went to field, visited 5 MCCs and identified 209 farmers with a serious problem related to that loss (Table 82).

Table 82: Number of farmers with milk rejection in different Milk Collection Centers (MCCs)

N°	MCC	Nbr of farmers	Farmers reared in Gishwati	Number of farmers facing milk rejection	Number of farms visited
1	Nyiragikokora	132	96	73	5
2	Bigogwe	71	71	39	4
3	Arusha	120	67	31	8
4	Mahoko	50	33	21	0
5	Nkomane	77	76	45	4
6	Gitwa	-	-	-	2
TOTAL		450	343	209	23

Table 83: Summary of number of farms visited, cows tested and mastitis occurence

N°	Variables	Counts
1	Number of farms visited	23
2	Number of cows tested	173
3	Number of cows tested negative	24
4	Number of cows tested positive	124
5	Prevalence per cow	72%
6	Number of teats tested	696
7	Number of teats tested negative	344
8	Number of teats tested positive	356
9	Prevalence per teat	51%

During the tour, the technical team visited 23 farms, screen 696 teats from 173 lactating cows with CMT, collected 173 milk samples, which have been analyzed in the Rubirizi National Veterinary Laboratory. The results from all analysis showed that subclinical mastitis disease was the cause at 72% rate per cow tested and at 51% per teat (Table 83).

Among pathogens shown from laboratory characterization there is 28.6% of coliform species, staphylococcus species at 6.9%, other staphylococcus species are at 43.4%, Bacillus species at 18.2% and Streptococcus species at 2.6%. The sensitivity test of antibiotics towards these milk isolates revealed that Penicillin G, which is the most available on the market and Cloxacillin are resistant.

Gishwati milk shed mastitis control campaign

Gishwati milk shed is area for dairy cattle, which has good weather for livestock activities but most of farms are inaccessible with impracticable and insufficient roads. Hence some of cow' owner visit their farms rarely in the year and most of staff responsible for livestock have difficulty to visit the area. Therefore, daily activities related to animal health, animal nutrition, milking, milk handling and management are duties of cow boys who do not care much about good milk hygiene practices. Thus, dairy farmers are challenged by subclinical mastitis disease, which is contaminated through poor hygiene practices to lactating cows. To tackle the mentioned challenge, a mastitis control campaign was organized to be held from May 7, 2017. Different activities were conducted in Nyabihu, Rubavu and Rutsiro Districts (Photo 50).

Photo 50: Gishwati mastitis campaign (left) and laboratory woth for pathogen identification (right)

Household screening of all lactating cows by CMT and milk sampling for laboratory analysis, identification of all chronic cases caused by mastitis disease, monitoring of antibiotic therapy for non-chronically infected cow's treatment and introduction of nation mastitis prevention and

control program and dairy dynamic management approach. Activities were divided into two parts; some based at field Nyabihu, Rubavu and Rutsiro Gishwati area and others based in Rubavu satellite laboratory; today working at border post of Rwanda and DRC. A total of 803 farms were visited and 5,289 cows were tested for mastitis (Table 84).

Table 84: Mastitis prevalence in Nyabihu, Rutsiro and Rubavu

NO	Variables	Nyabihu	Rutsiro	Rubavu	Total
1	Total number of farms visited	264	283	256	803
2	Total number of cows tested	1998	1929	1362	5289
3	Total number of cows tested negative	697	684	455	1836
4	Total number of cows tested positive	1301	1245	907	3453
5	Total number of chronic cases	48	30	34	112
6	Prevalence per cow	67,5%	66,0%	69,0%	67,4%
7	Total number of teats tested	7988	7684	5446	21118
8	Total number of teats tested negative	4823	4676	3346	12845
9	Inactive teats detected	50	32	36	118
10	Total number of teats tested positive	3116	3009	2061	8186
11	Prevalence per teat	39,6%	39,5%	38,5%	39,3%

