FOREWORD

In Rwanda, about 75% population are dependent on agriculture; and the economy of Rwanda is agriculture based. Agriculture can help farmers to make much more money today and in the future than in the past if they apply modern technologies. To increase a share of market oriented commercial agriculture, farmers increase quality and quantity of agricultural produce while producing from the same land area if appropriate innovations are applied, and thus to move from subsistence to modern agriculture.

Rwanda Agriculture and Animal Resourced Development Board seeks to develop modern technologies to increase productivity and reduce postharvest losses to improve food security and income from agriculture and livestock derived products. The research and extension activities in the Fiscal Year 2019-2020 were guided by key National policy documents –National Strategy for Transformation (NST-1) and Strategic Plan for Agriculture Transformation (SPAT 4), prioritizing crop and livestock intensification with increased irrigation and mechanization, addressing climate change and improving storage and postharvest handling.

I have a pleasure to introduce this annual report which contains the key achievements and milestones targeting to develop technologies that improve food security, generate income, create jobs, and improve well-being, particularly for small-scale farmers. Achievements summarized in this report cover research and technology transfer for Crops, Livestock, Land Husbandry, Irrigation and Mechanization. RAB has implemented its activities across the 12 RAB stations that covered all the 4 Provinces and Kigali City Districts. Partners in Agricultural sector, namely, agro-dealers and NGOs have worked with RAB to increase input use, training of frontline extension agents and mobilizing farmers for timely preparation and implementation of the seasons. Integration of RAB staff, Local Government and private sector was a key strategy for increasing agriculture production, supply, distribution and delivery of inputs, namely, fertilizers and seeds to strengthen the entire agriculture value chain.

RAB Board of Directors would like to appreciate support given to RAB by the Government through MINAGRI, local government agencies, private sector, NGOs and CBOs, other local and international partners. I also thank RAB management team and staff for their dedication to achieve institutional targets that contribute to National Development Goals.

Dr. Magnifique Ndambe NZARAMBA

Chairperson of the Board of Directors of RAB

EXECUTIVE SUMMARY

The Fiscal Year 2019-2020 is the third year of the National Strategy for transformation, NST-1(*), developed for 2017-2024, second year of the Strategic Plan for Transformation of Agriculture, PSTA IV (**), developed for 2018-2024. RAB research and extension plans were oriented to deliver to the strategic outputs of these key National policy documents. The main areas of research and technology transfer in 2019-2020 were crop and animal resource improvement, sustainable agriculture and livestock intensification, post-harvest management, land husbandry, irrigation and mechanization.

For Crops, RAB has done research on Cereals, Roots and Tubers, Pulses, Horticulture, Industrial Crops, Crop Protection and Agriforestry. Maize has submitted 8 hybrids for release, established 101 demo plots with about 8,000 farmer promoters, and 10 new highly performant hybrids which are locally bred were prepared for release. Rice has developed 6 long grain varieties that are able to be grown in environments with cold nights which cover most of rice growing areas in Rwanda. Five other rice varieties with resistance to rice blast are being developed. Wheat research evaluated 1895 lines and selected 202 lines. It has tested 12 varieties on farms and 7 lines were selected through participatory approach with farmers. New crop, barley, was introduced and 18 varieties tested with 49 demo plots established on farm. Cassava research has developed 21 parent lines used for crossing, which yielded 17 family nurseries from true seeds, out of which 220 promising lines were selected with very low virus incidence for both, CMD and CBSD, and are being observed further. Another set of 531 clones were evaluated and 37 selected from previously made crosses. A total of 13 clones were identified which are high yielding and virus tolerant. Participatory variety selection resulted in identification of 4 clones with virus resistance or tolerance. Irish potato research has conducted crossing of popular varieties with new promising lines with resistance to late blight and early maturity, from which true seeds were collected and will undergo preliminary yield evaluation. Another evaluation of 20 lines for late blight tolerance resulted in participatory selection of 7 varieties which are being prepared for release. Tissue Culture lab at Musanze produced a total of 1,533,900 plantlets for dissemination and research. Sweet potato research has evaluated 12 new clones with yield potential above 50t/ha and selected 2 clones (2017-4 and 2017-103) originating from local crossings. Another set of 19 clones was evaluated for drought tolerance with best clones achieving more than 37 t/ha under drought stress and vine yield of 16t/ha. Banana research has developed new method for banana wilt control, single diseased stem removal, known as SDSR, which allows to cut disease incidence to 1% in 2 months and 0% in 1 year without uprooting sick banana plantation at any high level of disease incidence. This method responds better to food security needs and prevents loss of banana harvest which were happening often in the past. Horticulture research developed recommendations for Stevia fertilization for obtaining high yield and has done sweet pepper variety selection. Besides, 163,780 scions were produced and

disseminated via partners for avocado, 107,200 for mango and 53,700 for Citrus spp. Coffee research has established through survey that the most dangerous pest on coffee was Antestia bag (55.2% incidence) and Coffee Leaf Rust disease (76.7% incidence). Coffee hybrids with tolerance to coffee leaf rust were developed and are being multiplied for farmers in collaboration with NAEB. Tea research continued to evaluate seven new tea clones and fertilizer formulas. Crop Protection has responded and developed recommendations to control the emerging pests and diseases outbreaks as Fall Army Worm, maize leaf blight disease, Maize Leaf Necrosis disease and grasshoppers in Maize; white grub pest in pastures; potato bacterial wilt and viral disease in Irish potato; thrips, fusarium, banana wilt in Banana; slugs and millipedes in Beans; mealybugs, fruit flies, anthracnose and powdery mildiou in Mango; alternaria, anthracnose, fusarium and phytophtora in Passion fruit. Agroforestry research has conducted 664 on-farm trials with 1,554 farmers to promote tree biomass applications combined with mineral fertilizers to improve crop yields (320 trials countrywide); promote stakes for climbing bean yield increase (250 trials) and promote fruit-based cropping for income and wellbeing (94 trials). Crop production research is supported by the promotion of mechanization and irrigation. In FY 2019-2020, mechanization was achieved on a total of 7,253.5ha. Irrigation was established on 4,068 ha and intervened to maintain the existing irrigation infrastructures on 10,000 ha, which required repair. Irrigation studies for various potential areas of irrigation have targeted a total of 31,776ha through feasibility studies and fund mobilization.

For Livestock, research and development activities were conducted on monogastric animals, ruminants, artificial insemination, veterinary services and animal nutrition, as well as fish, apiary and sericulture. Pig research has conducted detailed characterization of pig production systems and has extended artificial insemination to 298 sows, with study on semen quality during transport using local material. Chicken research has identified 4 landraces of local chicken with distrinct phenotypic and productive traits, Small stock project in Western Rwanda has mobilized 202 new groups of pig producers, 46 groups of chicken and egg producers, mostly, women and youth, and has distributed 1,680 pigs ans 27,000 layer chicken. Ruminant research focused on conservation of Inyambo local breed which is very resistant to diseases and local conditions, promoted artificial insemination for 99,558 cows, which produced 38,618 calves. Embryo transfer for cows has achieved success on 21 transfers out of 61 with 34% success rate. New feed formulations were developed, and fodder germplasm was maintained and characterized. Veterinary services conducted identification of mastitis in 7 districts with prevalence of 39.8%. Girinka Program has distributed a total of 23,735 heifers.

Bee keeping research has established 2 demo apiaries, developed new method for Varroa mite control and improved bee feeding formulation, and developed 4 new methods for queen rearing. Sericulture research concentrated on maintenance of mulberry germplasm and silkworm breeds, which were developed earlier, produced and distributed 200,000 saplings to silkworm rearing farmers and cooperatives.

These achievements have been realized with great support from Government, Ministry of Agriculture and Animal Resources and the RAB Board of Directors. We recognize substantial support and contributions from our stakeholders - Development partners, international research centers, service providers, local government, non-governmental organizations, private sector, and farmers. We remain committed to work through research and technology transfer to increase the value from Agriculture and Animal Resources and preserve the natural capital of agricultural systems.

Patrick Karangwa (PhD)

Director General of RAB

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* NST-1 can be accessed via https://www.nirda.gov.rw/uploads/tx_dce/National_Strategy_For_Trsansformation_-NST1-min.pdf

** PSTA IV can be accessed via http://extwprlegs1.fao.org/docs/pdf/rwa180543.pdf

LIST OF ABBREVIATIONS

AGRA	– Alliance for Green Revolution in Africa
AU	– African Union
BXW	– Banana Xanthomonas wilt
BXW App	– Free application for smartphones on Google Store for BXW control
CBSV	– Cassava brown streak virus
GxE	– Genotype by environment interaction
MD	– Cassava mosaic disease
ECABREN	– Eastern and Central Africa Bean Research Network
FRY	– Fresh root yield
FY	– Financial year
IITA	– International institute of tropical agriculture
MAP	– Months after planting
HA	– High altitude
MA	– Medium altitude
MAS	– Marker assisted selection
masl	– Meters at sea level
MLN	– Maize lethal necrosis
Mt	– Metric tonnes
NARO	– National Agriculture Research Organization
NPT	– National performance trial
SAH	– Semi -autotrophic hydroponic
SEDO	– Socio-economic development officer
TWCH	– Triple-way cross hybrid

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1.1 CEREALS PROGRAM

1.1.1 Maize Sub-Program

Maize research focused on characterization of 8 hybrids developed earlier, seed production, nicking optimization trials of new hybrids prior to release and maintenance of 11 parent inbred lines. The dissemination of 7 RAB hybrids was done through demonstration plots with 101 maize farmer cooperatives and more than 8,000 Farmer Promoters. The major constraint during the fiscal year was the outbreak of coronavirus disease (COVID-19) and the subsequent quarantine imposed in the country to prevent the wide spread of the pandemic, from which most of activities delayed. High rainfall occurred in November and December 2019 combined with inappropriate crop management especially inappropriate weeding caused nitrogen leaking in many maize fields. This caused decrease of maize yields.

Nicking optimization trials and description for 8 parent SCHs and 7 parent inbred lines of 10 new hybrids candidates for release in 2020

The optimization trials on 10 hybrids (6 for high and 4 for mid-altitude, Rubona and Cyabayaga (Table 1).

Table 1: Nicking instructions from optimization trials of 10 maize hybrids ready for release

No	Names	Pedigrees	Female parent	Male parent	Instructions for nicking obtained in optimization trials
			Rubona		
1	RHH1806	P017/P002//P016	P017/P002	P016	Plant female rows **2days after** male rows. Some male rows planted the same time with female rows
2	RHH1807	P017/P002//P006	P017/P002	P006	Plant female rows **10days** before male rows
3	RHMH1604	P006/P007//P013	P006/P007	P013	Plant female rows **10days** before male rows
4	RHMH1706	P013/P001//P015	P013/P001	P015	Plant female rows **2 days after** male rows. Some male rows may be planted at the same time with female rows
5	RHH1707	P019/P001//P006	P019/P001	P006	Plant female rows **8days after** male rows
6	RHH1708	P020/P008//P006	P020/P008	P006	Plant female rows **9days after** male rows
			Cyabayaga		
7	RHM1843	P001/P004//P008	P001/P004	P008	Plant female rows **6days** after male rows
8	RHM1702	P001/P004//P003	P001/P004	P003	Plant female rows **2days** after male rows
9	RHM1704	P002/P012//P003	P002/P012	P003	Plant female rows **4days** after male rows
10	RHMM1701	P008/P011//P003	P008/P011	P003	Plant female rows **4days** after male rows

The trial consisted of planting side by side a number of female and male rows and recording the planting date. Thereafter at flowering, the date of emergence of the silks at 50 % for female rows and the date of 50 % pollen shed for male rows were recorded as well. The silking of female parents was obtained in days from planting to 50 % silk emergence while the anthesis of male parents was obtained in days from planting to 50 % pollen shed. The nicking period was obtained in days by the difference between silking and anthesis. When the nicking period was positive, the female rows were proposed to be planted before male rows and when it was negative, female rows were proposed to be planted after male rows.

Registration of 8 maize hybrid varieties with superior traits that are in seed production

Eight hybrids with superior traits developed by RAB under the support of AGRA are at various stage of seed production. These varieties are on the national list of varieties in Rwanda. The descriptors of 11 parent inbred lines, five parent Single Cross Hybrids (SCHs) and eight Three Way Cross Hybrids (TWCHs) (RHM104; RHM1402; RHM1407; RHM1409; RHM1520; RHMH1521; RHMH1601; RHMH1611 –drought tolerant and with good adaptability; while the first three are MLN tolerant.

Descriptions of parent inbred lines and the parent SCHs of 10 hybrids selected for release

The inbred parents of 10 maize hybrids selected for release comprised seven lines: P001, P002, P003, P004, P006, P007 and P008. The description of these lines was done. A total of 17.8 kg of seeds were produced. Furthermore, the descriptors of the parents SCHs of the 10 new maize hybrids selected for release was done at Cyabayaga and Musanze.

Seed production and description

10 maize hybrids candidates for release: The production of the seeds for the 10 maize hybrid varieties to be released was conducted at Musanze and Rubona for the high altitudes varieties and at Cyabayaga for mid-altitude varieties. A total of 55.54 kg was produced and will be used in demonstration plots with maize farmers' cooperatives of 2020-2021.

11 parent inbred lines and 8 parent SCHs of 9 new maize hybrids candidates for release in 2021:
11 parent inbred lines of hybrids were increased in seed quantity, and a total 17.46kg of seeds were produced. Furthermore, the seed of 8 parent SCHs of the hybrids were produced (10.5kg) while confirming flowering synchronization and nicking information. However, it was not possible to confirm the nicking information for 3 hybrid varieties: RHH1801, RHM1810 and RHM1842. The confirmation will be conducted again in 2021 A (October 2020-February 2021). Some initial seeds were produced for 5 varieties for high altitude and 4 varieties for mid-altitude, all bred by combining parent inbred lines developed locally and CMLS introduced from CIMMYT. These are RHH1801; RHH1808; RHH1816; RHH1628; RHH1631; RHM1810; RHM1820; RHM1823; RHM1842.

Increase of parent inbred lines of maize hybrids selected for release after 2021: Six new maize hybrids including two Top Cross Hybrids and four TWCHS, two hybrids for high altitudes and four for mid altitudes are expected to be released beyond 2021 because one of their parents did not have

enough seeds during the season 2020 A. Hence, the seed production of their 7 parent inbred lines was conducted at Cyabayaga and Musanze with 20.1kg of seed produced and descriptors generated.

Adaptability trials for selecting new varieties for release

Fourteen new Three Way Cross Hybrids (TWCHs) and one Top Cross Hybrid were developed by RAB by combining CIMMYT inbred lines and parent inbred lines developed locally and targeting specific traits and new/non-registered varieties from Western Seed Company Ltd (WSC) and Kilimo General Business (KGB) were evaluated in comparison with RAB released varieties and one commercial variety from WSC in Bugarama, Rubona and Cyabayaga, in 2020A (Table 2).

Table 2: Harvest traits of 24 entries evaluated at Rubona and Cyabayaga, 2020A

No	Names	SIL	ASI	HT	TLB	MSV	EPP	ER	GY
1	RHM1962	77.0	1.0	2.52	2.1	1.0	1.0	1.3	7.51 def
2	RHM1963	76.2	1.2	2.76	2.8	1.0	1.1	1.4	8.00 cde
3	RHM1964	76.8	1.0	2.72	2.6	1.0	1.0	1.1	9.26 abcd
4	RHM1965	77.2	0.3	2.71	2.2	1.0	1.3	1.3	10.58 ab
5	RHM1966	77.7	1.2	2.71	2.2	1.0	1.1	1.3	8.99 bcd
6	RHM1967	76.2	1.3	2.70	2.8	1.1	1.1	1.4	9.31 abcd
7	RHM1968	76.5	1.0	2.69	2.8	1.0	1.1	1.8	7.23 fgh
8	RHM1969	79.3	0.5	2.82	1.9	1.0	1.1	1.3	11.14 a
9	RHM1970	78.0	1.0	2.72	2.1	1.0	1.1	1.0	10.65 ab
10	RHM1971	75.2	0.7	2.61	2.3	1.0	1.0	1.3	7.45 def
11	RHM1972	75.7	0.7	2.64	1.9	1.0	1.1	1.5	9.42 abc
12	RHM1823	77.3	1.2	2.57	2.7	1.0	1.1	1.4	5.93 g
13	RHM1843	74.0	1.0	2.54	3.1	1.0	1.0	1.3	7.29 efg
14	RHM1847	73.8	1.2	2.61	2.3	1.0	1.1	1.4	7.85 cde
15	RHM1858	72.2	2.0	2.50	2.7	1.0	1.0	1.6	5.80 gh
16	WH401	83.2	1.2	2.76	2.3	1.0	1.1	1.1	9.77 abc
17	WH101	73.3	1.2	2.84	2.8	1.0	1.2	1.3	8.40 bcd
18	WH504	79.7	1.7	2.81	3.1	1.0	1.1	1.4	9.63 abc
19	WH505	74.3	1.2	2.76	2.3	1.0	1.1	1.3	9.61 abc
20	CKDDHH170002	75.8	1.2	2.76	1.8	1.0	1.1	2.0	10.70 ab
21	RHM1407	75.3	0.7	2.62	2.9	1.0	1.1	1.6	8.41 bcd
22	RHM104	76.5	1.0	2.68	2.8	1.1	1.1	1.5	7.73 cde
23	RHM1402	76.3	0.8	2.65	2.4	1.0	1.1	1.6	8.86 bcd
24	RHM1409	75.8	1.3	2.70	2.1	1.0	1.1	1.6	9.23 abcd
P		<.001	0.61	<.001	<.001	0.47	0.01	<.001	<.001

SIL: Silking (d); ASI: Anthesis-Silking Interval (d); HT: Plant height (m); EPP: Ears per plant; TLB: Turcicum Leaf Blight (1-5); ER: Ear rot (1-5); MSV: Maize Streak Virus (1-5) GLS: Grey Leaf Spot (1-5); GY: Grain yield (t/ha at 15 % H_2O)

Grain yield (t/ha at 15% moisture) was the major agronomic trait recorded. Other agronomic traits observed included silking (d), Anthesis to Silking Interval (ASI) (d), plant height (m), Turcicum Leaf Blight (TLB) and Maize Streak Virus (MSV) severity scoring (scale of 1 to 5), number of ears per plant, ear rot (scale 1 to 5).
MSV and TLB severity scorings were recorded using a scale of 1 to 5 where: 1 - No symptoms, 2 - Low, 3 – Moderate, 4 - Heavy symptoms except panicle, and 5 - Whole plant very heavily infested including panicle, plants are dying.

Silking varied from 72.2 (RHM1858) to 83.2 days (WH401) indicating that all varieties were intermediate maturity (70 days <silking < 80 days) except WH401 which was late maturing (Table 23). Silking happened later in Rubona (1691m asl) than Cyabayaga (1392m asl) due to cooler climate of the first site. All varieties were tall (with height superior to 2.50 m), except RHM1858 (Table 23). For the same reason, all varieties in Cyabayaga were taller (data not shown). Grain yield varied from 5.90 t/ha (RHM1823) to 12.13 t/ha (WH505) in Rubona (with mean of 9.32 t/ha) whereas at Cyabayaga it varied from 5.03 t/ha (RHM1858) to 10.84 t/ha (RHM1965) with mean of 8.07 t/ha. Considering both sites combined, highest yielding varieties were: RHM1969 (11.14 t/ha), CKDDHH170002 (10.70 t/ha), RHM1970 (10.65 t/ha) RHM1965 (10.58 t/ha) and WH401 (9.77 t/ha). Considering other yield traits, morphology and disease incidence, RHM1969, CKDDHH170002, RHM1970, RHM1965. WH401, WH504, WH505 and RHM1972 were identified as best performing.

Maintenance of parent inbred lines of maize hybrid in seed production

To keep the purity of lines for quality seed multiplication, a total of 11 parental inbred lines were maintained in Musanze and Cyabayaga except CM216 that was maintained at Rubona. The methodology consisted of planting ear-to-rows each ear harvested and selected in the previous season and then proceed with manual pollination by self-pollinating all plants in a row. The monitoring was performed at early stage after germination so as to discard any row that might have resulted from the contamination in the previous seasons. At the same time, this row was discarded in the remnant seeds as well. Each selfed ear was harvested and kept separately. It was possible to produce 2,862 selfed ears i.e 2,862 families to maintain all the parents of hybrid seed production.

Breeder's seed of 11 parent inbred lines (P001 to P011) of hybrids were produced with 4.5 to 20.7 kg seeds per line and total of 121.3kg.

Pre-basic seed of 11 inbred lines parents of 8 hybrids was produced in Rubona, Rubilizi and Rwerere. The methodology of producing the seeds consisted in plant each inbred line in isolated plot with a minimum isolation distance of 400 m and thoroughly removing all off-types at all stage of plant growth. Inbred lines CML 202; 203; 204; 216; 442; 444; 445; 463; 464; 488; 539 produced 55 - 1,600kg of seeds per line (total of 5,510kg).

Formation of Three Way Cross Hybrid varieties

The formation of new Three Way Cross Hybrid (TWCH) varieties was conducted at Cyabayaga (76 TWCH) and Musanze (61 TWCH). The specific traits were drought tolerance, MLN tolerance, foliar disease resistance, early maturity, tolerance to fall armyworm and adaptability to true high altitudes superior to 2200 masl. Furthermore, 39 inbred lines parents of high altitude hybrids and 31 inbred lines parents of mid-altitude hybrids were increased at Musanze and Cyabayaga, respectively.

Advancing of inbred lines evelopment and seed increase of introduced lines

Approximately 85 inbred lines with specific traits were introduced and increased at Cyabayaga, Rubona and Musanze. Furthermore, 48 inbred lines were advanced to high level of inbreeding through pedigree breeding (Table 3).

Table 3: Seed increase of introduced inbred lines and advancing to high levels of inbreeding

No	Type of lines	Action	Station
1	14 locally developed inbred lines for mi	Seed increase	Cyabayaga
2	35 Pro-vitamin A inbred lines	Seed increase	Cyabayaga
3	14 Yellow kernel inbred lines	Seed increase	Cyabayaga
4	18 Inbred lines for mid altitudes at S3	Advancing to S4	Cyabayaga
4	22 MLN tolerant inbred lines	Seed increase	Rubona
5	11 Inbred lines for mid altitudes at S4	Advancing to S5	Rubona
6	19 Inbred lines for high altitudes at S5	Advancing to S6	Musanze

Demonstration plots

7 RAB hybrids: The demo plots with 7 RAB hybrids comprising RHM104, RHM1402, RHM1407 and RHM1409 for mid-altitude, RHMH1520, RHMH1521 and RHM1601 for high altitude were established in 2020A with 100 maize farmer cooperatives. Each farmer cooperative received two to four entries depending the availability of the plot and the agro-ecology. The fertilizers used were CE-REALS at planting and AMIDAS at top dressing six weeks after planting. They were supplied by YARA International ASA.

4 RAB hybrids: Demo plots with 4 hybrids for mid-altitude: RHM104, RHM1402, RHM1407 and RHM1409 were established in 2020A by 3 cooperatives (1 in Nyagatare and 2 in Gatsibo). The harvest is scheduled for July 2020.

Farmer promoters' demo: The demo plots were established by **9,174 Farmers' Promoters** in 253 Sectors (out of total 415) selected across the country. Each Farmer Promoter received one variety. Four hybrid varieties: RHM104, RHM1402 and RHM1407 for mid-altitude and RHMH1601 for high altitude were used in these demo plots.

National field day on maize hybrids in seed production on 25th February 2020

A national field day was organized on Tuesday 25th February 2020 at Shyogwe Site (demonstration plot with KIABR maize cooperative), in Nyarucyamo Village, Mubuga Cell, Shyogwe Sector, Muhanga; Gacurabwenge site (demonstration plot with a Farmer Promotor) in Ryabitana Village, Gahinga Cell, Gacurabwenge Sector, Kamonyi District and Bishenyi Site (certified seed production plot) in Kigese and Kagarama Villages, Kigese Cell, Rugarika Sector, Kamonyi District. It was attended by 196 participants comprising 83 men and 113 women, 160 farmers (60 men and 100 women) and 36 (23 men and 13 women) other maize value chain actors. Furthermore, the field day was attended by the Director General of RAB, the Vice-Mayors of Economic Affairs of Kamonyi and Muhanga Districts.

Photo 1 : Participants visiting the demonstration plot at Shyogwe (left) and Gacurabwenge (right)

The participants visited first the demonstration plot of KABR cooperative (Photo 1) where the compared the performances of the mid altitudes varieties: RHM104, RHM1402, RHM1407 and RHM1409. The cooperative members appreciated the performance of RHM104 and RHM1407 and accepted to plant them in the season 2021 A (September 2020-February 2021) provide the seeds will be available. Then the participants visited a farmer promotor in Gacurabwenge (Photo 1) site planted with a demonstration plot with RHM1402.

The farmers' promotors from Gacurabwenge gave a very positive testimony on the performance of the variety in the sector and accepted to plant it during the season 2021 A. Finally, the participants visited the seed production plot planted with the high altitude variety RHMH1520 by the Seed Company Rumbuka Seed Company Ltd. The seed production plot was approximately 89 ha. The Chief Executive Officer of the company gave a background on how the company was backstopped in hybrid seed production, how the seed production procedure created numerous jobs in the region and very positive expectation of the quantity of seeds that will be obtained.

Field days for harvesting demonstration plots in mid altitudes

The field days were organized during harvest of selected demonstration plots with maize farmers' cooperatives in mid altitudes of Rwanda. In total 55 cooperatives were selected and involved 1,462 farmers comprising 759 men (51.9 %) and 703 women (48.1 %). The demonstration plots involved four maize hybrid varieties: RHM104, RHM1402, RHM1407 and RHM1409 in seed production (Table 3; Photo 2). During each field day, the Participants formed a group of men and a group of women. Each group selected best variety. In all cooperatives men and women preferred RHM104.

Photo 2: Harvest of a demo plot in Huye (left) and Ruhango (right), 4 March 2020

The major criteria for selected a variety were (descending order): big ears, strong stalk and hence resistance to wind, early maturity, drought tolerance, high yielding and large kernels. However, there were slightly differences between cooperatives. Furthermore, the yield was not the first criteria as it would have been expected rather it was the size of the ear, the vigor of the stalk and early maturity.

Table 4: Farmers' choices of varieties to plant during the field days in mid altitudes

Hybrid variety	RHM104	RHM1402	RHM1407	RHM1409
Mean	12.78	13.80	14.24	12.39
Standard deviation	3.14	3.96	3.79	3.40
Standard error	0.49	0.61	0.59	0.52
Minimum	5.0	6.2	3.9	2.9
Maximum	19.0	21.7	21.3	19.0
Range	14.0	15.5	17.4	16.1
First choice by farmers	12.0	17.0	24.0	2.0
Second choice by farmers	13.0	12.0	21.0	9.0
Total choices	25.0	29.0	45.0	11.0
Percentage choice	22.7	26.4	40.9	10.0

The variety RHM1402 was the most chosen as it was selected by 24 cooperatives as the first choice and 21 as the second choice and hence totalizing 45.0 % of choices. The variety RHM1407 was the second to be chosen with 17 cooperatives as the first choice and 12 as the second and having 26.4 % of choices in general. The variety RHM104 was the third to be chosen while the variety RHM1409 was the forth to be chosen (Table 4). In fact, the variety RHM1402 was high yielding in most of the sites (Table 3) although it has been criticized for its small ear appearance. This is because it is flint kernel type.

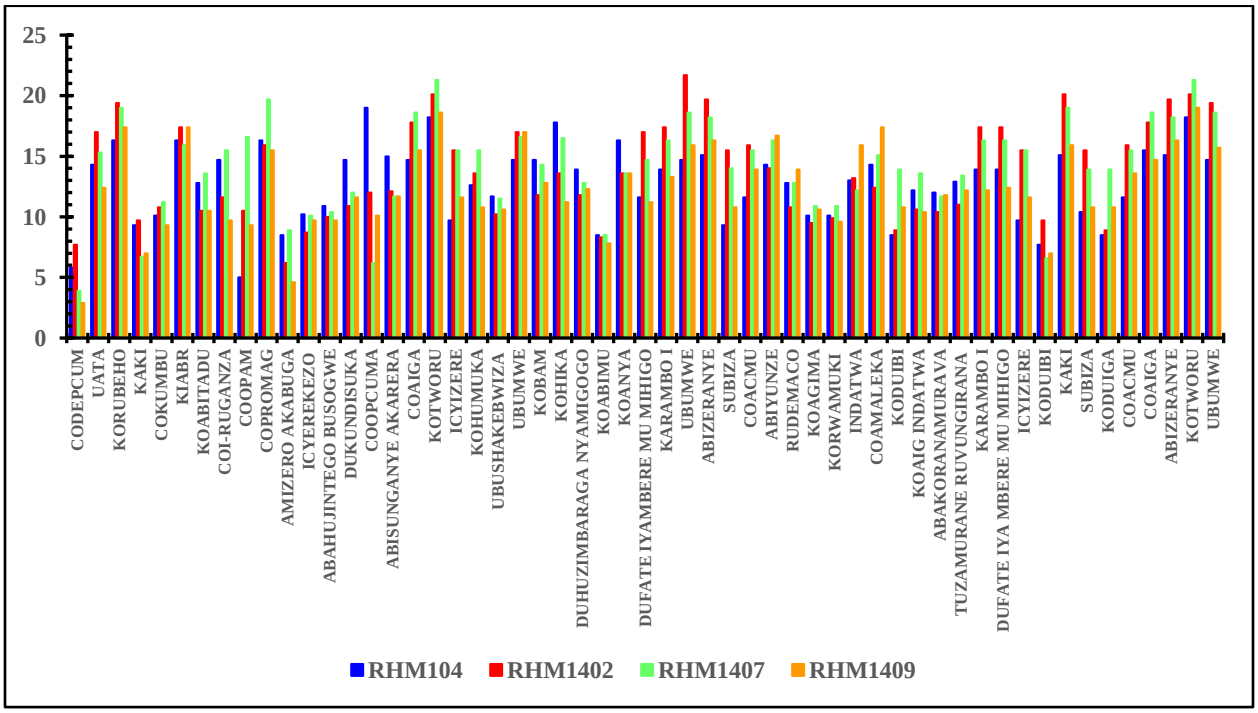

Figure 1: Yield (weight of ears per ha at harvest in MT/ha) of four maize hybrid varieties in demonstration plots with 55 maize farmers' cooperatives in mid altitudes of Rwanda

The variety RHM1407 gave the highest yields (weight of ears per ha at harvest superior to 15.0 MT/ha) in 28 cooperatives followed by RHM1402 (25 cooperatives) then by RHM109 (18 cooperatives) and finally RHM104 (14 cooperatives) (Figure 1). The variety RHM107 has the highest mean of 14.24 MT/ha of weight of ears per ha at harvest whereas RHM1402, RHM104 and RHM1409 had the means of 13.80 MT/ha, 12.78 MT/ha and 12.39 MT/ha respectively. The high yield of 21.7 MT/ha was obtained in the Cooperative Ubumwe with the variety RHM1402 while the lowest yield of 2.9 MT/ha was obtained in the cooperative COPEDCUM with the variety RHM1409 (Table 4; Figure 1).

Field days for harvesting demonstration plots in high altitudes

The field days were organized during harvest of selected demonstration plots with maize farmers' cooperatives in high altitudes of Rwanda. In total 18 cooperatives were selected for harvesting the

demonstration plots and involved 1,364 Participants comprising 780 men (57.2 %) and 584 women (42.8 %). The demonstration plots involved three maize hybrid varieties: RHMH1520, RHMH1521 and RHMH 1601 (Table 5). During each field day, the Participants formed a group of men and a group of women. Each group was requested to select a variety that they would grow as first choice and as second choice and to give the criteria used to make the choice. In all cooperatives men and women made the same choice of varieties to grow (Table 5, Photo 3).

Photo 3: Harvest of a demonstration plot in Nyabihu (left) and Rolundo (right), February 2020

The major criteria for selected a variety were (descendant order): Flint or semi-flint type, early maturity, excellent ear filling, excellent plant aspect and large kernels. However, there were slightly differences between cooperatives. Furthermore, the yield was not cited as a criterion for choosing a variety to grow as it would have been expected rather it was the flint type and early maturity.

Table 5: Farmers' choices of varieties to plant during the field days in high altitudes

Hybrid variety	RHMH1520	RHMH1521	RHMH1601
Mean	14.69	14.94	14.13
First choice by farmers	8	2	8
Second choice by farmers	5	7	6
Total choices	13	9	14
Percentage choice	44.4	11.1	44.5
% Choice 1	44.4	11.1	44.4
% Choice 2	27.8	38.9	33.3

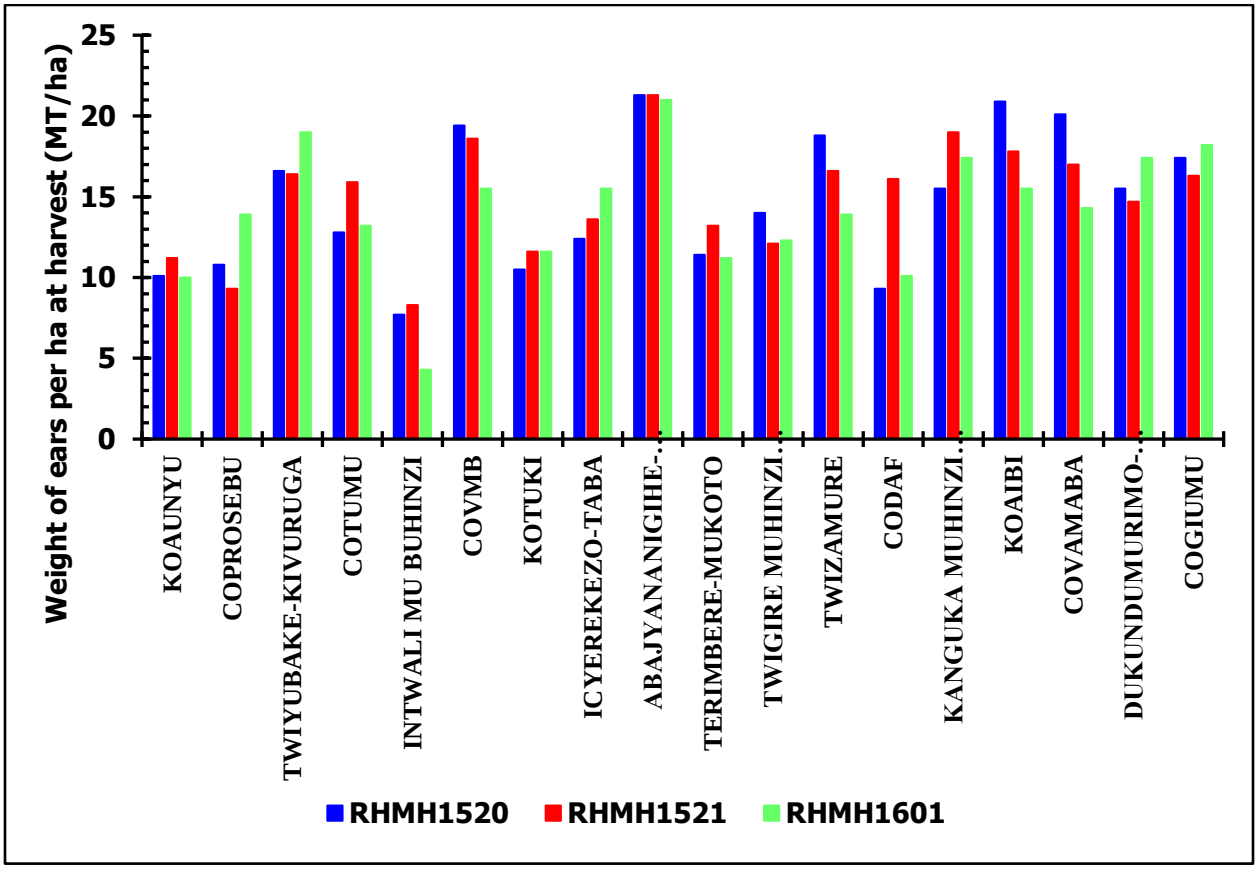

Figure 2: Performance of three maize hybrids in demo plots with 14farmer cooperatives in high altitudes of Rwanda

The varieties RHMH1601 and RHMH1520 with 44.4 % and 44.5 % respectively were almost equally chosen as the variety to grow while RHMH1521 was less preferred (11.1%) when combining choice 1 and choice 2. However, it was mainly chosen in the second with 38.9% of choices (Table 5).

The variety RHM1521 gave high yields (weight of ears per ha at harvest superior to 15 MT/ha) in ten cooperatives whereas RHM1520 and RHM1601 gave the high yields in nine and eight cooperatives (Figure 2). It had the highest mean of 14.94 MT/ha while RHMH1520 had 14.69 MT/ha and RHMH1601 14.49 MT/ha (Table 4). Together with RHM1520, they had the highest yield of 21.3 MT/ha in the TWIZAMURE Cooperative (Figure 2). RHMH1521 was less chosen by farmers because of its semi-dent kernel type despite the excellent performance.

Harvest of the demonstration plots conducted by the Farmer Promoters

A total of 94.0% of Farmer Promoters (8,626 out of 9,174) completed and harvested the demonstration plots. During harvest, the farmer promoters selected best variety in demo plots.

Table 6: Summary of choices per variety in the demonstration plots with Farmers' Promoters

Variety	Total number of Farmers' Promotors	Male Farmers' Promotors	Female Farmers' Promotors	Choice 1	Choice 2	Choice 3
RHMH1601	1,353	1,028	325	345	722	286
RHM104	2,561	1,857	704	1,187	939	435
RHM1402	1,626	1,117	509	1,050	464	112
RHM1407	3,086	1,831	1,255	1,923	987	176
Total	**8,626**	**5,833**	**2,793**	**4,505**	**3,112**	**1,009**

Demo plots were managed by 5,833 men and 2,793 women (representing 68 and 32% Farmer Promoters, respectively) (Table 6, Figure 3). A total of 4,505 Farmer Promoters chose a variety as their first preference, 3,112 as their second preference and 1,009 as their third preference. The variety RHM1402 was highly chosen as the first preference (61%) followed by RHM1407 (60%). This implied that 60% of Farmer Promoters are willing plant the two varieties. The variety RHMH1601 was chosen as second preference while the three others varieties were mainly chosen as the first preference (Figure 3).

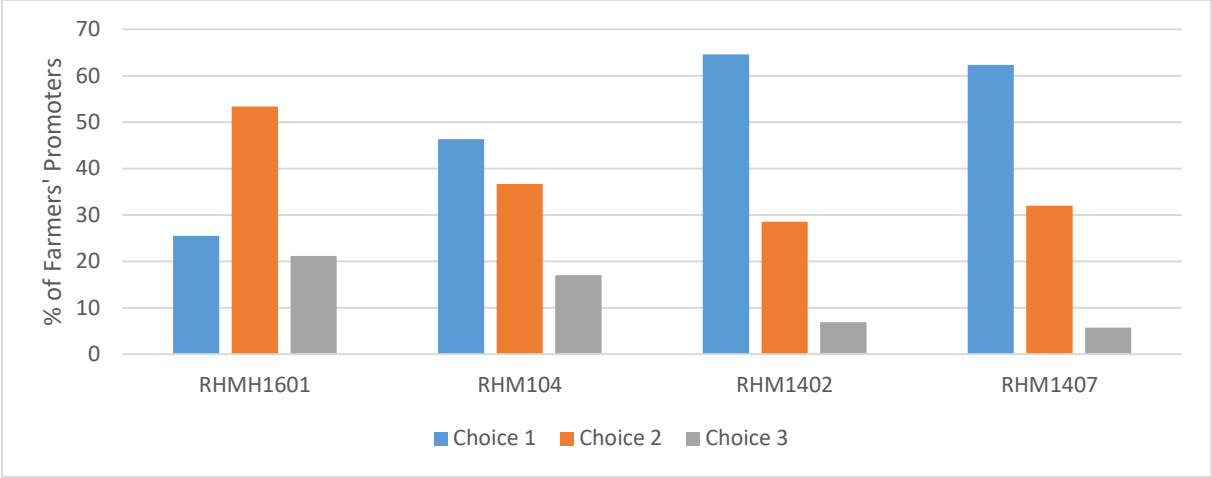

Figure 3: Percentage of choices in the demonstration plots with Farmer Promoters

Training of seed producers

The training of seed producers using RAB hybrid maize was conducted on maize seed production and requirements in March 2020 and it was supported by AGRA. The Participants were 41 comprising ten staff from RAB, 31 Representatives of seed companies, 31 males and 10 females. Two presentations were made: (1) the steps in maize hybrid seed productions, the constraints on each step and how to mitigate these constraints and (2) the requirements for a seed company to operate (Photo 4).

Furthermore, a field day was organized at Rubona where the Participants visited nurseries on the formation of the descriptors of hybrid in seed production and a plot of a planting ratio of four female rows versus one male row. The Seed Producers appreciated the important work being done on the description of the varieties in seed production. However, it is not possible to agree on the use of ratio of four female rows versus one male row instead of three female rows versus one male rows. It was proposed to conduct further trials on station before this ratio being used.

Photo 4: Participants to the training in Rubona (left) and Kigali (right), 5-6 March 2020

Backstopping Rumbuka Seeds Ltd for seed production

Following the instructions from the Director General, after having our effort through this project for increasing the awareness and adoption of RAB maize hybrid varieties, Rumbuka Seeds was approached and requested to link with two maize farmers' cooperatives: KAJYAMOGI in Gisagara District and KOWAMANYA in Nyanza District and request them to produce certified seeds using a high altitude variety.

The two cooperatives were chosen because they grow maize in May or at beginning of June and harvest at the end of September or at the beginning of October. They use Akanyaru river marsh-land and plant when the water has dropped while they harvest before the river overflow again. Furthermore, the two cooperatives were constantly involved in maize seed production using Open Pollinated Varieties (OPVs) and therefore, they knew most of the principles of seed production.

Rumbuka Seeds Ltd was linked to the two cooperatives with the following objectives:
1- To have adequate quantity of seeds for high altitudes for planting in the season 2021B (February 2021);
2- To mitigate the effects caused by outbreak of coronavirus disease (COVID-19) and the subsequent lockdown by making sure that seeds are available to farmers for planting.

The two cooperatives have planted an area of 300 ha, 220 ha for KAJYAMOGI and 80 ha for KOWAMANYA using the high altitude hybrid variety RHMH1520. The germination rate was above 90% and plants are currently at six leaves (Photo 5).

Photo 5: Member of KOWAMANYA cooperative in the seed production plot

Production of extension material

The guidelines for producing seeds of RAB hybrids were developed (800 copies). These hybrid varieties were: RHM104, RHM1402, RHM1407 and RHM1409 for mid altitudes and RHMH1520, RHMH1521, RHMH1601 and RHMH1611 for high altitudes. Additionally, 5000 copies of guidelines were written on selection of the variety, obtaining seeds for planting, planting (plot preparation, spacing, fertilizer application), weeding, harvest and post-harvest handling.

Backstopping seed producers in maize hybrid seed production

Ten emerging seed producers (Table 7) were backstopped through regular visits of seed production plots, exchange visits, meetings and social networks on maize hybrid seed production. All these seed multipliers were producing certified using RAB hybrid varieties. Some of them have undertaken the basic seed production.

Table 7: Status of certified seed production with RAB maize hybrid varieties in 2020A

No	Seed producer	Type	Province	RAB variety planted	Area (ha)	Seed (MT)	*Specific trait
			High-altitude varieties (>1700m asl)				
1	Rumbuka	Company	Southern	RHMH1520	87	191	Early
2	IABM	Cooperative	Southern	RHMH1520	100	220	Early
3	NVGS Ltd	Company	Eastern	RHH1601	50	110	Early
Total high altitudes					**237**	**521**	
			Mid-altitude varieties (900-1700m asl)				
4	Rumbuka	Company	Southern	RHM1409	83	183	MLN, DT
5	IABM	Cooperative	Southern	RHM1409	50	110	MLN, DT
6	RISCO LTD	Company	Eastern	RHM1407	50	110	MLN, DT
7	PRODEV	Company	Eastern	RHM1407	50	110	MLN, DT
8	NVGS Ltd	Company	Eastern	RHM1407	185	407	MLN, DT
9	NVGS Ltd	Company	Eastern	RHM104	152	334	Drought
10	NVGS Ltd	Company	Eastern	RHM1407	25	54	MLN, DT
11	NVGS Ltd	Company	Eastern	RHM1402	74	162	MLN, DT
12	E&B Seed Co	Company	Eastern	RHM1409	51	112	MLN, DT
13	Top Quality	Company	Eastern	RHM104	20	44	Drought
14	Top Quality	Company	Eastern	RHM1402	25	55	MLN, DT
15	Triseed	Company	Eastern	RHM1407	50	110	MLN, DT
16	Hakizimana Leo	Individual	Eastern	RHM104	19	42	DT
17	Gasengayire S.	Individual	Eastern	RHM1407	7	15	MLN, DT
Total mid altitudes					**840**	**1,848**	
Grand total					**1,077**	**2,370**	

DT- drought tolerant; MLN – Maize Lethal Necrosis tolerant

Number of maize value actors reached with interventions

A total of 46,968 actors composed 27,066 (57.6 %) men and 19,902 (42.4 %) women were reached with interventions comprising seven maize hybrid varieties in seed production: RHM104, RHM1402, RHM1407 and RHM1409 for mid altitudes, RHMH1520, RHMH1521 and RHMH1601 for high altitudes. These actors comprised 83 men and 113 women making 180 in total that attended the national field day on 25th February 2020; 1,462 farmers with 759 men (51.9%) and 703 women (48.1%) that attended the field days organized during harvest of selected demonstration plots with maize farmers' cooperatives in mid altitudes and 1,364 farmers comprising 780 men (57.2%) and 582 women (42.8%). Furthermore, the actors included 35,199 farmers with 19,543 men (55.5%) and 15,656 women (44.5%) who are members of 100 maize farmers' cooperatives and who completed the demonstration plots implemented in 2020 A season, 41 Representatives of the Seed Producers including 31 men (75.6 %) and 10 women (24.4%) trained on maize hybrid seed production steps and the requirements of a seed company to operate a seed company on 5-6 March 2020; 8,626 Farmers' Promotors comprising 5.833 men (67.6%) and 2,793 women (32.4%) that completed and harvested the demonstration plots and 100 farmers members (57

men and 43 women) of three maize farmers' cooperatives that conducted the demonstration trials in 2020 B season.

Seasonal maize cropping monitoring

The seasonal monitoring and the proximity services on maize cropping were ensured in collaborations with the RAB stakeholders specifically One-Acre-Fund-Tubura and HORECO. In the fiscal year 2019-2020, maize was planted on area equal to 311,487 ha. The average yield on consolidated land in 2020A was estimated to be 3.8 MT/ha. However, a thoroughly assessment is needed to ascertain this figure. During the months of November and December there was high rainfall in the country. This high precipitation combined with the poor crop management especially inappropriate weeding caused serious nitrogen leaching resulting in poor performance of varieties distributed to farmers. This was considered by farmers as poor performance of varieties while in reality the major problem was the low nitrogen in the fields. It the next fiscal year, it will be very important to emphasis on weeding system.

