REPUBLIC OF RWANDA

RWANDA AGRICULTURE AND ANIMAL RESOURCES DEVELOPMENT BOARD (RAB)

Huye-Rwanda

RAB ANNUAL REPORT FOR THE YEAR 2020/2021

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FOREWORD

Rwandan economy still has the majority of the population who depend on agriculture. Agriculture and livestock keeping can help farmers to make higher profits in the future than in the past if they apply modern technologies. To increase market oriented agriculture, farmers attempt to increase yields and quality and quantity of agricultural produce while producing more 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 aims to develop technologies to increase yield and reduce 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.

Chairperson of the Board of Directors of RAB

EXECUTIVE SUMMARY

The Fiscal Year 2020-2021 is the fourth year to implement National Strategy for Transformation (2017-2024) with Agriculture settled to increase productivity of Crops and Livestock and develop sustainable production systems. Crop Research and Innovation Department has translated these objectives into practice through development of new high yielding and pest and disease resistant varieties, bio-fortified varieties and improved production technologies. **Maize** research continued breeding and hybrid production, 22 new hybrids were prepared for official release, 15 varieties were planted in multiple demonstration plots with cooperatives and farmer promoters. **Wheat** research team conducted farmer managed trials with 6 best varieties, promoted improved management practices through farmer trainings and seed dissemination. **Rice** research continued breeding, prepared two varieties for official release, trained 1,300 farmers in improved practices, and established multiple demo plots with variety demonstration. **Banana** research team has introduced new ICT tool for banana disease management, which was tested with more than 2,000 farmers and 68 farmer promoters. **Soybean** research has selected 5 new varieties, promoted 9 other high yielding varieties in multiple demo plots in 14 districts. **Bean** research released 19 new varieties, of which 8 are Fe/Zn biofortified. Breeding work continued with production and advancement of different generations and more varieties are being tested in field. Climate smart crop management technology was tested on farm. **Cassava** research officially released 8 new varieties, and tested 21 other varieties in advanced yield trials. Testing and screening for cassava mosaic and brown streak diseases continued with new varieties in multilocational trials. **Irish potato** research evaluated 18 progenies, conducted trials on diploid and tetraploid biofortified potato varieties, continued agronomic evaluation of National Performance trials and Solynta potato varieties. A total of 1,699,463 mini tubers was produced with conventional and aeroponic technologies, focusing on end-user preferred potato varieties, such as Kinigi, Kirundo, Gikungu, Ndamira. A total of 150 farmers planted potato demo plots with improved varieties and practices. **Sweet potato** research focused on production of clean seeds, promotion of biofortified varieties and demonstrations. **Horticulture** research focused on scion harvest and grafting. A total of 428,043 scions were produced for avocado, mango and citrus spp. A total of 264 members of cooperatives were trained in macro-propagation of pineapple. New varieties of how and sweet pepper were evaluated for adaptability, stevia was evaluated for best agronomic practices package. Tamarillo and passion fruits produced clean seeds in RAB mother gardens. These seeds were used together with grafted seedlings of avocado, citrus and mango for Three fruit trees per family program. **Tea** research evaluated 8 tea clones for yield and tea output along with improved nutrient supply and plant densities. In **Coffee**, top 5 best performers were selected from National Performance trials and 5 F1 hybrids with resistance to coffee leaf rust and coffee berry diseases were evaluated. Moreover, coffee berry disease survey was conducted in major coffee growing areas, disease extent established, and pathogen isolated. Study of soil variability and development of new fertilizer recommendations were done. **Crop Protection** research team conducted bioefficacy trials against Fall Army Worms, including use of pheromones, has developed recommendation for the new emerging problem of banana thrips, and conducted training of extension agents on safe pesticide handling and pest and disease control. **Plant and Microbial Biotechnology** received training in genetic engineering, conducted establishment of plant genetic engineering and containment facilities, established demonstration plots for tissue culture derived plants, organized training of farmers on mushrooms production, and established demonstration plots to showcase mushrooms production technologies.