A total of 3,565 samples (67.4%) were found positive to mastitis disease; 3453 (65.2%) lactating cows, which have at least one teat affected by subclinical mastitis disease. The prevalence per cow of this disease in the three districts was similar ranging from 66.0% in Rutsiro, 67.5% in Nyabihu and 69.0% in Rubavu Gishwati area. A total of 8,304 out of 21,118 equivalent to 39.3% teats were producing milk with infection of subclinical mastitis disease; when mixed with other clean milk spoilt a good quantity of it. The prevalence per teat is find 38.5% in Rubavu, 39.5% in Rutsiro and 39.6% in Nyabihu. This rate is too high representing a big loss to dairy industry in this area. The figure show the comparison of the two prevalences (cows and teats) Thus, to reduce disease prevalence, Penicillin G that showed resistance to the disease should be replaced by other drugs for mastitis control

Training, Internships & Agrishow

The veterinary and laboratory Services organized farmer training on animal diseases impacting on the production and quality of milk (mastitis, brucellosis and tuberculosis) in Muhanga 151 farmers), Nyanza (50 farmers) and Huye (22 farmers). Two RAB staff attended training held at Rubavu on Biorisk Management (BRM) implementing AMP (Risk assessment, Mitigation and Performance) for Biosafety and Biosecurity in the laboratory. We actively participated in the preparation and flow of 13th National Agricultural show held at Mulindi, Gasabo (Photo 51). Production of 2 pull up to demonstrate the responsibilities of the veterinary services unit and

the services given by the Rubirizi National Veterinary laboratory, 1500 leaflets was developed for the prevention and control of animal diseases (Mastitis, RVF, Brucellosis, ECF, FMD).

Photo 51: 13ᵗʰ National Agrishow at Mulindi, June 2018

Virology laboratory

The activities done were epidemiosurveillance of Foot and Mouth disease (FMD) and the zoonotic Rift Valley fever (RVF). Staff also performed proficiency testing for rabies: Competitive ELISA test kits containing anti-RVF antibodies were used in testing for exposure of the animals to RVF. Diseases caused by viruses have assumed great public health significance in the recent past and increase in frequency and spread of such diseases observed globally. Several new viruses have been isolated. Virology Laboratory plays a critical role in surveillance, diagnosis and monitoring of viral disease as well as in the understanding of the genetic changes in the viral genome. The major activities on disease identification from annual pidemiosurveillance sampling are summarized in Table 86.

In virology laboratory, the following viral diseases are being identified: Foot and Mouth disease (FMD), Rift Valley Fever (RFV), Peste des petits ruminants (PPR), African Swine Fever (ASF), Rabies, Avian influenza and Newcastle disease. Regularly, lab staff participate in proficiency test from different references laboratory, Padova in Italy and OVIA in South Africa for check on quality control. During the fiscal year July 2017-June 2018, the achievement of the following activities from performance contract such as: Monitoring of the purchasing of laboratory reagents, consumables and small materials; Reception of some required laboratory reagents, consumables and small materials; Screening of Rift Valley Fever samples and serotyping of FMD disease.

Screening of Rift Valley Fever samples
Screening of Rift Valley Fever samples collected during outbreak from different districts (Table 85). The disease was confirmed in 48 samples.

Table 85: Result of Rift Valley Fever testing, May-July 2018

N⁰	District	Number of samples	Assay	Results	Comment
1	Kirehe &Ngoma	32	ELISA	6 positive	
2	Kirehe &Ngoma	9	Real Time PCR	7 positive	To be confirmed
3	Kamonyi	19	ELISA	11 positive	
4	Ngororero	1	ELISA	positive	
5	Muhanga	6	ELISA	3 positive	
6	Gicumbi	10	ELISA	5 positive	
7	Gatsibo	28	ELISA	11 positive	17 goat samples; 11 cow samples
8	Nyanza	6	ELISA	1 positive	
9	Rusizi	1	ELISA	Doubtful	
10	Ruhango	9	ELISA	7 positive	
11	Gisagara	1	ELISA	Negative	
12	Gasabo	5	ELISA	3 positive	
	Total	118		48 Positive	7 positive from Real time PCR