1.1.2 Rice Sub Program

Rice is the important food crop in Rwanda. In collaboration with international rice centers, research has developed more than 25 varieties with high yield, disease and drought tolerance. This was done along with expansion of rice area and production and increased demand for rice varieties with specific traits (long grain, aromatic).

Variety development

To improve the quality of rice varieties and meet market requirements, rice research embarked in developing and testing promising long-grain varieties in the areas where night cold temperatures are severe which pushes farmers to grow short-grain varieties which are cold-tolerant and produce high yield. The districts selected for the evaluation of promising varieties were: Nyamasheke, Huye, Gisagara, Nyanza, Ruhango, Kamonyi, Muhanga Bugesera, Gasabo, Kirehe, Gatsibo, Nyagatare. The varieties used in demo plots were Umutebo, Gwiza, Cyuzuzo, Kageno, Kira, Gacinya and Yunyin 4 as check. The ranking of varieties were done by farmers visiting the plots and scored each variety in comparison with the check (Popular variety). The scale used was 1-5 with 3 as check: 1=very poor 2= poor, 3=check, 4= Good, 5= Excellent. The evaluation resulted in observing strong effect of ecology where varieties performed differently depending to the site location. Cyuzuzo was ranked as best in Nyamasheke, Gwiza in Kirehe whereas Umutebo was dominating in Southern province. Other-were site specific varieties (Gacinya, Kageno) adapted to some marshlands. The passport data of the varieties ready for release were developed. As a result of this research, the

marshlands with severe night cold temperatures are now able to grow long-grain varieties alongside with the short-grain ones. This program of expanding as long grain in severe environments will be supported with funds mobilized for scaling up these products.

Breeder seed production: Seed production activities ranged from early generation seed multiplication and purification (nucleus seeds production) to the promotion of certified seed use. A total of 248 kg of breeder seeds were produced and availed for basic seed production (Table 8).

Table 8: Breeder seeds production

Nr	Variety	Rwamagana	Rubona	Bugarama	Total
1	Rumbuka	5	9	0	14
2	Mpembuke	5	9	0	14
3	Yun Er Tian	10	7	0	17
4	Nemeyubutaka	5	5	0	10
5	Yun Yin	10	5	0	15
6	V30	5	12	0	17
7	Yun Keng	10	0	0	10
8	Buryohe	10	0	0	10
9	Fac 56	5	0	0	5
10	Umujagi	10	0	0	10
11	Ndamirabahinzi	5	0	0	5
12	Fashingabo	5	6	12	23
13	Gakire	5	0	0	5
14	Mbakungahaze	5	0	0	5
15	Jyambere	5	0	10	15
16	Zhong Geng	0	4	0	4
17	Muturage	0	11	0	11
18	BR	0	13	0	13
19	Ngaruye	0	7	0	7
20	Icyerekezo	0	0	8	8
21	Basmati	0	0	10	10
22	Imbaturabukungu	0	0	5	5
23	Nerica 9	0	0	5	5
24	Twigire	0	0	5	5
25	Ndamirabana	0	0	5	5
	Total	100	88	60	248

In Rwanda, the rice is grown under a wide range of physical environments such as different elevations, soil and hydrological regimes and climate conditions vary from one region to another. Rice marshlands are distributed in different districts and agri- practices are almost common. Generally, the total land covered by rice crop was ranging between 24000 -25000 ha. We observed major challenges with severe floods in Bugesera district and some parts of western and southern provinces, shortage of labor and a swarm of birds in Nyagatare district.

The use of long-grain varieties covered 49% of total land under rice and the rate of seeds applied by farmers was 30kg/ha. The quality of seeds used by farmers has improved even if some parts (small marshlands) are still struggling to access good quality seeds. The certified seeds covered 59% of the total seed used whereas farmers saved seeds and quality declared seeds occupied 38% and 3%, respectively. The use of fertilizers is dominated by NPK triple 17 and Urea (46%) at dosage of 80N-34P-34K per crop cycle. Despite the reinforcement of fertilizer use in rice, the application of appropriate dosage and timing is still an issue due to weak cooperative management and control of fertilizer application and the proportion of rice area where mineral fertilizers are applied is about 60%. Fresh biomass from harvested rice is mostly sold as source of mulch, and only underground part is applied back to rice fields making approximately 1-2t/ha per year.

Disease management

During the season 2020A, a set of 23 monogenic lines and 12 other differential varieties with known resistance genes were used to analyze rice blast pathogen virulence frequency as well as assessing resistance of already known R genes. The experiment was conducted in the Eastern province namely in Kirehe/Sagatare and in Nyagatare/ Cyabayaga. The results revealed that 7 accessions developed incompatible reaction to the *Magnaporthe oryzae* strains in Sagatare whereas in Cyabayaga, only five (5) R genes showed resistance to blast causing strains (Table 9).

Table 9: Lines tested in Nyagatare and Kirehe and resistance genes present

Site	Sagatare-Kirehe	Cyabayaga-Nyagatare	
Line number	2020A	2020A	2020B
1	Pi-z; Pi-l; Pi-a	Pi5	Pb1
2	Pi`	Pb1	Pi1; Pi1b; Pi4-b
3	Pi5	Pik; pish	Piz-t
4	Pia+Pi19	pi-ka	Pia; Pik-p; pik
5	pi-ka	Pi5(t); Pi7	Pikh+Pi-1 +Pita+Pitp?
6	Pi7		pi-21
7	Pik-p, pia, pik		

During the same season, curiously two R-genes namely Pi5 and Pi-ka were proved resistant in both sites concurrently. In the same purpose, the trial conducted during Season 2020B, indicated that

six R-genes have shown incompatible reactions as well to rice blast causing strains of *M. oryzae.* When comparing with previous season 2020A, some R-genes have shown recurrent resistance within and across sites. Those are namely, Pb1, pia, Pik-p, pik, Pi5 and pi-ka. However, in season 2020B the trial failed to be completed in the Kirehe district due to the lockdown condition that was enforced across the country, impairing proper follow-up and management of that site.

Training

Rice farmers are struggling to increase their rice yield, however in order to have a satisfactory rice production, some favoring factors have to come together, namely, good agricultural practices, good soil fertility, good water and disease management and so on. It is in this regards that we have conducted a training on rice diseases management and on good agriculture practices in Muhanga Gasabo. The training aimed to help rice farmers increase their knowledge on the management of rice pest and diseases as well as on good rice agriculture practices. With the newly acquired skills, the trained farmers will transmit the knowledge to farmers in their group, thus would be able to cope with serious issues that are affecting their rice production.

The provided training was intended to 200 rice farmers in general but through their leaders. Among the trained lead farmers were both men and women who are known to influence other farmers around their respective fields. Management of major rice diseases with focus on RYMV, Rice blast, BLS, BLB, Sheath rot, Brown spot and Diopsis. T were emphasized and as well as seed quality maintenance. Considering the wish expressed by rice farmers in some of the visited sites, we would suggest that such trainings be extended to other rice cooperatives, in order to enable them to increase their yield through diseases management.

1.1.3 Wheat sub program

Wheat is one of the major cereals in Rwanda. However, wheat productivity is low due to low yielding varieties, low soil fertility, pests and diseases, and inappropriate production and post-harvest practices. Therefore, wheat research aims to increase on-farm yield through dissemination of best management practices, improved varieties with high protein and suitable for bread making.

Establishment of screening nurseries in Musanze & Rwerere RAB Stations

Sets of four newly-introduced nurseries from CIMMYT were evaluated for adaptability (Photo 6; Table 10). Based on agronomic performance, 930 entries and 965 entries evaluated over the two sites, 202 lines were selected from both sites.

Photo 6: Screening nursery, Rwerere, 2020 A and B

The 202 lines selected from the four nurseries evaluated in 2020A were advanced in the 2020B season for further testing in Rwerere and Musanze. Currently, additional 156 lines from 14th STEMRRSN newly-introduced from CIMMYT have also been tested for adaptability in Musanze and Rwerere Stations.

Table 10 : Selected lines evaluated in 2020A

No	Nurseries	Lines tested		Total
		Rwerere	Kinigi	
1	13th STEMRRSN	162	168	29
2	10th HPAN	226	230	86
3	52nd IBWSN[1]	270	284	52
4	37th SAWSN[2]	272	283	35
TOTAL		930	965	202

STEMRRSN: Stem Rust Resistance Screening Nursery; HPAN: HarvestPlus South Asian Nursery IBWSN: International Bread Wheat Screening Nursery; SAWSN: Semi-Arid Wheat Screening Nursery;

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Preliminary and advanced yield evaluations

Several sets of lines from 19 nurseries indicated in the table below were evaluated in both Musanze and Rwerere Stations. The purpose of the study was to (1) determine the agronomic potentials of wheat lines from CIMMYT and regional agricultural research and extension institutions and evaluate their adaptability to the environments of Rwanda, and (2) select the best lines for on-farm evaluation, baking quality tests and subsequent release to farmers. Only 270 genotypes were

selected for high yield in Rwerere and Musanze Stations, and few in Nyamagabe Station. In addition, 98 lines including 49 from 40th ESWYT and 49 from 27th SAWYT were obtained in February 2020 from CIMMYT and being tested for preliminary yield evaluation in Musanze and Rwerere Stations (Photo 7). Furthermore, a total of 16F_4 and 18F_5 were evaluated in 2020A in both Musanze and Rwerere, and 11F_4 and 15F_5 were respectively selected and advanced in 2020B for further observation. In addition, over 15 advanced populations evaluated in 2020A in Rwerere and Musanze, and 8 selected populations have been evaluated in different locations in 2020B.

Photo 7: *Population evaluation in 2020B Musanze*

Evaluation of planting dates

Effect of planting time on yield was studied in Musanze, Kinigi, Rwerere and Nyamagabe (Photo 8). Staggered planting was organized six times such that a planting session be done every other week up to 12 weeks in 2020A and B. Planting was arranged from September to November 2019 in season 2020A and from March to May 2020 in 2020B using two varieties, Gihundo and Nyaruka. This study is expected to produce recommendations for optimal planting dates for higher yield.

Photo 8: *Planting dates trial in Rwerere (Left) and Nyamagabe (Center), 2020A and Musanze (Right) in 2020B*

Evaluation of planting depth in Musanze

The purpose of this activity is to determine the right sowing depth for wheat seed and update the recommendations to farmers. Seed was sown at different depths starting from 1cm, 2cm up to 10cm deep. The experiment was established in Musanze, Rwerere and Nyamagabe Stations in two replications. Data have been collected on number of plants germinated, the dates of emergence, booting, flowering and maturity, and plant vigor. Data collected will be analyzed and results reported. The experiment has been established in Musanze in 2020A, then extended to Rwerere and Nyamagabe in 2020B (Photo 9).

Photo 9: Planting depth, Musanze, 2020A (left) and 2020B (right)

Establishment of mechanization trials in Kinigi and Rwerere

Mechanization trials (Photo 10) evaluates the performance of mechanized farming as compared to manual farming and effect on yield. Preliminary results indicated that mechanized farming is faster and more cost-effective than manual agriculture.

Photo 10: Mechanization trials in 2020A season in Kinigi (left) and Rwerere (right)

On-fam adaptation trials and participatory variety selection

The trials aimed to evaluate on farm performance of wheat varieties and farmers preferences. A total of 12 genotypes, namely, N^{r} 105, 103, 124, 104, 121, 109, 101, 110, 111, 116, 118 and 113, were evaluated under researcher-managed on farm fields in Rwerere, Musanze and Nyamagabe. Farmers from the surrounding areas and other stakeholders were allowed to view these varieties at different vegetative stages and select those they liked best. Based on yield and farmers preferences (such as good head, uniformity, plant vigour, tillering capacity, early maturity, resistance to pests and diseases, tolerance to abiotic stresses, etc), 7 lines (N^{r} 113, 121, 109, 118, 104, 111 and 116) were selected and will be prepared for release.

Photo 11: On-farm trials, Nyange, Musanze (left, 2020A) and Cyumba, Gicumbi (right, 2020B)

Establishment of demonstration plots in wheat growing areas

The demonstration plots showed to various stakeholders the importance of best management practices and variety performance. A total of 10 varieties were established in farmers' fields demo plots, namely, Nyaruka, Nyaruka, Gihundo, Kibatsi, Keza, Majyambere, Rengerabana, Reberaho, Majyambere and Cyumba in 2020A (20 sites) and 2020B (28 sites) in Burera, Gicumbi, Musanze, Rulindo, Gakenke, Nyabihu, Ngororero, Nyamagabe, Nyamasheke, Muhanga and Nyagatare districts.

Field days

Field days were organized in the demo plots in Nyamagabe and GIcumbi, when wheat was at late physiological maturity with aim to share knowledge and views on wheat and show the varieties (Photo 12). In Nyamagabe, 12 farmers, Sector Executive, Sector Agronomist, SEDOs, and 3 seed multipliers participated. Kibatsi and Gihundo were preferred varieties for their performance. In

Gicumbi participatory variety selection of 5 best lines was done out of 12 tested and 15 farmers participated.

Photo 12: Wheat stakeholders in field, Buruhukiro, Nyamagabe (left, 2020A) & Cyumba, Gicumbi (right, 2020B)

During the field days, trainings, community work (Umuganda) and other events that have been attracting different wheat stakeholders, more than 400 extension materials mainly composed of leaflets on appropriate crop and postharvest management practices were distributed to the participants.

Facilitation of seasonal action plan for wheat innovation platform (IP)

A planning meeting was organized in Gataraga, Musanze, to develop plan for 2020A activities within Gataraga wheat innovation platform (IP) and discuss the 2019B achievements. The IP has been built on a Cooperative known as COOAPAI (*Coopérative pour l'Augmentation de la Production Agricole et des Intrants*) composed of 54 members, including 25 females and 29 males. A group of 13 members and 2 non-members of COOAPAI, but all members of Gataraga IP had received a total of 192 kg of Gihundo variety for use in demo plots, meaning that all the 192 kg were dispatched among 15 farmers that have served as the models from which other IP members may come and learn about how to use appropriate agricultural practices (seedbed preparation, sowing, weeding, rouging, rate and type of fertilizer to apply, right time of fertilizer application, pesticide spraying, right time for harvesting and postharvest handling practices. The total production obtained from the 192 kg planted was 5,120 kg harvested from 1.92ha. The average grain yield was 2.6t/ha. The minimum grain yield was 1.38t/ha and the maximum was 3.37t/ha. Five farmers harvested at least 3.0t/ha, 6 farmers obtained a grain yield that is above the average and below 3.0t/ha, and 4 farmers obtained less than the average grain yield (less than 2.6t/ha). This implies that there is potential to get higher than 3.0t/ha grain yield once the agronomic and postharvest practices are the recommended ones used at the right time. The wheat IP members suggested that the exercise should continue in the coming seasons, while involving in the process various commercial wheat varieties.

Some of the demostration plots, agronomic and on-farm trials were established in 2020A and B within the wheat innovation platforms earlier formed in Gataraga (Musanze), Butaro (Burera) and Cyumba (Gicumbi).

Table 11: Summary of demo plots and trials in three innovation platforms (IPs)

Innovation platforms	Types and number of activities implented		
	Demo plots	On-farm trials	Agronomic trials
Gataraga	5	4	14
Cyumba	2	4	0
Butaro	4	2	0
TOTAL	**11**	**10**	**14**

The IP members were involved in selecting a farmer with land for establishing the demonstration plot, on-farm and/or agronomic trials. Farmers promised to provide and open up the land, plant/sow seed and use appropriate crop management practices such as sowing in rows, fertilizer application, weeding, thinning where applicable, harvesting and grain handling practices. On RAB side, the commitment was to provide seed, inorganic fertilizer and assist in providing advisory services from planting time to grain handling.

Training of key wheat stakeholders on best practices and wheat value chain

On 11-13 February 2020, RAB in collaboration with experts from CIMMYT held a training workshop in Musanze on quality wheat seed production, management and marketing. Training's aimed to develop viable wheat seed and phytosanitary systems, look at existing and/or required policies and regulations that govern and regulate these sectors, enhance manpower development to undertake the regulatory activities (seed and phytosanitary inspections), clarify the role of public-private partnership in wheat seed value chain. Training topics included variety testing, release and maintenance; wheat seed production and management; seed health; seed systems, policy and regulation in Rwanda; opportunities and challenges to wheat seed development in Rwanda, and seed business and marketing, they were presented by key speakers and discussed among the participants. After presentation and discussions of the topics, a field trip involving all the participants was organized to share knowledge information and experience based on what the participants were observing on the ground. The training involved 34 participants including wheat research and extension staff, seed production techicians, seed quality control officers, representatives of cooperatives and farmer'associations involved in quality seed production, and model farmers. Research and extension staff, seed production techicians, seed quality control officers were from CIMMYT and RAB Stations of Musanze, Rwerere, Tamira, Gakuta, Ngoma, Rubona, Gishwati, Nyamagabe and Muhanga. Other participants were from the Districts of Musanze, Burera, Gicumbi and Nyamagabe (Photo 13).

Photo 13: Participants in the training workshop, Musanze, February 2020

Seed production

Breeder and pre-basic seed of 10 commercial varieties were produced in 2020A (Table 12).

Table 12: Breeder and pre-basic seed produced for wheat in 2020A (kg)

Varieties	Breeder seed produced (Kg)			Prebasic seed	
	Kinigi	Musanze	Rwerere	Kinigi	Rwerere
Nyangufi	36	5.5	13	44	-
Gihundo	17	6	15	83	265
Nyaruka	12	5	5	48	11
Cyumba	12	5	0	33	175
Reberaho	10	4.5	0	18	19
Mizero	9	4	10	10	-
Rengerabana	17	4	9	22	
Keza	15	5	10	40	
Kibatsi	21	5.5	9	46	
Majyambere	11	5.5	9	30	
Total	**160**	**50**	**80**	**374**	**1,120**
Grand total		**290**			**1,494**

Land consolidation

The area planted to wheat in season 2020A on land consolidated in wheat growing Districts was of 6,201ha and the total wheat production was 20,668MT with mean yield of 3.3 t/ha grain. In season 2020B, a total of 35,545ha representing 88.2% of the targeted consolidated land (40,310ha) have been planted to wheat crop as indicated in Table 13.

Table 13: Land Use Consolidated area under wheat, 2020A

District	Season 2020A			Season 2020B	
	Area (ha)	Production (tons)	Yield (t/ha)	Target	Area planted (ha)
Burera	3,225	10,642.50	3.3	7,000	5,550
Gicumbi	1,685	5,392.00	3.2	3,950	3,670
Rulindo	104	356.59	3.4	1,018	1,005
Musanze	770	2,310.00	3	1,000	995
Gakenke	107	331.70	3.1	941	792
Ngororero	310	961.00	3.1	2,568	2,568
Nybihu				4,533	4,162
Rutsiro				1,500	1,299
Nyamagabe				10,800	9,639
Nyaruguru				7,000	5,866
TOTAL	6,201	19,994	3.2	40,310	35,545

In addition, more than 2,750 wheat stakeholders (especially farmer promotors, farmer facilitators, SEDO and sectors Agronomists) from Burera, Gicumbi, Nyamagabe and Nyaruguru were trained on appropriate wheat production and post harvest management practices; 154 demo plots and 48 FFS plots have been established in Burera and Gicumbi Districts.

Research on barley

Barley is a cereal crop used for beer making and which is having stable demand from BRALIRWA. The local beer making factory which mainly imports barley malt.

Barley variety evaluation on station: A total of 18 barley varieties were evaluated in 2020A in Kinigi, Rwerere and Musanze Stations with support from BRALIRWA and EUCORD (European Cooperative for Rural Development). Preliminary evaluation resulted in selecting Danielle, Traveller, Esma, Fortuna, Semper 9, Semper 10 and Grace, along with EN6, EN18, EN23 and EN155, as the most promising genotypes.

Barley variety demonstration on farm: Two varieties, Danielle and Traveller, were tested on farm for adaptability and farmers' preferences. A total of 49 farmers are participating. After sensitization of the participants on the economic importance of barley through increasing barley productivity and household's incomes, and improving farmer's livelihood, sector agronomists from different places decided to take barley to their homes and involve more farmers in growing barley as the market is assured.

Two field days were organized during the grain filling to physiological maturity stages to involve more farmers in the variety evaluation and selection. The first field day was organized on

21/08/2019 in a farmer's field of Gataraga Sector, Musanze District. It involved about 30 stakeholders, including those from RAB, EUCORD/BRALIRWA Plc, Sector Agronomist, and surrounding farmers. The second field day took place at Gataraga on 06/03/2020. At this time, the event was attended by more than 40 stakeholders, including participating barley farmers, Sector agronomists from Musanze, Burera, Nyabihu and Ngororero, those from BRALIRWA and RAB.

Phot 14: Field day in Gatagara, Musanze, on 21/08/2019 (left) and 06/03/2020 (right)

1.2 PULSES AND OIL CROPS PROGRAM

Pulses are priority for nutrition, food and income security in Rwanda. The most active Pulses' sub-programs are beans (*Phaseolus vulgaris)* and Soybean (*Glycine max*). The core mission of the program is to develop & disseminate appropriate productivity enhancing user acceptable & market demanded innovations for farmers and other stakeholders. They include release and promotion of high yielding, nutritious, multiple pests and climate resilient and marketable varieties with complementary yield enhancing agronomic and post-harvest management practices. The program also builds capacity and forges functional partnerships of farmers, seed producers, grain aggregators, traders, processors and exporters among other value chain actors. More than 1,000 representatives of the program's key partners were e-linked via WhatsApp groups such as the *Pulses and Oil Crops*, *Bahinzi-Borozi* and the *Rwanda Bean Alliance*. The research and technology transfer activities cut across major low, mid and high altitude agro-ecologies in Rwanda.

1.2.1 Beans

Variety development

Twelve bush or climbing bean varieties, including 7 new iron and or zinc biofortfied bean varieties (high iron beans-HIBs) were developed and ready for the release pending decision by the National Variety Release Committee at MINAGRI (Photo 15).

In addition, 16 bean trials have been established countrywide in on station and on farm trials. Under these, a total of 1367 lines have been evaluated among which 10 entries were in adaptability trials across the country.

Photo 15: New bean varieties display in Rutsiro (Nyabirasi sector) during World Food Day cerebrations

Yield enhancing innovations demos and farmer training

Eight yield enhancing technologies including the new bean varieties, planting in lines, weeding, fertilizers application, earthling up, staking, pest and disease and soil fertility management, including application of rhizobia and rotations have been promoted on a total of 467 farmer managed demonstration fields during the year (Photo 16). Field days were organized in demo plots, and a total of 716 farmers were trained across the country (Photo 17).

Photo 16: Proper staking of climbing beans (left); live staking demo at Nyirangarama (right)

Photo 17: Presentations, group work and field visits in Farmer Field Schools, Eastern Province

Seed production and distribution

A total of 16,667 tonnes of breeder and pre-basic bean seed were produced at RAB stations (Photo 18; Table 14; Figure 4). Another 36 tonnes of basic seed was produced by the RAB seed unit and partner RAB seed producer companies and private multipliers in the case of beans.

Photo 18: High Iron bean varieties (RWR 2245 & MAC 44) seed production in farmers' fields

Table 14: Breeder/ Pre-basic seed production on research stations in 2019

Variety	*Quantity (Kg)*	Note on variety status	*High Iron bush bean variety*	*Quantity (Kg)*	Note on variety status
CAB2	733	existing	MBC 23	162	new
Gitanga	70	existing	MBC 71	214	new
Kigondo	470	existing	N.Magorori	467	new
MAC 44	2094	existing	Rwibarura	440	new
RWV 2872	453	existing	RWV 2350-2B	508	new
RWV 3006	212	existing	RWR2154	2544	existing
RWV 3316	1717	existing	RWR2245	3832	existing
RWV 3317	1167	existing	RWR 3194	728	existing
RWV 1129	857	existing			
					Total : 16,667 kg

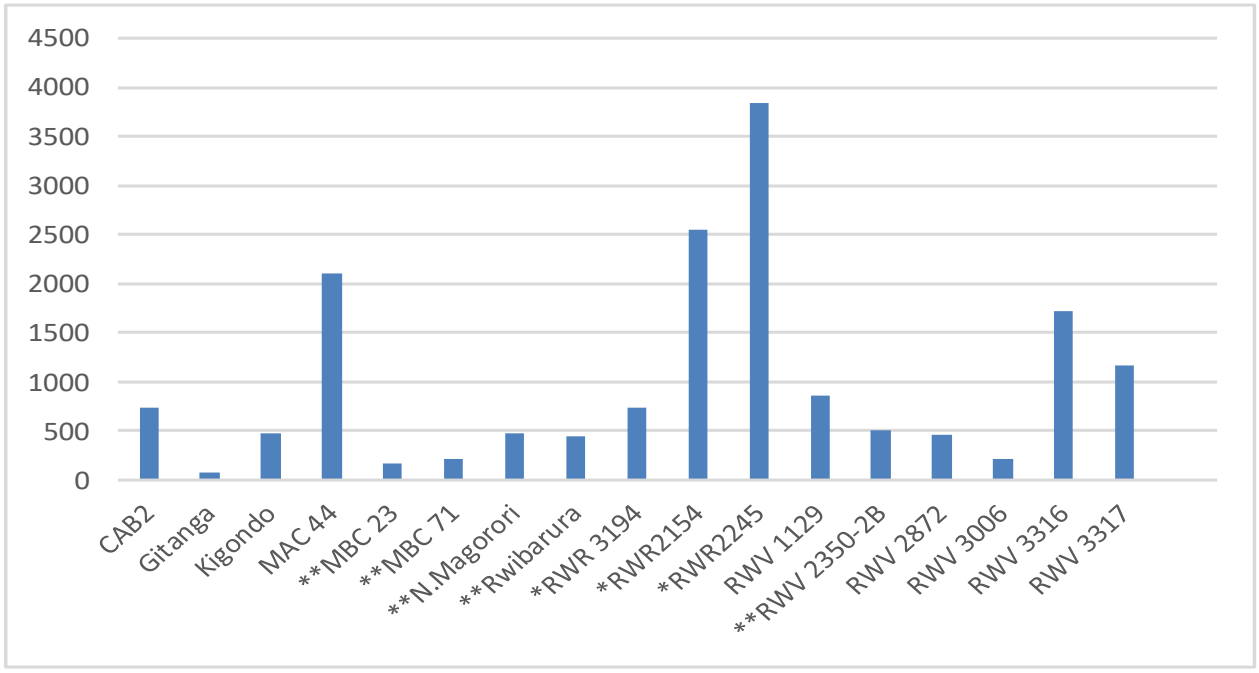

Figure 4: Comparative breeder/pre-basic seed production on research stations by variety

Seed distribution and demos in model villages

Other major developments in the year included direct distribution of high iron beans to government supported model villages / consolidated land that were enough to plant more than 3000 ha in Nyagatare (Kabologota, Karangazi), Gatsibo (Rwangingo), Musanze (Cyumve), Rutsiro (Nyabirasi) that with potential impact to mitigate mal-nutrition among the beneficiary vulnerable families (Photo 19).

Photo 19: Snapshots at the Word Food Day at Nyagatare/ Kabologota: Children fed with High Iron Beans (left); bean seed expo at same site (right)

While overall mean productivity for beans were around 0.8 -1.0MT/HA; this has increased to about 2.3 MT/Ha and 1.2 MT/ha for climbing beans and bush beans respectively in case of model demos, CIPs and model village sites in the country.

Role of private sector in structured trade and bean business models

Although common bean is a leading food and nutrition security commodity, its income potential is still under exploited. Besides the on-going deployment of adapted high yielding bean varieties that have greater internal and export market demands and the aggressive promotion yield-enhancing agronomic practices, stream-lining the current predominantly unstructured informal cross-border trade was essential. To address this, inclusive but decentralized value chain and bean based business platforms were created. This was being championed by existing and new small, medium and large off-taker enterprises and organizations to harmonize prevailing markets-led beam production and supply dynamics. More than 1,000 representatives of the program's key partners are electronically interconnected through WhatsApp groups such as the *Pulses and Oil Crops*, *Bahinzi-Borozi* and the *Rwanda Bean Alliance*.

They include researchers, seed producers, grain producers, collectors, aggregators, transporters, stockists, retailers, wholesalers, exporters, processors among other operators where-by each operator has a well-defined role in the chain. Defined markets for specific bean varieties, volumes and quality of production, the production and collection centres were defined. Eastern and North-Western bean based innovation platforms were identified as major production and distribution hubs for the identified market preferred bush and climbing beans (Photo 20; Table 15).

Photo 20: Specific variety demands & most popular varieties by region and production hubs

Table 15: Number of operators in 3 districts of Northern Rwanda

District	*Sectors*	*Big farms*	*Seed multipliers*	*Agro-dealers*	*Cooperatives*	*Collectors*	*Bean traders*
Musanze	14	269	14	65	24	95	109
Rulindo	12	06	03	06	13	05	17
Gakenke	05	32	01	05	03	07	12

Photo 21: Innovation platform meetings group work and mini-show of HIB varieties, Kayonza (right) and Musanze (right)

Table 16: Number of trained personnel in three platforms in Northern Rwanda

District or Innovation Platform	Facilitators trained	Males	Females
Gicumbi	25	20	5
Burera	32	19	13
Gakenke	31	17	14
Total	88	56	32

1.2.2 Soybean Program

A total of 10 new new high yielding and early maturing varieties were released for farmer production and industrial processing (Table 17).

Table 17: Soybean varieties yield and maturity from multi-locational and validation trials

Line	Yield (T/Ha)	Maturity Days	Altitude
S1109-1-6	3.5	96	Mid
S1207-1-6	3.3	104	Mid
S2508-5-1	3.5	92	Mid
S0809-3-1	3.8	97	Mid
S0302-4-2	3.4	96	Mid
S2508-6-6	3.1	97	Mid
S0302-5-1	3.0	94	Mid
S0719-10-3	3.2	100	Mid
S1007-6-2	2.9	91	Mid
S0802-1-4	3.2	96	Mid

1.3 ROOTS AND TUBERS PROGRAM

The Roots and Tubers research includes Irish potato, sweet potato and cassava. Research is focused on (i) Variety development; (ii) Development of new approaches of pests and diseases management; (iii) Development of good agronomic practices; (iv) Seed production and (v) Technology transfer.

1.3.1 Cassava Sub-Program

Cassava (*Manihot esculenta* Crantz) is important and priority food crop in Rwanda occupying 20% of the total cultivated land. Its production is severely threatened by cassava brown streak disease (CBSD) and cassava mosaic disease (CMD). Both diseases are propagated with infected planting material as well as being transmitted by the whiteflies, *Bemisia tabaci*, by graft or mechanical inoculation. Other challenges include low yields and poor seed systems. Cassava research aims to develop CBSD and CMD resistant varieties and promote seed system to produce and disseminate high quality cassava cuttings to farmers.

Crossing block and a Polycross nurseries

A crossing block/open field mating design of 21 Parental cassava lines was established at Rubona to generate true seeds and increase genetic diversity of cassava population. The selection of parent lines done by selecting best performing varieties/clones. Two methods for generating true seeds (controlled and open pollinations). During 2019-2020 FY, hand pollination and cross pollination were performed. More than 20,520 true seed were generated, in which 7448 true seed generated were sown at Mututu experimental site, Muhanga extension and research station in 2020A season. The seedling trial is composed by 78 families (full and half sibs), which is expected to generate clones in 2021A season.

New breeding lines selected from true seeds (new crosses)

Clonal selection from 17 families nursery trial conducted and 220 clones selected for further clonal evaluation trial at Gashora site (Bugesera) in Rubilizi station and at Mahama site (Kirehe) in Ngoma station. At 3 months after planting (MAP), the majority of clones performed well with excellent sprouting rate, vigor and very low incidence and severity of CMD and CBSD at Gashora site, while the sprouting rate and vigor were very low for some clones at Mahama site due to a short period of drought occurred a few days after trial establishment.

Clonal selection for Preliminary yield trial (PYT)

During FY 2019-2020 in season 2020A, 531 clones from seedling trial were selected and planted at two sites (Rubona and Mututu).

Table 18: Descriptive statistics of CMD and CBSD of 531 of selected F1 clones

Traits	Mean	SE	SD	Kurtosis	Skewness	Minimum	Maximum
Vigour	2.95	0.02	0.79	-0.19	0.42	1	5
CMDs	2.07	0.04	1.16	-1.45	0.40	1	4
CMDi	2.27	0.09	2.93	-0.32	1.02	0	10
CBSDs	1.21	0.02	0.65	18.04	3.63	0	8
CBSDi	0.33	0.03	1.13	22.44	4.41	0	10

CMDs: Cassava mosaic diseases severity, CMDi: Cassava mosaic diseases incidence, CBSDs: Cassava brown streak diseases severity, CBSDi: Cassava brown streak diseases incidence

The results indicates a high skewness of CBSD which explains genetic diversity among the generated F1 clones for that trait, and a moderate skewness also indicating genetic diversity among the generated F1 clones (Table 18). Out of 531 clones, 37 were advanced to preliminary yield trial (Rubona, Mututu) to screen CMD incidence and severity, and average root yield. Except MTT1901 clone, which had few CMD symptoms, all other selected clones had neither CMD nor CBSD visual symptoms (Table 19). The selected clones vary in terms of root pulp colour where they range from white to deep orange an indication of possible beta carotene bio-fortification.

Table 19: Selected for advancement to preliminary yield trial

Clones	Clonal ID	CMDi	CMDs	CBSDi	CBSDs	Yield (t/ha)	Pulp colors
Yizaso/1	MTT19-01	1	2	0	1	45.7	White
Albert/28	MTT19-02	0	1	0	1	50.0	White
UBJ120003/2	MTT19-03	0	1	0	1	50.0	Orange yellow
IBA9800505/2	MTT19-04	0	1	0	1	42.0	White
TMEB693/3	MTT19-05	0	1	0	1	40.0	White
Sagonja/2	MTT19-06	0	1	0	1	40.0	White
shibe/3	MTT19-07	0	1	0	1	35.7	White
IBA000338/5	MTT19-08	0	1	0	1	35.7	Orange
UBJ120003/5	MTT19-09	0	1	0	1	33.3	Orange yellow
Albert/26	MTT19-010	0	1	0	1	30.0	White
Mkombozi/5	MTT19-011	0	1	0	1	30.0	White
Kipusa/9	MTT19-012	0	1	0	1	30.0	White
Sagonja/1	MTT19-013	0	1	0	1	30.0	White
Kiroba NGR/8	MTT19-014	0	1	0	1	28.6	White
Shibe/4	MTT19-015	0	1	0	1	48.3	White
Kiroba TZ/4	MTT19-016	0	1	0	1	46.3	White
CH 05/203/1	MTT19-017	0	1	0	1	45.0	White
Kaleso/16	MTT19-018	0	1	0	1	35.7	Deep yellow
Mkuranga/7	MTT19-019	0	1	1	2	35.0	White
TMEB693/1	MTT19-020	0	1	0	1	34.0	White
Mkombozi/2	MTT19-021	0	1	0	1	31.7	White
Mkombozi/6	MTT19-022	0	1	0	1	30.0	White
Yizaso/11	MTT19-023	0	1	0	1	30.0	White
Eyope/2	MTT19-024	0	1	0	1	30.0	White
Mkombozi/3	MTT19-025	0	1	0	1	56.0	White
Kiroba NGR/3	MTT19-026	0	1	3	3	50.0	Yellow
IBA141099A/15	MTT19-027	0	1	0	1	70.0	Orange

IITA-TMS-IB070337/1	MTT19-028	0	1	0	1	50.0	Yellow
IBA141086/13	MTT19-029	0	1	0	1	42.9	Orange
IBA160072/3	MTT19-030	0	1	0	1	42.9	Deep orange yellow
IBA160073/9	MTT19-031	0	1	0	1	38.3	Deep orange yellow
IBA160072/6	MTT19-032	0	1	0	1	35.7	Deep orange yellow
IBA0705993/11	MTT19-033	0	1	0	1	34.3	Orange
IBA141099A/1	MTT19-034	0	1	0	1	31.3	Yellow
IBA141097/5	MTT19-035	0	1	0	1	30.0	Deep orange yellow
IBA160077/2	MTT19-036	0	1	0	1	30.0	Deep yellow
Kalawe/1	MTT19-037	0	1	0	1	30.0	White

Clonal selection for advanced yield trial (AYT)

The advanced yield trials (AYT) of the 13 clones name "RBN018-020, RBN018-051, RBN018-033, RBN018-028, RBN018-011, RBN018-032, RBN018-060, RBN018-056, RBN018-061, RBN018-036, RBN018-012, RBN018-025, and RBN018-054, were established at two locations (Rubona and Mu-tutu) during 2020A.

Table 20: Selected clones for advanced yield trial (AYT)

Sites	Clones ID	3CMDi	3CMDs	CMDi%	3CBSDi	3CBSDs	CBSDi%
Rubona	RBN018-020	0	1	0	0	1	0
	RBN018-051	0	1	0	0	1	0
	RBN018-033	0	1	0	2	4	4
	RBN018-028	0	1	0	0	1	0
	RBN018-011	1	2	2	0	1	0
	RBN018-032	4	3	9	0	1	0
	RBN018-060	0	1	0	0	1	0
	RBN018-056	0	1	0	0	1	0
	RBN018-061	0	1	0	0	1	0
	RBN018-036	0	1	0	0	1	0
	RBN018-012	0	1	0	0	1	0
	RBN018-025	0	1	0	0	1	0
	RBN018-054	0	1	0	0	1	0
Mututu	RBN018-060	0	1	0	0	1	0
	RBN018-032	1	3	3	2	2	5
	RBN018-020	0	1	0	0	1	0
	RBN018-025	0	1	0	0	1	0
	RBN018-056	0	1	0	0	1	0
	RBN018-011	0	1	0	0	1	0
	RBN018-012	0	1	0	0	1	0
	RBN018-051	0	1	0	0	1	0
	RBN018-033	0	1	0	0	1	0
	RBN018-054	0	1	0	0	1	0
	RBN018-061	0	1	0	0	1	0
	RBN018-028	2	3	6	0	1	0
	RBN018-036	0	1	0	0	1	0

Those 13 clones were selected from 63 clones originated from 444 seedlings plants from trues seeds. The preliminary observation at 3 months after planting (MAP) indicated that at Rubona site, only one clone (RBN018-032) showed a mild CMD symptoms with 8.7% of CMD incidence, and another one clone (RBN018-033) showed a mild CBSD symptoms with 4.4% of CBSD incidence. Also, at Mututu site, two clones: (RBN018-032 and RBN018-028) showed a mild CMD symptoms with 2.6% and 5.6% of incidence, respectively. For CBSD, only one clone, RBN018/032 had 5.1% of CBSD incidence 3 MAP (Table 20).

Multi-locational trial in selected target agro-ecologies

The genetic environment interaction (GxE) trial of 14 clones was planted in November 2019 (2020 Season A) at three sites (Rubona, Mututu and Gashora), representing three agro-ecological zones. The sites were identified based on representative of cassava growing zones, the altitude and diseases pressure also taken into consideration. The preliminary results indicated that at Rubona Station, only three varieties didn't show any CMD and CBSD symptoms three months after planting, those varieties are: Pwani, Tajirika and Mkumba (Table 20). At Gashora site, Kibandameno variety was very susceptible to CMD with 57.4% of CMD incidence at 3 MAP, while others varieties showed low CMD incidence. No CBSD symptom was recorded at Gashora site 3 MAP. The same situation was observed at Mututu site, Kibandameno showed very severe CMD symptom with 66% of incidence, no CBSD was recorded 3 MAP at Mututu (Table 21).

Table 21: Multi-location trial at 3 agro-ecological zones with data of 3MAP

Clones	Rubona				Gashora				Mututu			
	3CMDi (%)	3CMDs	3CBSDi (%)	3CBSDs	3CMDi (%)	3CMDs	3CBSDi (%)	3CBSDs	3CMDi (%)	3CMDs	3CBSDi (%)	3CBSDs
ALBERT	11.8	3	0	1	4.8	2	0	1	11.4	3	0	1
EYOPE	12.5	3	0	1	11.4	2	0	1	4.3	3	0	1
KBH2002/066	2.8	3	0	1	0.0	1	0	1	0.0	1	0	1
KBH2006/026	1.4	3	0	1	0.0	1	0	1	6.3	3	0	1
KIBANDAMENO	23.6	4	0	1	57.4	4	0	1	66.0	4	0	1
KIROBA	14.5	3	0	1	1.4	2	0	1	0.0	1	0	1
KIZIMBANI	1.4	3	4	2	0.0	1	0	1	0.0	1	0	1
MKUMBA	0.0	1	0	1	0.0	1	0	1	0.0	1	0	1
NAROCASS1	2.9	3	1	3	0.0	1	0	1	0.0	1	0	1
NASE1	27.8	2	33	2	1.5	2	0	1	2.2	3	0	1
NASE14	1.4	2	0	1	0.0	1	0	1	0.0	1	0	1
ORERA	6.3	3	6	2	2.9	2	0	1	0.0	1	0	1
PWANI	0.0	1	0	1	0.0	1	0	1	0.0	1	0	1
TAJIRIKA	0.0	1	0	1	0.0	1	0	1	0.0	1	0	1
TZ130	1.4	3	0	1	0.0	1	0	1	0.0	1	0	1

Degeneration rates trial

During season 2020A, a second generation of degeneration trial of eight new cassava varieties (Albert, KBH2006/026, Kibandameno, Mkumba, Nase14, Orera, Tajilika, and TZ130) was planted

at Rubona site. The purpose of this trial is to dissect degeneration of available cassava variety in the country, and advise famers on the frequent and necessity of sourcing clean planting materials. The trial was re-established at the same site as previous degeneration trial. Out of 8 improved varieties two of them indicated susceptibility to CMD and CBSD just 3 MAP. The variety Kibandameno and Albert showed 85% and 64% CMD incidence, respectively. The variety TZ130 showed also CMD symptoms with 23%. However, no CBSD symptom was recorded for all varieties at 3 MAP (Table 22).

Table 22: Second generation CMD and CBSD severity and incidence for degeneration trial

Clones	3CMDi	3CMDs	CMDi%	3CBSDi	3CBSDs
Albert	12	3	64	0	1
KBH2006/026	0	1	0	0	1
Kibandameno	14	4	85	0	1
Mkumba	0	1	0	0	1
Nase14	0	1	0	0	1
Orera	0	1	0	0	1
Tajilika	0	1	0	0	1
TZ130	5	3	23	0	1

Participatory variety selection (PVS) of pre-released varieties

During 2020A, 6 Participatory variety selection trials with 4 clones (Bulk 13 and 35, SEMAL150452 and MH95/0091) were established in Nyanza, Ruhango, Kamonyi and Gakenke.

Table 23: Participatory variety selection trials

District	Sector	Cells	Villages	Farmer name	Phones	Varieties
Nyanza	Muyira	Migina	Bugina	Bayingana Jean Claude	784019634	BULK35, BULK13, MH95/0091, SE.MAK150452
Nyanza	Kigoma	Murinja	Buharankakara	Bapfakurera Vedaste	788846947	BULK35, BULK13, MH95/0091, SEMAK150452
Kamonyi	Nyamiyaga	ngoma	Kabahazi	Gahigi Athanase	788868436	BULK35, BULK13, MH95/0091, SEMAK150452
Ruhango	Ruhango	Musamo	Jokoma	Ndahayo Abdala	784659079	BULK35, BULK13, MH95/0091, SEMAK150452
Ruhango	Ruhango	Musamo	Musamo	Matabaro David	788986350	BULK35, BULK13, MH95/0091, SEMAK150452
Gakenke	Muhondo	Huro	Huro	Twizeyimana Flugence	786584367	semak150452, bulk13, bulk35, mh85/0091, locale

Demo plots of cassava clones ready for release

During season 2020A, 18 demo plots composed by cassava clones selected for release were established in Ruhango, Kamonyi, Nyanza, Gisagara, Gakenke, Nyamagabe, Kirehe, Kayonza, Gasabo

and Bugesera. These clones were Bulk13 and 35, Gahene/2, Rutuku, Narocass1, SEMAK150139 and 150452, Ndamirabana/7 and Terurarire.

Pre-basic seed multiplication

Semi-Autotrophic Hydroponic (SAH) is a new technology for cassava seed multiplication, allows to speed up multiplication and shortens time spent for variety development. Within 2 months, a total of 4817 plantlets were produced with SAH (Table 24). The produced plantlets are pre-basic seed.

Table 24: Pre-basic seed multiplication under SAH at Rubona station

No	Variety	Initial plantlets	Plantlets produced	No	Variety	Initial plant-lets	Plantlets produced
1	TZ 130	208	796	9	MM96/4271	154	525
2	TME14-08M	85	250	10	Mkumba	45	75
3	Pwani	66	75	11	Kibandameno	24	75
4	Okhumelela	12	150	12	98/0505	12	100
5	NASE3	185	550	13	98/0002	28	125
6	NASE14	326	1308	14	97/2205	30	148
7	NASE1	70	340	15`	01/1098	60	200
8	Nam 130	30	100		Total	1335	4817

During FY 2019-2020, a total of 20,392 plantlets were multiplied using macro propagation through node stem cuttings under screen houses (Table 25).

Table 25: Pre-basic seed multiplication under Screen-house at Rubona station

No	Variety	Number of plantlets	No	Variety	Number of plantlets
1	NASE3	317	10	KBH2002/066	2115
2	Mkumba	930	11	F10-30-R2	140
3	Eyope	1670	12	Arbert	736
4	Orera	490	13	Kibandameno	209
5	Kizimbani	1105	14	NASE14	1782
6	Okhumulela	747	15	Pwani	3864
7	Tajilika	617	16	Kiroba	2127
8	Tz-130	794	17	NAM130	1060
9	KBH2006/026	799	18	NASE1	890
Total :	20,392 plantlets				

Basic seed production

A total of 12 clones were multiplied on a small area as basic seed in Gashora and Gakirage sites in Rubilizi and Nyagatare stations, respectively (Table 26). Two clones BULK 13 and Gahene/2 were selected from GxE trial 2018-2019 as elite clones at Gakirage site. Albert, Kiroba, Tagilika, Kizimbani, KBH2002/066, NASE 1, Mukumba, Eyope and TZ130 were the extra cuttings after establishment of GxE trial 2019-2020 while MH2005/0091/09/12 was maintained since 2018-2019. Unfortunately, 0.15 ha of MH2005/0091/09/12 was devastated by flooding in April 2020.