Crop Research and Innovation Department has concentrated on seasonal activities as season launching, trainings through Twigire Muhinzi initiative, distribution of agricultural input in form of annual crop seeds, mainly, maize, and chemical fertilizers, supply of lime where appropriate, seasonal follow up of consolidated land areas, progress of planting and harvest. In **2021 A**, a total of **814,137 Ha** were planted under land consolidation, which is **59.6%** of the total cultivated area. In **2021 B**, a total of **551,366 Ha** was planted in land consolidated sites, which was **40.4%** of the total cultivated land. While crops differed and depended on district and agro-ecological conditions, as well as farmer community decision, the main crops in land consolidated sites where most of agricultural input was applied were maize, beans, wheat, rice, Irish potato, cassava, soybean and vegetables. A total of **58,375 tonnes** of mineral fertilizer and **11,418 tonnes** of lime was applied in land consolidated sites. A total of **17,005 demo plots** were established in **2021A** and **15,388 demo plots** were established in season **2021B**. The most demonstrated crop was **maize** in season A and **beans** in season B.

Land Husbandry Irrigation Innovations and Technology Transfer (LII&TT) Department rehabilitated infrastructures for Bwera, Rwabiharamba, Kajevuba and Gashora Dams, Mukunguli and Cyabayaga marsland; established 296 FFS demoplots; A total of 2,815.5 ha of radical terraces were established. Over 45,000 ha of farmland have been tilled: 13000 ha for seeding, 9,500ha of crop treatment and 6,500 ha of harvesting through public and private hiring services, and different farmers/cooperatives started adopting the use of farm machinery in their daily farm activities. Irrigation activities include follow up and maintenance of 65 irrigation schemes with a total area of 10,330ha, located in 18 districts. ETI project has established irrigation facility on 5,000ha. CARAVAN project has started soil sampling to cover the major agricultural zones to develop precise fertilizer recommendations.

Livestock research has introduced new fodder species (Brachiaria) with high protein content; started multiple ovulation and embryo transfer study achieving conception rate of 47%; established elite goats and Inyambo cattle breeding stock for conservation; 2,114 farmers were involved in forage grass planting and establishment of 3,991 ha of new forage fields. New livestock FFS were established for chicken, swine reaching 175 facilitators and 498 group members. RAB monitors the bovine AI and identification of AI born calves across the country: a total of 110.232 cows were inseminated and 49,840 calves were born on AI identified.

Dr. Patrock Karangwa

Director General/RAB

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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

I. CROP RESEARCH AND INNOVATION DEPARTMENT

1.1 Cereals Program

1.1.1 Maize

Submission of 22 maize new hybrids to National Varity Release Committee for release

A total of 22 new maize hybrids (11 for mid-altitude and 11 for high altitude) were submitted for official release to the National Variety Release Committee after preparing hybrid/parent descriptors (**Table 1**).