Serotyping of FMD disease

Serotyping of FMD disease was done in collaboration with CSIR-South Africa. During the outbreak of FMD July 2017, the samples were collected, and the Standard Operation Procedure was developed with the assistance of the Molecular Diagnostics team CSIR. The samples were analyzed for epidemiological purposes. The purpose of the field exercise was to use OIE compatible methods in terms of samples collection, transportation, analysis, storage and disposal thereof within a Rwandan setting. Cross-pollination of ideals through the exchange of practical skills and techniques between veterinarians and biotechnologists were implemented in the field and during wet laboratory analysis at Rubilizi National Veterinary laboratory, RAB. The assay included OIE recommended PCR, isothermal PCR as well as nucleotide sequencing of selected PCR positive samples.

Three (3) field samples were collected, which included blood/serum and oropharyngeal fluid (OPF) from the animals that showed active clinical signs of FMD infection. These included blisters in the mouth, on hoofs, and general lethargy from anima, particularly young calves. Samples were also collected from asymptomatic animals as well as some animals with healed mouth, tongue and between -the- hoof scars. Name of the animal, owners, the location, the symptoms and the general history as well as the brief disease description by the owners were collected. Over one hundred and fifty (150) cattle were sampled for the duration of the sampling period. Samples were collected from all cattle following the methodology detailed in the OIE Terrestrial Manuel (2009) for Foot-and-Mouth Disease protocol (Photo 52).

Photo 52: Sample collection from cows infected by Foot and Mouth Disease

Based on data logging, data recorded on the sample registration form included; the name of the district where the samples were collected from, the name of the farm involved, the number of cattle, tag labels or name of cattle, age, color, and gender of cattle. The oropharyngeal fluid (OPF) sample, blood/serum numbers were linked with the data collected for each cow that the oropharyngeal fluid (OPF) sample, blood/serum was collected. During sample processing, 3 samples were analysed using different techniques such as Nucleic Acid Extraction, Polymerase Chain Reaction (One-step RT-PCR, Two step RT-PCR), Loop-mediated Isothermal Amplification and were posite on FMD virus. The next Generation sequencing results both sample 8 and 33, based on the sequence consensus, the causative outbreak virus was FMD SAT 2 serotype.

For further studies of cell culture, isolation of FMD virus there is a reception of laboratory reagents, consumables and small materials such as CO_2 incubator, gas cylinder containing CO_2 will be used in cell culture. Intervention and sample collection of rabies suspicion cases was done in cattle in Northern Province.

Additional the following activities were completed with different organizations:
1. IHR capacity requirements are defined as "the capacity to detect, assess, notify and report events" on "Core capacity requirements for surveillance and response"; and on "Core capacity requirements for designated airports, ports and ground crossings"
2. The external evaluation allows countries to identify the most urgent needs within their health security system, to prioritize opportunities for enhanced preparedness, response and action, and to engage with current and prospective donors and partners to target resources effectively. Transparency is an important element in order to attract and direct

resources to where they are needed most. After the visit of external evaluation, the analysis of the country's capabilities, gaps, opportunities and challenges well released and the activities in both animal and human health were done and the next step is to develop the action plan in both animal and human health based on the activities developed during joined workshop from different institutions.

3. Participation in the TOT training from OHCEA in Bio-Risk Management. In this training of TOT I had the mainly capacity on different part like: Orientation to Biorisk management, Biosafety and Biosecurity risk assessment, Biorisk mitigation, Good laboratory practices, Laboratory Biosecurity, Measurement and Analysis of Biorisk management.