Table 26: Clones in basic seed multiplication at Cashora and Gakirage sites

No	Location	Clone	Area (ares)	No	Location	Clone	Area (ares)
1	Nyagatare	Bulk 13	18	7	Gashora	KBH2002/066	3.15
2	Nyagatare	Gahene/2	13.5	8	Gashora	NASE 1	1.17
3	Gashora	Albert	2.8	9	Gashora	Mukumba	1.05
4	Gashora	Kiroba	2.1	10	Gashora	Eyope	1.05
5	Gashora	Tagirika	2.4	11	Gashora	TZ 130	2.28
6	Gashora	Kizimbani	3.15	12	Gashora	MH2005/0091/09/12	36

Training on cassava disease identification and seed certification

Training aimed to help seed inspectors in variety and disease identification and seed certification for pre-basic, basic and certified seed. 16 seed production and cassava research technicians from RAB were trained by experts. A total of 12 seed inspectors and 16 seed production and cassava research technicians were trained. The training focused on sampling protocol, inspection and certification guidelines, variety identification, seed systems and proficiency testing.

1.3.2 Potato subprogram

Potato (*Solanum tuberosum*) is one of the important staples and CIP priority crop since 2007. Potato productivity is challenged by lack of improved varieties, seed-borne pests and diseases, poor handling and storage facilities, insufficient clean potato seeds, poor seed distribution system, inadequate production technologies and maintaining seed through successive multiplications. Most of current commercial potato varieties were developed more than 30 years ago. Thus, potato research aims to develop new varieties, increase clean seeds, and provide advice on potato production management innovation.

Improvement of potato for high yielding, resistance to diseases and processing traits

The aim of potato breeding is to develop high yielding, high dry matter, early-maturing, short-dormant, and tolerant to Bacterial wilt varieties. A crossing block with selected parents has been

established at RAB Musanze using parents described in Table 27 to make crosses randomly between each other, to generate progeny families. Popular varieties Kinigi, Gikungu, Kigega, Peco, Rwangume, Cruza and Sarpomela were involved in the crossing block. The genotypes Twihaze (CIP 393377.58) and CIP395112.6 were involved in the crossing block due to their resistance to late blight, early tubers bulking (early maturity) and their yield potential.

Table 27: Selected potato varieties to generate new potato genotypes

Variety name/Parent	Reaction to BW	Reaction to Lb	Traits	Origin
1.Kinigi	Tolerant	Tolerant	High productivity < 20t/ha, red skin, deep eyes, high dry matter content, 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 content	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. Twihaze	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

At flowering, flowers selected for use as females were hand-emasculated before the petals are fully opened. This technique ensures that no self-pollination can occur. Pollen was collected from mature flowers of the selected male parent by shaking the anthers in an Eppendorf tube and used to pollinate the emasculated flowers. Crossings were done in the morning (7:00-9:00). A label showing the date of pollination, female and male parent was placed on the pollinated flowers. It is known that one berry can contain up to 200 seeds (Denny Griffin et al.2007), each of which is a genetically different individual representing a potential new variety.

At maturity, approximately 60 days after successful pollination, fruit berries of the identical crosses were identified, harvested and bulked together in labeled plastic envelops and kept in a room for

approximately two weeks to ripen. After softening, seeds were manually extracted by pressing the berries in a cloth bag. Extracted seeds were washed thoroughly with water and powder detergent, dried and packed in paper envelops for storage until planting time.

True potato seeds (TPS) of the generated families were sown in the screen house. After germination, the seedlings were treated with a contact fungicide (Agrozeb 80WP) to protect them from late blight attack at a tender age in the nursery. Seedlings were later transplanted at 5-leaf stage in the screen house. In the screen house, the seedlings were transplanted and spaced at 70 cm between rows and 40cm between seedlings. After transplanting, seedlings were manually irrigated to reduce transplanting shock and to ensure good field establishment. A label indicating each tuber family was fixed in the field. After seedling establishment, compound NPK 17:17:17 fertilizer was applied at the rate of 300 kg per hectare. The established seedling plants were sprayed with an insecticide (Rocket) at 3 ml l-1 of water to control aphids and leaf miner flies. The potato plants were progressively hilled up as to allow tuber bulking.

Potato seedlings from True Potato Seeds (TPS) have been planted is screenhouse to generate potato minitubers which in the next season were planted in the open field to generate tubers of new progenies. The F1 potato progenies have been generated season by season and the three generated populations are currently available. The population one of potato progenies was developed during the season 2018B and consist of 98 clones, clustered in 8 families. The population two of potato progenies was generated during the season 2019B and consists of three hundred and fifteen (315) potato clones grouped in nineteen families, and the population three of potato progenies was developed in the season 2020A and consists of 731 potato clones from sixteen crosses. During the season 2020B, the main activity conducted for these populations of new potato clones, was a seed bulking of the selected best families. Phenotypic, disease and yield data were collected and will be analyzed to select the best progenies to be advanced for further trials.

Based on the phenotypic characteristics of the above breeding materials, there is a hope that we will get the best genotypes that will be appreciated bay farmers. For this purpose, the following activities will be conducted (1) for all the population progenies, there is a need to start initiating the in vitro culture of the outperforming genotypes as well as cleaning them by thermotherapy to make sure that our breeding materials are free from viral disease, (2) Seed bulking will continue for the genotypes with few tubers under screen house, (3) on station preliminary yield trials will be conducted for the genotypes which have more than 200 tubers, (4) seed bulking of the same genotypes under yield trials will also be conducted in parallel under the screenhouse to avoid virus infection which can occur in open filed, and (5) the row data of phenotypic data supported by harvesting data will be analyzed to select the best performing clones to be advanced to next step of evaluation.

Yield performance evaluation of local potato varieties commonly grown in Rwanda

The objective of this study was to conduct field trials of local potato varieties commonly grown by farmers to assess their agronomic performance. Ten potato varieties namely Kinigi, Kirundo Twihaze considered as improved potato varieties obtained from RAB potato germplasm, and Japani, Kurugeri, Kuruseke, Nyoragatuku, Peko, Rundarunda and Rwangume (Rutuku) obtained from farmers were tested in the field trials. The origin of these varieties is not known. Kuruseke and Peko varieties were mainly grown by farmers in the districts of Nyabihu, Rubavu, Musanze and Burera. Rwangume variety also named Rutuku by some farmers is predominantly grown in the districts of Gicumbi and Burera. Nyiragatuku variety is predominantly grown by farmers in Nyaruguru district, while Rundarunda is predomintly in Musanze district.
Field experiments were conducted at four sites: Rwerere (2060 meters above sea level:m.a.s.l), Kinigi(2380m.a.s.l), Gakuta (2237m.a.s.l) and Sigira (2347m.a.s.l) RAB station located in Burera, Musanze, Karongi and Nyamagabe districts, respectively. The trials were established in October 2019, using the standards agriculture practices of potato in Rwanda. In these trials, the data collection has focused on all characteristics described in a procedure for standard evaluation and data management of advanced potato clone developed at International Potato Center (De Haan et al 2014). The statistical analysis was computed using GenStat 20th edition and consists of analysis of variance.

The analysis of variance of fresh tuber Yield (t/ha) revealed that there were significant differences among the varieties, sites and interaction of variety and site for the total fresh tuber yield. Varieties showed varations in tuber yields across sites (Table 28). The check varieties Kinigi and Kirundo revealed the highest fresh tuber yield within and across the sites with an average of 30 and 26.9 t/ha respectively. The lowest fresh tuber yields were obseverd on the variety Japani, Nyiragatuku and Peko with an average of 13.7 and 14.9 t/ha respectively. In general, no variety was the highest yield across all the sites. Instead, the tested varieties peformed differently at the sites. The highest yields were observed in Kinigi site with an average of 27.7 t/ha while the lowest yields were observed at Gakuta site with an average of 12.8 t/ha.

Table 28: Mean of 7 local potato genotypes and 3 check varieties on fresh tuber Yield (t/ha)

Variety/Site	Gakuta	Kinigi	Rwerere	Sigira	Average
Kinigi	NA	47.38	25.43	17.19	30.0
Kirundo	NA	32.45	21.47	26.71	26.9
Twihaze	7.81	25.51	29.54	19.12	20.5
Japan	12.03	20.3	10.31	12.26	13.7
Kurugeri	19.95	25.75	21.94	8.02	18.9
Kuruseke	16.67	28.54	15.05	14.2	18.6
Nyiragatuku	10.27	21.8	9.69	17.99	14.9
Peko	12.15	21.55	16.92	8.89	14.9
Rundarunda	14.7	28.44	16.46	31.43	22.8

Rutuku	8.68	24.97	15.01	24.25	18.2
Total	12.8	27.7	18.2	18.0	

LSD=8.2, CV=54.4, NA: No available data.

There is a need to repeat the trials at the same sites for the purpose of a deep analysis of the results and validation of the results obtained from the first trial. The evaluated local potato varieties are highly preferred and grown by famers. Therefore, considering the farmers consideration of the tested varieties and considering that there are no formal seed of those varieties, there in a need to clean them for possible viruses infection and integrate them into the seed value chain to avail clean seed to farmers.

Evaluation of local potato breeds developed in 2012 for late blight tolerance

The study aimed to evaluate yield of local potato breeds developed in 2012 for late blight tolerance in Musanze, Rwerere, Sigira and Nyamagabe RAB stations. A total of 17 potato clones and three local varieties were used. Tuber yield varied significantly in genotypes and sites (Table 29).

Table 29: Total tuber weight of 20 potato genotypes evaluated at three locations

	Nyamagabe		Musanze		Rwerere	
	Mean (t/ha)	Class	Mean (t/ha)	Class	Mean (t/ha)	Class
Kinigi*	16.81	MY	26.2	HY	26.18	HY
Kirundo*	17.11	MY	26.3	HY	20.64	MY
Twihaze*	18.28	MY	19.3	MY	29.67	HY
Rw 012-01	12.42	LY	13.3	LY	11.98	LY
Rw 012-02	14.74	LY	12.3	LY	11.71	LY
Rw 012-04	7.86	LY	14.2	LY	18.73	MY
Rw 012-08	16.14	MY	22.6	MY	14.26	LY
Rw 012-10	13.97	LY	19.1	MY	16.3	MY
Rw 012-12*	18.81	MY	28.5	HY	26.58	HY
Rw 012-14	11.38	LY	19.5	MY	14.24	LY
Rw 012-15	16.7	MY	19.8	MY	17.71	MY
Rw 012-16*	17.36	MY	25.5	HY	22.33	MY
Rw 012-17	10.56	LY	22	MY	14.58	LY
Rw 012-18	8.54	LY	19.6	MY	17.16	MY
Rw 012-19	11.89	LY	23.5	MY	18.17	MY
Rw 012-20	9.64	LY	19.5	MY	13.33	LY
Rw 012-24	12.39	LY	20.1	MY	15.31	MY
Rw 012-28	15.57	MY	22.2	MY	17.43	MY
Rw 012-29	18.93	MY	17.8	MY	17.01	MY
Rw 012-31	10.13	LY	17.4	MY	15.87	MY

HY: Means Genotype with higher yield, MY: Means Genotype with Medium yield, LY: Means Genotype with Low yield, *: Selected Genotype

Genotypes RW012-12, Twihaze, Kinigi and RW 012-16, with total tuber weight of 29.7; 28.5; 25.18 and 25.54 t/ha, respectively, were the best yielders across locations. While RW012-02 and at Musanze, Rwerere and Nyamagabe were lowest with 12.3; 11.7; and 7.6t/ha, respectively. At Rwerere, the highest yielder was genotype Twihaze with 29.67t/ha, at Musanze - RW012-12 with 28.5 and Nyamagabe was RW012-12 with 18.8t/ha.The overall mean for total yield across locations was 17.15 t/ha. Rwerere with 29.7 t/ha had the highest total yield, followed by Musanze with 28.5 t/ha and Nyamagabe with 18.8t/ha. In this trial the seven best genotypes with high yield were Rw 012-12, Rw 012-16, Rw 012-18,Rw 012-29, Rw 012-31, Twihaze and Kinigi. Except Twihaze and Kinigi, which are already released potato varieties in Rwanda, the others showed the potential to be released. However, further trials are needed to identify other characteristics such as adaptability, stability and drought tolerance.

Clean seeds production, distribution and delivering advisory services

The potato subprogram focus on in vitro potato plantlets production and minitubers production through screenhouses. The number of potato tissue culture plantlets produced under in vitro culture laboratory is provided in Table 30. In season 2020A, 1,048,425 plantlets were produced. Among them 918,700 plantlets were planted in RAB stations (Musanze, Gakuta, and Sigira) while 129,725 plantlets were sold to private's potato seed multipliers with screenhouses. In season 2020B, only 677,200 plantlets were produced. Among them, 615,200 plantlets were planted in RAB stations (Musanze, Gakuta, and Sigira) while 62,000 plantlets were sold to privates' potato seed multipliers with screenhouses.

Table 30: Plantlets produced under in vitro culture laboratory in fiscal year 2019-2020

Destination	Season A	Season B	Total	Ration (%)
RAB station	918,700	615,200	1,533,900	88.9
Private	129,725	62,000	191,725	11.1
Total	1,048,425	677,200	1,725,625	100.0
Ration (%)	60.75624774	39.24375	100	

In addition to potato tissue plantlets production, about 1,800,000 and 1,400,000 minitubers were produced by potato subprogram in season 2020A and season 2020B, respectively. To increase the technology adoption 33 demostration plots were established across main potato producing districts using new released potato varieties namely Nkunganire (CIP393280.64), Twihaze (CIP393371.58), Kazeneza (CIP393077.159), Izihirwe (CIP396018.241), and Ndeze (CIP398190.615), and two local potato varieties Kinigi and Kirundo. Moreover, 6 new potato verities namely Gisubizo, Seka, Twigire, Kerekezo, Jyambere, and Ndamira were released in February 2020. The released days were held at Nyamagabe, Karongi and Musanze districts.

1.3.3 Sweet potato sub-program

Sweetpotato [*Ipomoea batatas* (L.) Lam.] is an important food crop in Rwanda. It plays a critical role as a food security crop in the tropics because it can be harvested in 4 months with substantial root yield of up to 20 tones/ha, and complements other food crops and serves as a famine reserve. It is adaptable to a wide range of agro-ecologies in Rwanda. The growing awareness of health benefits attributed to orange-fleshed sweet potato varieties (OFSP) has stimulated renewed interest in the crop. Besides being a food security crop, it is also, increasingly becoming an important source of income to smallholder farmers in tropical Africa. The crop has, therefore the potential to contribute to the NEPAD/ STISA priority area 1 of ensuring food and nutrition security, and priority area 6 of wealth creation through innovation. In addition, the use of OFSPs is in line with the second aim of PSTA 4 emphasizing "nutrition". Although sweet potato is a very important crop, its potential contribution towards improvements in household food security and income is hampered by a low productivity. The low productivity is associated by various factors, but mainly (i) shortage of improved varieties resulting to relatively low yields compared to the attainable yields, (ii) the use of non-clean planting material by farmers, lack of new technologies and innovations with regard to sweet potato production. The emphasis during the season 2020A, was therefore put on conducting series of experimental trials aiming at selecting high yield varieties. In addition, effort was made to produce and avail clean planting material to farmers, while transferring technologies relevant to sweet potato production.

Development of new varieties

The lack of improved sweet potato varieties meeting end users' preferences was reported. The objective of this output is to develop sweet potato varieties with high fresh root yield, resistant to diseases mainly sweet potato virus disease (SPVD), with high dry matter content and other farmer-preferred traits, with good shape for commercial and export value. Regarding early breeding stages, 1000 botanical seeds were raised in a crossing block (Photo 22) at Rubona through both hand and open pollination. Four advanced trials comprising 6, 10, 12 and 18 genotypes, respectively, were planted in Rubona and Gashora experimental fields in season 2020A. The following trials were conducted in RUbona and/or Gashora: (i) Advanced yield trials for 6 genotypes and Kabode as local check; (ii) advanced yield trial of 10 genotypes evaluated against Kabode variety, (iii) Evaluation of the new 18 genotypes for their drought tolerance and (iv) Evaluation of orange-fleshed varieties for their storage root yield and dry matter content (DMC) and (v) on-farm trial of the 12 performing OFSP. Data were collected on marketable root number (MRN), marketable root weight (MRW), fresh root yield (FRY). Vine-based traits comprised of fresh vine yield (FVY), virus score (VS), Alternaria score and vine vigour.

Photo 22: A crossing block is a crucial step in developing new OFSP varieties

Multilocational trial for 6 genotypes and Kabode as local check

The FRY grand mean across sites was 38.5 T/ha. The analysis of variance showed significant differences between sites ($P < 0.01$) for sites. There were significant differences between genotypes for FRY, but no differences between replications. Gashora site performed well than Rubona, with a mean of 50.6 and 26.3 $T.ha^{-1}$. The top 4 perfroming genotypes for FRY were 2016-X2, Kabode, 2016-118 and 2016-25, with a mean of 50.49; 43.96; 42.24; 38.01, respectively.

Advanced yield trial for 12 clones with Kabode as a local check

There were no significant differences for genotypes, but sites differed significantly (52.1 T/ha at Gashora vs 26.9 T/ha for Rubona). Fresh root yield ranged between 33.07 T/ha (clone 2017-4) and 43.67 T/ha (Clone 2017-103).

Evaluation of drought tolerant varieties

Analysis of variance revealed that genotypes differed significantly ($P < 0.001$) for fresh root yield (FRY), marketable root weight (MRW), marketable root number (MRN), and at $P < 0.01$) for vine weight. There were no significant differences between genotypes for vine yield (VY).

Performance of genotypes for root yield and yield related traits

Table 31 shows fresh root yield (FRY) for the 19 clones evaluated for drought tolerance. The FRY ranged between 12.7 (RW20-54) and 37.6 t/ha (RW20-47). The best performer was RW20-47 with 37.6 t/ha FRY, which is 6 t/ha higher than Kabode, the local check. Regarding marketable root weight (MRW), the top two performing clones were Kabode (19.3 kg), followed by RW20-75 (18.87 kg). The best performer for marketable root number (MRN) was RW20-40 with a mean of 79 roots. The vine yield ranged between 7.5 and 32.3 t/ha.

Table 31: Mean root yield for 19 sweet potato genotypes evaluated for drought tolerance

S/N	Clone/ code	Fresh root yield (t/ha)	Marketable root weight (kg/plant)	Marketable root number	Vine weight
1	RW20-2	19.23^{a-c}	9.87^{a-e}	38.33^{b-e}	9.00^{ab}
2	RW20-3	27.78^{a-c}	16.47a-e	45.33^{a-e}	10.33^{ab}
3	RW20-8	22.35^{a-c}	12.33^{a-e}	44.00^{b-e}	5.00^{b}
4	RW20-11	22.80^{a-c}	13.20^{a-e}	51.33^{a-e}	7.33^{ab}
5	RW20-27	23.98^{a-c}	11.87^{a-e}	46.33^{a-e}	10.33^{ab}
6	RW20-33	30.64^{a-c}	16.93^{a-d}	54.67^{a-e}	7.00^{ab}
7	RW20-38	14.09^{bc}	6.40^{e}	22.33^{d-e}	13.33^{ab}
8	RW20-40	27-60^{a-c}	17.40^{a-d}	79.00^{a}	9.67^{ab}
9	RW20-42	17.88^{bc}	8.67^{b-e}	28.33^{c-e}	4.67^{b}
10	RW20-47	37.63^{a}	18.80^{a-c}	46.00^{a-e}	6.33^{ab}
11	RW20-54	12.71^{c}	6.00^{e}	21.33^{e}	16.00^{a}
12	RW20-55	20.58^{a-c}	8.33^{c-e}	41.00^{b-e}	12.00^{ab}
13	RW20-57	16.20^{b-c}	7.93^{d-e}	53.00^{a-e}	12.67^{ab}
14	RW20-59	20.41^{a-c}	11.20^{a-e}	58.67^{a-c}	9.67^{ab}
15	RW20-66	22.62^{a-c}	11.20^{a-e}	46.67^{a-e}	13.67^{ab}
16	RW20-69	20.46^{a-c}	9.40^{a-e}	53.33^{a-e}	8.00^{ab}
17	RW20-70	24.16^{a-c}	10.2^{a-e}	33.67^{b-e}	9.00^{ab}
18	RW20-75	29.91^{a-c}	18.87^{ab}	63.33^{a-b}	9.67^{ab}
19	Kabode	31.97^{ab}	19.33^{a}	56.67^{a-d}	7.00^{ab}
	Grand mean	23.32	12.34	46.5	9.51

Evaluation of performing orange-fleshed sweet potato clones from Mozambique

A total of 13 clones which are high yielding were introduced from Mozambique. They were evaluated for yield potential and adaptability under Rwandan conditions. These clones belong to orange fleshed sweet potato type, thus they have better potential to address malnutrition in kids, suffering from vitamin A deficiency.

All genotypes had similar Fresh Root Yield (FRY), Marketable Root Weight (MRW) and Marketable Root Number (MRN). FRY ranged between 11.41 (Rob1) and 24.01 t/ha (Jane) (Table 32).

The top three performing clones for FRY were Jane, Kabode and Lourde, with a mean of 24.0, 23.0 and 22.9 t/ha, respectively. Nine out of 13 clones performed above the grand mean of 20.6 t/ha.

Table 32: Performance of OFSP clones for root yield and other related traits

S/N	Clone	Fresh root yield (t/ha)	Marketable root weight (kg/plant)	Marketable root number
1	Anelia	20.96	10.667	38
2	Cecilia	20.69	9.267	29.67
3	Esther	17.87	9.867	39
4	Gloria	22.61	11.467	40
5	Irene	21.95	11.533	45
6	Jane	24.01	11.2	36.67
7	Kabode	22.98	11.667	32.33
8	Lourde	22.91	10.133	31.33
9	Maphuta	22.66	7.333	27
10	Melinda	21.92	10	38
11	Olivia	17.84	8	27.67
12	Rob1	11.41	4.533	24
13	Rob2	19.28	9.867	38.33
Grand mean		**20.55**	**9.66**	**34.4**

Responses of genotypes evaluated in demonstrations plots

Demo plots were established in Kayonza, Muhango and Rulindo with 6 OFSP clones: Cecilia, Esther, Kyabafurika New Kawogo, Otada 24 and Tura. Rulindo had the lowest ($p<0.001$) yield (11.3t/ha) as compared to Kayonza (33.5t/ha) and Muhanga (22.2t/ha) (Table 33). Clones New Kawogo, Tura and Cecilia were the best performers with 27.8; 27.4 and 24.9 t/ha, respectively.

Table 33: Fresh root yield and related traits for six sweet potato genotypes

N	Clone	Fresh Root Yield (t/ha)	Marketable root number	Marketable root weight (t/ha)	Vine yield (t/ha)
1	Cecilia	24.87^{ab}	49.56^{ab}	19.58^{ab}	16.66^{bc}
2	Esther	15.99^{c}	36.78^{a-c}	13.64^{b}	10.5^{c}
3	Kyabafurika	17.83^{bc}	31.44^{c}	13.64^{b}	15.97^{bc}
4	New Kawogo	27.8^{a}	44.67^{a-c}	22.7^{a}	29.77^{a}
5	Otada24	19.95^{bc}	32.78^{bc}	17.09^{ab}	31.44^{a}
6	Tura	27.4^{a}	51^{a}	23.42^{a}	25.4^{ab}
Mean: Kayonza		33.46	61.33	29.54	33.49
Mean: Muhanga		22.18	38.67	18.28	16.68
Mean: Rulindo		11.29	23.11	7.21	14.70
Grand mean		22.31	41.04	18.3	21.62

The GGE biplots analysis of fresh root yield is presented in Figure 5. The first principal component (PC1) representing genotypic effect showed a relatively high contribution (89.79%) to the total variance for fresh root yield compared to PC2. Genotypes Tura and New Kawogo showed a relatively high PC1 values, with a high mean fresh root yield of 27.4 and 27.8 t/ha, respectively.

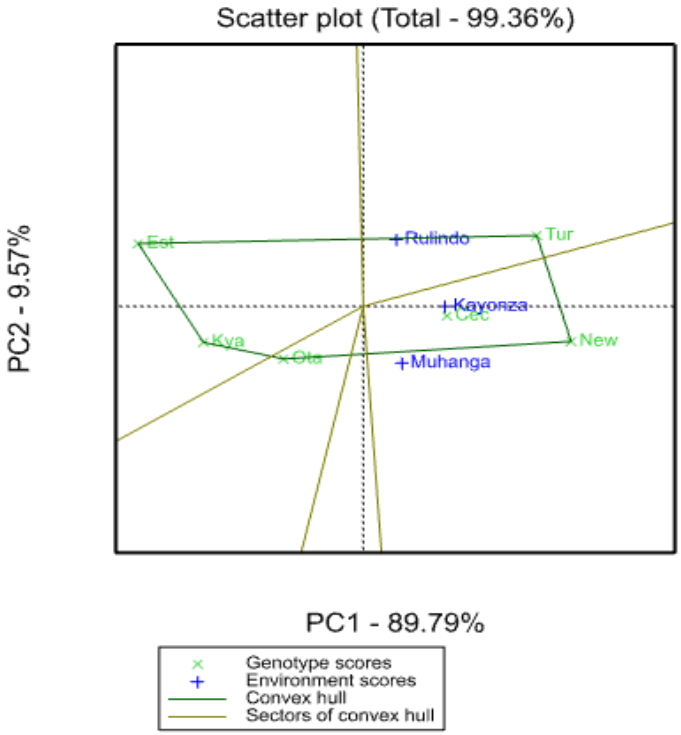

Figure 5: Genotype and genotype by environment biplots for fresh root yield of 6 clones evaluated at Kayonza, Muhanga and Rulindo sites

The conducted trials were at different breeding stages and current results pointed out performing clones for various traits such as high root yield, marketable root yield, and beta-carotene for OFSP clones. Selected genotypes from advanced yield trials are being confirmed for the second season (2020B) in order to confirm results for season 2020A. After harvesting season 2020B, selected clones will be moved to on-farm trials, whereas performing clones from on-farm trials (Cecilia, New Kawogo, Otada24) are to be submitted for official release.

Genetic diversity and germplasm conservation

The sweet potato breeding program contains 190 sweet potato genotypes. All these genotypes have been characterized and maintained for various attributes. Among them, only 18 varieties are maintained both in vitro and in vivo. These genotypes vary in traits of interest and can be combined in a crossing block depending on their general combining ability. Their use also vary over time since depending on the value chain actors' preferences (producers, cooking varieties, OFSPs, whites-fleshed types, early maturing varieties, dry matter content, disease resistant, various skin color, root shape, gustative taste, anthocyanin content, etc.). The future plan is to continue both methods of conservation (in vitro and in vivo), in order to prevent from genetic erosion that may occur when conserved in open field or any unwanted variation that may happen in tissue culture.

Seed production and availability (sweet potato clean seed)

The lack of sweetpotatto clean seed at farmer's level is one of the key constraints to improving sweetpotato productivity in Rwanda (Nshimiyimana et al, 2016). Similar study also showed that quality and availability of sweetpotato planting material is the most important limiting factor in developing the sweetpotato crop across districts. Another challenge is that most farmers in Rwanda obtain and use sweetpotato seed through their own conserved planting material, farmer to farmer exchange or purchase from the local market. This, therefore, creates a big challenge. Farmers end up resorting to recycling old planting materials most of which are diseased and with low yield potential. Therefore, it is necessary to ensure a sustained availability of quality, disease-free planting material, at required quantities and in a timely fashion. The main objective is to establish an efficient sustainable sweet potato seed production through multiplication and availability of cleaning planting material to different categories of farmers with clean planting material in sufficient quantities, at the right time, in an appropriate physiological state, vigor, and health at an affordable price.

RAB received confirmed virus-free tissue culture plantlets from the Kenyan Plant Health Inspection Service (KEPHIS). Then plantlets are cultured and multiplied in tissue culture laboratory at Rubona to produce clean planting material free of diseases, especially sweet potato viruses. Mature plantlets are raised and transferred from tissue culture lab to 2 screen-houses and 2 mobile nets for hardening and subsequent multiplications using ratooning techniques to produce basic seed. Health status of vines is maintained by doing negative selection—rouging plants that show visible virus symptoms and then transferred to open fields for pre-basic seed production. To satisfy the huge demand of planting material, the sweet potato sub-program collaborate and backstop Decentralized Vines Multipliers (who received RAB trainings in Rapid Multiplication Techniques) for more high quality vines production. The sweet potato sub-Program works with 68 decentralized vine multipliers (33 women and 35 men) in various districts of Rwanda (Figure 6), in order to ease the accessibility of OFSP clean cuttings. These vine multipliers are on the other hand coordinated by our partner organizations in their respective working areas. The 68 vine multipliers are located in various sweet potato growing areas of Rwanda (Northern Province: 27; South: 15; West: 14;

East: 11 and Kigali City: 1).

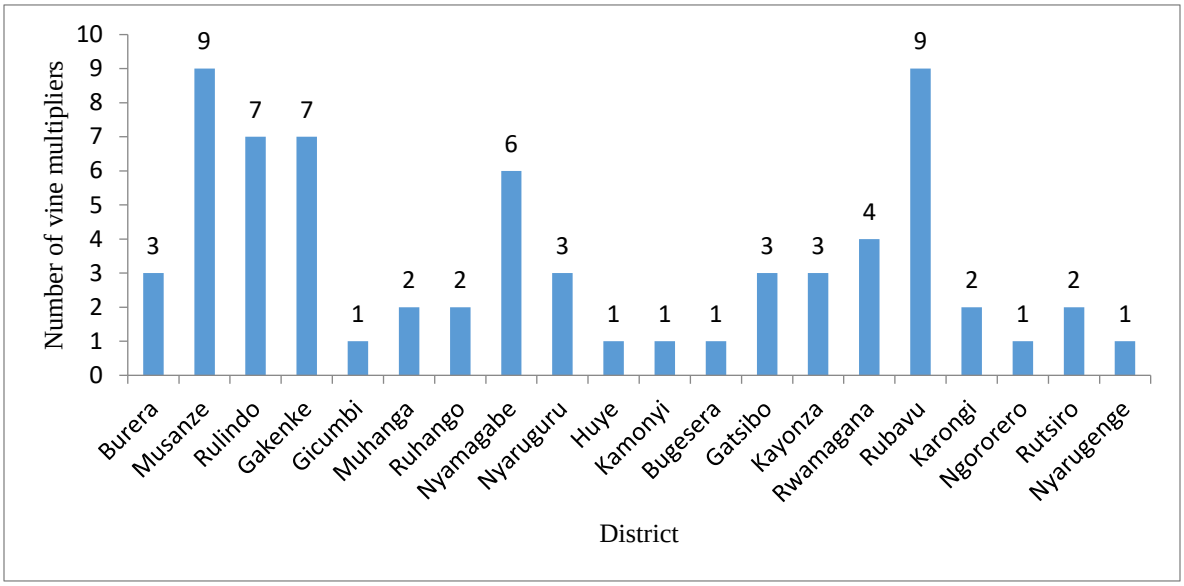

Figure 6: Number of DVMs per district

Progress to date

During this year 2019-2020, the normal clean seed production process was used from tissue culture lab, screenhouse and primary multiplication in the field (Figure 4). The current tissue culture (TC) work focused on the 8 popular OFSPs varieties (Table 4) which are rich in Beta-carotene content and therefore very useful in reducing malnutrition in districts that showed the highest rate. This year, 16,500 in-vitro clean plantlets from varieties Vita, Kabode, Ukerewe, Giramata, Maryoha and Ndamirabana were produced in tissue culture laboratory at Rubona. Mature clean plantlets from TC lab were transferred to screenhouse for hardening process. In total, 210,320 clean cuttings were produced, part of that was availed to DVMs. In collaboration with DVMs, around 416,000 cuttings were provided to Kabogorota village model in Nyagatare district.

Photo 23: Clean plantlets under hardening process in screenhouse (left), primary seed multiplication in open field (right)

Table 34: List of available OFSP under promotion

S/N	Variety name	Specific attributes
1	Cacearpedo	High root yield, high beta-carotene content
2	Gihingumukungu	High root yield, high beta-carotene content
3	Naspot 9 (Vita)	High root yield, virus resistance, beta-carotene content
4	Naspot 10 (Kabode)	High root yield, virus resistance, beta-carotene content
5	RW11-2560 (Terimbere)	High root yield, Deep orange with high beta-carotene content
6	SPK004	High root yield
7	Terimbere	High root yield, Deep orange with high beta-carotene content
8	Ukerewe	Excellent taste, high DMC, high root yield

The increase and availability of improved sweetpotato to different in different provinces has increased the sweetpotato production due to high yielding and resistant diseases free planting material. Farmers are excited to take up new clean varieties that have higher yielding year-round.

Promote different approaches of pests and diseases management

Increased sweetpotato production in Rwanda is hindered by high incidence of virus diseases as well as fungal and bacterial diseases. Sweetpotato virus disease (SPVD) which is the most constraint in sweetpotato cultivation is caused by synergistic interaction between Sweetpotato feathery mottle virus (SPFMV) and Sweet potato chlorotic stunt virus (SPCSV). Although the crop can be produced under difficult growing conditions with minimum inputs, the above pests and diseases need a thorough management by sweetpotato growers. The main objective was to teach or explain farmers how to recognize and control major sweetpotato pests and diseases.

The sub-program team used an Integrated Pest Management (IPM) approach which aimed at explaining to farmers and DVMs different methods how to understand and control the pests and diseases in sweetpotato cultivation. As a result, a sweetpotato module training manual which encompasses pests and diseases management as well as agronomic practices was developed and distributed to farmers in different districts in collaboration with JICA project. The manual is well elaborated for SPVD and *alternaria* control.

Although this training manual is not yet full used by the farmers, for sure its potential contribution will be perceived in near future because the pilot farmers who received the manual were asked to share the knowledge with their neighbors. Farmers were enthusiastic to see and read the manual in Kinyarwanda.

Development of good agronomic practices

Sweet potato has the potential to produce high yields if given the right growing conditions. The environmental factors such as soil and nutrients, water, light and temperature and with their management influence sweet potato production. The main objective was to give to the sweet potato growers the knowledge of best management practices for sweet potato in order to increase sweet potato productivity.

Farmer field school sessions were organized in South, North and Eastern province of Rwanda by sweet potato staff in collaboration with SMAP-JICA project. A training manual was prepared about sweet potato agronomic practices such as seed preparation, land preparation, planting on ridges and pest management.

Technology transfer

Demonstration plots: To make farmers aware of the new varieties in pipeline for release, and those already submitted to the release committee for possible release, the five performing clones were planted in 14 demonstrations plots at farmers' fields (Southern Province: 7, Northern Province: 4 and Eastern Province: 3). This activity was conducted in partnership with the International Potato Centre (CIP). Demonstrations plots were recently harvested while minimizing the risk of contracting the Covid-19 pandemic. Results showed that clones performed most in Eastern Province than South and North. In order to widespread the information about the new varieties, media was involved in piloting this activity in Kayonza where "Imvaho Nshya" was part of.

Farmer field schools: In partnership with JAICA through SMAP Project, a training material focusing on Orange-fleshed sweetpotato production was developed and 300 copies distributed to 6 FFS groups of 50 farmers each (300 farmers). In partnership with SMAP Project/ JICA, six (6) FFS groups were established in 6 Districts which showed the highest malnutrition rate (Nyamagabe, Nyaruguru, Rutsiro, Ngororero, Ngoma and gakenke); where FFS were about Orange-fleshed sweetpotato production.

Other extension services: In the framework of creating awareness of farmers about the new developed sweetpotato varieties, 6 radio &TV talks (2 at ISANGO Star Radio & TV; 1 at Radio Rwanda; 1 at Radio Flash; 1 at Radio Salus and 1 at RC Huye) were produced on the benefits of growing the new sweetpotato varieties. In addition, two pull banners describing the importance of using clean planting material were produced. Furthermore, a WhatsApp group was created as a social platform, where relevant information regarding sweetpotato value chain is easily exchanged between all actors involved. An ICT tool (mobile app.) is also planned to be used in the next season in order to easily coordinate the production and marketing of sweetpotato products.

Consolidated land covered by orange-fleshed sweetpotato: In total, 10.04 ha were covered by orange-fleshed sweetpotato varieties at Integrated Development Programme (IDP Model Village), Nyagatare. In collaboration with DVMs, clean seed from variety Kabode (420 000 vines cuttings) were planted for storage root production. In addition, in partnership with DVMs and Gicumbi District, 873,000 orange-fleshed sweet potato cuttings were planted, where 21 ha were covered.

1.4 BANANA PROGRAM

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 Xanthomonas 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, banana rehabilitation and disease control research.

Germplasm conservation

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

Technical support on banana rehabilitation and BXW disease control

For banana rehabilitation, the local field trainings were organized on banana rehabilitation, management and BXW disease (Photo 24) at Nyamasheke, Gisagara, Muhanga, Rubavu, Kayonza, Gatsibo and Rwamagana. District and sector agronomists and farmers groups were involved.

Photo 24: Field work on BXW control in Rwamagana district (November 2019)

Banana disease control on farm research: testing of Single Diseased Stem Removal

Banana wilt, the most serious and epidemic banana disease, is now present in all districts of Rwanda. The most common control involves heavy labor to fully uproot sick plants. Less labourious

control methods were shown by regional research in DRC and Uganda. Therefore, on farm trial was established at Gisagara, Rubavu, Rulindo and Kayonza to test new control method – Single Diseased Stem Removal (SDSR) in collaboration with Alliance for Bioversity International and CIAT and IITA. Sites were selected in the most affected by the BXW disease areas. Treatments consisted of old control method with full removal of sick plants; new method (SDSR) with cutting of banana stem; no control for BXW sick plants, and healthy plot without the BXW disease. Each treatment was with 4 replicate plots and 50 banana plants at the beginning of the experiment. The experiment was conducted during 2 seasons – 2019B and 2020A. Data were collected on disease incidence, economic cost, and production (Table 35, Figure 7, Photo 25)

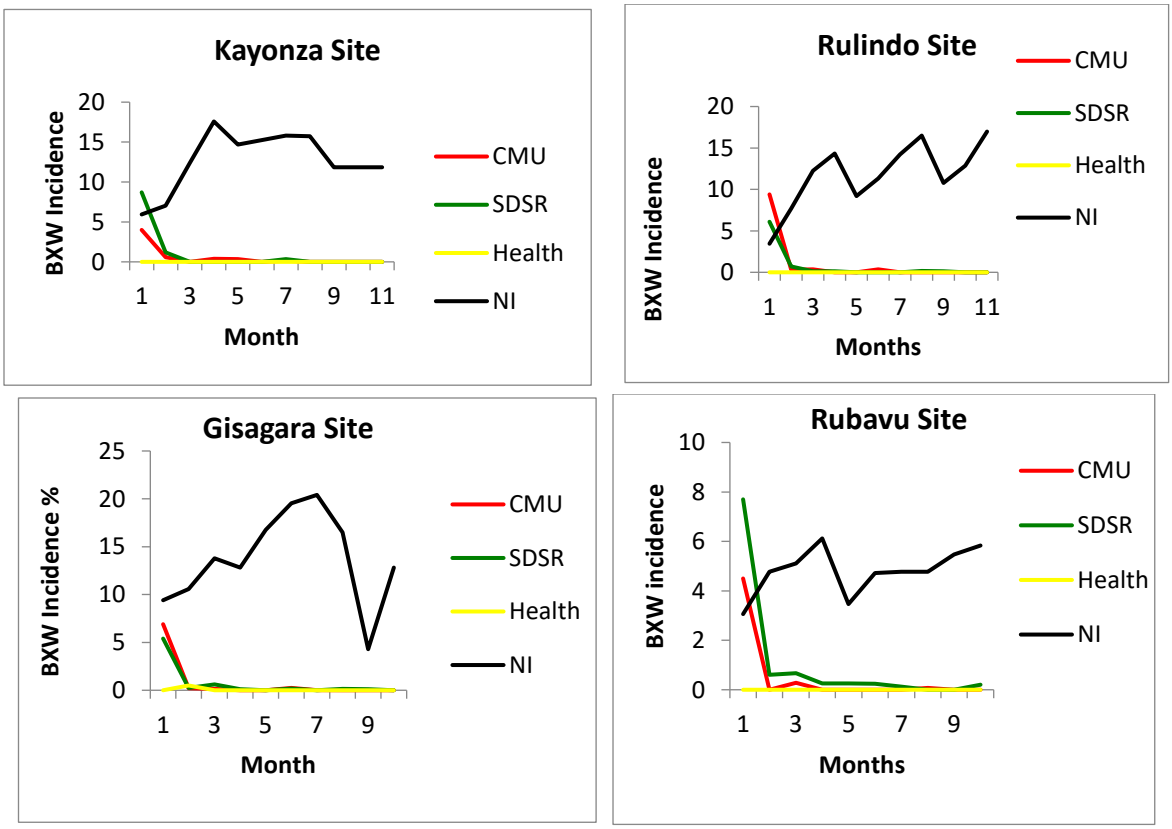

Figure 7: Graphs showing BXW incidence percentage for all treatment in the four sites during period of trials

Table 35: Data on economic benefits of Single Diseased Stem Removal vs Complete Mat Uprooting for Banana Xantomonas Wilt

Sites	Treatment	Labor cost for uprooting one mat /Cutting one stem (Rwf)	Labor for replanting one mat (Rwf)	Total cost per mat/stem	Total cost per mat/stem on 1100 mats (1ha)
Rulindo	CMU	138.9	84	222.9	245190
	SDSR	3.3	0	3.3	3663
Rubavu	CMU	125.8	78	203.8	224216.3
	SDSR	2.7	0	2.7	2937
Gisagara	CMU	58.2	72	130.2	143209

Photo 25: Picture showing current state of one of the farm in Gisagara: The upper Part on the picture is SDSR treatment while the down part is for CMU treatment

Development of mobile phone application to facilitate farmers to control BXW disease

Under the framework of the project "Citizen Science and ICT to control Banana Xanthomonas Wilt in Eastern and Central Africa) a new smartphone application was developed and included basic information on BXW symptoms and control. The application is now being tested with selected farmer promoters in 8 districts of the country, namely – Kayonza, Gatsibo, Rulindo, Burera, Rubavu, Karongi, Muhanga, and Gisagara. Farmer's facilitators were trained to use the BXW application and to report on the disease incidence. To date more than 2500 farmers were registered and reported about the disease. Some have provided update on the progress with the disease control. The application is being tested further.

Challenges

With one farm trial for BXW control, one treatment was cut by some workers related to WUP Gisagara district in attempt to keep the banana field 'clean' for imihigo evaluation disregarding the explanations of the farmer about research experiment. Therefore, this has led to missing research data for 2 months and new peak of the disease thereafter as the same machetes were used to cut sick and healthy plants in this field.

Technical support for banana seed production

Limited seed production via suckers was done at Ntendezi station for Injagi, Imizuzu and FHIA 25 varieties. Limited quantity of suckers was disseminated (Table 36):

Table 36: Banana plants disseminated to farmers in Rusizi and Nyamasheke

District	Sector/Cell/Village	Name	Phone number	Plants received	Area planted
Rusizi	Nkombo / Bigoga / Ngoma	Modeste Ntamuhanga	0784931000	50	5 ares
	Nkanka / Gitwa / Kanyombya	Daniel Ngwabije	0787496702	96	9.5 ares
	Bweyeye / Gikungu / Rwamagare	Zaccharie Bizimana	0783890308	50	5 ares
	Bweyeye / Kiyabo / Rutobo	Epiphanie Mukansanga	0725909354	25	2.5 ares
	Bweyeye / Kiyabo / Rutobo	Juvenal Nsekanabanga	0723507220	25	2.5 ares
		TOTAL		246	23 ares
Nyamasheke	Kanjongo / Kibogora / Gatabo	Malachie Twagirayezu	0788717411	86	8.5ares
	Karengera/ Ruhabwa / Mwezi	Mabaro Venuste	0788626075	188	19 ares
	Macuba / Kigandi / Vugangoma	Uzziel Habiyambere	0788375087	50	5 ares
	Gihombo / Rwamatamu / Butare	Aloys Nsengiyumva	0786366845	50	5 ares
	TOTAL			374	

A total of 29 Seeds multipliers were identified in Western Province: Rusizi (6); Nyamasjeke (4); Karongi (7); Rutsiro (2); Ngororero (3); Rubavu (6) and Nyabihu (1). A total of 180 seed producers are now active and certified as banana seed multipliers at country level. In partnership with local

government the training on Banana Xanthomonas Wilt and Banana rehabilitation was conducted in Nyamasheke Ditrict in middle February 2020, where Director of agriculture in Nyamasheke district , all Sector Agronomists, Cell's Sedos were participated in training concerning on Banana rehabilitation and banana xanthomonas wilt.

Advisory services delivered for increased banana productivity and sustainable disease control

Radio talk shows were delivered on February 4 and June 2, 2020, on RC Rusizi and focused on banana rehabilitation and banana disease control. During the reporting period, the program involved in training of Sectors Agronomists, Districts Agronomists, Farmers Farmer Promoters and some cooperatives growing banana. It was expected that after receiving the training, all farmers trained will be involved in banana rehabilitation and diseases management especially Banana Xanthomonas Wilt disease with help of Farmer Promoters under supervision of RAB/Banana staff, SEDO, Sectors and Districts Agronomists. Results were achieved as follow:

Table 37: Number of extension staff trained, new planting and BXW control in Souther Province

District	People Trained on banana husbandry and diseases management		Area rehabilitated (Ha)	Area planted (Ha)	Area controlled (BXW) Ha
	Function	Number			
Nyanza	Agronomists	11	766.5	0.5	0
	Farmer Promoters	17			
	Farmers	220			
Huye	Agronomists	15	300	0	4
	Farmer Promoters	31 (In Model villages)			
	Farmers	1,736			
Gisagara	Agronomists	14	250	2.6	26
	Farmer Promoters	35			
	Farmers	241			
Nyaruguru	Agronomists	15	11	0	0
	Farmer Promoters	12			
	Farmers	62			
Nyamagabe	Agronomists	*18*	37	1	0
	Farmer Promoters	15			
	Farmers	184			
TOTAL		2,626	1364.5	4.1	30

A part from these two activities reported above, we are working with IITA to test the use of new smart phone application use in BXW control for trained Farmer promoters. We are assisting them in all challenges they meet (update of software, Re-train them on how to use or give information…)

and their records. Banana staff in Rubona station, works with nine Farmer Promoters selected in Gisagara District (Save, Mukindo, Mamba, Kibirizi and Kansi sectors) and give supports in other stations where needed.

1.5 HORTICULTURE PROGRAM

Reference is made to the guidance of the Right Hon. Prime Minister to increase fruit trees in the country to fight against malnutrition and poverty by planting at least three fruit tress per household. The resolutions were set during a meeting held at PM office on 5th/12/2018. These resolutions were also in line with the recommendations of ECD 2018 single action plan that focuses on improving diet diversity, fight against malnutrition at household level, particularly for children suffering severe malnutrition. This is among the major challenges against which the government of Rwanda is putting more efforts to achieve the sustainable development. Since that time, MINAGRI started sensitization campaigns with different partners and institutions both public and private, schools, churches, health centres and set a target of three fruit trees per household in Rwanda. This programme will cover around 3 million households. As every household will plant 3 fruit trees, the total number of seedlings required is 9,000,000.