Table 1: New varieties submitted for official release

No	Names	Type of hybrid	Ecology	Specific adaptation	Specific trait	Progress for official release
1	RHMH1604	TWCH	HA	Up to 2200 masl	Extra-early	Descriptors for all parents and the TWCHs, nicking for SCHs, increase seed for all parents Nicking information and descriptors of the TWCHs and the parent SCHs, increase seeds of TWCHs, SCHs and parent inbred lines Descriptors for TWCHs, parent SCHs inbred lines, nicking for TWCHs and parent SCHs, seed increase TWCHs, SCHs and inbred lines
2	RHMM1701	TWCH	MA	Mid altitude	Foliar diseases resistance	
3	RHMM1702	TWCH	MA	Mid altitude	Drought tolerant, MLN tolerant	
4	RHMM1704	TWCH	MA	Mid altitude	Drought tolerant	
5	RHMM1843	TWCH	MA	Mid altitude	Foliar diseases resistance	
6	RHMH1706	TWCH	HA	Up to 2200 masl	Extra-early	
7	RHMH1707	TWCH	HA	Up to 2200 masl	Early	
8	RHMH1708	TWCH	HA	High altitude	Early	
9	RHMH1806	TWCH	HA	up to 2000	Early	
10	RHMH1807	TWCH	HA	High altitude	Early	
11	RHMM1820	TWCH	MA	Well-watered	Early	
12	RHMM1823	TWCH	MA	Well-watered	Foliar diseases resistance	
13	RHMM1710	TWCH	MA	Well-watered	Extra-early	
14	RHMH1628	TWCH	HA	High altitude	Early	
15	RHMH1801	TWCH	HA	High altitude	Early	
16	RHMH1808	TWCH	HA	Up to 2000 masl	Early	
17	RHMH1816	TWCH	HA	High altitude	Early	
18	RHMH1826	TCH	HA	Up to 2000 masl	Early	
19	RHMM1848	TWCH	MA	Mid altitude	Extra-early	
20	RHMM1969	TWCH	MA	Mid altitude	General adaptability	
21	RHMM1970	TWCH	MA	Mid altitude	General adaptability	
22	RHMM1964	TWCH	MA	Mid altitude	Drought tolerant, MLN tolerant	

Out of these 22 hybrids, description of 10 mid-altitude hybrids from Rubona and Cyabayaga) is advanced where ears and seeds are still being characterized: RHMM 1701; RHMM 1702; RHMM 1704; RHMM1843; RHMM 1820; RHMM 1823; RHMM1710; RHMM1848; RHMM1969; RHMM 1970. For mid-altitude RHMM1964 hybrid, nurseries are still in the field. For high-altitude hybrids from Rubona, Musanze and Rwerere, the description is advanced where ears and seeds are still being characterized: these hybrids are RHMH1604; RHMH 1706; RHMH 1707; RHMH 1708; RHMH 1806; RHMH 1807; RHMH 1628; RHMH 1801; RHMH 1808; RHMH 1816; RHMH 1817. Nicking information was completed for all hybrids out of 22 except for RHMM 1710, RHMM1848, RHMM1970, for which the nurseries are still in the field. Seeds nicking information was completed for RHMM1701; RHMM 1702 andRHMM1969. Seed conditioning is still under way for the rest of hybrids.

Breeder seed maintenance and production

Breeder's seed production concerned 11 parent inbred lines of 7 maize hybrids in seed production and 3 additional parent inbred lines of 4 new hybrids (**Tables 2 and 3**). The nurseries of 2021A season have been harvested in Cyabayaga, Rubona and Musanze, while those of 2021 B are still in the field.

Table 2: Breeder's seed production in 2021

Number	Name	Station	Seed quantity (kg)	Number	Name	Station	Seed quantity (kg)
1	P001	Cyabayaga	5.5	7	P010	Cyabayaga	5.0
2	P002	Cyabayaga	8.8	8	CML203	Cyabayaga	5.0
3	P003	Cyabayaga	5.8	9	P006	Musanze	8.0
4	P004	Cyabayaga	8.2	10	P007	Musanze	8.0
5	P005	Cyabayaga	3.5	11	P009	Rubona	6.0
6	P008	Cyabayaga	5.0	**Total**			**68.8 kg**

Table 3: Breeder seed production from 13 inbred lines which are parents of 7 old & 4 new hybrids