Table 86: Tests from epidemiosurveillance 2017-2018

Activities	Achievement	Results
Epidemiosurveillance Screening of NewCastle Disease :	163 samples from Nyabihu and Rubavu; 108 samples from Ruhuha and Nyamata; 171 samples from Nyagasambu, Fumbwe, Mukarange and Kabarondo; 71 samples from Mukura and Kigarama/ Huye; 114 samples from Musanze	All samples were negative
Rabies Proficiency test: Inter-laboratory test for the fluorescent antibody test (FAT) for the CADC and Congo Basin member countries	10 samples from South Africa	6 positive samples
In vitro diagnostic ELISA test allowing detection and titration of IgG anti rabies virus glycoprotein in dog using The PLATELIA™ RABIES II kit.	93 samples from Gasabo district	The test and titration was successfully.
FMD outbreak	- more than 85cattles were identified, tissues, blood samples and probangs were collected for serotyping.	FMD present; serotyping is the next step.

Proficiency testing for rabies: the capacity of Rubirizi National Veterinary Laboratory to effectively test and confirm rabies infection in animals was tested by conducting a proficiency test in partnership with the Agriculture Research Council-Onderstepoort Veterinary Research, University of Pretoria, South Africa, which is an accredited rabies laboratory. Fluorescent antibody technique was used and the results generated from 10 test samples sent from South Africa, two were positive and these were the expected results. Thus, there is adequate capacity, to confirm rabies infection in any suspected animal at Rubilizi laboratory.

Serology Section

This section supports animal health care by testing samples using serological techniques. The commonest techniques used are enzyme linked immunosorbent assay (ELISA). In the test for brucellosis, Rose Bengal plate test is used. Most of the blood samples of cattle and goats were collected as a pre-requisite of screening all animals for re-stocking before being handed over to beneficiaries. Serology lab receives blood samples for examining original entries and provides results of the submitted samples. Table 87 below shows the status of Brucellosis from Cattle, goats, sheep and pigs (July 2017- June 2018). The prevalence of brucellosis in cattle (based on testing of 12,435 samples) showed 0.69% of disease prevalence. One cow program has supported disease identification and sampling.

Table 87: Brucellosis prevalence on different livestock categories (Jul. 2017-Jun.2018)

Province	Cattle	Positive	Percentage	Goats	Sheep	Pigs	Total
Eastern	896	32	3.57%	2,397		44	
Kigali	592	4	0.67%	420	230		
Northern	6,166	34	0.55%	1,048	648	483	
Southern	2,370	12	0.50%	2,475	37	4,243	
Western	1,934	4	0.20%	258	99	100	
			Disease surviellance				
Rwamagana	131	-	-	-	-	-	
Bugesera	346	-	-	-	-		
Total	12,435	86	0.69%	6,598	1,014	4,861	

Epidemiosurviellance: Between 19th September and 20th October we carried out epidemiosurveillance activity in 4 provinces of the country (Table 88). A total of 2,101 samples were examined. Brucellosis prevalence was6.2% in Eastern and 2.7% in Southern province. No disease was detected in Northern and Western Province.

Table 88: Brucellosis prevalence in FY 2017-2018 based on epidemiosurveillance

Province	Cattle	Positives	Prev.	Goats
Eastern	1,346	84	6.24%	66
Northern	57	-	-	
Southern	531	11	2.7%	88
Western	167	1	-	
Total	2,101	95	4.5%	

Serology test on Brucellosis

Rose Bengal Plate test (RBPT) was used by Serology lab to test for exposure to Brucellosis. The RBT was selected because it is the most widely used screening test for brucellosis in both humans and animals. Overall 1,623 blood samples were collected as follows: 1,326 from cattle, 200 samples from goats, 71 sheep and 17 pigs (Table 89).