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 to develop new planting materials using the grafting method. The routine activities such as weeding, spraying pesticides and harvesting scions were continuously carried out in avocado, citrus and mango mother gardens established at Rubona, Mututu, Musenyi, Nyagatare, Bugarama, Musanze RAB stations. During 2020A, the number of scions produced is 163,780 for avocado, 53,700 for citrus and 107,200 for mango. The scions produced in RAB orchards were distributed to different beneficiaries including government projects like RSSP/LWH, NAEB, private companies and NGOs.

Seed production

Reference was made to the guidance of the Right Hon. Prime Minister to increase fruit trees in the country to fight against malnutrition and poverty by planting at least three fruit tress per household. Fruit tree seedlings have been produced in fruit nurseries established in 7 RAB stations, namely, Rubona, Muhanga, Nyagatare, Rwerere, Ntendezi, Gakuta and Gakuta. The number of seedlings produced and distributed was 73,592 Passion fruits, 79,200 tamarillo, 9,766 papaya and 4,105 grafted seedlings of avocado.

Additionally, a total of 402,680 avocado, 4,800 citrus and 122,100 mango scions were harvested and distributed to different beneficiaries from RAB stations (Rubona, Musenyi, Mututu and Kinigi). A total of 21 kg of clean seed of hot pepper have been harvested at Rubona and Bugarama and

30kg of clean seed of tamarillo at Rwerere stations. These seeds will be distributed to beneficiaries for season 2021A.

Adaptability trial for Hot and sweet pepper

Chili pepper is an important horticultural crop in the world. In Rwanda, it is mainly grown as cash crop and plays an important role in national economy. Despite the importance of this crop in the country, low yield and poor quality were constantly reported by farmers. Lack of quality seeds and seed producers, diseases and pests are the main challenges. Majority of the farmers used uncertified planting materials from their fields, neighbors and markets and, even some of the farmers who obtained from the exporting companies claimed that the seeds were impure, not of good quality and expensive. Pepper research focused on evaluation of new varieties of chili and sweet originated from World Vegetable Center, Tanzania.

Sweet pepper evaluation: Evaluation of 6 introduced varieties (PPISPN8-2, PPISPN11-2, PP04142-20, ISPN11-4, PP0537-7019, and PPISPN11-3) was done at Rubona and Bugarama. The variety PB04142-20 produced the highest fruit yield, 28.78 and 26.55t/ha), followed by PPISPN8-2 (25.17 and 27.01) in Ntendezi and Rubona, respectively.

Hot pepper evaluation: In Rwanda, hot pepper is mainly grown as cash crop. Its production and quality are challenged by pests and diseases, poor quality seeds and lack of research and seed producers. Therefore, five varieties of hot pepper, namely, PP9852-170; PP9950-5197; PBC462; ICP18-7; HP 0117 (5 g each) were introduced from World Vegetable Center, Arusha-Tanzania, multiplied and evaluated in Ntendezi and Rubona during season 2020A. The highest yield was recorded with ICP18-7 in Rubona (35.15t/ha) and PP9950-5197 in Bugarama (34.5t/ha).

Stevia fertilization trials

Stevia rebaudiana is new crop being promoted since recently. Fertilization trials evaluated the effects of alternative fertilization practices on crop yield. To develop optimum fertilization protocol, field trials are ongoing in Musanze and Rubona RAB stations.

Organic fertilization in Stevia production: Evaluation of various doses of organic and mineral fertilizers and their effect on stevia was carried out during season 2020A in Rubona. Stevia was harvested for the first time, and further data will be collected as stevia is a perennial crop. The application of 100kg/ha of urea has resulted in maximum fresh leaf yield of about 4t/ha because urea dissolves very quickly in contact with soil.

Development of extension material

Development of IPM and GAP on mango, citrus and avocado*:* Factsheets on integrated pest management were developed for mango Powderly mildew, fruit fly and mango mealy bug management. A detailed fruit production booklets on avocado, citrus and mango containing guidelines for

pests and disease management were also developed and validated by a team from RAB, RALIS and NAEB.

Trainings

IPM/Agronomy training: A total of 330 (ToTs) farmers have been trained on IPM and Good Agronomic Practices for mango, avocado and citrus in seven districts, namely, Kayonza, Bugesera, Rwamagana, Kicukiro, Gasabo, Nyanza and Huye.

Vegetable training: A total of 400 farmers have been trained in market oriented of vegetable production in Nyamagabe, Nyaruguru, Rutsiro, Ngororero, Ngoma and Gakenke in collaboration with JICA, Nutrition project.

Pineapple macropropagation: A total of 120 pineapple growers have been trained in macro-propagation in Gisagara and Nyamagabe districts.

1.6 INDUSTRIAL CROPS PROGRAM

Tea and coffee are the most prominent export commodities in Rwanda and represent 39% and 35% respectively of the formal export by value. During this fiscal year (2019 – 2020), our research focused on development of new coffee varieties/hybrids, insect pests and diseases surveillance and management, coffee – banana intercropping, strengthening the seed sectors along with training of lead farmers, sector agronomists and district cash crop officers. In Tea sub-program, our focus was on the evaluation of tea clones, fertilizer use and optimization of planting density.

1.6.1 Coffee sub-program

Variety development

Current coffee varieties were created for 20th century coffee sector. We already have significant evidence that they will not tolerate the environmental threats of the 21st century, changing weather patterns, and new disease and insect prevalence. This creates a potentially disastrous decline in supply in the coming decades. There is therefore a need to develop the next generation of coffee varieties that will be adapted to various agro ecological conditions in Rwanda and sustain the coffee industry. Among the demand driven breeding traits such as Disease resistance/tolerance, Cup quality, Productivity, traits linked to climate resilience, traits linked to harvest (e.g., uniform ripening time), traits linked to production efficiency (e.g., dwarf/tall), tolerance to abiotic stresses (drought, heat, light, cold) and fertilizer use efficiency. To this end two breeding programs are underway:

a) Multi-locational evaluation of 40 F1 hybrids for the aforementioned traits in various agro ecological conditions.
b) Multi-locational evaluation of 25 new fixed varieties for the afore-mentioned traits

Detailed yield and quality characteristics will be evaluated 3 years after trial establishment. In the same context the spatial temporal tolerance/resistance to selected biotic and abiotic stresses will be evaluated in this period. However, yielding potential of selected top 10 F1 hybrids and fixed varieties is showing promising potential as most of them have a cherry yield per tree already higher than the national average. Best performing F1 hybrids will be further evaluated, particularly on farm, before distribution to farmers through the clonal propagation. Other part of them will be submitted to male sterility to allow multiplication through apomictic seeds.

National coffee pests and diseases surveillance and monitoring program

In Rwanda, coffee farmers are continuously threatened by a range of insect pests and diseases. Many of these are minor in terms of the damage they cause and their effect on yield and quality. However some, such as coffee berry disease, coffee leaf rust, antestia bug and coffee berry borer cause significant yield losses and have a major impact not only on individual farmers but on the economy of Rwanda; a country heavily dependent on coffee for foreign exchange earnings.
It is vital that farmers are aware of the threats presented by insect pests and diseases and of appropriate steps that may be taken to help prevent their occurrence and to manage them in case they cause significant yield and quality losses. This research aims at informing farmers, directly or indirectly, of a number of the more major insect pests and diseases that threaten coffee production in Rwanda, as a consequence, to better empower them to take action as and when required.

This research is expected to improve the targeting and reduction in losses from these coffee pests and disease and this will benefit farmers directly. Information from this activity will also be disseminated via various farmers training systems (FFS and Integrated platforms for instance). The program will also lead to early warning systems for multi-actor stakeholders in coffee value chain.

Spatial distribution of major coffee pests and diseases

Regular surveillance programs allow needed for the purpose of pest and diseases detection and the supply of information for use in pest and disease risk analyses, the establishment of hot spots of occurences and, where appropriate, the preparation of pest and disease lists for the early warning systems. This allows decision making preparedness rather than responsiveness.

The surveillance survey was conducted in August 2019 to prepare for the following the spraying campaign. Spatial distribution of major coffee diseases is highlighted in this report.

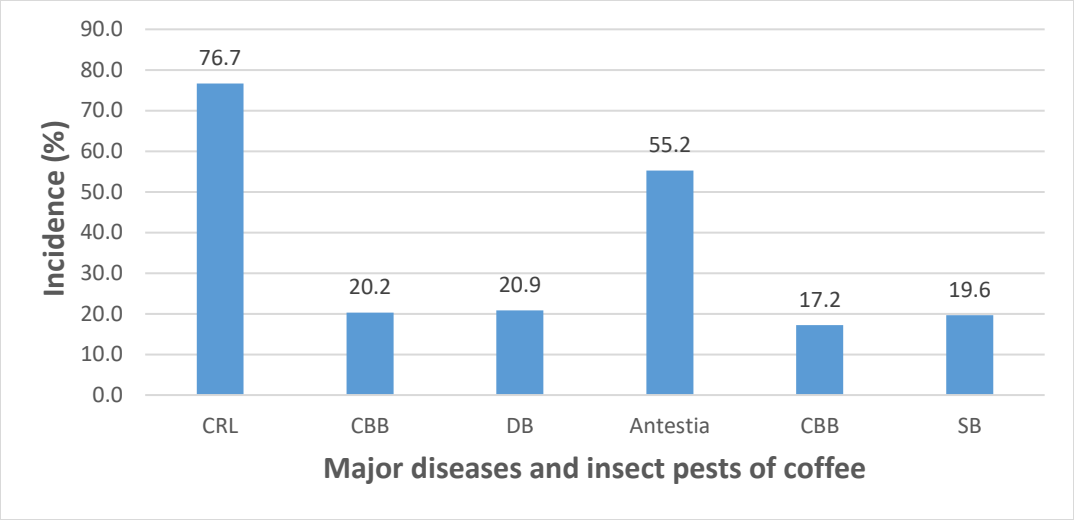

Figure 8: Occurrence of major pests and diseases of coffee

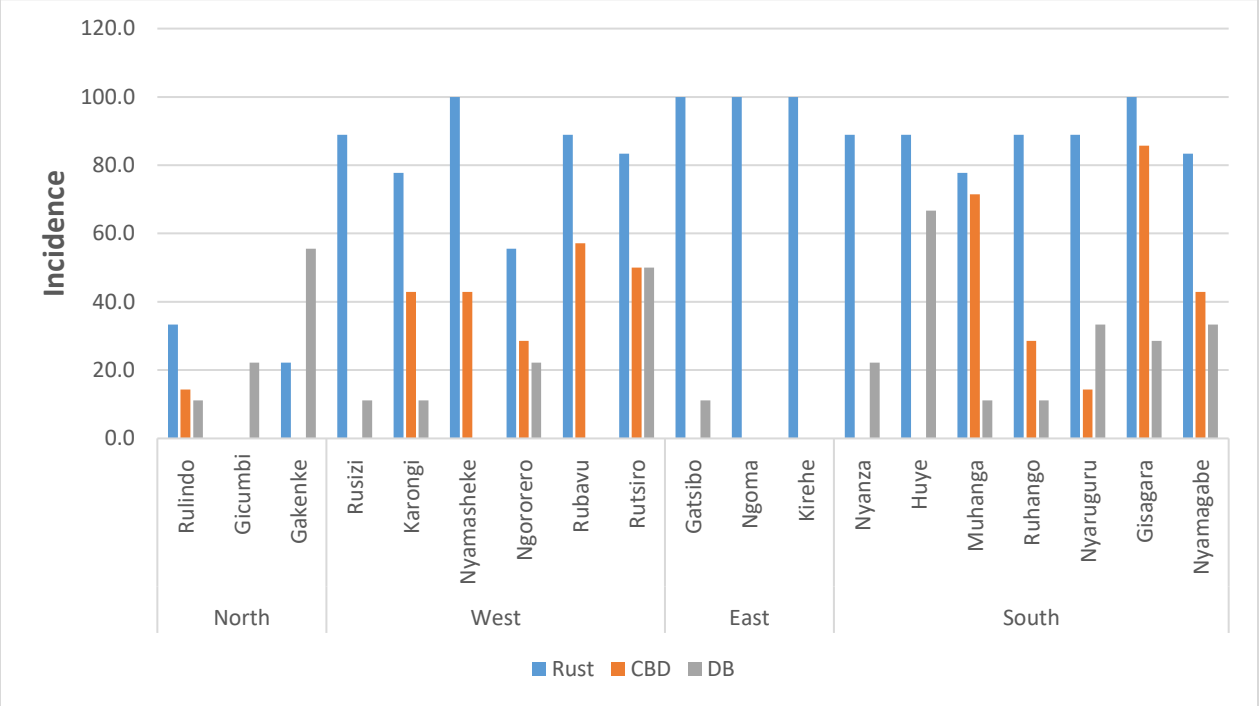

Figure 9: Spatial distribution of major dieses of coffee

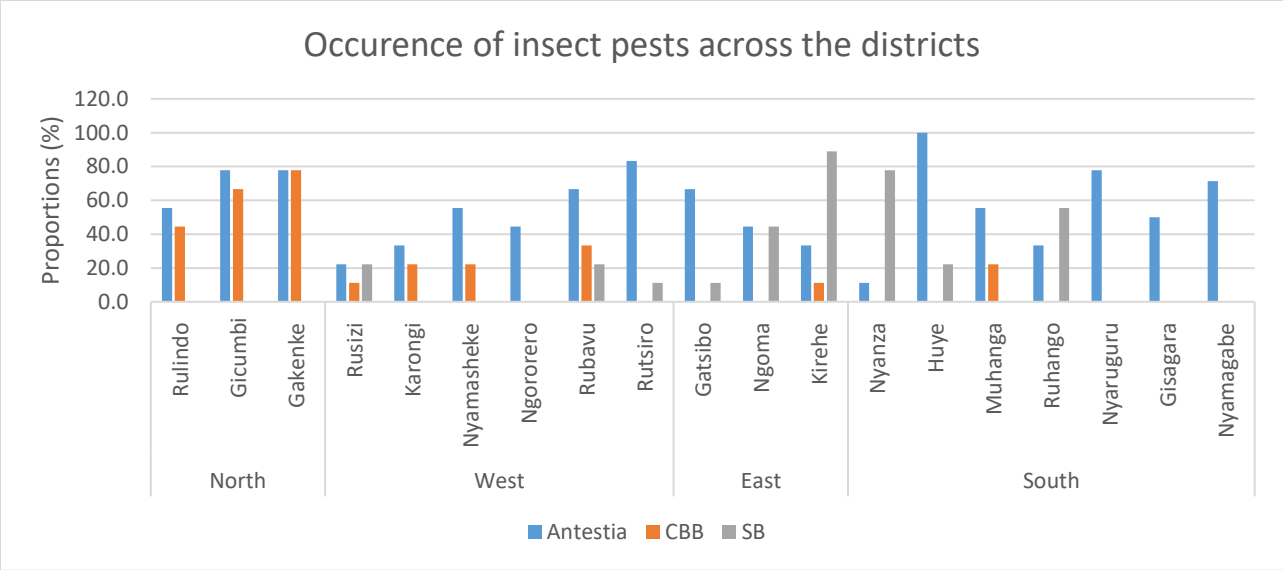

Figure 10: Spatial distribution of major insects of coffee

Results from this survey revealed that insect pests and diseases continue to threaten coffee productivity in Rwanda. Coffee leaf rust, coffee berry disease, antestia bug, and coffee berry borer were prevalent in all coffee growing zones of Rwanda and at a level beyond their economic injury levels. Apart from the long-known biotic stresses, the stem borer of coffee is also a serious issue especially in Eastern Part of the country.

Coffee – banana intercropping

The main advantage of intercropping coffee with banana is that the system is more profitable and resilient than the production of either crop grown as monocrops. Our research included: (i) establishing new fields with coffee – banana intercrops using Arabica coffee; and (ii) planting bananas in existing coffee fields. Trials are still at growing stage.

Strengthening nurseries to build a professionalized coffee seed sector

One of the essential, and largely invisible, problems facing the coffee industry is the lack of a coffee seed sector. When it's time to plant a new tree, most farmers either produce new ones from seeds collected in their fields or from neighbors, or obtain them from small local nurseries. On the surface, this sounds good: self-sufficient farmers making their own plants. But more often than not, it's a key constraint to profitability. On the other hand, the vast majority of smallholder farmers do not know the variety they grow in their fields, do not know that more appropriate varieties exist that could increase their profitability, and do not have access to better plants

Photo 26: (Left) Coffee – banana intercropping farm where bananas and coffee were planted at the same time, (Right) Coffee – banana intercropping farm where bananas were planted in an existing plantation of coffee.

This research was validated on February 12, 2020 with the training manual was produced and also validated on June 30, 2020.

Photo 27: A workshop that validated the research on coffee – banana intercropping

Many nurseries are in remote areas and primitive, producing questionable varieties of questionable plant health. In most cases, these nurseries take or buy seeds from local farmers or institutions but do not take into consideration genetic traceability and purity of the seed—in other words, they often don't know for certain what variety they are selling. The aim of this program is to build a strong and professional coffee seed sector that doesn't leave out smallholder farmers, RAB is implementing a Nursery Verification Program aimed at building the capacity of small entrepreneurial and cooperative nurseries to produce adequate volumes of genetically pure and healthy seedlings to small farms and farmers. Nursery staff will be trained right at the nursery using a RAB-

developed manual of best practices for producing genetically pure and healthy seedlings, as well as on good business practices. Nursery staff will be trained-as-trainers for lasting impact.

Training small nurseries to operate technically-sound and profitable nurseries will result in expanded access to improved, resilient varieties for smallholders—leading eventually to increased production and profits. It reduces farmer risk and strengthens needed renovation programs in target countries. The program will also build stronger rural organizations and and create new entrepreneurial business opportunities in coffee farming communities. To this end, five (5) tones of seeds were produced and distributed to various stakeholders

Trainings

More than 500 people, including Sector agronomists, District cash crop, lead farmers were trained and coffee washing station agronomists were trained on the best agronomic practices in various sessions organized in collaboration with NAEB - PRICE, Sustainable Growes and JICA Project.

1.6.2 Tea sub-program

Evaluation of tea clones

Yield data was collected from an ongoing tea clonal trial that was established during 2014/2015 FY at 4 sites of Mata (Nyaruguru), SORWATHE and ASSOPTHE (both sites of Rulindo) and Ntendezi (Nyamasheke). Yield recordings started in 2018. The objective of the study is the development and diversification of tea genetic resources suitable for different tea growing zones or agro-ecologies. Clones under evaluation were TRFK 303/577, TRFK 301/4, TRFK 301/5, TRFK 54/40, TRFK 6/8, TRFK 31/8, TRFK 11/4, TRFK 7/3, TRFK 12/19, TRFK 12/12, TRFK 12/56, SFS 110, SFS 475, SFS 204, SFS 371, SFS 150, PC 81 and TRFK 6/8. Yield data were collected up to end-February 2020 and cumulative yield was analyzed. Tea clones, sites and their interaction showed significant ($p<0.05$) made tea yield difference. Clones TRFK 301/5, TRFK 54/40, SFS 110, SFS 475 and SFS 204 yielded higher than other clones across all sites. Within sites, best clones with high yield potential were also identified. These were for instance, clones TRFK 303/577, SFS 475, SFS 204 and TRFK 301/5 at SORWATHE, SFS 150 and SFS 110 at Ntendezi, SFS 150 and TRFK 54/40, and clones TRFK 12/12 and PC 81 at ASSOPTHE. However, present data on short term are only indicative of suitability of clones to different agro-ecological zones. Yield recordings on long-term (6-8 years) coupled to quality and assessment of tea clones tolerance/susceptibility to drought and pest data will be necessary for drawing good conclusion.

With regards to newly established trials, there are clonal trials established during the 2nd Quarter of this fiscal year (2019/2020) and which were damaged by recent heavy rains. These were re-established in plantations of Rulindo (SORWATHE and ASSOPTE sites), Nyamasheke (Ntendezi) and Karongi (Karongi tea plantation). They comprise new accessions such as UTK 900244B, UTK 9710342, UTK 401658A, Matim1, and TN14/3 along clones TRFK6/8 and SFS475 already grown in

tea plantations and used as controls. These trials are replications of the clonal trial established in Nyaruguru (Kibeho sector) in November 2018 comprising the clones namely UTK 9710342, UTK 401658A, Martim 1 and UTK 900244B along with clones currently used in commercial production of Rwanda, including TRFK 31/8, TRFK 6/8, BB 10 and TRFK 11/4. This is being brought into bearing. Activities consisted of infilling (replanting with plant eroded by rains), mulching in hilly sites like SORWATHE and rehabilitating water drains in marshland (ASSOPTHE).

Photo 28: ASSOPTE (Rulindo, Kinihira) site during the time of tea plant infilling (replanting) after soil erosion

Study on fertilizer recommendations

Yield data was collected from an ongoing trial that was evaluating effects of splitting fertilizer on soil nutrients and tea yield. It was established at Nshili-Kivu, Nyaruguru District in June 2015. Seven rates and frequency of application of NPKS 25-5-5-3 were as follows: T1: nil fertilizer application; T 2: 200 Kg /ha/year (i.e. 50 kg N/ha/year) in two splits; T 3: 400 Kg/ha/year (i.e. 100 kg N/ha/year) in two splits; T 4: 400 Kg/ha/year (i.e. 100 kg N/ha/year in two splits long with foliar application of urea (2 % i.e. 8kg of urea in 400l of water/ha) at monthly interval during July, August and September; T 5: 600 Kg/ha/year (i.e. 150 kg N /ha/year) in three splits T 6: 600 Kg/ha/year (i.e. 150 kg N /ha/year) in four splits; T 7: 800 Kg/ha/year (200 kg N/ha/years) in four splits. Cumulative yield (2019/2020) of 7 fertilizer rates and splits from zero fertilizer application to 800 Kg of NPKS 25-5-5-3 for 8 months is illustrated on the graph.

The yield ranged from 1078 to 1201 kg made (dried) tea but yield was not significant (at 5% level). It would indicate that tea was not responding to fertilizer within the observed period of time. The lowest fertilizer rate 200 Kg of NPKS 25-5-5-3 per ha per year or 50 kg N/ha/year in two splits produced highest yield (1811 kg made tea/ha/year) which was in the same range as the yield

from the highest rate 1800 kg made tea/ha/year. This would imply that, given the current status of the plantation, application of lower rates of nitrogenous fertilizers from 50 to 100 kg N/ha/year in two splits would be sufficient. However, this result should not be conclusive.

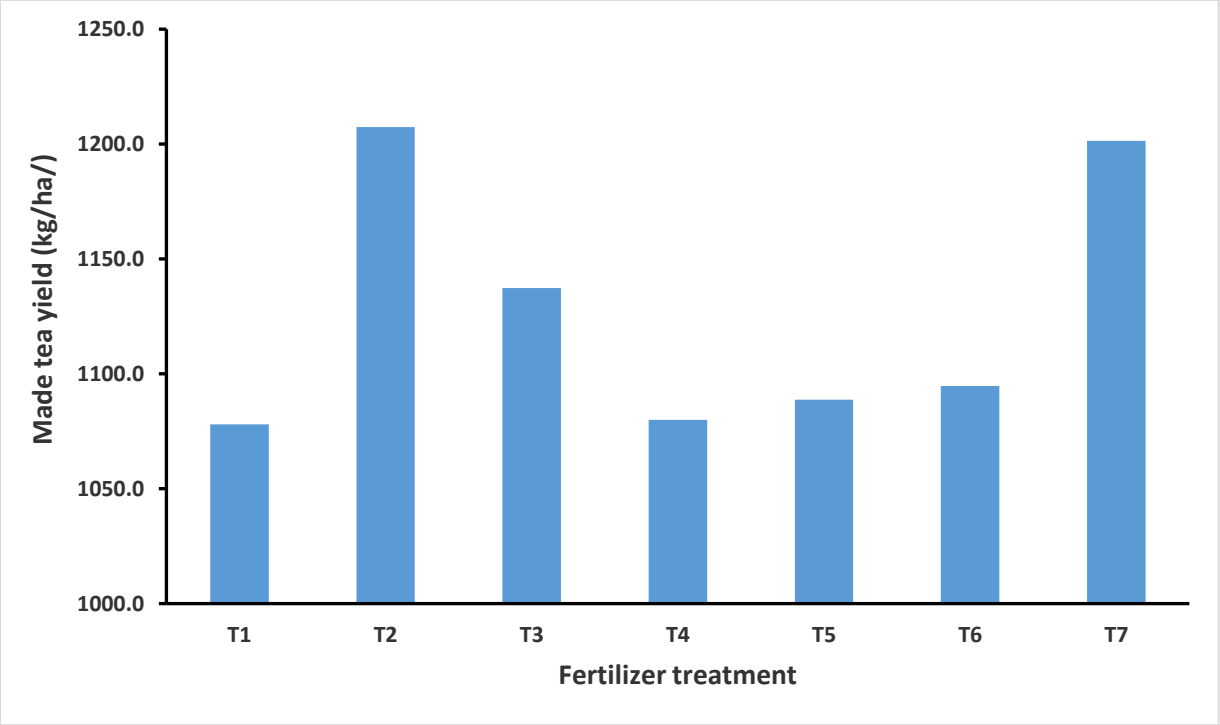

Figure 11: Yield of made tea as a result of application of various fertilizer treatment

1.7 CROP PROTECTION PROGRAM

Crop protection program is one of the programs operating under Crop Research and Technology Transfer Department and its main objective is to improve agricultural production through development and dissemination of pests and disease management technologies. The main activities include collects and regularly update information on pests and diseases situation in the country and develop programs and technologies for their management; capacity building of frontline extension agents and farmers; provide all information on the practices to control disease and pests in case of outbreaks and also make follow up for a better management of different grain stored insect pests found in seed storage facilities.

Following are main activities carried out in crop protection program in line with performance contract during FY 2019/2020.

- ✓ Monitoring and control of pests and diseases for priority crops through surveys for pests' presence and their identification.

- ✓ Strengthen advisory services for pests' management through development and distribution of extension materials, in area of crop protection, to beneficiaries and conduct mobilization campaigns.
- ✓ Capacity building of farmers and other extension agents on major pests and disease management (sector and district agronomists, CIP focal persons, farmer promoters, farmers) on management of different diseases & pests.
- ✓ Development of techniques on Pesticides safe use and handling and self-protection and disseminated to extension agents.
- ✓ Constitution of a strategic stock of pesticides to manage different identified pests in case of outbreak.
- ✓ Promote and strengthen plant clinic activities through Plantwise program.

Monitoring and control of pests and diseases for priority crops through surveys for pests' presence and their identification

Regular monitoring for pests' presence, their identification for different crops was done. Many interventions were done through field visits, meetings and community works in affected areas to manage identified pests especially FAW, maize leaf blight disease, MLN disease and grasshoppers in Maize; white grub pest in pastures; potato bacterial wilt and viral disease in Irish potato; thrips, fusarium, BXW and banana sigatoka in Banana; slugs and millipedes in Beans; mealybugs, fruit flies, anthracnose and powdery mildiou in Mango; alternaria, anthracnose, fusarium and phytophtora in Passion fruit and recommendations were given to farmers in order to manage those disease and pests. During seasonal survey, pheromones traps were used for FAW monitoring and AgriStrips were used for MLN disease diagnosis where among 731 samples collected in Bugesera, Burera, Gakenke, Gasabo, Gicumbi, Gisagara, Huye,Kamonyi, Kayonza, Kicukiro, Kirehe, Musanze, Ngoma, Ngororero, Nyabihu, Nyagatare, Nyamasheke, Nyanza, Rubavu, Ruhango, Rulindo, Rutsiro & Rwamagana, 138 samples were tested positive.

Strengthen advisory services for pests' management

Different Extension Materials on pests' management options have been developed for different crops. Fact-sheet on mango mealybugs, Powderly Mildiou and fruit fly; Fall armyworm for maize; Grasshopper ''*zenocerus ariegatus*''; powdery mildew of wheat and Desert locust identification and its management. Around 9,700 factsheets on pest management were distributed to beneficiaries.

Mobilization campaigns, radio talks (Radio Rwanda & Community Radio) on pest management were conducted especially on Fall army worm (FAW) pest and Mango mealybug across the country. RAB in partnership with CABI has organized and conducted an extension campaign through "Plant Health Rallies (PHR)" against FAW and 21,254 people from 14 districts were mobilized on

FAW identification, damage symptoms and its management and 6,389 people mobilized on Desert locust management options in all districts of Eastern province excluding Rwamagana.
Different technologies for pests and disease management were developed and are being evaluated. These include, pesticide evaluation trial for FAW, EPN research on FAW management, Trials on potato diseases…and Push pull strategy for FAW and maize stalk borer management.

Capacity building of farmers and other extension agents on major pests and disease management

Training modules on major pests and diseases management were developed for Mango pests; Fall armyworm identification and management; Pesticides safe use and handling and Desert locust identification, behavior and its management.
Training of extension agents including sector and district agronomists, CIP focal persons, farmer promoters and farmers on management of different diseases & pests was conducted. 1,571 farmers trained and mobilized on how to manage mango mealybugs, powdery mildew and mango fruit fly in 8 districts of Eastern province and Kigali City. Around 4,368 extension agents and security forces were trained on preparedness and response plan for Desert Locust in 7 districts including Nyagatare, Gatsibo, Kayonza, Rwamagana, Ngoma, Kirehe and Gicumbi.
30 community focal persons supporting on FAW monitoring and early warning system project using pheromone traps were trained on FAMEWS app on how to collect data from those traps and how to do field scouting while checking FAW in the maize fields.

Development of techniques on Pesticides safe use and handling and self-protection

Technical manual on pesticides safe use and handling was developed specifically on types of pesticides, labelling, mixing, loading, application, storage and disposal; personal protective equipment PPE and types of equipment to be used for pesticide application. Frontline extension agents were trained on pesticide safe use, handling and self-protection and above 5,939 people were trained.

Constitution of a strategic stock of pesticides to manage different identified pests

As strategic stock of pesticides, 8,000L of pesticide was purchased to be used in case of pests' outbreak across the country (especially for desert locust preparedness and response plan) including Cypermethrin 4%EC + Profenofos 40%EC, Lambdacyhalothrin 5%EC, Abamectin 18g/L EC and Fenitrothion 96%ULV. Around 3,676 L of pesticides were distributed to farmers specially to control Mango pests and to manage FAW and other pests during season 20A & 20B.

Plant clinics via Plantwise program

Sixty-six Plant clinics are operational now (32 being e-clinics). A total of 709 Farmers have received advice on plant problems management through Plant Clinic. A total of 35 Agronomist (31 Male and 4 Female) from Rusizi and Kayonza Districts trained on module I &II including field diagnosis, Plant Clinic operation and giving good advice on plant health problem management. Plant doctors in Rwamagana and Gicumbi 22 Plant doctors (Male: 15, Female:7) were backstopped. Regarding

linking of plant clinics to FFS and Twigire Muhinzi Groups, 65 Plant Clinics were running through linkage with FFS and Twigire Muhinzi group.

Biocontrol Laboratory

The benefit of using EPNs is that they can be easily mass produced in large numbers, they are non-toxic to the environment and are compatible with a wide range of chemical and biological pesticides used in IPM program. The mass production of EPNs is done in vivo or in vitro. Current research in our lab is to optimize the production and to screen for EPNs virulence against pest. EPNs being a soil inhabitant organism, the major limiting factor is their application to the leaf surfaces as their injuvenate juvenile IJs nematodes desiccate rapidly. The labs host one PhD student who is working on the efficacy of different formulation of nematode for FAW control on maize. During this fiscal year following activities were done.

Optimization Protocol for mass production of available EPN and their maintenance in the biocontrol lab.

Ten EPNs isolates (4 internationals and 6 local EPNs strains) were maintained in the biocontrol labs. They were checked daily for their mobility, vitality through the stereo -microscope. Some of the EPNs isolates were mass-produced through in-vivo process as shown in the table 1 below.

Table 38: Quantity of entomopathogenic nematodes (EPNs) produced at Rubona station

Scientific name	Code	Quantity of EPNs infective Juveniles (ijs)
Steinernema carpocapsae	RW-GR3a-2	74 933 648 IJs
Steinernema sp	RW-MC2b-1	23 994 970 IJs
Steinernema sp.	RW-MC2a-3	20 035 070 IJs
Heterorhabditis bacteriophora	RW-NC4a	8 952 500 IJs
Heterorhabditis sp.	RW18-M-1b	40 917 700 IJs
Heterorhabditis sp.	MD4S5Hr-1a	11 567 000 IJs
Steinernema carpocapsae	ALL	29 654 000 IJs
Heterorhabditis bacteriophora	HO6	16 948 000 IJs
Heterorhabditis indica	LN2	13 823 000 IJs
Steinernema Longidicum	X-7	I5 431 000 IJs
Steinernema carpocapsae RW14-G-R3a-2 isolated 2019	GR4	340 IJs
Total EPNs Produced		**246 257 228 IJs**

All the EPNs isolates were stored in cool place at 10^{o}C. The *in-vivo* mass production of nematode was based on the use of the alternative hosts, the wax moth, *Galleria melonella* (Lepidoptera: Pyralidae). As the EPNs shelf life is about 2 to 3 months, the rejuvenation was done continuously

by reinfecting *Galleria mollonella* to control the virulence capacity. Diet protocol using available local material was tested for optimum production of Galleria and gave promising result. In total 246 257 228 IJs were produced. The EPNs under 3 formulations were applied in 4 trials conducted at Rubona and on farmer's field in Nyamagabe in comparison of other control against FAW in maize; gel formulation appears to be promising. Rearing of *G. molonella* was conducted all over the year to avail continuously in the labs them in the labs from eggs, larvae to adult stage. The larva is used for reinfection, rejuvenation, symbiotic bacteria isolation and EPNs bait in searching for EPNs. More experience need to be done to optimize the EPNs mass production protocol.

Pesticide evaluation for different pests' management

- One efficacy trial is on evaluation of an insecticide called Radiant 120SC (Spinetoram) against fall armyworm and is being conducted in two different agro-ecological zones, one in Kicukiro district at Gahanga and another one in Rulindo district in northern part. Data collection activity is still ongoing.
- Another trial to evaluate an insecticide" Diatomous Earth" used to control stored grain insect pests is established at Rubilizi and Musanze stations and will also be evaluated at Rubona station. Data collection to evaluate the efficacy of that insecticide still going on.

Impact assessment of fungicide rates on late blight management

The trials for impact assessment of fungicide rates on late blight management have been established in Musanze and Rubavu districts and mainly objectives of this study are to evaluate the impact of late blight disease on potato yield, to confirm the efficient frequency of fungicide application for good management of Potato late blight and to determine the importance of fungicides application during season growing of potato. As expectations, at the end of experiment, two or three mancozeb (dithane M 45) application frequencies will be efficient for treatment of potato late blight. The efficient pesticide application frequencies will be sensitized to be used by the farmers for more economic control of the disease. The trial is still on g

1.8 AGROFORESTRY PROGRAM

Agroforestry research aimed to (i) Develop and scale-up agroforestry options for improved food security and resilient livelihoods, (ii) Select native tree species for multifunctional landscapes, and (iii) Climate sensitivity and reforestation of tropical trees.

Agro-forestry for Improved Food Security and Resilient Livelihoods

A total of 1,520 on-farm trials was established in Bugesera, Rubavu and Nyabihu districts (Table 39) and aimed to (i) assess the effect of tree biomass alone or combined with mineral fertilizers on crops yields (320 on-farm trials); (ii) determine the effect of agroforestry wood stakes on the

yield of climbing bean (250 on-farm trials); (iii) quantify the role multipurpose trees in soil conservation (856 trials in one agricultural landscape; and (iv) promote fruit-based agroforestry systems (mainly tree tomato) to increase income generation and nutrition in the households (94 on-farm trials).

Table 39: Types and number of participatory trials established at Bugesera and Gishwati

Types of trials	Bugesera	Gishwati
Biomass incorporation	214	106
Soil Conservation		3
Stakes for climbing beans	103	147
Tree tomato		94
Total	317	350

In total, 667 new trials were established and involved 1,554 farmers. The large number of trials was due to the set up on soil conservation trials in 3 agricultural landscapes at Gishwati with 1,222 farmers. Many farmers involved in participatory trials and beneficiaries of tree and fruit seedlings in the scaling up process of agroforestry technologies were profiled to understand their demographic profile, socio-economic status, current agroforestry practices, drivers and preconditions for adoption of agroforestry. At Bugesera and Gishwati, 85 and 162 farmers were profiled using Open Data Kit (ODK) tool, respectively. The trials assessed tree and fruit survival rates and crop productivity. Besides, tree management experiments were monitored to assess the long-term effects of agroforestry trees on crops, water and soil properties at Karama (Bugesera) and Tamira (Nyabihu).

Effect of wood stakes on climbing bean yield at Bugesera

It is known that climbing bean is generally more productive than climbing bean. However, stake quality that need to be used on climbing bean depends on tree species. Sources of staking materials used included Eucalyptus sp., *Calliandra calothyrsus, Senna spectabilis, Vernonia amygdalina, Gliricidia sepium, Grevillea robusta, Lantana camara* and *Leucaena diversifolia.* On farm trials of climbing bean with stakes from different tree species and bush bean as control were established in Musenyi, Juru and Nyamata in 2020A. Use of stakes significantly improved climbing bean yield as compared to bush bean, except for the plot where *Lantana camara* stakes were used, which yielded as low as bush bean control (0.65t/ha). Use of *Senna spectablis* and *Glricidia sepium* stakes resulted in highest yield with 1.9 and 1.6t/ha, respectively. In 2020B, the trial was repeated and expanded to Rweru and Mareba with the same stake types plus Markhamia lutea added. *Use of Gliricidia sepium* stakes produced the highest yield (2.1 t/ha), and *Vernonia amygdalina* lowest yield (0.6t/ha).

Effect of tree biomass incorporation and mineral fertilizer on maize yield at Bugesera

On farm trials were established in 4 sectors of Bugesera (Musenyi, Juru, Nyamata, and Mareba) and aimed to evaluate the effect of biomass applications combined with mineral fertilizer on maize yields in 2020A. Fresh biomass from various agroforestry species was applied to soil before planting alone or combined with mineral fertilizers (DAP and Urea), while non-fertilized plots were as control. The tree biomass types included *Senna spectabilis, Gliricidia sepium, Vernonia amygdalina* and *Lantana camara*. Use of biomass application alone resulted in doubling maize yields as compared to non-fertilized control in all sites (data not shown). Maize yields from fertilized plots were 2-3 times higher than the yields in control. Use of tree biomass of all species combined with mineral fertilizers led to highest maize yields in all sites, with highest effect at Musenyi (10 to 11.6t/ha).

Fruit trials for improved nutrition and income generation

Fruit trees (tamarillo, avocado, mango and pawpaw, distributed and planted between November 2018 and March 2019, were assessed for survival rate and growth performance at Rweru, Musenyi, Nyamata, Mareba and Juru sectors of Nyamata. Although the overall survival rate was nearly 75%, there were important differences between species and sites (Figure 12). In Juru, 95% avocado and only 26% tamarillo survived. In Mareba, both of these species survived with more than 80%. Musenyi had good survival of avocado, Nyamata – tamarillo and mango, and Juru – tamarillo (Figure 12). Therefore tree tomato appeared to adapt to the majority of the sites after planting. Growth performance (crown, basal diameter and height) by using Open Data Kit (ODK) tools was assessed for tamarillo through a survey which included 390 trees in 78 households. Basal diameter and total height were measured on all trees in the farm and diameter at breast height (DBH) measured for only trees with height above 1.3 m. Results are shown in Table 40.

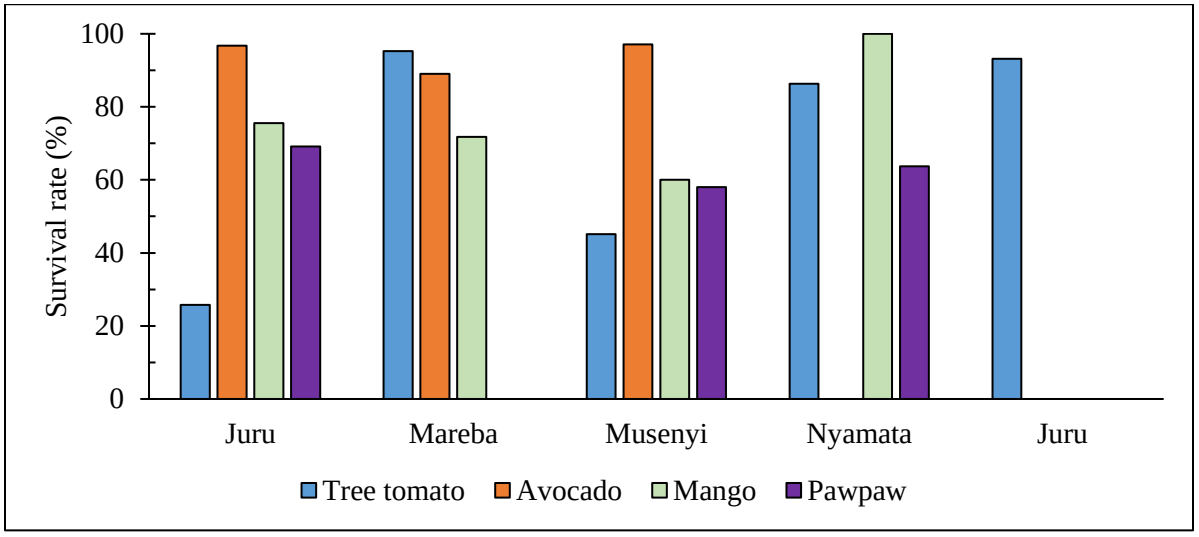

Figure 12: The survival rate (%) of fruit species in five sectors of Bugesera district

Table 40: Growth of tamarillo tree in Bugesera sectors, 9 to 12 months after planting

Site	Number of Households	Number of Measured trees	Mean Crown Diameter (cm)	Average Height (cm)	Mean Basal Diameter (cm)	Mean DBH (cm)
Juru	13	65	140.75	190.79	4.42	2.62
Mareba	14	70	140.93	188.41	4.26	2.67
Musenyi	44	220	127.01	192.32	5.57	2.42
Nyamata	3	15	48.07	61.40	2.05	1.43
Rweru	4	20	138.85	187.65	4.07	2.36
Total	**78**	**390**				
Overall average			**119.12**	**164.12**	**3.95**	**2.43**

Tamarillo trees had similar size of crown, diameter and height in all sites except Nyamata where trees were smaller and 4 months younger (Table 40). Age of tamarillo tree maturity and fruit number per tree were recorded. Trees reached maturity and produced fruits at 9-11 months after planting with single tree producing 16-66 fruits depending on site conditions (Table 41).

Fruit production was 159 kg per household per season. At the time of the assessment, the average selling price was nearly 500 FRW and the average income was 88,300 FRW. Therefore, the results of survey indicated that the average incomes were greater than expenses per household where the revenues per household and per season amounted to about 60,300 FRW.

Table 41: Estimates of fruiting age and average number of fruits per single tree tomato

Site	Number of surveyed households	Average age of maturity of tree tomato fruits (Months)	Average number of fruiting trees	Average number of fruits per tree
Juru	13	10.8	162	51
Mareba	14	9.5	326	46
Musenyi	44	9.9	33	43
Nyamata	3	10.3	4	16
Rweru	4	9.0	347	66
Total	**78**			
Mean		**9.9**	**145**	**44**

Profitability study of tamarillo

In a separate study, the profitability of tree tomato cultivation at model farm level in Bugesera district was conducted. It used the data collected for a period of four years (2015-2018). The data were grouped according to four harvests a year corresponding to the seasonal harvests in a year associated in general with tree tomato. The cost benefit ratio for the whole period of study was 4.36. This implied that the revenue from each 1 FRW invested in tree tomato cultivation was 4.36 FRW on average for each harvest or for a period of 3 months. However, when 12 harvests were taken together, tamarillo was less profitable for harvest 1 (January, February and March) and the cost benefit ratio was 4.06 and was more profitable for harvest 4 (October, November and December) at the cost benefit ratio of 17.41. For harvest 2 and 3, the profitability of the tree tomato cultivation was almost the same: the cost benefit ratio was 7.09 for harvest two (April, May and June) and 7.19 for harvest three (July, August and September). Thus, depending on the variety and pruning practices, tamarillo may be ready for harvesting from March or April. Not all the fruits ripen at the same time, and the season may continue as late as early December for late maturing crops. In addition, the new season growth began in October with shoot that originated in the axils of the previous season's leaf scars. There should be more investment in tamarillo production quality and quantity to meet market requirements and demand.

Tree and fruit seedling production and distribution in Bugesera

The management of Karama Rural Resource Centre (RRC) and satellite nurseries enabled the production of 249,922 tree and fruit seedlings of which 224,073 were distributed to 1,973 households for planting on their farms during the period of October to November 2019. Karama RRC produced 54,918 seedlings. Fruit seedlings of guava and grafted avocado were only 1,550. In partnership with community-based groups, 6 farmers cooperatives/groups were supported in Bugesera to establish satellite nurseries across 5 sectors of Bugesera (Juru, Rweru, Mareba, Musenyi and Nyamata) where 195,004 seedlings were produced (80,930 fruit seedlings and 114,074 agroforestry multipurpose tree species). Of the total production in satellite nurseries 181,382 distributed to 1,973 households, schools and church organizations in Bugesera district. Fruit seedlings distributed to these different types of beneficiaries comprised 17,172 tamarillo, 15,106 grafted avocado, 10,698 grafted mango and 18,971 pawpaw. The multipurpose tree species disseminated from satellite nurseries included 45,336 *Grevillea robusta*, 20,734 *Calliandra callothyrsus* and 18,118 *Gliricidia sepium*.

Evaluation of the performance of farmer trials at Nyabihu and Rubavu districts

At various sites in Nyabihu and Rubavu districts, assessments were made on tree and fruit survival rates after planting and data on yields of crops were collected and analyzed to quantify the effects of tree biomass incorporation and the use of wood stakes on the yields of crops. The performance

of tree tomato was also evaluated by providing information of growth parameters and fruit production across a range of farms.

Assessment of fruit and agroforestry tree survival at Rubavu and Nyabihu

The survival rates of 2 agroforestry species, Alnus acuminata and Acacia angustissima, and 3 fruit species, tamarillo, avocado and mountain papaya, were assessed in 49 farms at Karago (Nyabihu), at 27 farms at Nyundo (27 farms) and 29 farms at Nyakiliba sectors (Rubavu). Survival rate of fruit species was greater than 85% in all sites (Figure 2). The majority of the fruit species were planted in the home compounds or as orchards across the surveyed farms. High survival rates reflected the importance of fruits for nutrition and income as the farmers applied the required management practices to increase tree survival after planting. The more common practices by the farmers included weeding, fencing, watering, fertilization and pesticide applications.