Table 89: Livestock samples for brucellosis identification using RBPT test

Province	District	Cattle		Goats		Sheep		Pigs	
		Pos	Neg	Pos	Neg	Pos	Neg	Pos	Neg
Eastern	Nyagatare	5	139	0	13	0	7	0	2
	Kayonza	2	185	0	30	0	4	0	0
	Rwamagana	1	75	0	36	0	1	0	8
	Sub total 1	8	395	0	79	0	12	0	10
Northern	Gicumbi	0	85	0	15	0	6	0	0
	Musanze	0	83	0	5	0	3	0	0
	Burera	0	46	0	1	0	20	0	5
	Sub total 2	0	214	0	21	0	29	0	5
Sothern	Ruhango	0	128	0	31	0	9	0	0
	Nyanza	0	92	0	11	0	2	0	0
	Huye	0	147	0	22	0	0	0	0
	Sub total 3	0	368	0	54	0	11	0	0
Western	Nyabihu	0	117	0	3	0	2	0	0
	Rutsiro	0	68	0	10	0	10	0	2
	Rubavu	1	164	0	9	0	7	0	0
	Sub total 4	1	349	0	22	0	19	0	2
	Total	9	1,326	0	200	0	71	0	17

By Province, 504 were from Eastern of which 8 tested positive for brucellosis; 275 were collected from Northern and none tested positive; 445 samples were collected from Southern and none was positive and 399 samples were collected from Western and only one tested positive. Notably, all the nine samples that tested positive were from cattle. Complementary to other tests, serology test confirmed brucellosis prevalence in Eastern Province of the country.

Improved brucellosis control in peri-urban dairy production

Under the framework of the project "Multi-sectoral strategy for Brucellosis control in peri-urban dairy production zones of West and Central Africa" under zoonoses and Emerging livestock Systems (ZELS) Programme, RAB in collaboration with Royal College university has conducted sampling of milk in Gasabo and Nyagatare periurban areas. A total of 908 samples from Gasabo and 97 from Nyagatare were collected and tested by ELISA serology test. Positive cases in Gasabo samples have lead to do second round of sampling by taking individual milk samples. This activity is still going on. Out of 97 farms in Gasabo district sampled, 3 farms were positive. Thus 2nd round

of sampling will also be done in Nyagatare. For sustainable disease management, we have developed activities essential to be conducted in positive and negative herds:

Activities in positive herds:
- The field technician will establish a relationship with the herd owner so that the herd owner reports to the field technician abortions when they occur; if abortions are detected the field technician will take the samples.
- The field technician will visit every farm/herd every 4 weeks and complete form
- During the first visit, collect individual milk samples from lactating cows, collect 15 individual samples if the number of lactating cows is more than 15. If the number is less than 15, sample all lactating cows.
- Once during the whole period blood samples will be taken from all animals in milk from each herd.

Activities in negative herds:
- The field technician will visit every farm/herd every 4 weeks and complete form.
- Blood samples taken at month.

In addition, the field technician will provide feedback every week to the coordinator confirming the farms that have been visited and whether any abortion has been detected. Since most of the samples tested in serology belong to Girinka program to support beneficiaries, to have Brucella-free cattle, goats, pigs and sheep for the Program. However it is difficult to trace the exact origin of an animal because they were selected from different regions of the country. Between January and June 2018, the total samples from cattle were 6,246; goats – 3,440; pigs – 3,003 and sheep – 211. Only 7 Brucella-positive were detected among cattle samples. Apart from government programs, we sampled 40 cows from Nyabugogo abbatoir and all were negative for brucellosis. A total of 587 cows were sampled in Bugesera and Rwamagana farms in April 2018, and 32 of them tested as Brucella-positive.

Helminthology section

During 2016/2017 fiscal year, an epidemio-surveillance was conducted to examine the status and distribution of helminthes in bovine and caprine in different districts of Kicukiro, Nyagatare, Bugesera, Huye and Gatsibo districts. A total of 395 samples from cattle were collected with 91 positive with various species of helminthes, all the districts that were sampled, Huye had the highest (72.5%) prevalence of helminthes (Table 90).

Table 90: Summary of helmithology tests during FY 2017-2018

	Districts	Species	No. Samples	No. of positive samples	Prevalence (%)
1	Kicukiro	Bovine	7	0	0
2	Nyarugenge	Bovine	59	20	33.9
3	Bugesera	Bovine	13	0	0
4	Huye	Bovine	40	29	72.5
5	Nyagatare	Bovine	158	12	7.6
6	Kabarore	Bovine	118	20	16.9
	Total		395	81	21.8%

3.7 One Cow per poor family

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 mindset towards cattle as a status symbol (the more cows one had the better) to a source of income and livelihood, etc. Girinka Program targets was to distribute 31,190 cows to poor households in the fiscal year of 2017-2018. By the end of June 2018, 32,973 cows had been distributed to the poor families (Table 91).

Since Girinka program introduction, the data evaluation illustrates that 331,295 cows had been distributed countrywide, and it was achieved at the rate of 95% with a gap of 18,705 cows. Girinka week led the mobilization of taking care to the cows, especially, Girinka cows and motivating the beneficiaries in their daily life of livestock. With 32,973 cows distributed in 2017/2018 the achievement was 105.7 % compared to targets.

Girinka awareness (Girinka week) is an annual event established to aware Girinka program within the country (Photo 53). In the last years, this activity were prepared and conducted at province level where each province scheduled its own date to launch this activity with specific theme regardless other contrary this it has been planned at National level with the same theme entitled as "*Duteze Imbere Gahunda ya Girinka, twihutisha Intego zayo, Dusigasira Ibyagezweho*'' and countrywide it has been launched between quarter one and quarter two (Q1-Q2).

Table 91: Cows distributed and achievements during FY 2017-2018

| District | Target | Number of cows distributed by | | | | |
		Earmarked	Partners	Pass On	Local	Total
Bugesera	1018	471	442	741	39	1693
Burera	1212	433	153	455	13	1054
Gakenke	1270	380	275	589	4	1248
Gasabo	196	92	111	205	13	421
Gatsibo	600	713	49	631	4	1397
Gicumbi	1581	499	96	1033		1628
Gisagara	1581	565	407	609	343	1924
Huye	1200	298	197	639	69	1203
Kamonyi	1500	375	294	597	102	1368
Karongi	800	347	173	301	32	853
Kayonza	900	300	214	202	48	764
Kicukiro	120	63	43	66	2	174
Kirehe	1350	451	218	506	3	1178
Muhanga	750	346	316	508	87	1257
Musanze	900	209	107	497	34	847
Ngoma	600	231	126	422	19	798
Ngororero	1200	234	320	496	205	1255
Nyabihu	620	220	220	212		652
Nyagatare	1678	465	123	335		923
Nyamagabe	2000	1086	241	481	67	1875
Nyamasheke	800	470	25	388	18	901
Nyanza	1140	418	110	521	17	1066
Nyarugenge	109	81	26	57	43	207
Nyaruguru	1300	361	240	544	212	1357
Rubavu	500	248	154	171	206	779
Ruhango	1640	374	286	266	726	1652
Rulindo	900	264	162	433	76	935
Rusizi	1500	385	141	347	321	1194
Rutsiro	1067	362	174	456	182	1174
Rwamagana	1000	311	238	511	136	1196
Total	31,032	11,052	5,958	13,264	2,699	32,973

During FY 2017-2018, we carried out Girinka Impact assessment to establish the impact of Girinka. The assessment involved 1092 households including beneficiaries and non beneficiaries of Girinka program countrywide excluding City of Kigali.

Photo 53: Girinka week

This activity has been conducted within wet season where there was much rainfall and this resulted the delay and then extending the desired time for extra data collection. From this it is recommended to conduct the data collection activity in summer season to come out the aforementioned challenge. For future further assessment, the data collection should be done by use of soft questionnaire in Smart phone or tablets.