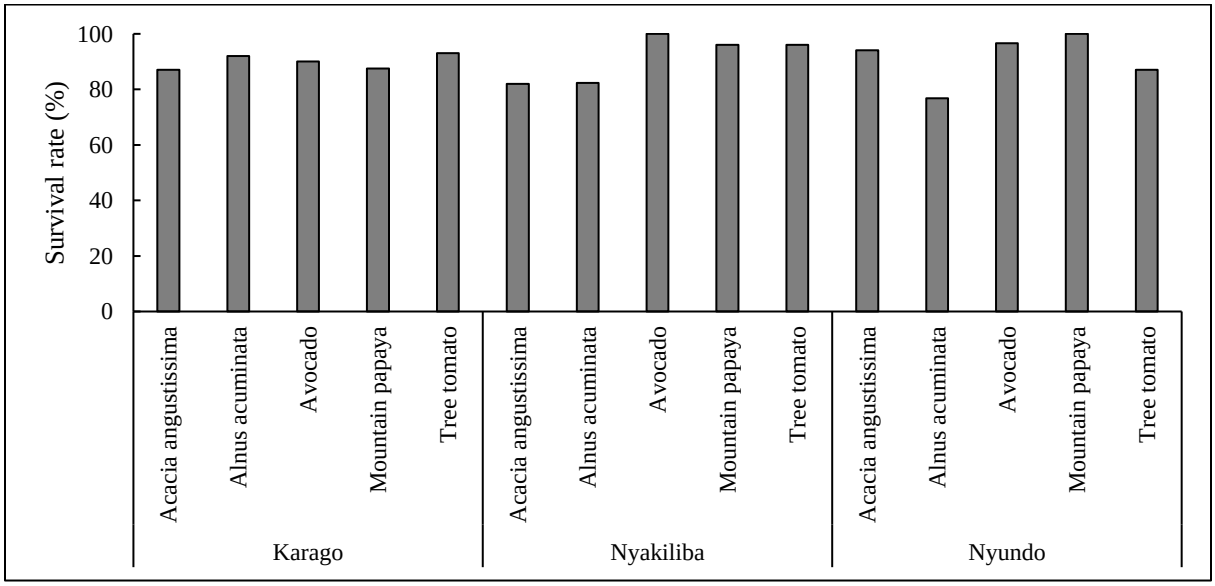

Figure 13. The survival rate (%) of three fruit species and two agroforestry multipurpose tree species planted at Karago, Nyundo and Nyakiliba sectors

The survival rates of agroforestry multipurpose tree species planted at various farms at Karago, Nyakiliba and Nyundo sectors were satisfactory. The survival rates below 85% was found on Acacia and Alnus planted at Nyakiliba, and on Alnus at Nyundo farms.

Tree biomass and mineral fertilizer application for Irish potato and maize yield at Nyabihu

Irish potato: At Karago (Nyabihu), 23 on-farm trials were set out to evaluate the effect of the incorporation of Alnus biomass and NPK17-17-17 on Irish potato yield as compared to farmer' practice in potato cultivation. Combined NPK with Alnus biomass plots produced the highest yield, 13.7t/ha, followed by NPK alone (10.8t/ha) and farmer' practice plot had 8.8t/ha. Untreated plots

(no fertilizer) produced low yield of potato (8.6 Tha^{-1}) similar to plot with Alnus biomass alone. Thus, Alnus biomass alone could not substantially improve soil fertility nor increase potato yields, and NPK inputs are needed.

Maize: At Nyundo sector, Rubavu district, the analysis of maize yields gathered from 28 farm trials assessed the effect of Alnus biomass and NPK17-17-17 as compared to farmer practice. Alnus biomass applied to soil in combination with NPK produced the highest yield (3.9 t/ha) as compared to plots with NPK alone or Alnus alone that produced 2.2 t/ha.

Effect of wood stakes on the yield of climbing bean at Nyabibuye Sector, Rubavu district

The effect of the use of wood stakes on the yield of climbing bean was investigated through the set up and evaluation of 16 farmer trials established at Nyabibuye, Rubavu district. The farmer trials compared the yields of bean when Alnus stakes and Pennisetum stakes were used. The yield achieved was not statistically different and averaged 2 Tha^{-1}.

Assessment of trials on fruits for improved nutrition and income generation at Gishwati

Tree tomato was among the fruit trees promoted and evaluated for growth performance. At Karago, the average total height and diameter of tree tomato were 1.94 m and 3.90 cm, respectively. However, there was a very high significant difference in the growth parameters among the farmers. Taller plants of tree tomato had 2.4 m while the shorter recorded 1.5 m. The diameters of tree tomato ranged from 2.2 cm to 4.7 cm.

The average crown diameter was about 1.6 m but the difference among the farmers was highly significant ($p<0.001$). It ranged from 1.1 m to 2.3 m. The crown diameter was positively correlated with the tree tomato total height in almost 63% of the cases and with the number of fruits produced in 40% of the cases. The average number of fruits produced per tree was about 100, with no significant differences among farms ($p>0.05$). Similarly, the correlation between the root collar diameter and the diameter at breast height was positive and significant for nearly 48% of the cases but the later was negatively correlated with the number of fruit per tree. This implied that tree tomato with smaller DBH tended to produce less number of fruits. Vigorous trees, measured by their RCD, were likely to produce higher number of fruits in 34% of the cases.

Assessment of the effect of trees on crop, soil and water in the agroforestry long term trials established at Karama and Tamira

During the cropping season 2020A, the key activities were conducted in the long-term trials included the assessments of effect of tree management on crop (Irish potato, wheat, maize) yields in the long term trials established at Tamira (Rubavu district) and Karama (Bugesera district). The objective of these trials was to assess the effect of tree cover change on soil fertility, water and crop productivity in semi-arid and sub-humid regions of Rwanda.

At Tamira long-term trial, Alnus tree management consisted of: (i) branch pruning at 75% and (ii) branch pruning at 90%, referred as farmer practice. These pruning levels and associated sub treatments of alnus green manure application (at a rate of 7.5 Tha-1 DM) and without biomass incorporation were compared for their impact on Irish potato yields. The results of the study (Figure 3) indicated that:

- The lowest potato yields were obtained in treatments with 75% branch pruning;
- There was no significant effect of incorporated green manure on potato yields under both pruning treatments (75% and 90% branch pruning of Alnus). However, the treatment with 90% Alnus pruning produced significantly higher yield (7.3 tha^{-1}) than the treatment with 75% branch pruning (6.3 Tha^{-1});
- *Alnus acuminata* green manure produced higher potato yields ($P<0.05$) in the plots with no trees. In the plot with no trees, the treatments with green manure recorded significantly ($P<0.05$) higher yield (9.2 Tha^{-1}) than its homologue with no green manure incorporation (8.45 Tha^{-1}).

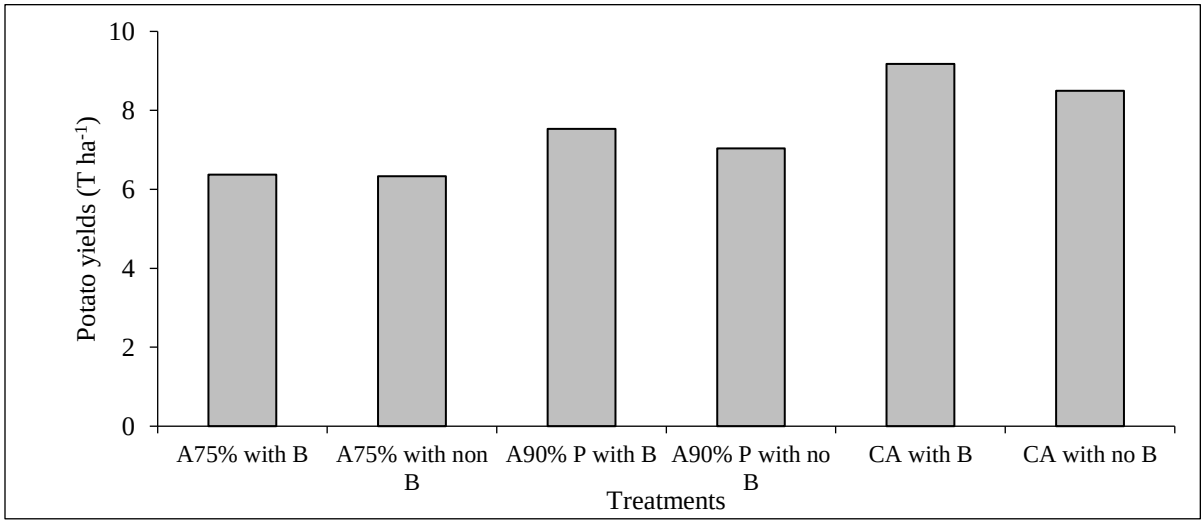

Figure 14. Effect of tree pruning and incorporated Alnus green manure on potato yield (Keys: A=Alnus; B=biomass; NB=non biomass incorporated; CA=crop alone)

The treatments described above were also applied to wheat crop in the same long term experiment. No results are available yet, as the trial is on-going. The following pictures depict the progress of the trial. Likewise, in Tamira long term trial, maize crop planted in Karama long term experiment is still young and data collection in line with growth parameters is on-going. Treatments consisted of two levels of Grevillea pruning (50 and 75% branch pruning). All the data will be compiled after harvesting and results reported through paper writing. The available tree species on site consists of *Grevillea robusta*, *Markhamia lutea*, *Faidherbia albida* and their combination. A plot with crop alone was also included in order to compare the performance of maize under trees and in the plots without trees.

Scaling up agroforestry practices at Gishwati

The adoption of agroforestry practices by Gishwati farmers was increased by conducting training of trainers in agroforestry and by producing and distributing tree and fruit seedlings for management in different agroforestry systems.

Training of trainers in agroforestry practices

The training of farmer trainers in agroforestry was organized in collaboration with Urugaga Imbaraga in the context of the Trees for Food Security Project supported by ICRAF. Training on quality germplasm testing for agroforestry typology and Training on tree propagation methods were organized for 60 farmers and 27 farmers, respectively. The trainees on quality tree germplasm testing for agroforestry typology comprised 19 male farmers, 30 female and 11 young people to represent the youth category. Training on tree propagation methods benefited 13 male farmers, 8 female and 6 young people. In total, 87 farmers were trained. Training on quality tree and fruit germplasm testing or Agroforestry typology aimed at improving knowledge on the importance of quality tree seed and seedlings by presenting and discussing the quality aspects, seedlings germination management and seedlings development, nursery establishment and management, tree and fruit seeds and seedlings businesses and the importance of trees and fruits in the livelihood and landscape restoration.

The training on propagation methods focused on vegetative propagation notably by cuttings and grafting propagules. Handling techniques such as phytosanitary issues including -prevention, treatment and control of pests and diseases were presented and discussed.

Production and distribution of tree and fruit germplasm

In 2019-2020, the total of 190,556 tree and fruit seedlings were produced at Karago and Nyundo sectors. The number of agroforestry tree and fruit seedlings produced were 118,511 and 72,045 respectively. About 163,300 seedlings comprising 112,700 seedlings of *Alnus acuminata* and *Acacia angustissima*, and 50,600 seedlings of three fruit species (pawpaw, avocado, and tree tomato) were distributed to various groups including individual farmers, school and church organizations. The fruit seedlings were planted by 2,124 households of whom 68.5% were registred in Karago and 31.5% in Nyundo.

The Agroforestry tree seedlings were planted by the farm owners for soil conservation and erosion control. The total number of farmers who planted *Acacia angustissima* was 743 of whom 586 were Karago farmers and 157 Nyundo farmers. *Alnus acuminata* was planted by 631 farmers distributed as follows: 415 farmers at Karago and 216 farmers at Nyundo.

Umuganda was used as an approach to planting tree seedlings for soil conservation and erosion control at landscape scale at Karago and Nyundo. At Karago, 5000 seedlings of Alnus and 15,350 seedlings of Acacia were established for the benefit of 166 households. At Nyundo, only 5,300 seedlings made up of 3000 seedlings of Alnus and 2,300 seedlings of Acacia were planted in the agricultural landscape exploited by some 34 households. The management of the planted seedlings will provide wood stakes and fuelwood to farmers as co-benefits from the main objective of soil conservation and erosion control.

Selection of native tree species for multifunctional landscapes supporting food security in agro-ecological regions of Rwanda

This study was carried out to analyze: (i) Vegetation types in relation to topography, environment and tree traits, (ii) ecosystem services provided by trees from different vegetation types and environments as well as trees with different traits and (iii) the multi-functionality of different species based on their potential ecosystem services.

Vegetation types vs topography, environment and traits

The results showed clear difference both in elevation, climate and traits between species from different Potential Natural Vegetation (PNV). PNV was based on characterizing which species are adapted to certain climatic regions, but are not necessarily there today, thus indicating what they could potentially be the natural vegetation in the specific area. The highest precipitation increased significantly with increasing upper elevation range of the species ($p = 0.037$) while low precipitation and low elevation range did not correlate significantly. The maximum tree height increased significantly with elevation until it reached a maximum at approximately 2700 m, where after the tree height declined (Figure 15 a-d). The wood density increased significantly with decreasing lowest precipitation range, while both tree size and wood density have implications for wood quality and carbon storage capacity, but they have opposite relationship to elevation and precipitation, as precipitation is increasing with elevation. The fruit size decreased with increasing elevation ($p = 0.061$) and increasing maximum tree height $p = 0.013$), although only nearly significant for elevation. Most trees at high elevation therefore have smaller fruits, although there are exceptions. As expected, the frequency of montane species according to both Kindt et al. 2014 and Blosch et al 2009 is significantly higher at elevation class > 2000 m a.s.l. ($p = 0.001$).

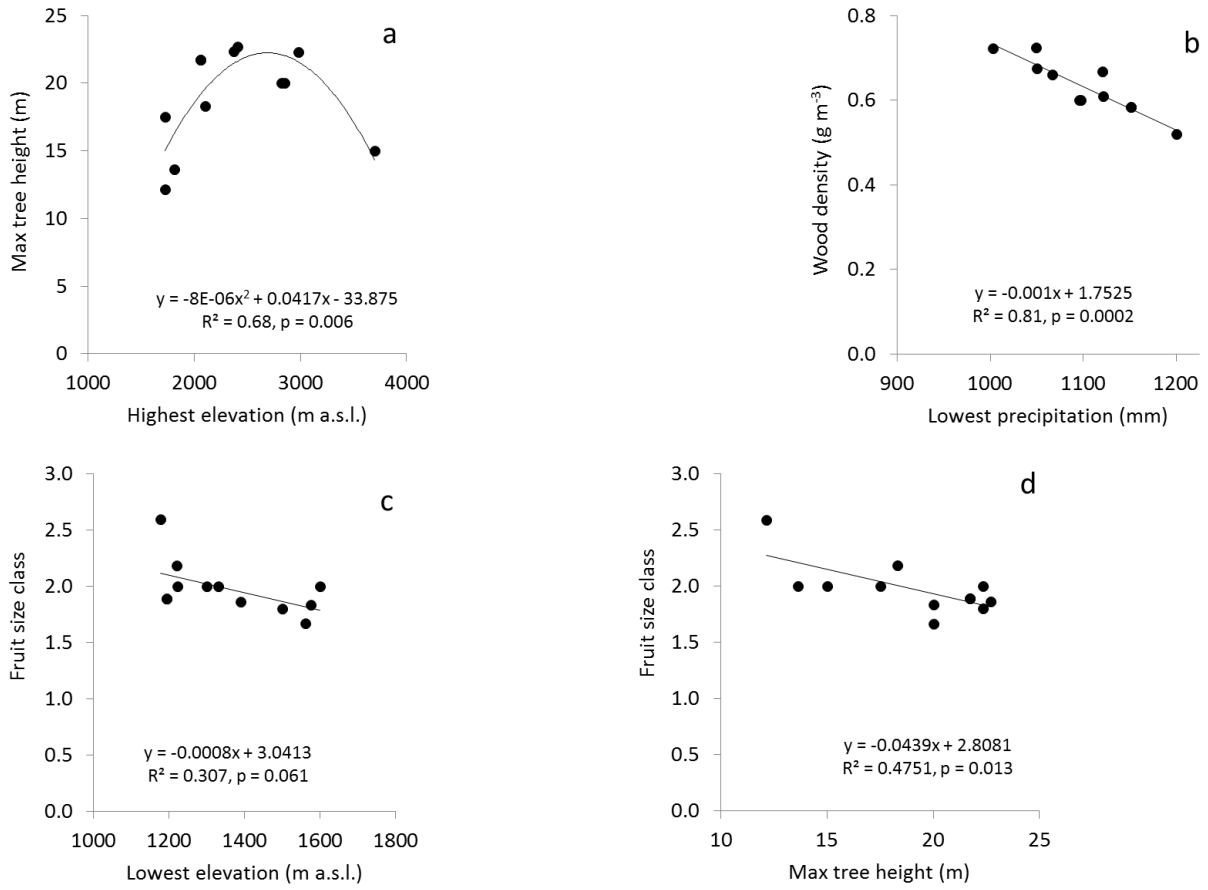

Figure 15 a-d: The maximum tree height versus highest elevation where the species occur (a), wood density versus lowest precipitation requirements of the species (b), fruit size class versus lowest elevation where trees occur (c), and fruit size class versus maximum tree height (d). All values are the average for the selected species within a vegetation type according to Kindt et al. 2014.

Ecosystem services

Most commonly among the selected species were the provision of medicine (83%) and for constructions (79%) followed by fuel (68%) and edibility (58%). Cultural and supporting ecosystem services were documented at 56% and 53 % of the species respectively, while regulating services were only provided by 31% of the selected species (Table 42). Tree species providing food and fodder are significantly more frequent at elevation < 2000 m compared to ≥ 2000 m a.s.l. (p = 0.054 and 0.024, respectively). This is also supported by a significantly lower frequency of fodder providing trees in montane forest compared to other PNVs. Tree species providing packing material and handicraft are more frequent at high compared to lower elevation (p = 0.003 and 0.011, respectively) and trees providing building material are more frequent in montane forest.

Table 42: The number of species in different vegetation types (montane/others) and environments (elevation classes and their lowest precipitation) in relation to different documented provisioning services by the species occurring in these types of vegetation[3] and environments

	Vegetation type (Kindt et al.2004)				Vegetation type (Bloesch et al.2009)				Altitude (masl)				Min.precipitation (mm/year)			
	n	Montane	Other	P	n	Montane	Other	P	n	<2000	>2000	P	n	<1200	>1200	P
Food	42	23/26	19/13	0.386	41	17/21	24/11	0.07	42	24/13	18/26	**0.054**	42	21/23	21/16	0.557
Fodder	20	5/44	15/17	**0.001**	19	5/33	14/21	**0.019**	20	14/23	6/38	**0.024**	20	7/37	13/24	0.082
Firewood	53	29/20	24/8	0.221	49	5/33	26/9	0.317	53	28/9	25/19	0.123	53	28/16	25/12	0.892
Charcoal	32	20/29	12/20	0.947	29	17/21	12/23	0.501	32	16/21	16.28	0.687	32	15/29	17/20	0.39
Clothes	9				9				9				9			
Packing material	11				10				11	0/37	11/33	**0.003**	11	7/37	4/33	0.733
Poles	26	13/36	13/19	0.278	24	11/27	13/22	0.62	26	13/24	13/31	0.766	26	13/31	13/24	0.766
Building material	43				40	26/12	14/21	**0.028**	43	16/21	27/17	0.16	43	23/21	20/17	1
Furniture /tools	46	32/17	14/18	0.092	42	25/13	17/18	0.211	46	18/19	28/16	0.258	46	28/16	18/19	0.258
Handcraft	33	23/26	10/22	0.241	30	20/18	10/25	0.064	33	9/28	24/20	**0.011**	22	22/22	11/26	0.105
Medicine	67	40/9	27/5	0.985	60	29/9	31/4	0.289	67	32/5	35/9	0.597	67	36/8	31/6	1

n = the number of species with a documented service

Tree species providing fodder has commonly larger fruits compared to species that has not been documented to provide fodder, although only nearly significant (p = 0.054; Table 42). Tree species used for charcoal production have higher wood density (≥0.6 g cm^3), while those used in clothes production more frequently have lower wood density (<0.6 g cm^3; p =0.032 and 0.016, respectively). Species providing material for packing, building, furniture and tools, as well as handcraft are frequently taller (max height >20; p = 0.006, 0.002, <0.001 and 0.037, respectively) than trees not providing these goods. In addition, species providing building material are more frequently slow growing trees (p =0.04). Other provisions were not significantly related to vegetation type, elevation, minimum precipitation, tree traits or successional class.

Tree multi-functionality: In the multi-functionality assessment, 17 out of the 81 selected tree species provided ecosystem services in all four main categories: provision, supporting, regulating and cultural (Table 43).

[3] Bloesch, U., Troupin, G. & Derungs, N. (2009). *Les Plantes Ligneuses du Rwanda. Flore, Écologie et Usages.* Shaker Verlag, Aachen, Germany.

Kindt, R. P., van Breugel, J.P., Lillesø, B., Minani, V., Ruffo, C.K., Gapusi, J. R., Jamnadass &. Grauda, L. (2014). *Potential Natural Vegetation of Eastern Africa (Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia) Volume 9". Atlas and Tree Species Composition for Rwanda.* Department of Geoscience and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark, 2014.

Table 43. *Species ecosystem services in 4 main categories (provision, supporting, regulating and cultural).*

		Fraction of ecosystem services a species contributes (%)					
Scientific name	Family	Aggregated	Provision	Support	Regulating	Cultural	All Ecosystem Services
Trema orientalis	Cannabaceae	100	57	29	14	40	43
Afrocarpus falcatus	Podocarpaceae	100	43	57	29	20	40
Albizia gummifera	Fabaceae	67	35	57	43	40	40
Albizia adianthifolia	Fabaceae	83	39	57	29	20	38
Ficus thonninghii	Moraceae	83	39	43	14	60	38
Acacia polyacantha	Fabaceae	83	35	43	43	20	36
Acacia seyal	Fabaceae	83	39	43	14	20	33
Markhamia lutea	Bignoniaceae	50	30	57	14	40	33
Acacia sieberiana	Fabaceae	67	30	43	14	40	31
Cordia africana	Boraginaceae	67	22	57	14	60	31
Hagenia abyssinica	Rosaceae	67	35	14	29	20	29
Lannea chimperi	Anacardiaceae	100	35	29	14	20	29
Prunus africana	Rosaceae	50	30	14	29	40	29
Acacia gerardii	Fabaceae	67	26	43	14	20	26
Vepris nobilis	Rutaceae	50	26	14	29	20	24
Albizia amara	Fabaceae	67	22	29	14	20	21
Enebergia capensis	Meliaceae	50	17	14	29	20	19

The fraction of services for all services and within each category is given as percent. Eighteen species contribute to at least five out of six aggregated provision categories. The fraction of services for all services and within each of the main categories is given as percent. However, only seven tree species were in common provision category between the two assessment criteria: *Acacia polyacantha, Acacia seyal, Afrocarpus falcatus, Albizia adianthifolia, Ficus thonningii, Lannea schimperi*, and *Trema orientalis*. These species represented different agroecological zones and successional stages.

The study showed that medicine, building material, firewood and food respectively were the main provision services. Due to the variability in topography, precipitation and other environmental variables the country hosts many different vegetation types contributing to high biodiversity. The study showed that traits of tree species (height, wood density, fruit size etc) varied between vegetation types and climate regions of Rwanda. These traits are linked to the provision of different ecosystem services directly linked to food security. On the other hand, native trees provided material for buildings, handicraft and packing as well as shade for tea and coffee plantations suggesting that trees from the higher elevations will support income beside the food production in an agroforestry system and thus indirectly increase the food security for individual farmers. However, it has to be noted that the analyses of ecosystem services provided by different species are based on current documentation, which may be biased due to the traditional use of the trees in different regions. One example, historically more agriculture at lower elevations has resulted in larger demand for fodder in these regions. It is therefore important to continue searching for traits among tree species that guide the use of new species for different ecosystem services.

This study showed that a number of species that had a very wide range of ecosystem services, indicating that they are well suited to support multifunctional landscape development and as such can provide several ecosystem services, such as additional sources of food, medicine, climate change mitigation and adaptation and income for households in different ecological regions of Rwanda. This suggests that native tree species in Rwanda can play an important role in complementing agricultural production in providing better and more nutritionally-balanced diets. As different types of agroforestry have positive impact on climate mitigation and adaptation and food security, the use of native tree species could establish self-sustaining ecosystems and their services, with the added advantage that native species are adapted to local biotic and abiotic conditions and thus support native biodiversity and ecosystem function to a greater degree than exotics used in agroforestry systems predominantly.

At the landscape level, the review indicated that the selection and involvement of native trees species is also a key multifunctional land-use practices for enhancing food security, because trees can provide fruits and other forest- and tree-based diets. Trees can also support ecosystem services (stable hydrology, water quality, soil quality, carbon storage, biodiversity). Trees in addition can enhance long/term sustainable food production and can improve and sustain crop and livestock production. Based on these results people can select species according to the planting objectives (ecosystem services) that trees offer and species suitability in relation to topography and environment as well as tree traits.

The question about why native trees species are less used in the plantation efforts of Rwanda is due to lack of knowledge on the suitability of native tree species in different agro ecological regions of Rwanda. Many people think that native species are slow growing because they don't have database characterizing native tree species with regard to the growth rate and dimension of trees. Another reason of not choosing native species for the plantation is the lack of knowledge of their ecosystem services. This should be answered using our review based on traits and function of native tree species to determine which species are suitable at which location.

Based on literature review of our study, tree species should be characterized by their products that support sustainable commercialization in the smallholder farming system intensification, and integrate tree management with value chain development and landscape beautification. Fulfilling this, development and landscape planners will have multiple benefits for poor people, such as improved food security and smallholder livelihoods through transforming practices toward more efficient land use, improved hydrology, climatic cooling, prevention of soil erosion, landscape beautification and the provisioning of a broad range of tree products and cultural values. They also can enhance widespread adoption of agroforestry technologies in smallholder farm land for increased crops and trees production. This review can guide the planning of tree plantation activities and climate change adaptation in Rwanda and also provide practical advice to smallholder farmers and unemployed youth with business opportunities, for tree seedlings production and commercialization of crop/trees produced products.

Climate sensitivity and reforestation of tropical trees

An experiment to assess the sensitivity of physiology of 20 native tree species to drought and heat was established in December 2017 in 3 sites at Sigira (altitude 2400 masl, mean temperature 14.6 °C, rainfall 1750 mm, Nyamagabe), Rubona (1600 masl, 19.1 °C, 1230 mm, Huye) and Ibanda-Makera (1300 masl, 21.0 °C, 850 mm, Kirehe) to represent altitudinal gradient as Montane rain forest (Nyamagabe), Transitional rain forest (Rubona) and Evergreen and semi-evergreen bushland and thicket (Kirehe). These sites offer potential to study temperature responses of plants and ecosystems under ecologically realistic conditions.

Twenty native species were (10 climax and 10 pioneers) from Nyungwe National Park, referred here as "Afromontane rainforest species" (high elevation) and from Ruhande or Rubona defined here as "Transitional rain forest species" (mid elevation) were selected and propagated in the Rubona tree nursery (Table 44). 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 had a stronger negative effect on growth in climax species than in pioneer species.

Table 44. 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*
Harungana montana	*Entandrophragma excelsum*	*Croton megalocarpus*	*Markhamia platycalyx*
Macaranga kilimandscharica	*Faurea saligna*	*Dombeya torrida*	*Newtonia buchananii*
Maesa lanceolata	*Ficus thonningii*	*Harungana madagascariensis*	*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 per species were planted, with 18 plots of 100 plants and 3 replicates. Maintenance, including irrigation and fertilization was done at all sites. Height and mortality rates data were collected (Figures 16 and 17). Early succession species grow better in height at warmer sites except *M. kilimandscharica* (Figure 16). Several of the late successional species have similar or lower growth in low and high temperature sites. Tree mortality was higher at warmer sites as compared to cooler sites (Figure 17). Mortality was variable among the tree species, but many species that had similar or lower growth at low and high temperature, showed higher mortality at high temperature. The species having higher mortality hare are mostly late successional species.

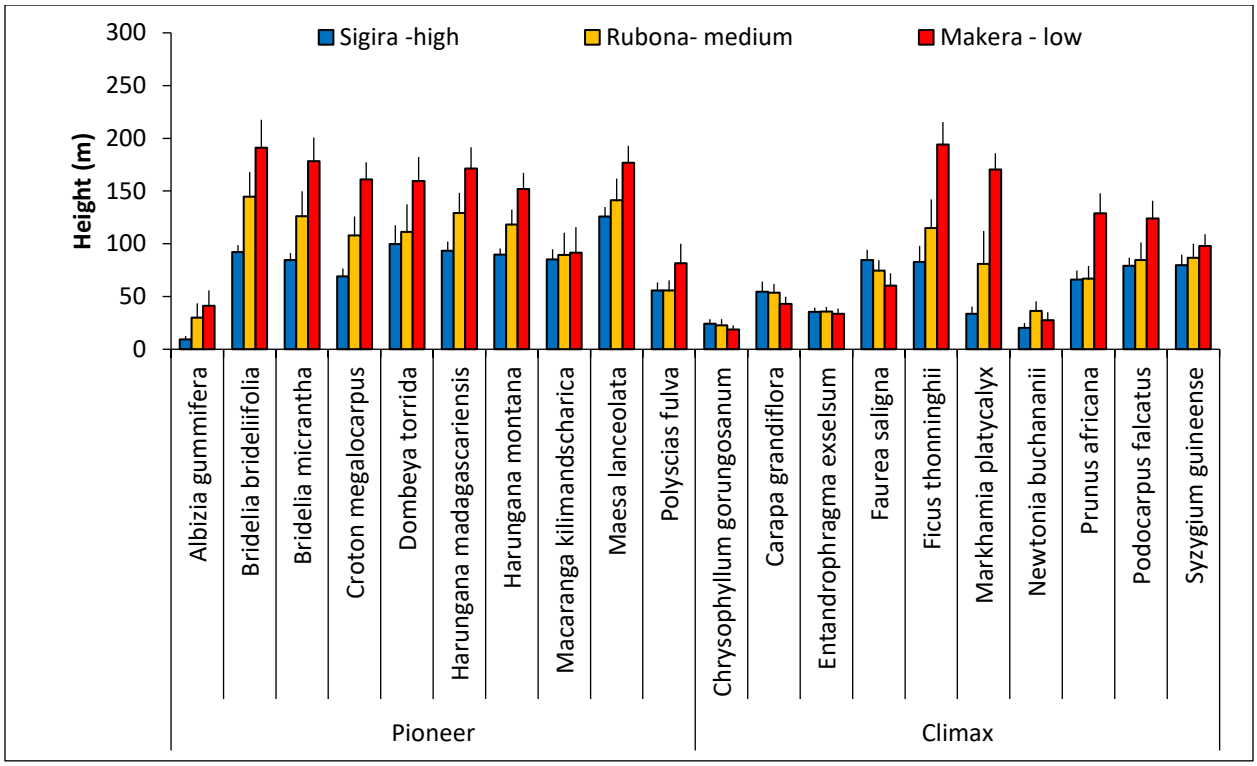

Figure 16. Height of pioneer and climax tree species at Sigira, Rubona and Makera, 1.5 years after planting

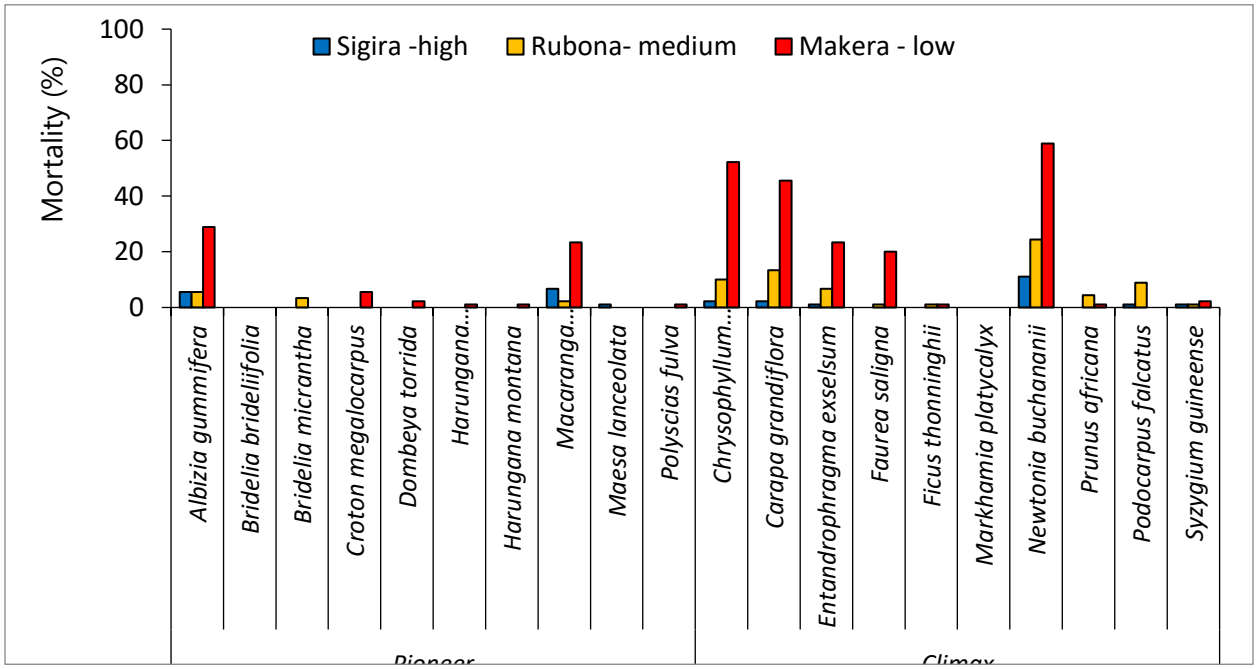

Figure 17. Mortality rates of pioneer and climax tree species at Sigira, Rubona and Makera, 1.5 years after planting

1.9 MECHANIZATION PROGRAM

The mechanization activities aim to promote use of farm machinery in different farming operations for rural farmers, develop local skills and strengthen capacity in agricultural mechanization. For the agricultural mechanization, national goal was to achieve 25% of operations (land preparation, planting, crop treatment, harvesting, post-harvest handling, agro-processing) to become mechanized by 2017, allowing one in every four Rwandan farmers to access mechanization services.

Private sector involvement in mechanization service provision started in 2013. To date (FY 2019-2020), a total of 24 service providers operate. Six of them are new and started during 2019-2020: OUSAC, BUNGABUNGA UBUTAKA, TRIOMF, REDEM LTD, ALPHA AGRITEC and Mr Pascal.

In terms of land coverage with various mechanization activities in 2019-2020, over 40,000 ha of farmland have been tilled, 11000 ha for seeding, 9000ha of crop treatment and 6000 ha of harvesting countrywide through public and private hiring services, and different farmers/cooperatives started adopting the use of farm machinery in their daily farm activities. Rwanda today is close to achieve 25% of mechanized farm operations and they are planned to reach 50% by 2024 (PSTA-4).

During FY 2019-2020, agricultural mechanization was expanded and used on 7,253.5ha versus planned 6,500ha. A total of 458 tonnes baling of hay was produced, and 82.6 tonnes of Irish potato was harvested with use of mechanized machinery. A total of 780ha of Irish potato was planted using mechanization and 557 tonnes were dried after harvest. For pest control, a total of 500 ha was sprayed with pesticides using on farm machinery tools. This was achieved after awareness for farmers and new companies on access to on-farm machinery and service provision for tillage with mechanized land labor. Awareness activities embraced planting, crop treatment, demonstration and training, engagement of youth in agricultural mechanization service through training of youth on agricultural mechanization technologies.

A total of 6 local manufacturers and artisans involved in agricultural machinery have been trained on farm machinery design, material of fabrication by RAB in partnership with IPRC Kigali

Training of youth cooperatives or companies in small agricultural machinery technologies: 30 youth cooperatives/ companies trained on agricultural mechanization technologies were increased because we preferred to choose two cooperatives or companies in each district and the trainees were very interested to involve in mechanization services provision.

A limited number of awareness meetings for mechanization were conducted (22 out of planned 33). This activity was constraint with COVID-19 pandemic restricting movements and meetings during lock down time.

Increased investment in mechanization included 6 out of planned 3 private partners who started to provide mechanization services.

1.10 IRRIGATION PROGRAM

Irrigation activities at RAB operate through different projects and studies (Table 45).

Table 45: Irrigation activities at RAB during FY 2019-2020

Irrigation project	Area irrigated	Comment
Irrigation studies		
Irrigation Master Plan		Updated Master Plan completed
Ndego Feasibility and detailed design study for Kayonza		Study completed; Project funding approved, targeted 2,000ha for irrigation
Mugesera Feasibility and detailed design study		Project in preparation, 3,500 ha potential for irrigation
Bugarama Feasibility study		Feasibility study completed, 2,176 ha potential for irrigation
Karangazi detailed design study		Inception report for feasibility study approved, 11,000 ha potential for irrigation
Marshlands development		
Marchland development activities	180 ha	
Existing irrigation schemes management		
Operation, maintenance and management of irrigation schemes	10,000 ha	
Irrigation projects		
Small Scale Irrigation Technology (SSIT)	3,189 ha	
Irrigation development in RAB Stations	40 ha	Targeted 50ha for irrigation
Rehabilitation of irrigation facilities in Rwamagana District		Targeted rehabilitation area for irrigation of 170ha.
Export Targeted Modern Irrigation Agriculture Project (ETI)	659 ha	Achieved 659ha, targeted 7,000ha for irrigation
Gabiro irrigation project		Design validated; bush clearing for demo plot establishment started. Targeted area for irrigation – 15,600ha. 5,600ha for 1st phase

1.10.1 Irrigation Studies

Update of Irrigation Master plan

The "Irrigation Master Plan (IMP)" refers to the Contract between RAB and the Joint Venture composed of Z&A Consulting Engineers International Ltd (Z&A) and SOCOSE Sarl. The first IMP of Rwanda was prepared in 2010. Thereafter, with new irrigation technologies, the developing national policies, particularly the Water Resources Master Plan (2013), the IMP required update.

Table 46: Areas with irrigation potential from the Updated Irrigation Mater Plan (2019)

	Catchment area (Ha)									
Sub-categories	CRUS	CKIV	NMUK	NNYU	NNYL	NAKN	NAKU	NAKL	NMUV	All
Runoff for small reservoir domain	2,148	5,179	4,165	7,155	7,056	7,270	6,521	9,162	3,344	52,000
Dam potential	167	1,447	172	7,058	15,610	12,859	894	1,430	12,464	52,100
River potential	-	-	-	12,424	4,710	36,171	25,868	48,241	8,466	135,880
Lake potential	-	23,909	-	-	28,372	9,125	26,816	14,142	-	102,364
Marchland potential	3,700	4,702	6,398	9,060	8,998	26,656	33,184	22,731	7,735	123,164
Groundwater	3,000	5,000	5,000	7,000	4,000	5,500	2,500	3,000	1,000	36,000
Sum	9,015	40,237	15,735	42,697	68,746	97,581	95,783	98,706	33,009	501,509

CRUS-Congo basin, Rusizi catchment Rusizi; CKIV Congo basin, Kivu lake catchment; NMUK – Nile basin, Mukungwa catchment; NNYU –Nile basin, Nyabarongo Upper catchment; NNYL –Nile basin, Nyabarongo lower catchment; NAKN – Nile basin, Akanyaeru catchment; NAKU - Nile basin, Akagera Upper catchment; NAKL – Nile basin, Akagera lower catchment; NMUV – Nile basin, Muvumba catchment.

The Update study aimed to review and improve the IMP: e.g. mark potential areas for Marshland and Hillside irrigation opportunities from a variety of water resources; update map of all potential irrigable areas; establish linkages to enhance profitability of the proposed interventions; and to develop prioritized irrigation framework. The study produced Irrigation Potential Map for each catchment (Table 46). According to the master plan recently completed by MINAGRI/RAB, 84,000 Ha were identified in the Eastern (54,340.2 Ha) and Southern Province (30,363.5 Ha) (Table 47).

Table 47: Potential irrigable areas in East and South from Updated Irrigation Master Plan

Eastern Province (54,340.2 ha)		Southern Province (30,363.5ha)	
District	Potential area (ha)	District	Potential area (ha)
Bugesera	14,166.60	Gisagara	11,559.6
Gatsibo	2,804.70	Huye	8,565.5
Kayonza	4,652.30	Kamonyi	480.5
Kirehe	6,130.00	Muhanga	532.0
Ngoma	12,903.30	Nyamagabe	1,930.1
Nyagatare	6,349.00	Nyanza	1,229
Rwamagana	7,334.30	Nyaruguru	5,415.8
Total	54,340.20	Ruhango	651.0

Ndego feasibility and detailed design of 2000ha hillside irrigation at Ndego, Kayonza district

Feasibility Study implemented for the design of irrigation systems in Ndego sector. Three block areas were delineated, each tapping water from different lakes, mainly the Lake Kibare, Lake Ihema and Lake Nasho. Additional options were analyzed to pump water only from Lake Kibare and Lake Nasho. The total surface area of the three blocks exceeds 2000ha. RAB is carrying out the Environmental Social Impact Assessment (ESIA) via Agritaff, and feasibility study is awaiting approval after ESIA report is out. As part of the Feasibility Studies, the Consultant who is SMEC International Ltd conducted: Socio-Economic Study; Topographic Survey; Soil survey; Agricultural survey and study; Land husbandry study; Bathymetric survey; Hydrologic and Water Resources Assessment; Assessment and selection of different types of irrigation systems; Development of irrigation scheme layout; Analysis of Crop Water Requirements; Preliminary designs of irrigation blocks, pumping stations, water mains and balancing reservoirs; Estimation of the quantities and costs and Financial and Economic Assessment.

Karangazi feasibility and detailed design study

Karangazi feasibility study was initiated during FY 2019/20. The consultants, Joint Venture Z & A Consulting Engineers International Ltd and SOCOSE Sarl, submitted the inception report and it was approved. The report targets 11,000ha for irrigation. The predominant farming practice in the project area is cattle (for beef and milk), with relatively large herds of *Ankole* and cross breeds (average size around 70 head), grazing on natural pasture on fenced (or hedged) farms. The design of this project will require land use change and switch to agriculture on irrigated land (Figure 18).

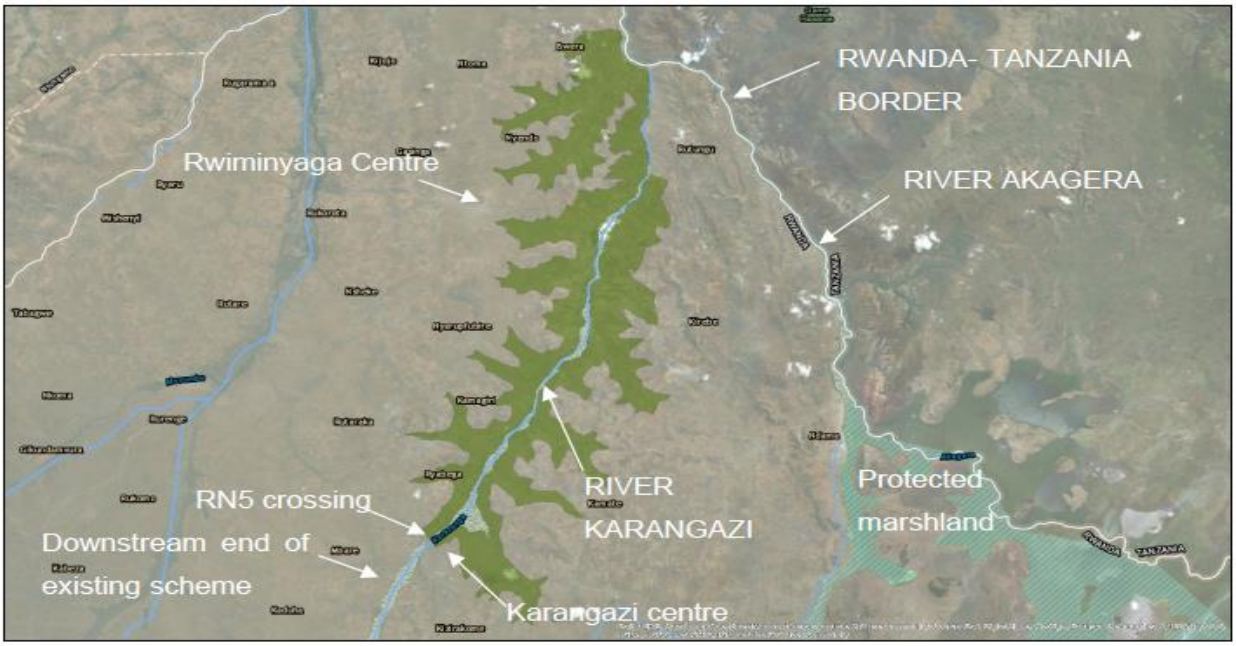

Figure 18: Location of the Project area

Mugesera feasibility and detailed design

Mugesera feasibility and detailed study was initiated during FY 2019/20. RAB received the submitted inception report and it was validated by the client. The Contract was signed between RAB and the Joint Venture (J/V) composed of G.Karavokyris & Partners Consulting Engineers S.A. (GKC) based in Greece, Z&A Consulting Engineers International Ltd. (Z&A), based in Cyprus, and SOCOSE Sarl, based in Rwanda. The potential area around Lake Mugesera is very large with 130 km or shoreline and over 10,000 ha gross area that could feasibly be irrigated by pumping from the lake. The area is characterized by long ridges or peninsulas that protrude into the lake with water on both sides. The tops of the ridges are typically 40-70m above the lake level and are where most of the roads, utilities, schools and houses are located.

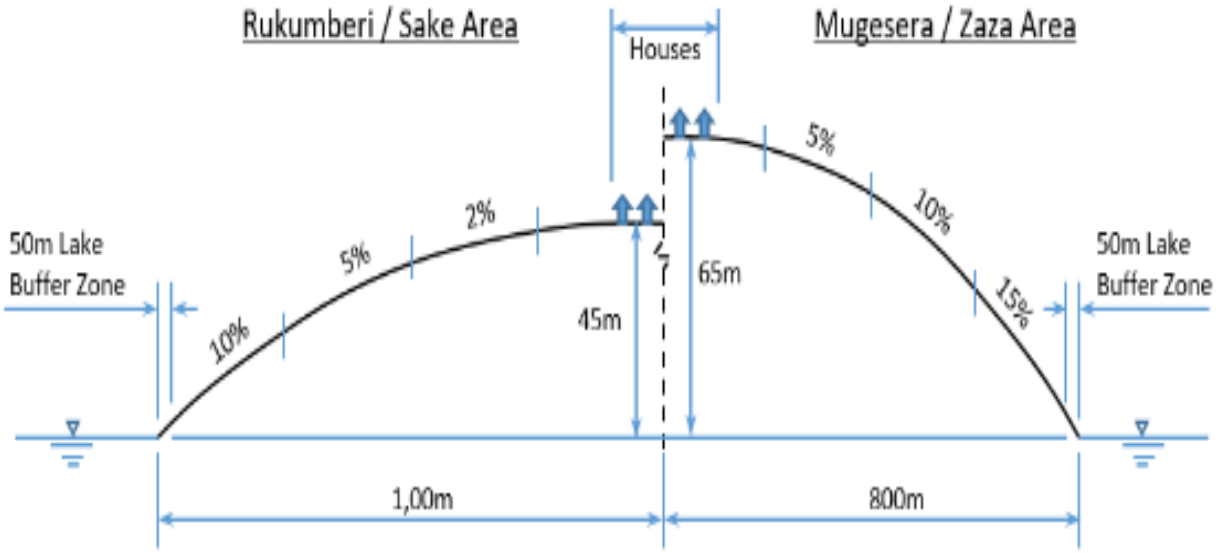

Figure 19: Typical cross-sections in RUkumberi and Mugesera areas

Generally, the slopes are steeper near the lakeshore (10 – 20%) and become flatter as you move up the hillsides. The ridges tend to be higher and steeper on the north side of the lake in Rwamagana, Karenge and Rubona Sectors, a little less so on the east side of the lake in Ngoma, Mugesera and Zaza Sectors, and even less high and steep in southwest Ngoma, in Rukumberi and Sake Sectors (see typical cross sections below, Figure 19). Further development of this study will be done in the new fiscal year 2020/21.

Bugarama feasibility study

This project called "Programme Régional de Développement Intégré de la Plaine de la Rusizi-PRE-DIR" is a regional project targeting to irrigate Rusizi plain using Rusizi River located between Lakes Kivu in the North and Tanganyika in the South on 117 km. The total area of irrigated agricultural land is estimated at 61,742 ha and the share of Rwanda in this valley is 2,176 ha. The master plan and detailed study were funded by African Development Bank with the agreement and in collaboration with the CEPGL Member States and completed. For Rwanda the implementation of this Master plan will need a total investment cost of 133.7 Million USD including 8 750 000 Million USD short-term investments (2019-2023) and 46.2 Million USD Medium term (2024-2028) investments. The next step will be to seek fund for its implementation.

1.10.2 Marshlands development

The key RAB activities for marchland development and sustainable water use by farmers and co-operatives include: expanding irrigated area of cultivated marshlands through rehabilitation and

development; construction of rural commercial infrastructure for developed marshlands that support the commercial activities handled by cooperatives or small groups; and strengthening producer organizations, including WUAs and cooperatives. The marshland development is financed by RAB through Government Funded Irrigation (GFI) and use of consulting firms for feasibility and participatory design studies, construction and construction supervision. A total of 280 ha marchlands were developed through GFI in FY 209-2020 (Table 48).

Farmers access to prime marshland agricultural land and contribute to development costs (including for example bush clearing and final land leveling activities) and pay for operation and maintenance (O&M) costs as contribution to the project funded support for irrigation infrastructure development. Districts provide guidance and leadership to WUAs to organize schemes and reinforce compliance with the WUA's internal rules and regulations. Districts play a lead role in mobilization of stakeholders for implementation of sustainable land management activities on hillsides.

Table 48: Marchland area developed in FY 2019-2020.

No	Marshland	District	Sector	Area(Ha)	Developer	Progress
1	Urwonja	Nyaruguru	Nyagisozi, Cyahinda	105	GFI	completed
2	Nzavu	Nyamagabe	Mugano	75	GFI	completed
3	Mwura-Gatare	Rwamagana	Musha, Gikonko	100	GFI	85%
Total				280		

1.10.3 Existing irrigation schemes management

MINAGRI/RAB developed various irrigation schemes across the country. The developed irrigation schemes were characterized by poor management of the owner-farmers after being established due to lack of ownership spirit of the beneficiaries (farmers' organizations), lack of technical skills as well as lack of capacity in different aspects such as best farming, operation and maintenance, governance of farmers' organizations (Cooperatives and WUOs) and loss of investment due to low yield found. RAB decided to work with youth cooperative to capacitate the cooperatives and water users association through Operation, Maintenance and Management of Irrigation Schemes Project that will be achieved through daily proximity coaching of WUOs and Agricultural Cooperatives/ Individual farmers working in different developed irrigation schemes.

Development, validation and production of training modules

The modules for Operation and maintenance of irrigation infrastructures, Cooperatives and WUOs administration, Conflict management, Best Agricultural Practices, Horticulture, Soil Conservation and Financial management &Audit have been updated and validated.

In -Class Training of the Scheme Farmer Promoters (SFPs)

The training of Scheme Farmer Promoters (SFPs) planned was done by teaching farmers through demonstration and trials plots established and in additional some particular training offered where 71 leaders from cooperatives, WUOs and zone leaders have trained on their responsibility to boost crop production, cooperative and WUO management and maintenance of irrigation infrastructures, financial management and audit in coop and WUO.

Facilitate cooperatives in registration process

Cooperatives of Agatorove and Nyagisenyi Rufigiza (after merging seven cooperatives working in Nyagisenyi Rufigiza scheme) were cooperatives targeted to be supported. Both Cooperatives have been supported to organize all documents where KOABIGA (Koperative y'Abahinzi Bahuje Intego ba Gasabo) still was on starting level of organizing the members where the activity was constrained by the covid-19 but for Agatorove's cooperative (DUTERIMBERE-KIBEHO) has deposited all documents at RCA level but it has constrained to be known as cooperative which has got the final certificate in RCA system, therefore, the cooperative was in process of requesting the correction of those errors in order to have the final certificate.

Facilitate WUOs in registration process

All WUOs hold district collaboration letter for further process to get final registration certificate from RGB. In fact, 48 WUOs hold district collaboration letters as basics and all are planned to be supported for being legally known at District level. The implementation of this activity was at 100%. Further process will be done to have full certificate from RGB for some WUOs while others have already received the final RGB certificate.

Establishing FFS demonstration plots within every 20Ha

The target was to establish at least one demo plots within 20Ha, from the baseline of 404 demonstration plots, the annual target of 280 demo plots, 281 demo plots have been established and obviously the demo-plots put in place exceeded the targeted. Farmers are committed to provide plots and some inputs for establishing FFS (demonstration plots) and those demo-plots help farmers learning by doing different best farming practices where the outcomes of those demo plots encourage farmers to use quality seeds, required fertilizers and chemicals and timely application of inputs. The implementation of this activity was above 100%.

Conducting field exchange visit (study tours)

The field exchange visits have been planned to be conducted in different irrigation schemes in aim of exchanging skills and knowledge among farmers, change and update in quick way farmers

'mindsets. Field exchanges visit have been done within the schemes where farmers visited their neighbors and demonstration plots to learn from their performances.

Daily proximity coaching of farmers on good agricultural practices

Through daily proximity coaching of farmers by using FFS demonstration plots as a simple tools of learning by doing, farmers were benefiting different farming skills (GAP), practical practices and mindset are changing slowly where the adoption of good agriculture practices is at good rate. From the baseline of 75.5% with the target of achieving 100% in applying GAPs, the average number of farmers applying GAPs is at 83.3% where the activity was constrained by covid-19 effects, lack of quality seeds (case of Nyagatare on soybeans and beans) and heavy rain occurred in this season 2020B.

Establishment of annual cropping plan

All cropping plans were established as planned and farmers are being mobilized to respect the cropping pattern as defined in cropping plan. Actually, the annual cropping plan was prepared in August up to September in the beginning of season 2020A of every year. The implementation of this activity was at 100%.

Supporting the cooperatives in market negotiation

During season 2020A, 54 farming contracts were negotiated and signed with different buyers. The negotiated markets include vegetables buying companies and rice and maize industries. Most of them were named Izere services & Trading Co. Ltd, Big Seller, Green growth co.ltd, AIF Ltd, AEX Ltd, Gikonko Rice Mill, Kinazi Rice, Mukunguri Rice etc. All cooperatives have market for their produces for season 2020A others are taken by farmers for home consumption and some vegetables have taken at local markets. Some negotiated markets are seasonal and others are annual based markets, where the buyer signed contract on annual basis or seasonal basis. This activity was implemented at 100%.

Mobilize farmers towards community work

Farmer participation in community work increased and is at 79% (from baseline 76.5%) with target to achieve 100% of farmers attending community works in their respective irrigation schemes. The total number of farmers participated were 122,290 and the community work value equaled to 116,523,165 Rwf.

Challenges

The presence of more than one cooperative with legal personality in the same irrigation scheme results in conflict of interest and mismanagement but we are in merging of those cooperatives in

one with RCA collaboration. Necessary arrangements have been made to maximize the crop production but in all irrigation schemes, farmers are still facing a problem of shortage of postharvest facilities (warehouses, storages etc.). High massive erosion from unprotected catchment area of different irrigation schemes is still a big challenge and results in productivity losses. Some irrigation infrastructures were destroyed by erosion as well as mass movement and farmers' organization ability for rehabilitation is too low compared to the damaged infrastructures, but some of the damaged infrastructures have been rehabilitated (in Gashora and Rurambi).

1.10.4 Irrigation projects

Small Scale Irrigation Technology (SSIT)

Rwanda is blessed with abundant water resources (Rivers and lakes), however, the population around those water bodies continues to suffer from drought. In order to alleviate poverty and reduce dependency on rain-fed agriculture, the Government of Rwanda started to provide subsidy for small-scale irrigation equipment to farmers who needs to irrigate their crops. The program started in July 2014. Up to now 12,000 Ha (**3,189 Ha** developed during FY 2019/20) were equipped with SSIT and 24,000 households benefited from the Government support. A total of 85% SSIT needs are located in the Eastern Province. A total area irrigated with solar pumps is 925 ha (Table 49).

Beneficiaries of Small Sale Irrigation Technology program are individual farmers and communities, having consolidated land area ranging between 0.5 to 10 hectares, which access to a water source like lakes at least 50 m away or river at least 20 m away. Similarly, special groups like Youths, Young Farmers Clubs (YFC) as well as Cooperatives are encouraged to procure and use the Small Scale Irrigation equipment to make their agriculture commercial and resilient to drought.

The small scale irrigation technology includes: Portable diesel/petrol motor pump; Solar pumps; Sprinkler/Rain-guns; Pipes (hose pipes, HDPE, PVC); Drip kit; Dam sheets; Tanks especially with drip system. The variability in SSIT design and irrigation kit is according to land topography, soils, water availability & storage, and crop productivity.

Solar pumps is good technology for mitigation of climate change through reduction of electricity or diesel use for irrigation. Table… shows the area irrigated with use of solar pumps.

Table 49: National area irrigated with use of solar pumps (FY 2019-2020)

District	Area irrigated with solar pumps (Ha)
Bugesera	120
Rwamagana	10

Kayonza	60
Ngoma	60
Gatsibo	40
Kirehe	500
Nyagatare	50
Ruhango	10
Gisagara	20
Burera	10
Nyamasheke	5
RAB Rubilizi station	30
RAB Mututu Station	10
Total area	925

The Private sector has been involved in the implementation of SSIT program as service providers. The service providers through their contracts with RAB are responsible for Supply, Installation of the SSIT Equipment, and supporting farmers in understanding the operation of the equipment.

The Government of Rwanda avails a budget to SSIT as an approved program, it is implemented by District through Earmarked Transfer and coordinated by RAB. MINAGRI and RAB mobilize farmers to adopt climate resilient method, which includes irrigation equipment at a subsidized cost; Interested farmer submits to the District, Sector or cell a signed application letter and fill, sign the project description form. RAB/SSIT staff are deployed to work closely with the beneficiaries visit the farmer and provide quotation as per the technician recommendation but also considering applicant financial capacity to contribute to SSIT Program, some adjustment can be made to meet the applicant demand. The District issues a letter to approve the demand, then the farmer can pay his contribution per the approved subsidy, then he/she is given the equipment. After installation a technical team made of SSIT Engineers, monitoring and evaluation staffs go to the field and approve the equipment then the supplier is paid by submitting an invoice to the District. A 1 year warranty of supplied and installed SSIT is provided by the supplier but also farmers are trained on the operation, maintenance and management of the irrigation infrastructure.

Among the challenges are: Lack of finances to buy SSIT, limited training of SSIT beneficiaries; high cost of irrigation equipment due to importation costs and high topography. To overcome these challenges, farmers are advised to form cooperatives or buy SSIT Kits in groups (One can irrigate today and the other can irrigate tomorrow). Farmers are also advised to request for loans from financial institutions (RAB in partnership with CNFA HINGA WEZE are piloting this model). The District can increase the subsidy at 75% depending on farmers category (in Kamonyi, Ruhango, Kayonza district provides 75% subsidy to farmers in category 1). Farmers can also pay in install-

ments after approval from District. RAB has training program for agronomists and SSIT Beneficiaries. The Government removed VAT to help reduce the cost of irrigation equipment. Currently the COVID 19 is also impacting on the importation of SSIT kits. This might affect supply and distribution of SSIT kits among farmers.

Solar pumps: In order to alleviate climate change induced droughts which are now threatening Rwanda's twin goals of food security and poverty reduction, Rwanda has been obliged to accelerate the development of sustainable, affordable, farmer owned irrigation systems by providing 50% subsidy to individual farmers or cooperatives, the Government also developed irrigation system with support from buffet in Kirehe which is hybrid.

The irrigation uptake through this program increased and now farmers and Government are investing in solar powered irrigation system since the operation cost is highly reduced because no fuel is bough and the maintenance costs are minimized.

Solar powered irrigation initial investment is expensive, that is why its development is slow. Since the beginning of SSIT only 925 hectares were equipped with this technology.

Irrigation development in RAB Stations

RAB through Market Responsive Project started the installation of irrigation facilities for crop research and seed production. Irrigation establishment was in Rubona, Muhanga and Rubilizi stations. The total area developed is 50 Ha (Rubona station: 20 Ha, Muhanga station: 10 Ha and Rubilizi Station: 20 Ha (Photo 29). Rubona station is one of the major station where research is being conducted, to sustain this project an irrigation system by use of electric pump and water storage facilities were constructed. At Muhanga station, Mututu site, a solar powered irrigation system was established to sustain seed multiplication. Different systems were installed such as drip and pipe flow for demonstration purposes, after different trials, researchers will choose the system to be adopted.

Photo 29: Electric Pump installed (left); Covered reservoir for water collection (right) at Rubona Station

At Rubilizi station (Muyumbu and Gashora sites), solar powered irrigation system were installed to sustain seeds multiplication (Photo 30). Different systems were installed such as drip, sprinklers and pipe flow for demonstration purposes, after different trials, researchers will choose the system to be adopted. Gashora site has been selected for crop research and seed production and RAB needs to expands to other stations, as it has been noted that construction of irrigation facilities are the key input to support productivity.

Photo 30: Solar panels and pump station (left) and water tankls (right) at Gashora site

Rehabilitation of irrigation facilities in Rwamagana District

In March 2017, the Japan International Cooperation Agency and the GoR concluded the Grant agreement for the rehabilitation of irrigation facilities in Rwamagana District. The implementation of the project is being done by two (2) Japanese companies: NTC International Co., Ltd. for the detailed design, bidding procedure, supervision of construction works and soft component activities and TOBISHIMA Corporation for construction works. Under this agreement the Government of Rwanda must spend 1,911,504,703 RWF mainly for compensation of affected assets, erosion control on catchment of dam and tax refund. The project includes Three (3) sites totaling 170ha. Two dams, Cyimima and Gashara are being improved and one new dam, Bugugu, is under construction (Table 51). A total of 23.5 km of main canal will be constructed in reinforced concrete. These irrigation facilities will serve 555 direct beneficiaries grouped in 3 cooperatives. Three dams were constructed by grant aid of China about 35 years ago and now were having two problems: High siltation has reduced considerably their storage capacity; Leakages in the dam body. Currently the overall progress is 90% and planned completion date is 30th October 2020 and the following is the summarized table of technical aspects.

Table 50: Rehabiliated dams in Rwamagana district

Dam	Storage Capacity ('000 m^3)		Height (m)		Area to be irrigated (ha)	Length of concrete canal to be constructed (Km)
	Current	Required	Current	Required		
Cyimpima	400	640	7.8	11	56	8.8
Gashara	220	640	6	13	66	7.0
Bugugu	30	580	3.5	12	48	7.7
Total					170	

Export Targeted Modern Irrigation Modern Agriculture Project (ETI)

The ETI project is financed by EXIM Bank of India through a Line of Credit of USD 120.05 Million, with objective of developing 7,000Ha area, in Mpanga, Nyamugari and Mahama sectors of Kirehe district by supplying and installation of modern irrigation facilities that are needed to allow farming throughout of the year. Mpanga site is at advanced stage with installation of irrigation system progress between 70 and 100%. The site is having 209Ha of Center Pivot, 29 Ha Sprinklers, 34 Ha of Travelers with the tractors and 387 Ha of Pipe flow (Flood irrigation system) (Photo 31).

Photo 31: Pumping house (left); Water supply pipe (right)

Gabiro irrigation project

The Eastern Rwanda is the most affected by drought, which has impact on food security and crop harvest that is why the Government of Rwanda in partneship with Netafim decided to develop irrigation system on 15,600 ha. In FY 2019/2020, Designs were validated and activity related to bush clearing where demonstration plot will be established has started. The first phase of the project (18 months) will cover 5,600 ha and grow maize, soybeans and high-value crops. About 70% of the land will be leased to private investors, and 30% is being developed and maintained by the local communities for agriculture and livestock growing. Due to the hilly terrain and limited water resources, it was decided to deploy drip-irrigation system, which will increase land utilization to 93% while decreasing water use by 40%. The Gabiro project will support the production of staple crops for local consumption, export and agricultural value-added products like pastes, powders, oils and beverages intended primarily for export.

Part 2. Livestock Division

2.1 Mono-gastric program (pigs and poultry)

2.1.1 Pigs

The program research is focused on animals with single stomach, namely, pigs and poultry, whose digestive system is different from ruminant animals with multiple stomach sections. Program research aims to increase contribution of poultry and pig to food, nutrition and income security of rural households through improved productivity. The national target is to increase poultry products and pig meat by 30% using genetic improvement and innovation platforms for gender sensitive enterprise development for poultry and pig value chain development. The key activities were characterization study of pig production systems, and small stock dissemination.

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Characterization study of pig production

Pig farming fits very well for integrated farming and may be complementary to intensive crop production. In Rwanda, the majority of pigs are kept in traditional small-scale subsistence production systems. Pigs in such low-input systems provide value-added output for farmers by consuming feed that would otherwise be lost. A study conducted in May-June 2019 (Figure 20) aimed to characterize pig production systems in five Provinces, to establish constraints in pig production system and to determine the strategies that can enhance the performance of the pig production.

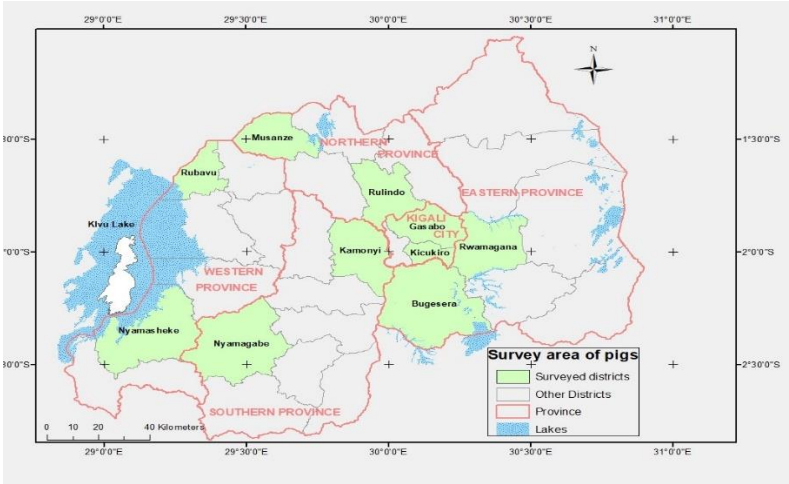

Figure 20: Map of the study area (Showing all Districts covered by the survey)

Study areas covered Eastern province (districts of Rwamagana and Bugesera); Southern (Kamonyi and Nyamagabe), Western (Rubavu and Nyamasheke), Northen (Rulindo and Musanze), and Kigali City province (Gasabo and Kicukiro). A total of 900 households – pig keepers in 36 sectors of 10 districts were randomly selected.

Data from questionnaires were collected on gender, age, education and marital status of pig keepers, pig characteristics, source of germplasm, type and characteristics of production systems including feeding, cooling, selling, health care; reasons for pig keeping, pig marketing, income from pig rearing and challenges in pig production.

Gender: A typical pig keeper is a middle-age male (mean 46.7 years). Most of the respondents (81.2%) were from Western province and the majority of the respondents were males (76.1%). Eastern province had younger pig keepers with the age of pig farmers ranged between 31-40 years. Marital status of household head: 82.8% of pig farmers being married. Education of household head: About 41.2%, t of pig farmers had primary school education, 21.6% had incomplete primary and 21.4% had no formal education.

Pig genotypes: Pig breeds were reported as crossbreeds (kept by 41.2% farmers), local (19.7%), landrace (18.7%), large white (12.1%), pietrain (8.1%) and other (0.3%). In Eastern province Landrace breed was dominant, while in Western province the Local breed was dominant. However, crossbreed pigs were the most preferred pig breed because of better adaptability, fast growth, low mortality and high number of piglets.

Pig categories: Pig population as reported comprised piglets (17.6% males and 17.2% females), growers (8.7% males and 8.1% females), boars (7.3%), gilts (15.5%), sows (18.9%) and finishers (5.7% males and 1.1% females).

Experience, reasons of keeping the major breeds and source of pig stock: The mean experience for pig rearing was 5.7 years. The main reasons for pig rearing were: pigs are highly productive (44.2%), pigs generate high profit (22.4%), pigs are disease tolerant (11.8%), and they are easy to manage (10.8%), minimum resource requirement (5.8%) and (5.0%) mentioned it as the only breed available in the area. The main objective for rearing pigs was income generation (81.4%). Pigs contributed about 33.4% to the household income.

Pig marketing: Marketing methods were different ($p<0.05$). Predominant method of selling pigs (83.8%) was selling of whole live animals to other pig farmers and (15.8%) were sold live to butchers and traders, only (0.4%) were sold as meat directly to consumers. Selling of whole live animals predominated (83.9%) as only 8% of the respondents possessed slaughter slabs and 8.1% had cold storage facilities for the carcasses. The main reasons for selling pigs (98.1%) were need of cash by farmers. Reasons like controlling the stock size and disposal/culling were less reported with (1.7%) and (0.2%), respectively. Different reasons of culling/disposal of pigs were reported by farmers. The most common reasons for culling/disposal of pigs were controlling of stock size and for young pigs both females (77.4%) and males (70.6%), and the old age (57.8%) and (51.9%) for boars and sows, respectively. Other reasons were mentioned as poor health/diseases (both males (14.7%) and females (15.1%), avoiding inbreeding (boars, 17.8%) and poor production (sows, 19.2%).

Pig management type: Pig management type is linked to the purpose of pig rearing. The main purpose for farmers rearing pigs include piglet production for the market (63.7%), multipurpose production (13.7%), fattening (10.0%), finishing (9.8%) and keeping breeding stock (Table 51). Piglets were sold off to other farmers at 2.3 months with 12.4kgs at 15,868 Frw.

Table 51: Pig management type

Characteristics	Provinces					P-value
	East	West	North	South	Mean	
Pig business purpose (%)						
Piglet production	48.0	67.0	65.3	75.2	63.7	
Finishing pigs	14.4	11.3	8.3	5.0	9.8	
Producing breeding stock	7.2	3.5	0.8	0.0	2.9	0.000
Mixed purposes	27.2	17.4	5.0	5.0	13.7	
Fattening	3.2	0.9	20.7	14.9	10.0	
Average age, weight and price of piglet sold off to other farmers						
Age (Months)	2.3	2.4	2.4	2.3	2.3	0.649
Weight (Kg)	12.4	14.3	11.2	11.2	12.4	0.000
Price (Frw)	15456.3	20301.9	14517.6	12623.7	15863.2	0.000
Average age, weight and price of buying piglet for fattening						
Age (Months)	4.0	4.3	3.4	3.5	3.8	0.012
Weight (Kg)	23.1	29.1	15.8	17.2	21.8	0.000
Price (Frw)	29918.2	39734.9	20459.0	21454.5	28707.5	0.000
Average age, weight and price of fattened/ finished pigs are sold for slaughter						
Age (Months)	8.4	9.2	12.1	10.8	10.1	0.000
Weight (Kg)	54.2	57.2	61.2	57.7	57.5	0.578
Price (Frw)	70698.7	83179.5	70925.9	67819.4	73237.9	0.226
Price/Kg of breeding pig	1703.4	1608.0	1630.0	1654.0	1647.2	0.972
Price/Kg of slaughtering pig	1510.1	2016.7	1467.8	1816.2	1697.3	0.191

Fattened piglets were bought at the age 3.8 months, with 21.8kgs and at 28,707Frw. Piglets for slaughtering were sold at the age of 10.1 months with 57.5kgs at the price of 73,237Frw. No significant difference ($p > 0.05$) in pig price (per kg) was reported between pigs reared for breeding (1,647Frw) and those reared for slaughtering (1,697Frw) (Table 51). Pig castration techniques were adopted by 13.1% farmers in all provinces (Table 52). The limiting factors to adopt castration could be lack of specialized market for meat and breeding stock with the service for selection of best male piglets for breeding and castration of all male piglets, which are not intended for reproduction. Castration practice could be promoted as castrated piglets have more rapid and uniform growth than non-castrated ones.

Table 52: Pig castration and reasons of castrations

Characteristics	Provinces					
	East	West	North	South	Overall	P-value
Do you castrate pigs						
Yes	10.3	16.2	16.9	8.8	13.1	0.151
No	89.7	83.8	83.1	91.2	86.9	
Average age of castration (Months)	3.0	3.0	2.6	3.9	3.0	0.390
Reasons of castration						
Fast growth	76.9	94.4	94.7	91.7	90.3	0.399
Make them docile	0.0	5.6	0.0	0.0	1.6	
Control breeding	15.4	0.0	5.3	8.3	6.5	
Practical for students	7.7	0.0	0.0	0.0	1.6	

Household ownership of pigs and participation in selling decision making: Pig ownership (64.5% and decision making (60.6%) in selling were mostly joint at family level in all provinces of the country (Table 53). This could have been result of gender sensitive policy in recent years and the implementation of sharing family properties. Husbands alone owned pigs in 19.5% and took decision on selling on their own in 25.1% cases.

Table 53: Household ownership and participation in selling decision making of pigs

Characteristics	Provinces					
	East	West	North	South	Overall	P-value
Ownership of pigs (%)						
Family	48.8	50.9	80.2	77.5	64.5	0.000
Husband	35.5	32.5	5.8	5.0	19.5	
Wife	8.3	12.3	4.1	10.0	8.6	
Children	7.4	4.4	9.9	7.5	7.4	
Decision making on selling pigs (%)						
Family	45.5	45.6	77.7	73.1	60.6	0.000
Husband	39.7	37.7	9.9	13.4	25.1	
Wife	6.6	11.4	3.3	7.6	7.2	
Children	8.3	5.3	9.1	5.9	7.2	

Management systems in pig keeping: In all provinces, most of pigs are confined in their sheds where feeds are brought (Table 54). Feed is served in movable containers or thrown on the flour. Water is mostly served in movable container (75% respondents).

Table 54: Feeding and general management system of pigs

Characteristics	Provinces					
	East	West	North	South	Overall	P-value
Management system						
Free range	3.7	10.1	0.0	1.7	3.5	
Confined in house	94.5	84.3	100.0	98.3	94.8	0.000
Tethering	1.8	5.6	0.0	0.0	1.6	
How feeds are offered						
Scattered on floor	21.6	33.3	31.1	46.3	33.0	
Feed through	16.0	24.8	5.7	7.4	13.4	0.000
Movable container	61.6	41.9	63.1	44.6	53.0	
Other	0.8	0.0	0.0	1.7	0.6	
How is water offered						
Movable container	80.8	68.4	72.7	77.7	75.0	
Water through	13.6	14.5	7.4	7.4	10.7	0.000
Water given with feed	5.6	17.1	19.8	10.7	13.2	
Other	0.0	0.0	0.0	4.1	1.0	
Source of feeds						
Farm	48.8	59.8	42.6	49.2	50.0	
Commercial	3.3	6.8	1.6	3.3	3.7	0.021
Both	48.0	33.3	55.7	47.5	46.3	
Methods of carrying feeds obtained						
Wheelbarrow	1.7	3.7	0.0	0.0	1.3	
Bicycle	49.6	31.8	10.8	10.8	25.5	0.000
Head	42.0	59.8	87.5	88.3	69.7	
Car	6.7	4.7	1.7	0.8	3.4	
Season experienced shortage of feeds						
Dry season	93.5	92.3	98.3	94.7	94.8	
Rain season	5.7	7.7	1.7	5.3	5.0	0.305
Both seasons	0.8	0.0	0.0	0.0	0.2	
Season experienced surplus of feeds						
Dry season	7.4	7.6	1.7	7.5	6.0	
Rain season	91.7	92.4	98.3	90.6	93.3	0.163
Both seasons	0.8	0.0	0.0	1.9	0.7	

Few others are getting their feeds in the fields where they are free to move during day time. A very limited numbers of pigs are tethered. Feed source is farm (50%), commercial (3.7%) and both

(46.3%). Most of farmers transport feed on head (69.7%). The majority of pig keepers mentioned dry season as short of feed and wet season as when the feed is abundantly available.

Pig housing and feeding management: The floor of pig house is mainly made of timber in most of the provinces except in South where pigs are left on the ground without housing. The roof for many pig sheds are mostly made of iron sheets although polythene sheets and grass are also used. A considerable number of pig sheds remain uncovered which exposes the pigs to permanent stress from sunshine or rains. The walls are dominantly made of pieces of timber but also bricks, iron sheets and woods are used.

Pig feeding: Farmers reported that growing more crops or use of kitchen waste would help to increase availability of feed. Farmers grow a lot of crops to have enough feed for pigs. Others buy from outside their farm to complement what they get from their own farms. In case of overproduction of feeds, the surplus is stored, sold to needy farmers or give it away for free. When feeding their pigs becomes difficult, some farmers prefer to sell some pigs and remain with a few number they can satisfy with available feeds. The main reason for limited use of commercial feed is that it is highly expensive. Others said that they did not know the existence of balanced feeds for pigs or they were not available. The main challenges in pig rearing were insufficient feed availability, high cost of feed, poor genetic stock of pigs and difficulty to restrain pigs.

Pig feeding types: Pig feed sources were diverse and their use depended on their availability for pig keeper and season: cassava peels, leaves and roots, potato vines, peels and roots, maize bran and maize grain, yam leaves and roots, brewery residues, pumpkin, banana peels, rice and wheat bran, tree foliage, kitchen waste, commercial feed, vegetables, napier grass. Kitchen waste and weeds followed by potato leaves, vines and peels were mentioned as major source of pig feeds in all provinces. In addition to the above feed resources, few farmers (23 out of 486) have added different flours from milling machine (60.9%), brewery wastages (21.7%), rumen digest from butcheries (8.7%) and milk waste (4.3%) as other source of pig feed. The most used feeds are mostly sourced at home. However, some quantities come from purchasing, from the neighbors and even from the bushes. Most of feed is given fresh as reported by 96.6% pig keepers. Only 1.8 to 27.1% farmers boil pig feed (Table 55). Boiling is desirable as feeding with boiled feed results in less fibrous fat and more tender meat, however, cooking wood resources become more and more scarce.

The feeds are mostly fed fresh but some are cooked or dried before feeding (Table 55). As for the kitchen waste, mainly food remains are mixed with water before feeding. However, in few cases, they are fed alone without adding water or mixed with other feeds. All categories of pigs, adults and young are able to eat all feeds available. However, for the piglets, there are feeds that are not fed to them due to high fiber which is hard to digest. The most available feeds are mostly fed during the season when they are available or during wet season. However, some farmers make

sure that they have them throughout the year. There are some farmers that affirmed obtaining pig feeds during dry season while others declared having them very rarely.

Table 55: The forms in which five most common feed resources were used

Feed resources	Form of feeds used	Provinces				Total
		East	West	North	South	
Potato vines	Fresh	94.6	96.6	98	97.2	96.6
	Boiled	2.2	2.3	2	0.9	1.8
	Other	3.2	1.1	0.0	1.8	1.6
Potato roots	Fresh	70.4	91.1	55.2	72.1	70.3
	Boiled	28.4	8.9	41.6	23.3	27.1
	Other	1.2	0.0	3.2	4.7	2.7
Potato peels	Fresh	93.5	95.9	86.4	100.0	93.0
	Boiled	2.2	0.0	11.9	0.0	4.3
	Other	4.3	4.1	1.7	0.0	2.7
Weeds	Fresh	94.5	98.9	98.2	95.9	96.9
	Dry	3.3	1.1	0.9	0.0	1.3
	Other	2.2	0.0	0.9	4.1	1.8
Kitchen wastes	Food remains only	36.1	12.5	15.4	24.1	22.5
	Mixed with water	44.3	61.6	55.8	47.4	52.0
	Mixed with other food	12.3	24.1	9.6	8.6	13.7
	Boiled	7.4	1.8	12.5	13.8	8.8
	Other	0.0	0.0	6.7	6.0	3.1

Other include: wilted and dry

Breeding and performance indices: Gilts and boars reach sexual maturity at seven to nine months with East having the earlier maturity than other provinces due to probably higher temperature (Table 56). Number of litter farrowed per year varied within a range of three to two times in a year, with an average of seven piglets per sow.

The mean weight of newborn piglets was reported to be two kilos per piglet. Most of piglets were weaned over 2-3 months with an average of seven piglets (Table 56), and a sow come back on heat after 6-8 weeks maximum. This makes farrowing interval to vary within a range of 5-7 months. 35.9kg was the average weight for 6-months gilts was 35.9kg and this could double up to 69.6kg at 12 months.

Table 56: Reproduction and production parameters

Performance indices	Provinces					P-value
	East	West	North	South	Mean	
Average age at sexual maturity (in months)						
Male	7.6	8.2	9.1	8.6	8.3	0.000
Females	7.4	7.9	9.4	9.1	8.4	0.000
Average number of litter farrowed per sow in a year (times/year)	3.3	2.6	2.0	2.1	2.5	0.000
Average number of piglets born per litter						
Maximum	9.6	9.3	9.7	9.5	9.5	0.713
Minimum	5.9	5.4	4.9	5.3	5.4	0.002
Average	7.1	6.9	7.0	6.9	7.0	0.783
Average weight at birth (kg)	1.9	2.1	2.1	2.1	2.1	0.185
Average number of piglets weaned in a litter	6.8	6.5	7.0	6.9	6.8	0.258
Age at weaning (in month)	2.4	2.6	2.4	2.7	2.5	0.369
Average length of time from weaning to coming on heat of sow (in weeks)	6.9	5.9	6.8	8.4	7.0	0.145
Farrowing interval in months (period between successive births)	5.5	5.1	7.1	6.6	6.1	0.000
Approximate weight (in kg) of females at						
6 months	39.1	39.7	32.2	32.4	35.9	0.000
12 months	76.9	80.3	60.6	62.2	69.6	0.000

Breeding method: The natural mating is the most method use for breeding (99.1%), only 0.2% use artificial insemination and 0.7 of the interviewed farmer use both methods (Table 57). Most of the farmers don't keep boars on the farm (71.2%) and reported high cost of management, difficult to manage and that boar eat more feeds were the main reasons for not keeping boars at farm. 67.2% of farmers who doesn't have boars at the farm level source it at village with an average distance of 1.3km.

Most of the farmers pay cash to receive a boar service (92.1%) with an average of 3980Frw. However, high cost of a boar service, long distance and difficult of accessing a boars were the major challenge reported by 51.3% of farmers, but 45% of them reported to not have any problem on accessing a boar. 28.8% of farmers that keep a boar in their only half of them could use their boar to serve sows of other farmers (51.1%) and most of them use cash to pay the service (81.4%) with an average of 4150Frw per sow served. 59% of farmers check the parentage of boar before using it, these help farmers to avoid inbreeding or bad crossing.

Table 57: Method used for breeding pigs

Parameters	Provinces					P-value
	East	West	North	South	Mean	
Method used for breeding (%)						
Natural mating	100.0	98.2	98.9	99.0	99.1	0.668
Artificial Insemination	0.0	0.9	0.0	0.0	0.2	
Both methods	0.0	0.9	1.1	1.0	0.7	
Does farmer keep a boar						
Yes	31.4	20.0	40.4	24.3	28.8	0.007
No	68.6	80.0	59.6	75.7	71.2	
If no why/reasons						
High cost of management	38.9	60.5	18.4	42.4	39.0	0.000
Difficult to manage	5.6	7.9	34.7	15.3	17.0	
Boars eat a lot of feeds	16.7	18.4	8.2	5.1	11.0	
Control of stock size	0.0	0.0	8.2	16.9	7.7	
Sold once young	19.4	2.6	0.0	8.5	7.1	
Easy to get from neighbors	2.8	5.3	10.2	6.8	6.6	
No need	13.9	5.3	6.1	0.0	5.5	
Other*	2.8	0.0	14.3	5.1	6.0	
If no, source of boar						
Within a village	87.8	73.3	55.9	51.8	67.2	0.000
Within a cell	6.8	25.3	32.2	40.0	26.3	
Within a sector	2.7	1.3	8.5	7.1	4.8	
Within a district	2.7	0.0	3.4	0.0	1.4	
Beyond a district	0.0	0.0	0.0	1.2	.3	
Average distance to the boar source						
Within a village	1.7	1.3	1.2	0.9	1.3	0.066
Within a cell	1.5	2.1	2.4	2.6	2.4	0.994
Within a sector	.5	1.5	4.4	2.8	3.0	0.058
Within a district (Only 2 farmers)	0.0	0.0	19.0	0.0	19.0	-
Beyond a district (Only 1 farmer)	0.0	0.0	0.0	15.0	15.0	-

**Other reasons include low growth rate, avoiding inbreeding, not profitable, aggressiveness, etc*

Most of the farmers choose crosses (47.4%) and exotic (34.2%) breeds because they are more productive in terms of growth rate and weight of piglets. Farmers reported that crossed boars of Landrace are the more preferred followed by Large Wight with 59.2% and 2.5% respectively.

Farmer could allow for a sow to give birth 5 times before culling, and this was observed in all provinces.

Pig health care and challenges: Most of farmers (66.2%) dewormed their pigs one of routine diseases control and 76.5% do the deworming at least three to four times in a year other routine activity done are like cleaning the shed, vaccinations, avoid contact with other pigs from other farmers, spraying and to give vitamins (Table 58). The frequency of cleaning of the pigsty was reported differently in all provinces, Eastern and Western provinces most of the farmer clean it every day while farmers in Southern province clean it within a range of once to three times in a week but famers of Northern provinces reported to clean the pigsty regularly (66.7%). Clean of the pig's place is key of diseases preventions and other related infections (Table 58).

Table 58: Routine diseases and common health problems in pigs

Parameters	Provinces				Overall	P-value
	East	West	North	South		
Routine control measures of diseases						
Deworming	62.9	52.0	68.4	77.5	66.2	0.016
Cleaning the shed	22.5	34.7	24.2	11.8	22.4	
Avoid contact with other pigs	4.5	4.0	0.0	6.9	3.9	
Vaccination	3.4	6.7	3.2	2.0	3.6	
Spraying	3.4	1.3	1.1	2.0	1.9	
Give vitamins	3.4	1.3	3.2	0.0	1.9	
How often (Deworming)						
More than 5 times a year	9.1	0.0	14.8	0.0	7.4	0.848
Three to four times a year	90.9	100.0	70.4	70.8	76.5	
One to two times a year	0.0	0.0	14.8	25.0	14.7	
How often (Cleaning a pigsty/Pig pen)						
Everyday	44.4	42.9	0.0	0.0	33.3	0.154
Two to three times a week	22.2	14.3	0.0	50.0	19.0	
Once a week	11.1	14.3	0.0	50.0	14.3	
One to two times a month	22.2	0.0	33.3	0.0	14.3	
Regularly	0.0	28.6	66.7	0.0	19.0	

Health problems in pigs: Swine erysipelas is the most reported by 40.6% of farmers in all provinces and is more frequent in Southern province with 68.7% of farmers reported to have experience it. The swine erysipelas is very strong because it infection affect all categories of pigs as it was reported by farmers 81.2% but worm infection affect more piglets and growers as it was reported by 36.9% and 26.2% farmers respectively. Most of the farmers showed to take care of their pigs

once affected by swine erysipelas and worms, farmers always seek help from the veterinary as it was reported by 80.9% and 82.7% farmers respectively. Other activities done are like quarantine of the sick animals, vaccinations and traditional cooping. Twelve farmers only (2.7%) use traditional copping strategies to treat different diseases, third of them use oil, mixture of ashes and breweries, Umuravumba and other grasses to treat swine erysipelas while two farmers use petrol to treat worms (Table 59).

Table 59: Health problems in pigs

Parameters	Provinces				Mean	P-value
	East	West	North	South		
Nature of health problem in pig						
Swine erysipelas	15.1	44.7	50	68.7	40.6	
Worms infestation	50.0	34.1	21.4	7.8	32.2	
Diarrhea	11.6	4.7	14.3	7.8	9.1	
Skin diseases	9.3	5.9	2.4	5.9	6.4	
Coccidiosis	3.5	0.0	7.1	0.0	2.3	
Other*	10.5	10.6	4.8	9.8	9.5	
Age group most affected by swine erysipelas						
All	75.0	77.4	88.2	82.8	81.2	
Adult	0.0	12.9	0.0	10.3	8.2	
Other	25.0	9.6	11.8	6.8	10.5	
Age group most affected by worms						
Piglet	41.9	32.1	22.2	50.0	36.9	
Growers	30.2	32.1	0.0	0.0	26.2	
All	7.0	14.3	77.8	25.0	17.9	
Other	20.9	21.4	0.0	25.0	19.0	
How swine erysipelas is controlled?						
Vet treatment	71.4	68.2	100.0	83.3	80.9	0.303
Quarantine	14.3	9.1	0.0	4.2	5.9	
Vaccination	0.0	4.5	0.0	12.5	5.9	
Other	14.3	18.2	0.0	0.0	7.4	
How worms are controlled?						
Deworming	88.4	82.1	62.5	50.0	82.7	0.110
Vet treatment	11.6	14.3	25.0	50.0	14.8	
Other	0.0	3.6	12.5	0.0	2.5	

**Other health problems include respiratory diseases, accidents and wounds, abnormality, etc.*

Disease outbreak were reported by only 12.9% of farmers and most of them experienced it (43.4%). Swine erysipelas is the most reported diseases (83.02%) and this caused death of pigs with average of three to four pigs per farmer (Table 60).

Table 60: Experience in disease outbreak

Parameters	Provinces				Overall	P-value
	East	West	North	South		
Did you experience a disease outbreak in your Flock?						
Yes	9.9	19.1	9.3	12.6	12.9	0.112
No	90.1	80.9	90.7	87.4	87.1	
How long ago did you experience a disease outbreak?						
< 3 month	22.2	14.3	20.0	38.5	22.6	0.837
3-6 months	11.1	19.0	20.0	7.7	15.1	
6-12 months	11.1	19.0	30.0	15.4	18.9	
>12 months	55.6	47.6	30.0	38.5	43.4	
What was the name of the disease/Signs?						
Swine erysipelas	66.67	95.65	88.89	66.67	83.02	0.015
Diarrhea	11.11	4.35	11.11	25.00	11.32	
Skin diseases	22.22	0.00	0.00	8.33	5.66	
Other*	22.2	0.0	0.0	25.0	9.4	
Were there any deaths during the outbreak?						
Yes	61.5	83.3	44.4	84.6	69.1	0.027
No	38.5	16.7	55.6	15.4	30.9	
Total number of died pigs	13	61	62	31	167	0.206
Number of died pigs per farmer	2.17	3.05	7.75	2.82	3.71	
Maximum number of pigs died per farmer	8	7	40	7	40	

** Other diseases include worms, skin diseases and wounds*

Record keeping: Most of the farmers (87.7%) don't take records of pig management in their farm, some of them judged that it is not necessary (20.5%); others mentioned lack of knowledge (28.6%) or they didn't know that is important (29.4%). Farmers who take records (12.3%), keep it in note-book 98.2% of them use the information recorded and are mostly kept in a note book (76.9%). The recorded information was used for planning (73.5%), for example, the date of breeding served to help farmers to prepare for delivery date, especially for stocking feed, cleaning, and preparing the place for sow with piglets. Birth date was kept by 15.8% farmers and helped them to plan for the weaning period of piglets.

Source of information about pig management: Most farmers acquired information about pig keeping from family members (40.8%) or from other farmers (34.3%). Radio was reported by 10.7% farmers. Other sources were very minor –government (4.9%), farmer groups (3.3%), NGOs (1.6%) and even own trial by the farmer himself. Most of pig farmers never attended any training (92.6%) on pig management, only 7.4% attended training at least once. Trainers were from NGOs (54.8%), local authorities (16.1%), private vets (9.7%) and RAB (6.5%). Most of pig keepers (86.0%) reported no extension worker visiting them. Those who received visits from extension workers reported that they were from Sector vet (44.9%) and private vets (28.6%). Feeding, disease treatment, general pig management and breeding were main topics advised.

Pig artificial insemination and assessment of transportation methods for fresh boar semen quality

The Artificial Insemination (AI) for pigs was introduced in 2009, and currently two AI centers are operational, private farm at CPPA Kisaro (Centre de Perfectionnement et de Promotion Agricole de Kisaro), and UR-CAVM Busogo. The progress of AI is shown in Table 61. Since 2013, RAB is investing efforts to strengthen pig genetic improvement by training of technicians to perform pig artificial insemination. By December 2019 a total of 84 veterinary technicians have been trained by RAB in Rulindo, Gasabo, Musanze, Rubavu and Nyabihu.

Table 61: Progress with pig artificial insemination in AI Centers (UR-CAVM Busogo, CPPA Kisaro)

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
2018/2019	248	1,350
2019/2020	298	-
Total	**1,361**	**5,052**

Apart from requiring specific catheters and trained staff, preserving and transporting boar fresh semen in proper conditions is needed to ensure high reproductive performance. Fresh semen has to be stored at 17^0C, and we have two operational AI centers in Northern and one in Rwamagana. A study was done to assess conservation and transportation methods for fresh semen and deliver recommendations on their improvement so that the semen could be easy handled by veterinary technicians from pig AI center up to farm for immediate use. Tests on viability and fertility of boar spermatozoa under various temperature were conducted. All currently used conservation and transportation methods were assessed including comparison of age of semen donor's effect on semen viability and fertility.