3.8 Gako beef project

Gako integrated beef production project is implemented in partnership with private sector It is located in Bugesera aiming to produce meat of good quality and quantity to meet the national consumption demands and also for international exports.

Table 92: Activities implemented for Gako project in FY 2017-2018

No	Key activities	Status
1	Farmers mobilization to introduce cattle in the farm	13 farms established 2,977 head cow was introduced
2	Set up irrigation water supply infrastructure	DPR completed, Delivery pipeline /Rising pipeline completed, water intake under completion, equalizing tanks
3	Establishment of project access and feeder roads	53 km completed
4	Drill of bore hole	4 out of 9 completed

The project consist on the farm land preparation through bush clearing and establishment of forage plot; set up irrigation water supply infrastructure on 2,377 ha, drilling of 9 boreholes to provide water for cattle; construct electric power line for both water intake and other field farm activities, slaughter infrastructure construction and 53 km of feeder road to ease access and transportation. The table below shows the implementation status of key activities under Gako beef project.

Part 4. Support Services

4.1   Planning, Monitoring and Evaluation

The planning, monitoring and evaluation unit has the mandate of, among other thing, developing technical   tools for planning and managing data collection, analysis, and use. The PM&E process expands the Log frame to identify key information requirements for each indicator and summarizes the key monitoring and evaluation tasks for the existing strategic plan (2013-2018).

Table 93: Planning, Budgeting, Monitoring and Evaluation Calendar for FY 2017- 2018

Period	Planned activities
October	Issuing of the 1st PBCC from MINECOFIN,
	Quarterly reporting on Action Plans ,Imihigo and budget execution
November	Investments plans (PPDs and OPAFs Submitted to MINECOFIN)
	RAB action plans submitted to the Mother Ministry
January	2nd PBCC from MINECOFIN to Publics institutions
	Quarterly reporting on Action Plans, Imihigo and budget execution
February	Data entry in IFMIS
	Received budget Ceiling from MINECOFIN
March	Budget consultation/ defense,
	Budget allocation (departments, programs, support services...)
April	Internal budget ceiling (departments. Programs, Projects)
	Quarterly reporting on Action Plans, Imihigo and budget execution
May	Elaboration of Annual Work Plan and Budget for FY 2017/2018
	Elaboration of Joint & individual Imihigo for FY 2017/2018
June	Development of End Year (2016-2017) reports
	Staff Performance contracts entry in RBM/IPPIS

It helps staff to determine if the proposed indicators can effectively measure the results linked to the single action plan. A good application of monitoring and evaluation rules helps the institution to tackle accurate information from achieved and under implementation activities; information that are used for further planning, learning and accountability. Tables 93 and 94 below show the calendar of PM&E activities during 2017-2018 fiscal year.

Table 94: RAB reporting Framework

Period	Report	Dead line
Quarter 1: July - September	Quarterly - Action plan - Performance contract	**25 September** (Every year)
Quarter 2: October- December	Quarterly - Action plan - Performance contract	**24 December** (Every year)
Quarter 3: January –March	Quarterly - Action plan - Performance contract	**25 March** (Every year)
Quarter 4: April – June	Quarterly - Action plan - Performance contract	**25 June** (Every year)
Annually: July	Annually - Narrative annual Report	**15 July** (Every year)

4.2   Legal Advisory Services

The role of legal advisory services is to advise the senior management of the organization/ institution to comply with regulations in force in order to prevent unnecessary legal issues and provide equal treatments to beneficiaries. The following tasks have been executed during this financial year by RAB legal advisory services during 2016-2017 fiscal year:

1. Drafting and editing different draft bills and other Legal documents as requested;
2. Rendering legal opinions and advice the Institution in matter related to the Acts, Agreements, or any other commitments of RAB before its signature;
3. Conducting preliminary investigations on litigious affairs in which RAB is involved;
4. Representing RAB in justice sectors; and Requisition and follow up of RAB Land Titles.

All the above mentioned activities were successfully.

4.3   Human Ressources Management

The main role of Human Resources Management unit in RAB is to make sure that rules and regulations governing public servants, ethics, entitlements and conditions of service as well as standard operational procedures regarding their daily responsibilities are respected. To ensure the effective Human Resources Management, RAB top Management organized different meetings during 2016-2017 FY whereby HR related issues were raised and solved. The performance appraisals for all RAB staff for the fiscal year 2017-2018 were conducted. The number of RAB permanent staff in October 2017 was 441. In September 2017 two of them had retired while 2 others had resigned, making the total permanent staff reduced to 438 (Table 95). RAB has also 187 contractual staff some of them being paid on RAB revenues while others are paid by externally funded projects. The table below provides more information of RAB permanent and contractual staff.

Table 95: Changes in RAB staff 2017-2018

	Total number, October 2017	Total number, September 2018
Permanent staff	441	438
Contractual staff	180	187
TOTAL	621	625

To date, RAB has 24 PhDs and 112 MScs. A total of 43 staff went for a long term training, 22 on PhD and 21 on MSc. RAB hosted 350 professional internees in 2017-2018 fiscal year.

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4.4 ICT Unit

The ICT unit is one of four support Units forming RAB's Corporate Services Division and has the following roles and responsibilities.
  ➢ Planning, implementing ICT infrastructure that includes (Setting and supporting Local Area Networks(LAN), Wide Area Network (WAN)s,);
  ➢ Responsible for the overall functioning and effective management of RAB's systems and related technology.
  ➢ Developing an IT strategy on data security, back up and support systems;

- ➢ Participate in elaboration of ICT sector strategic plan, RAB national ICT policy, annual action plans as well as operational plan;
- ➢ Plan for capacity building for RAB staff in Knowledge of computer hardware/software technologies.
- ➢ Develop specifications for procurement of systems/software and IT equipment;
- ➢ Ensure network connectivity throughout RAB's LAN/WAN infrastructure is realized;
- ➢ Ensure the maintenance of RAB's network facilities in individual machines, such as drivers and settings of personal computers as well as printers;

During the fiscal year 2016-2017 ICT unit purchased IT equipment and participated in ICT infrastructure development.

- 🔸 Purchase of IT equipment:

In line with equipping RAB staff with sufficient and modern IT equipment, RAB purchased local made products laptops (Positivo BGH), Desktops, printers, scanners, Cameras, GPS, Antivirus, wireless routers.

- 🔸 ICT infrastructure development:

As part of the implementation of the government policy the baseline IT infrastructure and equipment assessment come up with recommendation on how ICT can be enhanced to effectively meet staff needs. This started with connecting Nyagatare center to fiber optic network backbone to enable researchers and support the access to high-speed internet connectivity.

The unit implemented a full and modern network IT infrastructure in the new constructed RAB new Headquarters with full applications and domain servers operational and optimized high-speed internet access through fiber optic terminals; with powerful surveillance cameras at every single corner of the premise, modern IP handsets to enable internal voice call. These infrastructure are also highly protected by powerful cyber security equipment, which meets the National cyber security requirement and standards. In the same line RAB purchased a good number of 4G LTE wireless routers and single point connectivity (Modems) to facilitate staff with full mobility of data connectivity.

Through ICT unit and in partnership with Rwanda Development Board (RDB) end users, administrative assistants were trained on the use of document tracking Management System, specifically on omni scan and omni flow platforms. With the aim of facilitating communication among RAB staff based in different parts of the country, RAB implemented closer user group (CUG) communication facility with latest smart phones with mobile data connectivity, where RAB staff are making calls among themselves. Furthermore RAB toll free line 4675 up and running where farmers from different parts of the country and abroad call in for various queries on matters related to agriculture and get interactive responses. RAB has implanted ICT policies, procedures and disaster recovery plan manual by hosting RAB systems in the National Data centers to make sure that government data and information are hosted in safer environment.

Part 5. Published papers

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