Photo 32: Different tools used for transportation of pig semen

Photo 33: Sample analysis

Table 62: Spermatozoa motility after 3 hours 31minutes out of recommended temperature

N	Method to be tested	Temperature	Motility (%)
1	Cool Box +Ice pack at 5^0C+ Semen	14	55
2	Cool box +Special Envelope +Ice pack at 5oC+Semen	17	60
3	Cool Box +Ice Pack at 17^0C + Semen	23	65
4	Ordinary Bag +Ice Pack at 17^0C + Semen	23	73
5	Ordinary Bag +Special Envelop +Ice Pack at 17^0C+Semen	24	75
6	Cool Box +Special Envelope +Ice pack at 17^0C	25	75
7	Ordinary Bag +Wet Clothes +Semen	26	80
8	Banana Stem+ Semen & Bag	26	80
9	Ordinary Bag +Special Envelope + Semen	28	80
10	Air conditioned Box + Semen	30	80

Table 63: Spermatozoa motility after 6 hours 47 minutes out of recommended temperature

N	Method tested	Temperature	Motility (%)
1	Cool Box +Ice pack at 5oC+ direct contact with semen	13	45
2	Cool box +Special Envelope +Ice pack at 5oC+Semen	16	40
3	Ordinary Bag+Special Envelope + Ice Pack+Semen	25	60
4	Cool Box+ Ice Pack at 17oC + semen	26	45
5	Ordinary Bag+Wet Clothes+Semen	26	65
6	Cool Box+Special Envelope+Ice pack at 17oC	26	65
7	Ordinary Bag+ Ice Pack at 17oC + semen	27	50
8	Banana Stem +Semen	27	65
9	Ordinary Bag+Special Envelope + Semen	28	70
10	Air conditioned box +semen	30	65

Table 64: Spermatozoa motility after 17 hours from recommended temperature

N	Method to be tested	Temperature	Motility (%)
1	Banana Stem + Semen	23	50
2	Cool Box +Ice pack at 5oC+ direct contact with semen	23.5	30
3	Ordinary Bag+Wet Clothes+Semen	24	30
4	Cool box +Special Envelope +Ice pack at 5oC+Semen	24	40
5	Cool Box+ Ice Pack at 17oC + semen	24.5	55
6	Ordinary Bag+ Ice Pac7k at 16oC + semen	25	20
7	Ordinary Bag+Special E8nvelope + Ice Pack+Semen9	25	60
8	Cool Box+Spe10cial Envelope+Ice pack at 17oC	25	40
9	Ordinary Bag+Special Envelope + Semen	25.5	20
10	Air conditioned box +semen	26	30

Table 65: Temperature and motility after 17 hours out of recommended conditions

N	Method to be tested	Temperature	Motility (%)
1	Ordinary Bag+Special Envelope + Ice Pack at 17^0C+Semen	25	65
2	Banana Stem+ Semen & Bag	25	65
3	Cool Box +Special Envelope+Ice pack at 17^0C	25	60
4	Ordinary Bag+Wet Clothes+Semen	25	58
5	Air conditioned Box + Semen	29	58
6	Ordinary Bag+Special Envelope + Semen	27	57
7	Cool box +Special Envelope +Ice pack at 5^0C+Semen	22	53
8	Cool Box +Ice Pack at 17^0C + Semen	21	48
9	Ordinary Bag +Ice Pack at 17^0C + Semen	25	48
10	Cool Box +Ice pack at 5^0C+ Semen	17	43

Tables 62-65 and Photo 32 show that by using cool ice packs from fridge at 5^0C, the lab tests (Photo 33) showed that the temperature was maintained near recommended temperature, which means that semen can be well packed and transported to a long distance (many hours). The spermatozoa can be alive with good motility (›60%) even above the recommended temperature (over 25^0C) in more than 6 hours which means that the pig semen can be used almost in all districts without special conservation (only cool box, ordinary bag and ice pack/wet clothes). With increase of conservation time out of the recommended temperature, semen motility has reduced significantly. The semen motility rate depends on conservation temperature where spermatozoa move in temperature over 20^0C. This is why the motility of semen conserved at 5^0C is very low as compared to that conserved at 17^0C. In average, 7 available and affordable materials to conserve temperature showed over 50% of mobility rate (Tables 62-65).

Comparison of materials which conserve well temperature and motility rate: In batch 2, the comparison was made to see the effect of temperature on sperm motility while use of different materials for semen storage/transport. Table 66 shows that all semen samples were evaluated with very low motility rate and it was bad surprise to the team, we knew all conservation and transportation conditions were maintained as for the first batch of samples. Concerning temperature factor, this table shows that there is no significant difference between materials used to evaluate temperature preservation capability. These results have strongly oriented us to make other comparison between semen collected from young and old boars.

Table 66: Spermatozoa motility after 3 hours 17 minutes out of recommended temperature

N	Method to be tested	Temperature	Motility (%)
1	Ordinary Bag +Ice pack at 5^0C +Semen	18	5
2	Ordinary Bag +Special Envelope + Ice Pack +Semen	20	5
3	Cool Box +Ice pack at 5^0C +Semen	20	5
4	Cool Box +Special Envelope +Ice pack at 17^0C	21	20
5	Ordinary Bag +Ice pack at 17^0C+Semen	22	0
6	Cool Box +Ice pack at 17^0C+Semen	25	5
7	Cool Box +Wet Cloth +Semen	25	5
8	Ordinary Bag +Semen	26	5
9	Cool Box +Semen	27	5
10	Air conditioned box+ Semen	30	10

Motility of semen collected from young and old boars : Tables 67-68 show that at same temperature, there is significant difference on motility rate between young and old boar where none old boar rated over 20% while that of young boar vary between 60 to 80% which justify the previous

results obtained in batch 2. Table 67 shows that there is no significant difference between materials evaluated for conservation of temperature (cool box and bag) which means that it is easy to transport boar fresh semen.

Table 67: Spermatozoa motility after 5 hours 30 minutes from recommended temperature

Materials evaluated	Boar ID	Temperature	Motility (%)
Cool box + Ice pack at 10^0C+ Semen	Young Boar_Kisaro	22	50
	Old Boar_Kisaro	22	10
	Old Boar_Busogo	22	5
Cool box + Semen	Young Boar_Kisaro	26	60
	Old Boar_Kisaro	26	10
	Old Boar_Busogo	26	20
Ordinary Bag+ Ice pack at room t^0+ Semen	Young Boar_Kisaro	22.5	50
	Old Boar_Kisaro	22.5	0
	Old Boar_Busogo	22.5	5
Ordinary Bag+ Semen	Young Boar_Kisaro	24	70
	Old Boar_Kisaro	24	10
	Old Boar_Busogo	24	30

Table 68: Spermatozoa motility after 7 hours from recommended temperature

Materials evaluated	Boar ID	Temperature	Motility (%)
Cool box + Ice pack at 10^0C+ Semen	Young Boar_Kisaro	26	60
	Old Boar_Kisaro	26	10
	Old Boar_Busogo	26	20
Cool box + Semen	Young Boar_Kisaro	26	80
	Old Boar_Kisaro	26	10
	Old Boar_Busogo	26	20
Ordinary Bag+ Ice pack at room t^0+ Semen	Young Boar_Kisaro	26	70
	Old Boar_Kisaro	26	0
	Old Boar_Busogo	26	0
Ordinary Bag+ Semen	Young Boar_Kisaro	26	80
	Old Boar_Kisaro	26	10
	Old Boar_Busogo	26	20

Note: All semen samples were exposed to room temperature for good comparison

This study revealed that (1) boar sperm preservation and transportation can be done easily and with affordable materials. It is resistant to high temperature above 25^0C over 6 hours, which allows

sufficient time for handling by inseminators. (2) The significant difference was noted on sperm motility from young and old boar, which requires further analysis, however, the semen from young and old boars shows no difference in the efficiency of AI (CPPA Kisaro AI records). The technology of freezing semen is not practiced in Rwanda yet, and it is not advised for commercial semen due to its suspicion to reduce fertilizing ability, its high costs and necessity of equipment and trained staff. However, frozen boar semen may be used in some cases, such as germplasm banks and importation of new genetic material.

The following guidelines for pig semen handling may be recommended:

- Boar fresh semen, particularly from young/mature boar, may be used, when conserved in cool box or bag and ice packs or wet clothes added, that could give good result to AI success.
- The use of special envelop *(Peak Pack/TAP Comebag E)* may be recommended to inseminators and AI centers for safe control of spermatozoa shock during transportation and it contributes also in temperature preservation.
- The use of banana stem, even if gives good result, can be replaced by above recommended materials as it is not presentable and cannot be found everywhere when needed (Eg. Kisaro, Busogo).
- When fresh semen has to be transported for long distance and/or used in over 6 hours, must be well conserved in temperature below 10^0C by using cool ice packs and avoiding direct contact with semen bottles by adding foam or clothes.
- Even though significant variation of semen motility between the boars tested after 3 hours of transportation, further study may be recommended to RAB and AI centers for finding the real cause and implication of age factor both in laboratory and on farm analysis.

2.1.2 Chicken

Characterisation of local chicken

Poultry research focused on phenotypic and genetic characterization of local chicken in all provinces of Rwanda. Four types of indigenous chicken were identified: Umurangi (Umujosi), Inshenzi, Sekaganda (Inganda) and Indayi (Photos 34-37). All types has similar female age sexual maturity - 6.6 months; similarly for males achieving maturity in about 7 months.

Photo 34: Umurangi type of local chicken

Photo 35: Inshenzi type of local chicken

Photo 36: Indayi type of local chicken

Photo 37: Sekaganda (Inganda) type of local chicken

There was no significant difference in number of eggs per clutch (13-18) and number of clutches per year (3-4), age of female maturity (6-9 months), annual egg production (38-72) and hatching rate (80-89%) between four types. Indayi and Umurangi achieve point of lay significantly earlier (at 6 months) than Inganda and Inshenzi (7 months). Cocks of four types did not differ in age of maturity. Rwanda indigenous chickens might have useful genetic potential, which can be used further.

2.1.3 Small Stock Project in Western Rwanda

Small Stock Project was implemented in in Western Province, Rusizi, Nyamasheke, Rubavu, and Rutsiro, the districts with high potential of cross-border trade of live animals, animal products, high level of malnutrition, and poverty.

Engagement of new producers

Before 2016, Western province was counting a lower number of poultry and pig farmers. Thus, engagement of new producers in pig and poultry production was done. These were unemployed rural youth who embarked in poultry and pig business for income generation and job creation.

Photo 38: Youth cooperative feeding kids with eggs (left); eggs prepared for sale (right)

A total of 202 new groups of pig producers and 46 new groups of poultry producers were formed during the project (Table 69). They are now involved in pig and egg marketing. As a result, earlier importation of eggs has stopped, and some eggs are now exported at Rusizi and Rubavu borders. Youth cooperatives established have started an initiative to distribute eggs (as donation) to mal-nourished children & households in rural area and at nearest health centres (Photo 38).

Table 69: Number of cooperative groups formed during the period covered by the assessment

	Rutsiro	Rubavu	Nyamasheke	Rusizi	Total
FY 2016/17					
Pig (Groups)	N/A	N/A	50	0	**50**
Poultry (Groups)	N/A	N/A	9	17	**26**
FY 2017/18					
Pig (Groups)	38	38	38	38	**152**
Poultry (Groups)	5	5	5	5	**20**

Distribution of pigs and poultry

A total of 1680 pigs and 27000 layer chicken were distributed by the project in Rutsiro, Rubavu, Nyamasheke and Rusizi (Table 70, Photo 39). Because of increase and availability of eggs on the market (Photo 40; Table 71), egg prices have decreased from 95-100 Frw before the project to 70-80Frw after the project.

Table 70: Pigs and chicken distributed during the project period

FY 2016/17	Rutsiro	Rubavu	Nyamasheke	Rusizi	Total
Pigs	N/A	N/A	550	N/A	550
Layers/Isabrown	N/A	N/A	9000	18000	27000
FY 2017/18	Rutsiro	Rubavu	Nyamasheke	Rusizi	Total
Pigs	420	420	420	420	1680
Layers/Isabrown	5000	5000	5000	5000	20000

Photo 39: Piggery established by youth cooperative (left); sow with piglets (right)

Table 71: Eggs produced by the distributed chicken

Districts	Chicken distributed	Mortality (%)	Chicken alive	Laying rate (%)	Eggs produced
2016/17 Financial Year					
Rusizi	18,000	12.2	15,800	80	4,320,195
Nyamasheke	9,000	10.4	8,065	81	2,290,418
Total	**27,000**		**23,865**		**6,610,613**
2017/18 Financial Year					
Rusizi	5,000	10.1	4,495	78.4	1,234,660
Nyamasheke	5,000	8.2	4,600	81.4	1,311,013
Rutsiro	5,000	11.4	4,435	80.8	1,254,470
Rubavu	5,000	11.4	4,435	82.0	1,273,458
Total	**20,000**		**17,965**		**5,073,600**

Photo 40: Poultry keeping by youth cooperative (left) and egg harvest (right)

Impact assessment study

This study aimed to assess impact of small stock program on income, food and nutrition security The impact of poultry and pig distribution was measured on household income, food security and nutrition, and crop productivity through focus group discussions and key informant interviews which covered 550 farmers. The study involved beneficiaries of pigs and poultry and non-beneficiaries served as control groups. To assess farmers' livelihoods, six indicators of four household livelihood outcomes were considered for poultry and pig farmers. These indicators were respectively: (1) household annual income, (2) household weekly expenditures, (3) household food security, (4) household crop productivity for maize and beans as well as (6) household nutrition. Project beneficiaries outweighed non-beneficiaries in five out of six indicators for poultry production and for three out of six for pigs ($p<0.1$). Poultry beneficiaries' income increased but they are not spent for nutrition improvement. Therefore, nutrition education should be given especially the women members that have children. For nutrition, chicken beneficiaries consume almost two

times more eggs than non-beneficiaries. The most (≥ 75% of respondents) of beneficiaries and non-beneficiaries had enough food 7/12 months of the year (Figure 21). Furthermore, over a half (> 50%) of the respondents reported having enough food 10/12 months of the year. A bigger percentage of pig beneficiaries confirmed having enough food throughout the year than non-beneficiaries except during the last three months of the year.

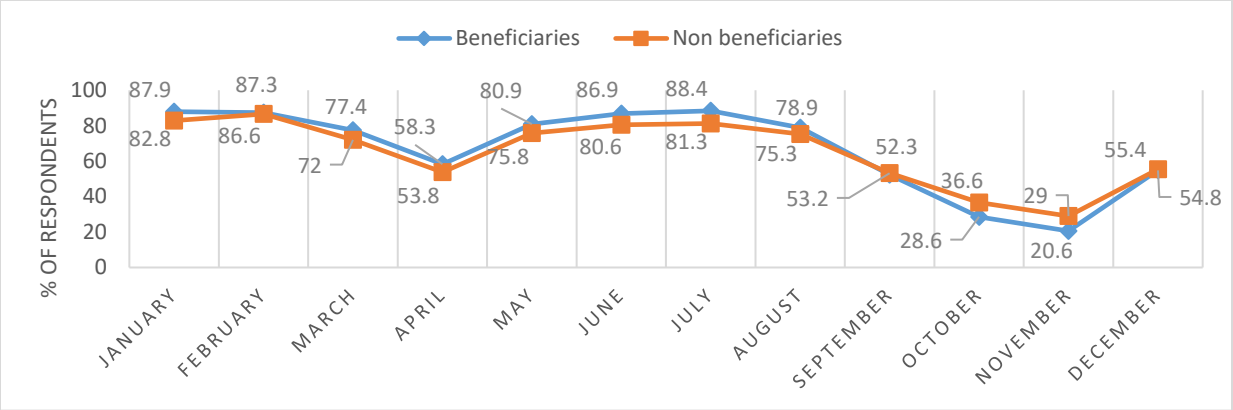

Figure 21: Food availability among pig beneficiaries and non-beneficiaries

More than 65% of poultry beneficiaries indicated to have enough food 8/12 months of the year whereas more than 65% of poultry non-beneficiaries had enough food to feed their families only 4/12 months of the year (Figure 22). Over a half (> 50%) of the respondents reported having enough food throughout the year except in April and November. A bigger percentage of poultry beneficiaries confirmed having enough food throughout the year than non-beneficiaries except during the months of April (48.8% and 48.8% for beneficiaries and 49% non-beneficiaries) and December (55.8% beneficiaries and 55.1% non-beneficiaries). Moreover, increase in egg consumption was recorded after the project activities (Figure 23).

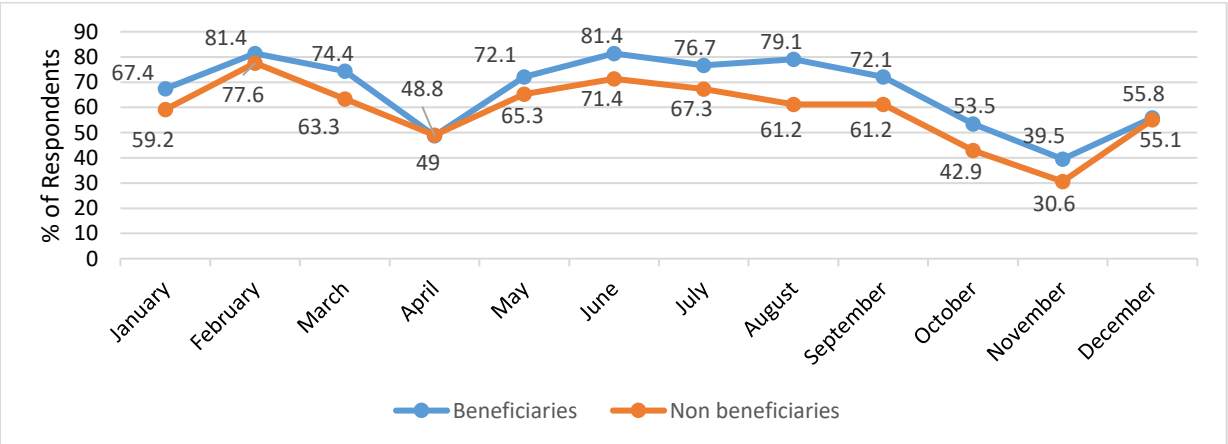

Figure 22: Food availability among poultry beneficiaries and non-beneficiaries

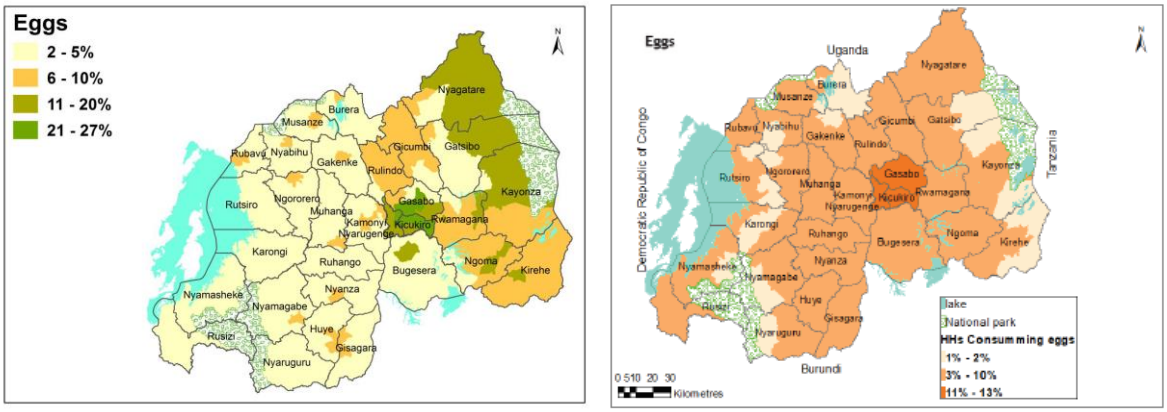

Figure 23: Percentage of households consuming eggs at least once a week: CFSVA 2012 (left) and CFSVA 2018 (right)

Therefore, we recommend to strengthen nutritional training program, especially for mothers having kids; Availability and accessibility of industrial feeds and vaccines should be guaranteed for beneficiaries through establishment of feeds industries and agro dealership in their locality; Although the project had encouraging impact on beneficiaries' livelihoods, expected income, job creation and food security have not been attained satisfactorily. This reveals the necessity to improve the project design, implementation, and monitoring and evaluation so as to unlock its full potential; Up-scaling of the small stock project should focus on identification of good practices in the pilot area.

Chicken and pig distribution in other districts

Distribution of chicken and pigs continued to other districts (Table 72; Photo 41) - Gisagara, Nyaruguru, Nyamagabe, and Nyabihu. Gicumbi.

Table 72: Chicken distribution under small stock project

S/n	Districts	Target	Chickens distributed	Rate of distribution %
1	Gisagara	9000	9000	100
2	Nyaruguru	9000	9000	100
3	Nyamagabe	9000	9000	100
4	Nyabihu	9000	9000	100
5	Gicumbi	9000	8000	90
6	Burera	9000	0	0
7	Ngororero	9000	0	0
	Total	63,000	44,000	

Photo 41: Distributed sows with piglets at Kansi, Gisagara; youth group Twishakemo Ubushobozi preparing to receive one-day old chicken, Mukindo, Gisagara

2.2 Apiculture and Commercial insects program

2.2.1 Bee and Apiary

Bee research aims to develop technologies for increased and safe honey production for increased income, better health and wellbeing.

Construction of demonstration apiaries

Two new apiaries were established in Huye with collaboration from COPABUHU cooperative. One of them was set in arboretum and another in Ibisi bya Huye. Among 52 colonies, 34 were strong bee colonies which well colonized.

Photo 42: New apiaries installed in Huye

Due to insufficient pollen, all the colonies were feeding by bee fonda rich in protein and vitamin to accelerate the laying activities of the queen. Worker bees were feed by bee fonda also because they require proteins (amino acids), carbohydrates (sugars), lipids (fatty acids, sterols), vitamins and minerals (salts) in their diet in a definite qualitative and quantitative ratio for optimum nutrition.

Evaluation of bee feeding and mite control for elimination of Varroa destructor

Varroa mite has been found in Rwanda since 2000, it remains as the worst pest nowadays. Fluvalinate is the only tested chemical for the Varroa control since 2010, and cases of pest resistance to this chemical appeared to happen. Alternative chemical reported is oxalic acid, which is a natural substance of honey. It is also allowed for use in the organic apiculture to control V. destructor (EU Council Regulation, No. 1804/1999). In Rwanda, it is brood-right all year round in the most honey bee colonies, which limits control efficiency. Therefore, the application method of oxalic acid in Rwanda needs to be combined with other methods or using different products. In this study. This study tested bee fonda (rich in proteins and vitamins) for bee feeding and use of strips to eliminate Varroa. Thirty infested by Varroa bee colonies in ordinary hives. Bee fonda was used to replace pollen for feeding nurse bees and also as a varroacide. Trial was conducted in rainy and dry season in Rubona with treatments of bee fonda (50g, 100g and 120 g) and strips (1, 2 and 3 per hive) for three weeks. No more brood death was found during the testing period. This witnesses that all three treatments were efficient (Table 73).

Table 73: Varroa drop-down (%) expressing efficiency of honeybee colonies receiving three successive treatment of bee fonda with strips

Treatment	Apiary 1 (H1-10)	Apiary 2 (H11-H20)	Apiary 3 (H21-H30)	Cumulative mortality
50	2.5 ± 1.3a	5.1 ± 1.9a	9.2 ± 3.4a	15.3 ±5.1a
100	27.7 ± 6.9b	27.6 ± 8.4b	20.5 ± 7.3b	82.7 ±12.3b
120	22.9 ± 1.1b	39.2 ± 5.2c	20.3± 6.4b	95.5 ±9.8c

**Means in the same column followed by a different letter are significantly different by Duncan's multiple range test (p<0.05)*

Nurse bees are the nutritional center of the colony, they are the main bee fonda consumers and feed royal jelly to all other colony members. The results showed that the more we increased the treatment with bee fonda, the more we found Varroa mites on the bottom of the hives. The Duncan's test showed the significant differences among different treatments. This shows that the bee fonda increases the hygienic behavior of honey bees which become able to fight against Varroa. The third treatment, which consisted to insert three strips at a time in the bee colony, eliminated

more Varroa. The highest drop of Varroa was 69.3% of mites per hive when the lowest was 28%. There has been increase in dear Varroa after every week.

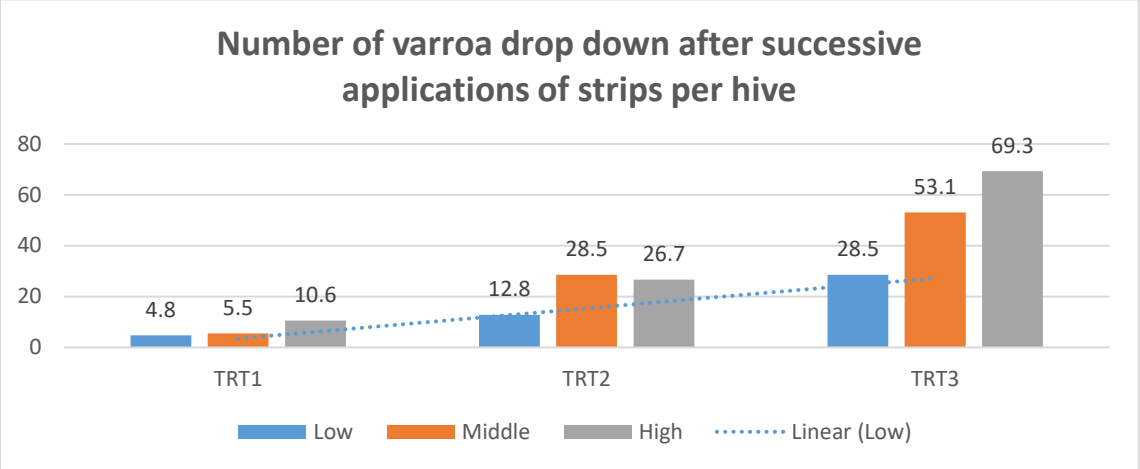

Figure 24: Quantity of varroa drop down after successive applications of strips per hive

Table 74: Percentage of dead varroa in the brood cells before and after treatments by bee fonda and strips

	Pre-treatment	Strips			Strips + Bee fonda
Doses	May 9*	May 18	May 27	Juin 6	Juin 15
1 strip/hive	53.3±5.7a**	87.8±5.9a	90.3±9.2a	87.3±5.3a	86.0±3.2a
2 strips/hive	66.5±4.2a	89.3±8.7a	84.5±5.1a	87.0±6.0a	87.5±6.3a
3 strips/hive	58.3±8.0 a	91.8±9.1a	85.8±6.0a	88.8	94.0±4.3a

**Means in the same row followed by a different letter are significantly different by Duncan's multiple range test ($p<0.05$).

The strips mixed were applied from May and after every nine days and Duncan's test showed also a significant difference among different treatments. On 15th June 2020, the bee fonda product combined with strips were also applied at different doses and the dead mites were also increased in the broods the more we increased the doses. Strips are natural products isolated from plants. They have also been found to present a high control efficacy on Varroa mites. In wet season, putting strips combined with bee fonda controlled Varroa more efficiently with any varroacide (Figure 24; Table 74). Using strips as the alternative Varroa mite control, lethal effect could persist for more than 30 days or more except when it is dry time, it is very convenient and you do not need to always open the hive before 9 days. In rainy season, we suggest using the combination of strips and bee fonda for Varroa control because it feeds bees at the same time it treats Varroa mites. Strips can be use alone during dry season or be combined with bee fonda. These products should replace chemicals, which leave their residues in honey.

Capacity building of master beekeepers and technical practices in beekeeping

A total of 210 master beekeepers from different districts (Bugesera, Kamonyi, Huye, Rusizi, Musanze, Gasabo, Rubavu, Nyabihu, Nyagatare, Rwamagana and Gatsibo) received skills training on beekeeping management, hives construction, bee suits making, bee feeding, colony multiplication, queen rearing and other beekeeping skills (Photo 43). The training aimed these to help youth and women in addressing challenges related to beekeeping techniques, create market linkages and promote sustainable management of the natural and planted woodlands. A training manual was designed and distributed. After the training, some beekeepers started to practice hive making (top bar hives) and to multiply their bee colonies.

Photo 43: Training of bee keepers

Development of queen-rearing technologies

Four technologies for queen rearing were developed (Photo 44), namely, Jenter, Hopkins, beeswax cells and Dolittle. Jenter or cupularva and Hopkins technologies were disseminated to farmers through training and trials but the beeswax cells and Doolittle technologies will be disseminated in different cooperatives next fiscal year.

Photo 44: From left to right: wax cells, Jenter, Dolittle and Hopkings technologies for queen rearing.

The Jenter and Dollitle techniques were developed and disseminated to 7 cooperatives in Musanze, Rubavu and Rutsiro as nucleus of beekeeping in the communities (Photo 44). The master

beekeepers prefer to use Jenter technology because it's easier to use in raising queen bees but it's expensive. We recommended them to use Hopkins technology because it uses the same techniques as Jenter technology but using local materials. The dissemination of those technologies will continue next fiscal year 2020-2021.

Support to COPABUHU Cooperative with 30 honey bee colonies

In the night of 6th April 2020, the apiary of Cooperative COPABUHU practicing apiculture in 'Ibisi bya Huye' was vandalized, by robbers. The Cooperative lost 112 honey bee colonies out of 524 bee colonies, which were producing 10 tons of honey per year. About 80% of the bees were destroyed by hoaxes equivalent to 3.9 million Rwandan francs. The case was reported to the police and the Governor. Two suspects are in the custody of RIB, but there is another set of 5 suspects who have not been caught yet in Simbi Sector. From a meeting held between RAB and the cooperative leadership, RAB agreed to offer 30 honey bee colonies to the cooperative and in June RAB will help the cooperative with queen rearing and honey bee colony multiplication.

Photo 45: COPABUHU cooperative apiary in Huye

The cooperative requested for advocacy for professional security organs such as police and military to patrol the forest because robbers there are armed with traditional arms. From 20th to 21st April 2020, RAB provided a total of 30 strong honey bee colonies, one bee smoker and promised them to multiply their bee colonies during the honey flow in June (**Photo 45**). The president of COPABUHU cooperative Mr. Uwingabire Patrick was very grateful for the donation received and he required more support from the Ministry of Agriculture and Animal Resources in terms of advocacy and capacity building.

2.2.2 Silkworms and mulberry

Since 2005, Sericulture was formally introduced in Rwanda. It has been practiced by individual farmers and cooperatives wherever the mulberry is grown in various parts of the country. Currently the area covered by mulberry plantation in Rwanda is about 950 ha and the total production of Cocoon expected out from the current tree population is only 30,436 kg per year. Besides low production, sericulture is challenged by low mastering of production technologies for cocoon and raw silk, and inadequate experience and training of farmers. Sericulture research aims to develop high yielding and disease resistant silkworm breeds and mulberry varieties; develop appropriate sericulture technologies, and strengthen capacity of farmers in appropriate production techniques of both mulberry cultivation and silkworm rearing.

Characterization of 4 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 leaf moisture content and moisture retention capacity of four mulberry varieties were conducted. These mulberry varieties include Diamond, as control, KANVA, RSC-2, and Thailand. 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.

Determination of leaf moisture content and moisture retention capacity

Leaf moisture content and moisture retention capacity were determined. Mulberry varieties varied in moisture and moisture retention capacity. Moisture content was significantly high in tender (88.00 %), medium (75.10%) and coarse (70.40%) leaves of RSC-2 and lower was recorded in leaves of Kanva (60.20%, 54.70%, and 57.16% respectively). Moisture retention capacity was highest in tender, medium and coarse leaves of mulberry variety RSC-2 (71.50%, 69.04%, 67.90% respectively) and lowest was recorded in Kanva (58.20%, 56.40%, 54.70%) (Table 1).

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 enhance feeding efficiency of silkworm larvae, which in turn increases growth rate. Moisture content and moisture retention capacity was superior in RSC-2 followed by Thailand, Diamond and Kanva.

Table 75: Moisture content and moisture retention capacity of different mulberry varieties

Mulberry variety	Leaf maturity	Moisture content (%)	Moisture retention after 6 hours (%)
RSC-2	T	88.00	71.50
	M	75.10	69.04
	C	70.40	67.90
Thailand	T	80.10	68.16
	M	70.41	65.19
	C	68.03	65.61
Diamond	T	76.72	62.26
	M	64.77	60.84
	C	63.16	59.78
KANVA	T	60.20	58.20
	M	54.70	56.40
	C	57.16	54.70
T: tender, M: medium, C: coarse			

Characterization of 12 good performing silkworm breeds

The aim of this study was to evaluate quantitative characteristics of silkworm germplasm. The experiment was conducted in RAB Rubona. Twelve silkworm breeds namely: B2 (m), B2 (L), B3, B4, Luc, Demon, Progress, KN, Rub-1, Rub-2, C and J were used. At least 200 eggs of each breed were prepared and pasted on a paper sheet, wrapped and covered by black polyethylene to synchronize embryonic development. On the hatching day, eggs were exposed to an intensive light for obtaining uniform hatching, and immediately fresh chopped mulberry leaves were fed to the newly young larvae.

Young age instar (from 1st to 3rd Instar) silkworm larvae were conducted according to the standard rearing package (Singh et al., 2010) by proving adequate temperature (25 – 28°C) and humidity (70 – 80%), and follow proper hygienic conditions. At the onset of the 4th instar stage, 100 silkworm larvae were randomly selected per replication for each parental breed (300 larvae in total) and then transferred into the shelves for further rearing process. For maintaining adequate moisture of mulberry leaves fed, polyethylene sheets covered silkworms in the rearing shelves. Demon,

Progress and E-08 recorded the higher cocoon weight for both female, above 2.5 g and males (> 2.1 g). Similar trends were observed in pupal weight and shell weight (Table 76), where Demon, Progress, E-08, B2 (M), and Luc were highly ranked, while KN, C and Rub-2 recorded the lowest values.

Table 76: Descriptive statistics of morphological and economic traits of 12 silkworm breeds

	Larva, days	Cocoon weight (g)		Pupal weight (g)		Shell weight (mg)		Shell ratio (%)	
		Female	Male	Female	Male	Female	Male	Female	Male
B2 (M)	26.2	2.35	2.06	2.03	1.61	493	503	20.3	23.6
B2 (L)	26.0	2.17	1.88	1.78	1.4	467	488	18.4	22.1
B3	26.3	2.28	1.76	1.84	1.38	471	481	19.2	22.1
B4	27.2	2.34	1.98	1.81	1.47	516	520	20.6	25.8
Luc	26.9	2.56	2.07	2.07	1.57	504	513	18.7	22.6
Demon	27.1	2.72	2.13	2.13	1.62	550	522	20.3	24.2
Progress	27.2	2.61	2.11	2.09	1.6	509	468	19.7	21.8
KN	25.8	1.88	1.55	1.39	1.24	341	325	19.1	20.4
Rub-1	25.3	1.97	1.91	1.55	1.53	420	427	17.6	21.3
Rub-2	25.4	1.83	1.83	1.41	1.48	437	418	18.9	21.4
C	25.1	1.91	1.86	1.47	1.42	450	432	19.1	20.8
E-08	27.4	2.66	2.18	2.08	1.62	528	536	20.3	25.2
Means	26.3	2.27	1.94	1.80	1.50	473.8	469.4	19.3	22.6

Maintenance of mulberry plantation and plant material production

Mulberry plantation in Rubona serves as mother garden for production of cuttings. The mulberry variety used to produce saplings in the nursery was Diamond. More than 200 000 mulberry cuttings were sourced from Rubona mulberry mother garden and planted for the production of saplings (Photo 46) that were distributed in different districts of the southern province (Huye, Nyamagabe, Gisagara, and Nyaruguru).

Photo 46: Mulberry cuttings preparation at RAB Rubona (left); saplings preparation (right)

Maintenance of 40 silkworm breeds and silkworm hybrid eggs production

It is known that in practical sericulture hybrids of mulberry silkworm are of higher performance due to heterosis effect. A total of 40 breeds of silkworms were maintained for hybrid egg production (Photo 47).

Photo 47: Incubation process for silk worms (left) and silkworm larvae (right)

Such tasks proceeded with the main goals of producing silkworm hybrids, which are resistant to diseases; perform well in unfavorable conditions of the environment; high viability and silk productivity. During this fiscal year (2019-2020), 200 hybrid eggs were produced from our best hybrid combinations. These hybrid eggs are ready to be distributed.

Screening of mulberry varieties

The quality of cocoons in which silkworm larvae produce depends on quality of mulberry leaves. Information on good mulberry varieties to be used for cocoon production is still limited. It may be valuable to study the nutritional value of different mulberry varieties grown in Rwanda. In this study, we evaluated the effect of different mulberry varieties on silkworm larva growth and economic traits. Four Mulberry varieties namely Diamond, RSC-2, Kanva-2 and Polyploid were selected to feed SH silkworm breed. Feeding assay was prepared to investigate which mulberry is the best. On the second day of the third instar, 200 randomly selected silkworm larvae were collected and divided into four groups (treatments) with four repetition each group. Each treatment was distinguished by the mulberry variety fed, whereby four varieties were used: Diamond, RSC-2, Polyploidy and Kanva-2.

Rearing technology and feeding was the same for each treatment, and even quality and quantity used were uniform. The difference between mulberry varieties whose leaves were used to feed silkworm larvae was concluded by the difference in larvae growth (i.e. weight). The worms were fed with same quantity of mulberry leaves. Larvae fed with leaves of polyploidy variety Diamond were significantly different compared to those fed on other varieties.

Economic traits: Cocoon weight, shell ratio were similar for all cocoons developed from silkworms fed with different mulberry varieties, however, shell and pupal weights were greater in cocoons developed from silkworms fed with Diamond mulberry. Irrespective from variety use, females had higher cocoon weight (1.8g) as compared to males (1.43g); higher pupal weight (1.45g than males 1.10g) and greater shell weight (344.3mg than males (327.6mg), but lower shell ratio (19.2mg than males, 22.83mg). Therefore, use of polyploid variety would lead to better performance of silkworms.

Screening of 7 silkworm breeds

The experiment was carried out on seven *B. mori* parental breeds viz., Pr, J, C, D, Luc, B2 (m), and B2 (L), which were maintained at RAB-Rubona laboratory. Breeds varied in growth of larvae and cocoon characteristics, without having one which is significantly better in all traits. The observations will continue with further evaluation.

Establishment of on-farm trials

The superiority of polyploid mulberry variety Diamond let to the decision to establish this variety on farm and evaluate its performance. Hardwood stem cuttings of Diamond mulberry variety were used. The number of sprouted cutting, average number of sprouts per, length of longest sprout, diameter of thickest sprout, number of leaves on new shoots, shoot percentage, fresh and dry weight of shoot, root percentage, number of primary root, secondary root, length of longest root,

fresh and weight of root were recorded after three months. The preliminary data show that Diamond variety grows well, and the trial is 3 months old.

2.3 Aquaculture and Fisheries program

2.3.1 Capture Fisheries

Fishing has traditionally been an important socio-economic activity of communities living on the shore of the Rwandan Lakes since the ancient days. Fish production has been given priority in the recent years, and it has significantly increased from **24,877 tonnes** in FY2018-2019 to **35,312 tonnes** in FY 2019-2020. Fingerlings production has increased from **9,390,740** in FY 2018-2019 to **21,535,500** in FY2019-2020. The size of capture fishing is shown in Table 77 and total fish production including capture fisheries and aquaculture is in Table 78.

Table 77: Capture fishing in Rwanda, FY 2019-2020.

Lake or area name	Q1	Q2	Q3	Q4	Total (kg)
Northern Province					
Ruhondo	33,693	675,658	900,878	90,900	
Burera (COOPERU)	135,920	1,493,163	2,126,524	529,150	4,284,758
Nyirakigugu-Zamuka-fishing coop	1,123	3,730		1,077	
Karago Kotunya cooperative	1,000	2,840		2,140	
Total Northern Province Capture	171,737	2,175,392	3,027,402	623,267	5,997,797
Southern Province					
Water Pulls, Rivers and Dams	18,853	75,691	132,489	1,203,389	1,430,422
Eastern Province					
Gisaka Lakes	123,668	944,077	1,182,982		2,250,727
Bugesera Lakes	235,513	950,587	880,324	589,203	2,655,628
Nasho-Akagera	385,169	945,143	532,076		1,862,388
Akanyaru	102,280	128,017	442,544	145,973	818,814
Akagera	18,957	272,505	63,347	130,687	485,495
Nyabarongo & Masaka	52,467	38,850	72,658	87,627	251,601
Muhazi	3,535	97,469	128,230		
Total Eastern Province Capture	869,123	3,596,183	3,229,504	865,863	8,560,672
Western Province (lake Kivu)					

Rusizi	102,753	209,167	602,900	129,702	1,044,522
Nyamasheke	311,323	265,700	3,177,614	2,309,454	6,064,091
Karongi	59,692	697,933	244,765	283,240	1,285,630
Rutsiro	250,690	3,513,450	1,374,833	1,140,577	6,279,550
Rubavu	112,089	1,078,956	124,308	577,083	1,892,436
Total Western Province Capture	836,547	5,765,207	5,524,420	4,440,055	16,566,229
TOTAL CAPTURE	**1,893,260**	**11,612,472**	**11,042,961**	**7,132,574**	**31,681,267**

Table 78: Total fish production in Rwanda (FY 2019-2020)

Type of fish production	Q1	Q2	Q3	Q4	Total (kg)
Fingerlings Production	3,265,704	6,183,000	8,740,554	3,164,242	21,353,500
TOTAL AQUACULTURE (Kivu)	431,085	636,558	586,649	1,973,934	3,628,225
TOTAL CAPTURE	1,893,260	11,612,472	11,042,961	7,132,574	31,681,267
Total Aquaculture & Capture	**2,327,345**	**12,249,030**	**11,629,610**	**9,106,508**	**35,312,493**

2.3.2 Aquaculture

Aquaculture, in Rwandan context, fish farming, started in Rwanda at the end of the 1940s during the colonial period, and it was promoted mainly as a government-sponsored activity. In 1954, direct support was provided to fish farmers in form of extension services, seed, and other inputs. Aquaculture that existed until recently was subsistence fish farming with low input and low output, based on pond fertilization from livestock wastes with inherent managerial weakness of the public sector dependent on hand-outs to subsistence farmers. Nile Tilapia, Catfish, and Carpe were mainly cultured species reared in aquaculture. Types of aquaculture used were Pond culture, Pen culture, RAS tank culture, and Cage culture system in Kivu, Muhazi and Ruhondo Lake. Aquaculture Production in 2019/2020 FY was **3,630** tonnes (Table 78). In fingerlings production, 14 farms with hatcheries produced a total of 21,353,500 of fingerlings.

Facilitation of new investors in Cage Fish Farming

Currently, 18 investors are active and were facilitated by RAB. 13 investors have already received a concession for fish farming (Modern Fish Farming ltd; Hauge Aqua Rwanda ltd; Habineza Emmanuel; Cyatengwa Fish Fram ltd; Mr. Fish ltd; Fish Farm Rwesero ltd; Abadatenguha-Muvumba P8; Uwimana Agnes; Rwanda Fish Industries ltd; Nile Quality Food ltd; Mukamwiza Agnes; and

Musha Fisharies ltd., and 5 others are in the modality of application: Rwansir ltd; Fish Far Forces ltd; Sekamana Thesese; Build's One Company ltd; and E&M Tilapia Farm ltd.

Awareness Campaign

In February 2020, with assistance from 2020 RDF COP a team composed with RDF, RAB, MINAGRI, and Districts staff have conducted a mobilization campaign at the district level in the preparation of operationalization of fish ponds. During the campaign Farmers, Water users association, and Districts were requested to start harvesting existing fish species from operational ponds and dams. Preparation was undertaken for stocking, Farm clearing (cleaning), Rehabilitation of non-operational ponds; Removing mud, dyke compacting, bottom leveling, Installation of inlet and outlet system with assistance of hired by RAB company RARICO. RARICO was hired to provide technical assistance to enhance the management (production in quantity& quality, coop. management & organization) of existing fish ponds in the country; to provide training (capacity building and technical skills) to fish farmers (cooperatives and individuals); to prepare, organize and implement coaching of fish farmers on the cooperative building, its management, and leadership; to mobilize fish farmers (cooperatives and individuals) to access credits from financial institutions; to develop an action plan that includes the road map on fish production improvement in each fish ponds/farms assisted; To establish a database related to the reported production; and to link the fish farmers to the market. RARICO technician was assigned to support 96 pond farms on a daily basis. Water was removed in 938 ponds out of the existing 1099; equal to 725,044m^3 while the area target was 235,811.5 m^3. A total of 510 ponds equal to 352,854 m^3) ponds out of 1,099 have been rehabilitated and now are ready to be restocked.

Fish production was 9,856 Kg from 652 ponds equal to 487,313 m^3. The production sold to the local market, where fish farms operate. Cooperative members and customers consumed 5,432Kg (55.11%) and 4,424Kg (44.89%), respectively, while income generated 11,058,258Rwf.

Fish farming activities on pond rehabilitation contribute to the government policy of job creation. Farming families living near these fish ponds benefited from available daily job opportunities: 50 out of 96 farms recruited daily workers. They got an average daily payment of 2,000 Rwf for a total of 2,959 workers; (1514 men; 771 women and 674 are youth). The total circulating liquid cash was more than 130,588,000Rwf. Fish cooperative members committed their time (days) every week. Total participants per quarter involved were 5,921 members; 2887 men, 2584 women, and 450 youths. At a daily remuneration of 1,000Rwf, they covered activities of around 215,583,000Rwf.

Growth of newly Introduced Nile Tilapia at Kigembe fish farm

Nile tilapia, *Oreochromis niloticus*, is an important aquaculture fish species. Previously introduced from lake Albert and reared since 2010, fish stock was maintained for long and started to have some signes of degeneration, e.g. stunted growth of fingerlings as reported by fish farmers. Therefore, new introduction was made to regenerate fish stock, and research observations on growth of both populations were undertaken. This study was compares growth and feed utilization of Nile tilapia from Muhazi farm with the existing one reared in Kigembe farm.

Newly introduced Nile Tilapia from Muhazi farm, the mean final weight, weight gain, growth rate, differed significantly ($P<0.001$) as compared to the existing stock at Kigembe. Tilapia from Muhazi reached weight of 137.1g/fish, while the existing Kigembe Tilapia achieved only 89.6g/fish. Other measurements have shown the similar trend. Similarly, weight gain and specific growth rate (SGR) exhibited the same trend. However, the survival rate was similar for two tilapia strains. The introduced Tilapia from Muhazi farm (296.8g feed/fish) had significantly higher feed intake but lower Feed Conversion Ratio (FCR). Thus, Muhazi tilapia was more efficient in feed utilization and protein turn over than Kigembe Tilapia. Future prospects from this study will be crossing between the two strains while selecting for fast growth and lower FCR to improve the existing fish stock and quality of fingerlings.

Bromatology testing for various ingredients

One of the limiting factors in fish feed production is the cost of protein additives and their source. To address this problem, alternative sources of protein were identified and sampling done for protein content analysis for Spirulina, Water hyacinth, Azola (Duckweed), Cassava, Irish potato, Colocase leaves, and Brewery waste from Skol factory. Results are being analysed and will be reported later.

2.3.3 Restocking Lakes Ruhondo, Burera and Muhazi

According to the 'Plan d'Aménagement des 17 Lacs Intérieurs', the primary production (natural food) of Lakes Bulera and Ruhondo is not fully consumed by available fishes. It recommends restocking of species that can exploit various layers of lakes. The recommended rate of restocking is 10% for these lakes. The feeding of *Rastrineobola argentea* introduced in 1990-1991 in Lake Burera from Lake Victoria is based on invertebrates. It has been demonstrated that it feeds twice a day (early morning and in the evening) just as *Limnothrissa miodon* of Lake Kivu. The Zooplankton constitutes the main feeds in the morning and aquatic insects in the night. Considering the ecological requirements and feeding behavior of both sardine species, *Limnothrissa miodon* can be introduced in Burera and Ruhondo Lakes and increase fish production. *Limnothrissa* was proposed as a restocking species for both lakes. It is an omnivorous species endemic to Lake Tanganyika with a known lifespan of 2 years, admitting it feeds predominantly on zoo- and phyto-plankton

and insects as alternative feed with similar to Rastrineobola feeding schedule (morning and evening).

Limnothrissa reproduction is distributed all over the year but most often with a pick all along a prolific period of zooplankton bloom (September-February), and its spawning zone is in the littoral. The fecundity increase with size and varies from (600 eggs 55000 eggs). The population generally increase steadily from February to August and then fall because of high mortality and decreased recruitment.

From 11th – 16th November 2019, a total of about 650,000 *Limnothrissa miodon* (Isamabaza) fingerlings and fries were collected from lake Kivu, prepared, transported, and stocked in Bulera and Ruhondo lakes for adaptation with aim of enhancing fish production (fish catches) in those twin lakes. Fish collection was done in Kigufi, Brasserie, and Amashyuza bays. In Burera lake, they were released in Runyinya, Gitare, and Mugu bays, while in Ruhondo they were released in Murwa, Ruta, and Ntaruka bays. Besides, a total of 100,000 Tilapia fingerlings have been released in Muhazi Lake to increase production of this species for capture fisheries in this lake.

It is important to note that the restocking activities in the lakes are expected to have adaptation effect for newly introduced fish populations, however, such adaptation may take some time: with the example of Kivu lake, from the moment of *Limnothrissa* introduction from lake Tanganyika into lake Kivu to the start of fishery activities, there has been a span of 15-20 years.

2.4 Ruminant program (Cattle)

Multi- ovulation and embryo transfer activities

Seventy-two cows and heifers were successfully tested to be suitable for receiving embryos after an attentive recto palpation of the corpora lutea. Then 62 received fresh and frozen embryos at Rubona, Nyanza and Songa. Utrasonography was used in 1st Pregnancy Diagnosis (PD) for early pregnancy while manual palpation associated with Utrasonography were good for heavy pregnancy (Photo 48). On the 1st Ultrasound-PD test, 23 out of 62 recipients were pregnant (Success rate= 37%). With the aim of testing if there is no loss of conceived embryos, another PD test was organized for the 23 recently pregnant cows (20 in Songa, 1 at Rubona and 2 at Nyanza SHF) while on the 2nd Ultrasound-PD test 21 out of 61 were pregnant (Success rate= 34%) at Rubona, Nyanza and Songa.

: *Photo 48: Donors and recipients' selection, as well as PRID insertion*

Adoption of artificial insemination and success rate in dairy cattle in Rwanda

An effective way to increase milk production is to breed dairy cattle using reproductive technologies, for example Artificial Insemination (AI). Information on use of bovine AI in Rwanda remains inadequate, and a few past studies indicated that the use of bovine AI is both not a common practice and well adopted by the dairy farmers because of poor pregnancy results and low quality of the service provided. The dearth of documented information on the use of AI in dairy cows in Rwanda is a serious constraint to adoption of adaptive research approach to correct existing reproductive problems. In light of the limited information, household survey was conducted in nine Districts (RDDP sites) to shed some light on adoption and success rate of AI and challenged that impair reproduction and fertility of dairy cow with view of mapping out interventions that address these constraints. The specific objectives were;

1. Characterize dairy farmers' production environment and herd structure;
2. Gain insights on existing dairy farmers management practices and milk production levels;
3. Determine the awareness level of AI technology in Rwanda;
4. Assess the determining factors of AI services adoption by smallholder dairy farmers;
5. Assess the AI adoption status and AI success rate in the study area;
6. Identify some of the animal health major concerns for farmers.

A three-stage clustered, purposive procedure was used to select a representative sample of dairy cattle farmers in a number of cells throughout the 12 districts. The interview targeted a sample size of 1067 people who included only dairy farmers using AI technology (adopters) and their counterparts using natural mating (non-adopters). However, this target was not achieved and data was collected from1044 farmers only, which is 97% and a semi-structured questionnaire was administered. Cross tabulation frequencies and non-parametric analysis were used to analyze the data. The number of respondents were dominated by the male (61%) while the female took 39% of the total respondents in the households surveyed. The average age of the respondents and household head ranged between 43.4 – 55.1 and 47.4 – 55.6 years respectively. The farming experience

ranged from 11 to 25 years and land owned was reported be 2ha on average of which half of it was used for animal production, however, wider variation in land size was observed with a range of 0.6-7.3 ha across Districts.

Overall, mature cows (dry cows, lactating cows plus heifers) formed 63% of the whole herd leaving only 26.5% for calves and weaners. This may be a poor strategy for replacement and growth of the herd. At 14%, heifers are not able to meet the requirement for replacement stock for the milking herds, which is pegged at around 33%. Also very few farmers in kept records. Twenty-seven percent of the farmers responded to the question, which required them to indicate calving date, date of service after calving, or date of birth. Records and record keeping is one the most critical area in improved dairy productivity as evaluation is based on performance records.

The most commonly used mating method among the surveyed households was the use of bulls (natural service). Those who used AI were 33% (Adopters) farmers against 38% and 29%who use respectively natural service and both. The high number of farmers using both AI and natural mating (29%) is indicative of the poor performance of the AI program.The most AI adopters were respectively found in the districts of Gicumbi (45.3%), Nyanza (43.7%), Rwamagana (44.2%) and Burera (40%) while Low level AI userswere found in the districts of Nyagatare with 7.7% followed by Rubavu (15.6%) and Musanze (23%). The main challenges revealed by farmers in use of AI were reported in the following order; low rates of conception i.e. several repeat services (25.9%), poor timeliness of inseminator visit (24.3%),not possible to get hold of inseminator (10.6%), no availability of inseminator (9.5%), inadequate semen/liquid nitrogen and other consumables (2.9%), lack of details on the breeds and bulls available at the time of insemination (1.4%) and those that reported not to have any challenge were 16.4%.

When production milk from AI adopters and non – adopter was compared, the former on average milked 9.6 litres while the later acquired 6.07 litres, However, this was not the case for Musanze District where non – adopter milked higher (9.3 against 8.6liters) and from FGDs farmers revealed that such discrepancy came into being because AI users in the respective district did not pay more attention on cattle management (i.e feeding, watering and health). Higher milk production was reported from the Districts of Burera, Gicumbi, Rubavu, Nyabihu and Huye with variation ranging from 10-16 litres while least for AI and AI adopter was reported in Kayonza District (5.4 l/day and 3.5 l/day respectively). The reported number of insemination per conception was on average 1.93 timed, which is rather close to a good indication of high success rate of AI and this contradicted other pointer of infertility in the herd obtained in this study. Considering the sample size that was very small to make a valid conclusion we recommended this activity to be repeated. A big majority of respondents (74.3%) reported also that they are willing to continue pay artificial insemination service and in average they would be willing to pay up to 2,615 Frw per dose. Tick borne diseases (Theileriosis) (35.9%) were the major animal health problem being faced by farmers in the study areas. Farmers could not distinguish between individual tick borne diseases, but we learnt that

ikibagarira or Amashuyu refers to either theileriosis, anaplasmosis, or any other tick borne diseases. Theileriosis was followed by intestinal worms (16.2%), Mastitis (7%) and Lumpy Skin Disease (4.5%).

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

This study assessed daily milk yield (DMY), 100-day (MY100), and 305-day (MY305) milk yield, and lactation length (LL) in purebred Ankole cattle and Ankole crossbreds, and the influence of environmental factors on these traits. Milk yield data were obtained for 865 cows and 1234 lactations and analyzed using a mixed linear model. The overall least squares mean of DMY, MY100, andMY305 across breed groups was 2.7 L (N = 1234, SD = 1.7), 262 L (N = 959, SD = 176), and 759 L (N = 448, SD= 439), respectively, while the average lactation length was 256 days (N = 960, SD = 122). All factors included (breed group, season and year of calving, and parity) were significant for yield traits, except season of calving forMY305. First-parity cows had the lowest milk production, and fourth-parity cows the highest. For all traits, pure Ankole cows had the lowest milk yield. Among the crossbreds, there was no significant difference between Ankole × Friesian, Ankole-Jerseymother × Sahiwal sire, and Ankole- Sahiwal mother × Jersey sire, or between Ankole × Sahiwal and Ankole-Sahiwal mother × Sahiwal sire. It was concluded that Ankole crosses with Friesian or Jersey can be beneficial, even under a management system of limited nutrition as in Rwanda.

Conservation of indigenous Animal Genetic Resources

The need to increase productivity has compelled agricultural sector to adopt high yielding crop varieties and livestock breeds to match production of animal products to the rising demand of the population. Both breed substitution and breed synthesis threaten indigenous conservation efforts under the International Conventions of Conservation of Plant and Animal Genetic Resources. To respond to this concern, the Animal resources department has initiated formation of Rwanda indigenous cattle association and also maintains the elite herds of more 250 Ankole cattle for *in-situ* conservation at Nyagatare Research Station/ karama site.

Effect of genotype and concentrate supplements to urea-treated rice straw on performance of cattle for feedlot beef production

Feeding and metabolic trials were conducted to determine growth and faecal and urinary outputs of purebred Ankole (AA n=16), Ankole x Friesian (AF, n=16) and Ankole x Sahiwal (AS, n=16) steers. The rations were made from ground 4% urea treated rice straw (UTRS) mixed with graded levels (0 g, 500 g, 1000 g and 2000 g) of concentrate. The concentrate was a composite of maize bran (MB: 66%) and decorticated cottonseed cake (dCSC: 34%). All the parameters were analysed using Mixed Model with polynomial contrasts (SAS 2010). Total dry matter intake (TDMI) differed significantly by both cattle genotypes and levels of concentrates. Growth rates in AS steers were higher than growth rates in AF. It was significantly higher in AS than in AA steers. Feed Conversion Ratio

(FCR) differed significantly by cattle genotypes and levels of concentrates. Dry matter digestibility (DMD) differed significantly across cattle genotypes and levels of concentrates. Nitrogen retention (NR) was affected by cattle genotypes and levels of concentrates. It is concluded that feeding UTRS to AS will affect growth and economic return when fed with concentrates ranging between 0.5 to 1kg/day per animal. Therefore, AS steers are recommended because of better straw utilization, higher growth rates, lower FCR, and lower peak nitrogen at peak NR.

Growth performance of steer genotypes fed on *Chloris guayana* and *Panicum coloratum* supplemented with Leucaena leaf meal and molasses

The feeding trial was conducted at Mirama (RAB-Nyagatare). Growth performance of steer genotypes fed on *Chloris gayana* and *Panicum coloratum* supplemented with Leucaena leaf meal and molasses was evaluated. The dietary treatments were (1) *Panicum coloratum* or (2) *Chloris gayana* fed as basal diets, which were conserved as hay. All animals received supplement of Leucaena leaf meal (2 kg/day) harvested from Mirama station and dried under shed. Water and mineral blocks were provided *ad libitum*. The basal feeds (grasses) were harvested (15 cm above ground) from the station plots where they were planted without fertiliser application. The soil type of the plots is sandy clay. The hay was chopped (10 cm length) using forage chopper (Mild steel, 7 HP of power, electric motor/diesel engine, BrazAfric Ltd) before feeding. Basal diets were given at *ad libitum* based on individual body weights. After adaptation period of 14 days, daily feed offers and refusals, respectively were weighed, recorded and sampled at 8:00 h and 15:00 h for a period of 12 weeks. Fortnightly, individual animals were measured to the nearest 100 g using mechanical Weigh Bridge (PORTEE 1000 kg, 2x1 m, B.C, 188021, RAPPORT). The results showed significant difference ($P<0.05$) of growth performance of steers fed on two types of diet. Daily body weight gains (DWG) of the steer AF fed on Chloris had the highest daily weight gain. Generally, steers fed on Chloris with Leucaena leaf meal and molasses had higher DWG compared to those fed on *Panicum coloratum* with Leucaena leaf meal and molasses. Chloris and Leucaena leaf meal (C+L) increased body weight up to 77.2% more than Panicum and Leucaena leaf meal (P+L) for crossbred (Friesian × Ankole) steers while C+L increased body weight up to 17.5% more than P+L for Ankole steers.

On-station forage evaluation

The following activities have been successfully achieved: On-station evaluation of forages in Nyagatare, Rubona, and Rwerere research stations; Training and installation of automatic weather station in the experimental sites in Nyagatare, Rubona and Rwerere and recruitment of new farmers and follow up the existing ones in order to increase number of farmers in adoption of improved forages in Nyagatare, Nyanza and Burera districts. The selected forages and crop to be as treat-

ments at on-station for full replicated trials were: *Brachiaria* hybrid cv. Mulato II; *Pennisetum purpureum* (Napier grass); Desmodium distortum/intortum (for Burera site); Maize monocrop; Desmodium + maize; Desmodium + Brachiaria cv. Mulato II; Napier + Desmodium. Data on pests and diseases, number of tillers and plant height was recorded. Furthermore, after three months of trials establishment, harvesting started (Photo 49). This was to collect data on biomass production, as well as nutritive values of the forages.

Photo 49: On-station forages harvesting

Table 79: Disease and pest in experimental sites

Sites	Harvest	Treatment	Pest (0-5)	Disease (0-5)
Rwerere	1	Desmodium-Molato II	0.3	0.3
		Desmodium-Maize	1	0.3
		Desmodium	0.3	0
		Maize	1	0.3
		Mulato II	0	0
		Napier-Desmodium	0.3	0
Karama	1	Desmodium-Molato II	0.3	0
		Desmodium-Maize	0.3	0.3
		Desmodium	1	0
		Maize	1	0
		Mulato II	0	0
		Napier-Desmodium	0.3	0
	2	Desmodium-Molato II	0.5	0
		Desmodium-Maize	0.5	0
		Desmodium	0.5	0
		Maize	0.3	0.3
		Mulato II	0.3	0.3
		Napier-Desmodium	0.3	0
	3	Desmodium-Molato II	0	0.3
		Desmodium-Maize	0.8	0
		Desmodium	0	0

		Maize	0.5	0.3
		Mulato II	0.3	0.3
		Napier-Desmodium	0	0.5
Rubona	1	Desmodium-Molato II	0.3	0
		Desmodium-Maize	0.3	1
		Desmodium	0.8	0
		Maize	0.5	1
		Mulato II	0.3	0.3
		Napier-Desmodium	0.3	0
	2	Desmodium-Molato II	0	0.25
		Desmodium-Maize	1.3	1
		Desmodium	0	0
		Maize	2	1
		Mulato II	0	0
		Napier-Desmodium	0	0
	3	Desmodium-Molato II	0	0.3
		Desmodium-Maize	0.3	0
		Desmodium	0	0
		Maize	0	0
		Mulato II	0	0
		Napier-Desmodium	0	0.5
Source of variation		Sites	0.7770	0.0011
		Treatment	<.0001	0.0003
		Harvest	0.0007	0.5803
		Site*Treatment	0.0313	0.0005
		Site*Harvest	0.0904	0.0011
		Treatment*Harvest	0.0010	<.0001
		Site*Treatment*Harvest	<.0001	0.0203

Results on pests showed significant difference (P<0.05) treatment, harvest, interaction between, treatment-harvest and, sites-treatment-harvest. The results are similar for the diseases, except for harvest and interaction site-harvest (Table 79). Nevertheless, results on pests and diseases suggest that there was no threat because scores range from 0 to 1 (Table 79).

Table 80: Dry matter analysis from fodder production in experimental sites

District	Harvest	Treatment	DM (ton/ha)
Burera*	1	Desmodium-Mulato II	7.4
		Desmodium-Maize	1.8
		Desmodium	2.8
		Mulato II	4.2
		Napier-Desmodium	44.5
		Napier	55.8
Nyagatare	1	Desmodium-Maize	3.2
		Desmodium	3.0
		Mulato II	9.0
		Napier	27.1
	2	Desmodium-Mulato II	7.2
		Desmodium-Maize	58.1
		Maize	63.6
		Mulato II	6.5

		Napier-Desmodium	26.7
		Napier	27.9
	3	Desmodium-Mulato II	4.7
		Mulato II	7.0
		Napier-Desmodium	47.3
		Napier	45.5
	1	Desmodium-Maize	0.6
		Desmodium	5.9
		Mulato II	10.2
		Napier	19.9
Rubona	2	Desmodium-Mulato II	7.2
		Desmodium-Maize	31.8
		Maize	22.0
		Mulato II	10.8
		Napier-Desmodium	17.1
		Napier	22.6
	3	Desmodium-Mulato II	5.0
		Mulato II	8.5
		Napier-Desmodium	19.0
		Napier	23.1
Source of variation	Sites		<.0001
	Treatment		<.0001
	Harvest		<.0001
	Site*Treatment		<.0001
	Site*Harvest		0.0523
	Treatment*Harvest		<.0001
	Site*Treatment*Harvest		0.1270

* Other harvesting periods were not yet done during this reporting time.

Table 79 shows that maize alone had higher disease and pest in Rubona and Burera than maize in Nyagatare and other treatments. This suggest that maize intercropped with desmodium could reduce severity of pests and diseases. The same trends are found on Mulato II where the grass tolerate the diseases when it is intercropped with desmodium.

On-farm forage evaluation

Four *Brachiaria* grasses including, *Brachiaria decumbens* cv. Basilisk*, Brachiaria brizantha* cv. MG4*, Brachiaria brizantha* cv. Piatã and *Brachiaria* cv. Cayman with *Panicum coloratum* as control were planted in two contrasting areas (low rainfall-Kirehe district and acidic soils - Nyamagabe district) and harvested after 60 days and 90 days. The experiment was set in a randomized complete block design (RCBD) with four replications. The data collected were dry matter (DM), crude proteins (CP), organic matter (OM), cellulose, neutral detergent fibre (NDF), acid detergent fibre (ADF), ash content and macro minerals. *In vitro* gas production was used to estimate metabolisable energy (ME), organic matter digestibility (OMD) and kinetic parameters. The results showed that the DM, CP, NDF, ADF, OM, Cellulose and ash were significant difference (P<0.05) among improved *Brachi-*

aria grasses and increased from 60 to 90 days of harvest except CP that declined as grasses matured. There was significant difference (P>0.05) among *Brachiaria* grasses for ME and OMD. Quickly degradable fraction (A) and slowly degradable fraction (B) did not show any significant difference (P>0.05) but rate of degradation (C) varied among species and with harvesting time. Time required producing half of the gas volume ($T_{1/2}$) declined as grasses matured. All improved *Brachiaria* grasses had better nutritional attributes than *Panicum coloratum*. Additionally, grasses planted in Kirehe had high nutritive values compared to those planted in Nyamagabe districts. The results suggested that three (3) improved Brachiaria grass could be an alternative forage for dairy farmers in both contrasting environments.

Maintenance of fodder production and germplasm

At Nyagatare research station, a total number of 33ha of land were maintained at Karama farm and Mirama feedlot for fodder, forage seed production and germplasm maintenance (Photo 50).

Photo 50: Forage production at Karama and Mirama farms/ Nyagatare station

Generally, forage seed and fodder production was estimated at 100.5 ha of forages at on-station especially, Rubona, Karama, Kinigi and Songa stations. At least 100,000 Napier grass cuttings of and 956 kg of seeds of Chloris gayana, Panicum and Desmodium were produced from the on-station forage development.

Hay production

Biomass of fodder produced was mainly based on Chloris gayana and Brachiaria for hay making (Photo 51). Hay made was used to the RAB farms or sold to the private farmers. Around 58 tons of grass hay baled in fiscal Year 2019-2020 were produced.

Photo 51: Grass harvesting and drying and Hay making at Karama farm

2.5 Veterinary Services for animal health

Prevalence of bovine mastitis and pathogen distribution in selected districts of Rwanda

The objective of this study to estimate the prevalence of sub-clinical mastitis, identify the major risk factors and isolate both contagious and environmental etiological agents for mastitis, from dairy cows in intensive and semi intensive management systems in selected Districts of Rwanda.

Table 81: Quarter-wise prevalence of sub-clinical mastitis using CMT in Seven districts of Rwanda

Quarter	Number of Quarters	Positive sample	Prevalence (%)
LF	5611	2082	37.1
LH	5609	2376	42.4
RF	5614	2164	38.5
RH	5605	2319	41.4
Total	**22439**	**8941**	**39.8**

Left Front (LF), Left Hind (LH), Right Front (RF), Right Hind (RH), California Mastitis Test (CMT)

It was found out that out of 5725 animals that were tested, the overall SCM prevalence at cow level was found to be 65.6% (3755/5725). Out of 22439 quarter (5725 cows) examined, 8941 (39.8%) had subclinical mastitis (**Table 81**). Quarter-wise examination showed that, 2082 (37.1%) quarter of left front, 2376 (42.4) quarter of left hind, 2164 (38.5%) quarter of right front and 8941 (41.4%) quarter of right hind were respectively CMT positive (**Table 81**).

Prevalence of mastitis across the districts and parity categories of cows

A highly significant (<0.001) difference in prevalence of mastitis was observed among Districts and high incidence was recorded in the districts of Gicumbi (88%) and Gasabo (86.6%) (**Table 82**). In our study no significant difference was observed between indigenous cows and their crosses

with Jersey and Holstein- Friesian (P> 0.05), however, as the prevalence of mastitis rose significantly with increase of the parity number (**Table 82**).

Table 82: Invariable logistic regression analysis of the association of cow-level mastitis by location and parity risk factors

Variable	Number of animals	No. Positive	Prevalence (%)	P-Value
District/location				<0.001
Gasabo	82	71	86.6	
Gicumbi	100	88	88	
Huye	207	140	67.6	
Nyabihu	2001	1277	63.8	
Rubavu	1338	883	66	
Rutsiro	1925	1241	64.5	
Rwamagana	72	55	76.4	
Parity				<0.001
1	1280	773	60.4	
2	1206	794	65.8	
3	1062	695	65.4	
4	716	504	70.4	
5	392	271	69.1	
6	177	117	66.1	
7	215	161	74.9	

Degree of subclinical mastitis score by quarter

Results of positive CMT realized on quarters showed that 8941 out of 22439 (39.8%) quarters were reached with variable degree of infection with subclinical mastitis. The degree was related to the CMT score as represented in **Table 83**. It was found that 3166 out of the totally 22439 quarters (14.1%) showed degree (+++), 2681 ones (11.9%) showed degree (++), 3094 ones (14%) showed degree (+) and the rest 13498 (60.2%) showed negative (-).

Table 83: Subclinical mastitis score by quarter using CMT and prevalence in %

Degree	LF (%)	LH (%)	RF (%)	RH (%)	Total	Total Prevalence (%)

-	3529 (62.9)	3233 (57.6)	3450 (61.5)	3286 (58.6)	13498	60.2
+	735 (13.1)	809 (14.4)	748 (13.3)	802 (14.3)	3094	14
++	623 (8.6)	709 (12.6)	632 (11.3)	717 (13)	2681	11.9
+++	724 (12.9)	858 (15.3)	784 (14)	800 (14.3)	3166	14.1
Total	**5611 (100)**	**5609 (100)**	**5614 (100)**	**5605 (100)**	**22439**	**100**

Note: Negative (-), Weak positive (+), Distinct positive (++), Strong positive (+++), Left Front (LF), Left Hind (LH), Right Front (RF), Right Hind (RH), California Mastitis Test (CMT)

Bacterial isolates from milk samples with subclinical mastitis

The cow-level results of the bacteria isolate from cultured samples in the current study are provided in **Table 84**.

Table 84: Bacterial agents isolated from milk samples collected from mastitis cows from three Districts of Rwanda

Bacterial Species		**Total number of isolates**	**Prevalence (%)**
Valid		18	3.2
	Bacillus species	50	8.8
	Coagulase negative Staphylococcus	99	17.5
	Coliform species	47	8.3
	Staphylococcus aureus	105	18.6
	Staphylococcus species	195	34.5
	Streptococcus species	51	9
	Total	**565**	**100**

For all test isolates in three Districts, larger zone of inhibition was observed around gentamycine

The common bacteria found was *Staphylococcus species* (34.5%) followed by S. aureus and Coagulase Negative Staphylococcus, 18.6 and 17.5% respectively. The less common bacteriological findings were *Streptococcus* species (9%), *Bacillus* species (8.8%) and *Coliform* species (8.3%).

Table 85: Antimicrobial susceptibility to Antibiotics in the Districts of Nyabihu, Rubavu and Rutsiro

District	**Antibiotics**	**Resistant %)**	**Intermediately Susceptible (%)**	**Susceptible (%)**	**Total**
Nyabihu	Peniciline	155(84)		29(16)	184
	Gentamycine	3(1.6)	1(0.5)	180(97.8)	184
	Streptomycine	127(69)	49(26.6)	8(4.3)	184

	Tetracyline	51(27.7)	16(8.7)	117(63.6)	184
Rubavu	Peniciline	125(88)		17(120)	142
	Gentamycine	0	1(0.7)	141(99.3)	142
	Streptomycine	88(62)	43(30.3)	11(7.7)	142
	Tetracyline	36(25.4)	36(25.4)	70(49.2)	142
Rutsiro	Peniciline	210(97.2)		6(2.8)	216
	Gentamycine			216(100)	216
	Streptomycine	142(65.7)	59(27.3)	15(7)	216
	Tetracyline	81(37.5)	18(8.3)	117(54.2)	216

2.6 National Animal Genetic Improvement Center

The bovine genetics in Rwanda is in constant improvement to increase production, efficiency and farmers income from cattle farming. The bovine genetic improvement is implemented by different partners; mainly, cattle farmers, Local Government, livestock professional organizations, NGOs and all are supervised by Rwanda Agriculture and Animal Resources Development Board (RAB) through Animal Resources Research and Technology Transfer (ARR&TT). The National Artificial Insemination Center (NAIC) Division of ARR&TT implemented, monitored and supervised bovine genetic improvement activities which are here reported for the fiscal year 2019-2020.

Photo 52: Bulls used for semen sampling: Jersey for dairy Ileft); Holstein-Fresian (center); and Inyambo (rigjt)

In 2019-2020 fiscal year NAIC division has focused on the following:

- Management and replacement of the bull stud (Masaka bull station);
- Ensuring the availability of quality and genetically superior cattle breeding germplasm, especially through 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;

- Studies to improve bovine genetics and accuracy of AI services;

Management and replacement of bull stud

Masaka Bull station hosts a team of around 12 best bulls selected to produce semen in order to ensure fast dissemination of superior genetics and faster genetic improvement and conservation of local breeds (caption 1 for illustration). In the fiscal year 2019/2020, the routine work focused on management of bulls; feeding; disease prevention and training of new bulls on mounting to teaser bull or dummy cow and semen production. Also, RAB through Jersey Inka Nziza project funded by Jersey Overseas Aid (JOA) has selected 3 young Jersey bulls from calves born through embryo transfer (**Photo 52 and 53**).

Among the information considered to select these young bulls were breed standards and pedigree and also biological (samples) samples have been taken for genotyping to analyze their genomes compared to other Jersey cattle in Jersey Island. These 3 young bulls are now being reared at Masaka bull center and trained on semen production.

Photo 53: New young Jersey bulls kept for semen sampling

Availability of quality 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 2019/2020 a total of 81,405 semen doses were produced and processed. To ensure accelerated genetic improvement, a proportion of bovine semen used in Rwanda is imported mainly for farmers to benefit from higher genetics of bulls of higher genetic merit “Super bulls” and to increase the genetic diversity of our breeding stock. Under Jersey Jersey Inka Nziza project funded by JAO, we imported around 59,688 semen doses and 60 embryos and we facilitated MSAADA to import 5,000 semen doses.

In the context of ensuring the quality of semen being used across country, RAB conduct a quality control, at least twice a year. This fiscal year, 2 sessions of semen quality control were conducted. During the quality control, all AI sub-centers were visited by RAB experts where by 2 to 4 semen samples were collected from each semen tank. In average 3 sites were visited in each District and samples collected and brought to laboratory for analysis. The analysis revealed that semen quality was maintained at the majority of AI sub-centers except 3 sub-centers in Kamonyi and 1 sub-center in Ruhango where analysis resulted in very low motility of the semen (around 5% or below). The semen with low motility were recalled by RAB and replaced to ensure that the service delivery is not interrupted.

To ensure availability of Liquid Nitrogen (LN2) and increased access to AI inputs for improved service delivery, RAB has ensured maintenance and good operation of the two Liquid Nitrogen plants installed at Rubilizi and Rubona Stations. In the same fiscal year a total of 137,312 liters of liquid nitrogen (LN2) have been produced and distributed (55,624 L from Rubilizi Plant and 81,688 L from Rubona Plant). All bovine artificial insemination inputs were availed to stakeholders (**Photo 54**).

Photo 54: Distribution of AI inputs: liquid nitrogen and semen from RAB to Districts

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. Progress with AI is shown in **Table 86**.

Table 86: Cows inseminated and AI calves registered for 2019-2020 (accessed MIS, 03 July 2020)[1]

	Number of cows inseminated		Calves born from AI	
District	Target	Achieved	Target	Achieved
Bugesera	2,800	3,002	869	912

Burera	4,500	4,128	1,890	1,859
Gakenke	6,300	6,607	2,525	3,130
Gasabo	2,800	3,810	960	1,269
Gatsibo	2,520	2,421	955	941
Gicumbi	8,000	9,224	2,556	2,813
Gisagara	4,280	4,350	2,502	2,423
Huye	4,557	4,591	1,568	1,661
Kamonyi	3,721	3,020	1,200	1,207
Karongi	2,704	2,477	1,040	922
Kayonza	2,500	2,793	840	842
Kicukiro	1,200	1,242	600	690
Kirehe	3,000	3,206	1,085	845
Muhanga	3,000	2,953	1,000	1,011
Musanze	4,026	3,850	1,225	1,262
Ngoma	2,200	2,904	880	773
Ngororero	2,550	1,432	800	584
Nyabihu	2,550	2,241	800	795
Nyagatare	3,050	2,387	1,156	1,161
Nyamagabe	2,000	2,023	1,203	1,153
Nyamasheke	1,200	810	450	466
Nyanza	5,099	5,874	1,774	1,902
Nyarugenge	700	643	280	283
Nyaruguru	3,000	2,629	1,000	849
Rubavu	2,010	2,001	790	801
Ruhango	5,271	5,251	2,101	2,056
Rulindo	4,300	4,777	1,587	1,651
Rusizi	2,000	1,657	821	787
Rutsiro	2,500	1,819	871	581
Rwamagana	6,000	5,436	2,400	2,989
Total	**100,338**	**99,558**	**37,728**	**38,618**

[1] This information was accessed from MIS on 03rd July 2020, just 2 days before deadline of inputting June 2020 data by Districts. After 5th July 2020, the achievements will increase.

Especially for Girinka beneficiaries and other smallholder cattle farmers, artificial insemination is the only option to breed their cows since they cannot afford to keep a good bull for breeding. To ensure that farmers benefits from this technology, RAB monitors the bovine AI and identification of AI born calves across the country. In the 2018/2019 fiscal year, a total of 99,558 cows were inseminated and 38,618 calves born on AI identified. In this fiscal year we achieved 99% in AI and

more than 100% in calves registration of the targets planned (Table 1). This commendable improvement was mainly due to significant efforts invested in by availing liquid nitrogen; training of more inseminators; availing different inputs to technicians and training of farmers via RDDP project and other partners such as Send a Cow, Heifer International Rwanda, Jersey Island, Bothar, MSAADA, etc.

Establishing breeding centers to ensure availability of high genetic merit breeding stock

A feasibility study for establishing cattle breeding centers in Rwanda to ensure availability of high genetic merit cows and semen production bulls was contracted to establish nucleus cattle breeding farms through public private partnership; to establish and institutionalize cattle identification, registration and routine data recording; to ensure availability and use of best cattle genetics for Rwandan cattle farmer and for export; to institutionalize and operationalize cattle breeding centers.

2.7 Gako Beef project

The Rwandan Government wishes to develop its livestock and meat sector by developing a significant block of land at Gako in the Bugesera District. Through the development of an irrigated forage supported beef production project, the government plans to: Improve farm productivity and production; Process live cattle in Rwanda into meat; Add value in Rwanda by developing quality meat products; Attract investment into the Rwandan agriculture and meat sector. Gako integrated commercial farm is an integrated forage production, intensive cattle production, fattening, meat processing project intended for private sector investors. The Gako project has been set up as a PPP between GOR and 13 private investors. In the beginning; the land was allocated to the the following Investors as follows: One Cooperative (Horana Inka Bugesera that has 75 members) has 2 farms with 2 land titles, Three (3) Companies namely a) Cattle Ville Ranchers Ltd (5 members allocated 5 farms each farm having a land title); b) Gako Friends Farmers Ltd (5 members allocated 2 farms each farm having a land title); and c) APTC Ltd allocated 4 farms each farm having a land title. 4 Separate individual investors each having one land title. The land was operated as separate farms, organized in companies and individuals as detailed above. GoR has invested hugely to develop the site including access roads, water for irrigation, drinking water for the livestock, and electricity. Likewise, the investors have so far invested in different activities including bush clearing, purchase of cattle, planting of fodders, fencing and other equipment. The Gako Beef farms cover a total area of 5,919 ha allocated as follows: 5,286 allocated land for intensive cattle breeding &fattening; 433 ha allocated land in the communal paddock for fodder production;200 ha allocated land for Meat Processing Plant. Recently it was agreed to group the investors in one company already in place (Gako Beef Company Ltd) to make easier the operations and management.

Implementation status

	Description	Implementation status	Comments
1	Demarcation of farms and roads network	100% done	
2	Construction of feeder roads, phase I	100% done	The access feeder roads will be handed over to RTDA & District for their routine maintenance
3	Construction of feeder roads, phase II	100% done	
4	Providing water to Gako Integrated Beef Project (Drilling boreholes)	100% (all works done & provisionally accepted on 12/06/2020 done	9 boreholes have been completely drilled& are already installed &providing water. the pre-provisional handover was done on 05/03/2020 while the provisional handover was done on 12/06/2020 from that date, the works are still under liability period for 1 year.
5	Construction of an irrigation scheme for Gako Beef Project	100% (all works done & provisionally accepted on 30/09/2019	• Water intake structure is completed • Distribution network is completed • Transmission line completed • Pumping station is completed, connected to the electricity grid to be able to pump water from Lake Cyohoha & to do the pressure test of the whole irrigation system but the electricity connection above mentioned is still a temporary solution as stated by EDCL awaiting to set the permanent one by the latter(EDCL). • The irrigation scheme works are still under liability period which will end up end September 2020
	Capacity building for investors (technical support &assistance) Conducted	1.One. Study tour for all investors done in Botswana 2.One company was formed for the investors "Gako Beef Company Ltd.3. 3.A company for valuation of investors shares was hired	- Despite the investments that have been put in Gako Beef Project; this project has not yet achieved its prime objective so far. The number of cattle is brought while there is no feedlot, breeding systems not well developed, slaughterhouse and processing facilities not in place, etc. It is against this background that some efforts are being done to strengthen and empower the investors (hiring professional management Company).Also a study visit was organized to enable stakeholders involved in this project particularly the investors to learn best practices that are being conducted in Botswana where beef industry is by far advanced.

	Description	Implementation status	Comments
		4.A professional management company to strengthen Gako Beef Company ltd was hired	- It has been an emergency where the activities of capacity building have been concentrated on the exercise of Mobilizing farmers/cattle keepers on Animal epidemic diseases; taking blood sampling from the livestock into farms and laboratory analysis of the sampled blood was carried out

Progress on the issues raised

	Description	Comments
1	Organizational structure of Investors	- The Company has been registered as "Gako Beef Company Ltd" and a board of Directors put in place - The audit firm already hired and the contract with GPO partners is - Technical Professional management company hired and the contract with Professional Management Company-**Burmeister** is under execution
2	Infield irrigation	- ToRs for infield irrigation have been shared with Netafim and Culligan for quotation. Netafim has submitted their quotation but Culligan has requested for an extension of 45 days but finally this method was refused by RPPA recommending the open tender procedure - Open tender which was internationally published and the site was so far visited by the companies intending to bid.
3	Business Plan	- A work on feasibility study&Business Plan were completed by RDB
4	Electricity supply	- Pumping station is completed, connected to the electricity grid to be able to pump water from Lake Cyohoha & to do the pressure test of the whole irrigation system but the electricity connection above mentioned is still a temporary solution as stated by EDCL awaiting to set the permanent one by the latter (EDCL). - Electricity has reached farm gate
5	Food an Mouth Disease (FMD) - free certification of Gako Beef Farm	WTO has approved MINAGRI's request to start a 'commodity based trade' which is a certified process through which meat treated through it are declared FMD free and safe for export. We are also pursuing the certification of areas where we do not vaccinate as a 'protected area' for FMD free.

Issues for consideration

	Description	Comments
1	Budget for infield irrigation	- Initially this activity was supposed to be carried out by investors. After creation of a single company from individual farms, it was decided that government will cater for this activity. RAB/MINAGRI needs to secure budget for the fiscal year 2020/2021 to do infield irrigation.
2	Government involvement in the Gako Beef Project	- Given the fact that there will be a management company for the Gako Beef Company. The government involvement needs to be redefined so as to cater for changes in the ongoing planning cycle. The Government will be paying the management company for the first 3 years so as to plan for this budget.
3	Provisional handover of the irrigation facilities	- Culligan handed over the irrigation facilities to RAB on 30th September,2019. Since the handover, we notice incidences of robbery and maintenance of the structures. - It is not clear whether the investors should take them while they themselves are not yet organised or if RAB should continue taking care of them in which case a budget for maintenance and security guards should be planned.
4	Permanent Electricity	- Electricity connection is currently temporary solution it needs sustainable/permanent solution from EDCL. - There is a need for guidance as to who will cater for Electricity bill during the provisional Handover phase
5.	Technical Capacity to operate the automated control system which regulate the flow from intake facilities throughout the distribution line of the network	- RAB needs to provide a team to be trained during the Liability period

2.8 Girinka program

To alleviate extreme poverty persisted in Rwanda, the President of the Republic of Rwanda initiated on 26/02/2006 the Program known as ''*One Cow per Poor Family*'' countrywide with the main objectives of reducing poverty through dairy cattle farming; improving livelihoods through increased milk consumption and income generation; promote climate resilience among poor rural families, environment protection, participation in decision making, environment protection, improving agricultural productivity through the use of manure as fertilizer. The program contributes to build and promote unity and reconciliation among rural Rwandans based on the cultural

principle that if a cow is given from one person to another, it establishes trust and respect between the donor and the beneficiary.

The Girinka Program is managed by the Rwanda Agriculture and Animal Resources Development Board (RAB) is funded through Government earmarked funds and donations. The beneficiaries of Girinka are households classified in the first and second categories of Ubudehe selected at the village level and these activities are chaired by Girinka committee members from village level to District level as its stipulated in the ministerial guidelines N° 001/2018 of 13/07/2018, and then by RAB.

From many of testimonies of Girinka program beneficiaries; this program reveals highly remarkable impacts in changing livelihood of beneficiaries countrywide. The general target of Girinka program was to distribute 350000 cows to poor families by the end of 30 June 2017, the total number of cows distributed was 354,713 with the achievement rate of 101% and so far, by the end of June 2020 the total cows distributed is 380,007.

Sources of heifers distributed under Girinka Program were various institutions (Government, NGOs both local and International ones, Private institutions and individual contributions); Girinka decentralization through Earmarked funds to district level; RAB ad hoc purchases; Local initiatives, which is a donation in the Rwandan culture where a person donates a cow to another one; Pass on the Gift Scheme (PoGs). Every year, at each level there is a target to be achieved and this is done in the complementarily of levels till national level.

With end of this FY the target **2019-2020** was **23,300** cows to be distributed but the program managed to achieved **23,735** of cows distributed to new Girinka beneficiaries is 102% compared to the initial target**.**

Cows distributed to beneficiaries during FY 2019-2020

The total cows distributed via earmarked funds and partners were 23,735 (**Table 87**).

Table 87: Cows distributed during FY 2019-2020

District	Target	Earmarked Cows Distributed	Partner Cows Distributed	Pass On Cows Distributed	Total Cows Distributed	%
Gasabo	253	36	57	218	311	123%
Kicukiro	100	16	18	64	98	98%
Nyarugenge	100	22	20	92	134	134%
Bugesera	900	144	25	604	773	86%
Gatsibo	1000	136	50	896	1082	108%
Kayonza	855	317	40	452	809	95%

Kirehe	800	121	10	526	657	82%
Ngoma	618	186	14	552	752	122%
Nyagatare	850	232	38	396	666	78%
Rwamagana	600	203	89	410	702	117%
Burera	1082	308	58	812	1178	109%
Gakenke	917	169	0	611	780	85%
Gicumbi	1115	87	16	1112	1215	109%
Musanze	943	125	0	599	724	77%
Rulindo	600	204	0	479	683	114%
Gisagara	940	273	71	573	917	98%
Huye	806	170	26	616	812	101%
Kamonyi	796	137	63	877	1077	135%
Muhanga	525	74	12	547	633	121%
Nyamagabe	1222	376	135	641	1152	94%
Nyanza	838	207	117	468	792	95%
Nyaruguru	900	370	10	500	880	98%
Ruhango	752	127	22	383	532	71%
Karongi	714	80	30	432	542	76%
Ngororero	986	349	44	507	900	91%
Nyabihu	800	1395	67	474	1936	242%
Nyamasheke	800	374	32	522	928	116%
Rubavu	518	120	3	417	540	104%
Rusizi	962	182	104	434	720	75%
Rutsiro	1008	340	103	367	810	80%
Total	**23,300**	**6,880**	**1,274**	**15,581**	**23,735**	**102%**

Cross-checking of the lists of new Girinka Beneficiaries FY 2019-2020

The concept note of Cross-checking of the lists of new Girinka Beneficiaries FY 2019- 2020 and Implementation of Girinka Ministerial Guidelines was compiled indicating the methodology of the activity, plan and the approach in each district. Then after there was cross-checking of list of names of new Girinka beneficiaries and review on implementation of Girinka ministerial guidelines was done in all districts new beneficiaries were visited in their homes. The new beneficiaries were visited in homes, house-to-house. During these activities, it was noticed that in some Districts their Girinka committees submit lists without reviewing the lists as Girinka committees at village and also at cells level because sometimes the team could find the lists signed by only executive secretary of the cell and social affairs and other times finding beneficiaries in category three of Ubudehe that excludes a beneficiary from a list.

The deep cross-checking list revealed the following: one of beneficiaries belongs to category 3 and have already received cow through PoGs. Some are not person of integrity because found given a more than two times. Others are not eligible because found a beneficiary on waiting list be having 95 years of old. Few have their own cow and appearing on the list to be given another

cow. Beneficiary appearing on the list yet migrated to Countries eg Uganda and others have shifted to other province. Some of the beneficiaries do not even a single acre for planting of pastures. Majority of beneficiaries don't have cow shed. Others receive other supports for example direct support from Ubudehe and yet want to get a cow. Beneficiary has sold a given cow before passing on and yet want another cow.

Training of New Girinka Beneficiaries and Girinka Committees

Every year Girinka team together with the Districts provide the basic training to the new family who wish to be given a cow at the first time. The beneficiaries were trained on animal husbandry practices so as to get the basic knowledge on how to look after their given cows. In these trainings together with the attended participants, it has been discussed and reviewed all achieved Girinka activities of previous years and also the implementation of Girinka activities guided by Girinka ministerial Guidelines.

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

The aim of this follow up was to visit Girinka beneficiaries at their homes and observe how their cows are managed, understand their opinions on the importance of the cows given to them under Girinka program and implementation of Girinka ministerial guidelines.

Follow up of Girinka beneficiaries was done in all districts where beneficiaries were visited at their homes (House to house visit). Generally, it was noticed that the farmers have benefited from the program through getting milk and manure but their cows are grazing from outside. Majority of the beneficiaries still lack better cowsheds for their cows and shortage of forages for feeding. The meeting with Girinka committee members at Cell and Village level on implementation of Girinka Ministerial Guidelines was conducted. The Girinka committees were reminded of the **DO's** and **DOn'ts** of these ministerial guidelines and their responsibilities as committee members.

The monitoring of Girinka Program activity consists, follow-up of the program on daily basis, organize the field visit to farmers, provide technical assistance to the District during the selection and distribution of heifers. During this Fiscal year there was an incidence of Covid -19 that occurred in the country and this affected some activities like Girinka week and organising fundraising.

Girinka impact

Girinka program through cows distributed has increased milk production and income from milk sales, helped to get access to loans, has created employment, improved health status of the beneficiaries, increased manure and crop yields. Increased milk sales have also contributed to pay

school fees, thus it created opportunity for better education for kids of the beneficiaries. Improved soil fertility, improved nutrition access to the shelter and different equipment, strengthened social cohesion. Also the program beneficiaries participated in communal cowsheds in various districts where were advising farmers to harvest and storage of forages to use in dry season.

Challenges and recommendations

Girinka week and fundraising were not done due to COVID-19. Lack of Girinka data base in some districts does not allow RAB to access information. MIS system between MINAGRI and Districts should work hand in hand to avoid missing data. Delay in tendering cows and drugs for earmarked funds for districts delayed reporting to RAB. Insurance of Girinka cows was not paid in time, which has led not compensating cows in case of death or any problems to farmers. Poor management of heifers distributed like lack of cowshed, lack of pastures resulted to the emaciation of cow hence has led to low yield. Suppliers have requested RAB without having cows, have win but did not accomplish tenders. Delay of new Girinka beneficiaries list and to some districts did not involve RAB Staff for validation. Tenders of purchasing heifers to be supplied have delayed. Lack of data base at district level as well as at RAB level.

To overcome these challenges, we recommend that the lists of Girinka beneficiaries should indicate gender and in MIS reporting system as well. Both Girinka beneficiaries, Sector vets and Districts vets should report on regular basis to each other in order to avoid lack of compensation for cows to insurance companies. All Communal cowsheds should be monitored to insure that they have forages to eat in dry season so as to avoid death during dry season.

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