N0	Names	Hybrid variety	Station	Methodology
1	P001	RHM104, RHM1402	Cyabayaga	Plant ear-to-row each family, self-pollination as many plants as possible, eliminate off-types, harvest only selfed ears and shell in bulk kll
2	P002	RHM104, RHM1402, RHM1407, RHM1409, RHMM1704	Cyabayaga	
3	P003	RHM104, RHM1407, RHMM1704, RHMM1710	Cyabayaga	
4	P004	RHM1407, RHM1409	Cyabayaga	
5	P005	RHM1402, RHM1409, RHMM1704	Cyabayaga	
6	P008	RHMH1601, RHMH1611, RHMH1628	Cyabayaga	
7	P009	RHMH1611, RHMH1628	Rubona	
8	P010	RHMH1520	Cyabayaga	
9	P011	RHMH1520	Cyabayaga	
10	P012	RHMM1704	Cyabayaga	Plant 0.5 to 2 kg seeds (what available), self-pollinate as many plants as possible, eliminate off-types, harvest selfed ears and shell in bulk
11	P014	RHMH1604	Rubona	Plant 0.5 kg of seeds, self-pollinate as many plants as it is possible, eliminate off-types, harvest selfed ears and keep ears separately
12	P022	RHMM1710	Cyabayaga	
13	P028	RHMM1710	Cyabayaga	

The methodology used in breeder' seed production consisted of planting ear-to-rows each ear harvested and selected in the previous season and then proceed with manually pollination by self-pollinating all plants in a row. The monitoring is 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 is also discarded in the remnant seeds. Selfed ears are harvested and shelled in bulk. Furthermore, the breeder's seed production from the parent inbred lines of the new hybrid varieties in seed production was done by planting a quantity of seeds bulked in previous season and thereafter proceed with self-pollinating as many as it is possible while systematically removing any off-type plant or apparent off-type plant. Only the selfed ears were harvested and shelled in a bulk.

Formation of new crosses targeting superior traits

1) Preparation of the dissemination of two Provit A maize hybrid varieties through producing the seeds of two maize varieties: RAHA03 and RAHA05 and breeder' seeds production from six parent inbred lines. The production of seeds was done at Nyagatare Station, Cyabayaga site. Seeds of the parental lines are being condionned.
2) Generation of 156 testcross hybrids using five testers. The activity was conducted at Nyagatare Station, Cyabyaga site, Rubona station and Rwerere Station. The harvest has been completed at Nyagatare and Rubona sites. It is undergoing at at Rwerere site.
3) Formation of 50 Three Way Cros Hybrids (new hybrid varieties) for mid altitudes with various traits including fall armyworm tolerance, drought tolerance, MLN tolerance and earliness. The formation was done at Nyagatare, Cyabayaga site. The nurseries have been harvested and the seed for each variety is still under conditioning.

Inbred line development

1) Advancing 15 S2 inbred lines for high altitudes to S3 level of inbreeding. The activity was conducted at Rwerere and Musanze. The nurseries are being harvested.
2) Increasing seeds and advancing to high level of inbreeding 16 inbred lines developed for mid-altitudes. The activity was conducted at Rubona Station. The nurseries have been harvested

Multi-location trials in high altitudes

1) Evaluation of 28 new hybrids for highlands at Rwerere, Kinigi, Rubona and Tamira in 2021 A and at Rwerere, Kinigi and Tamira in 2021 B with hybrids for which P1 and P2 are either from RAB lines or from CIMMYT. The trials of 2021 A seasons have been harvested at Rubona and Rwerere. They are being harvested at Kinigi and Tamira. The trials of 2021 B are still in the field.
2) Evaluation of 50 new hybrids for highlands at Rwerere, Kinigi, Rubona and Tamira in 2021 A and at Rwerere, Kinigi and Tamira in 2021 B for which P1 and P2 are inbred lines from CIMMYT-Ethiopia. The trials of 2021 A at Rubona and Rwerere have been harvested while they are under harvest at Kinigi and Musanze

Demonstration plots with maize farmers' cooperatives

A total of 128 maize farmers' cooperatives were selected in September 2020 throughout the country in 24 Districts to conduct the demonstration plots with maize hybrid varieties with superior traits. The criteria for selecting a cooperative included:

- Accessibility and visibility of the field;
- Cooperative with consolidated land so that the demo plot is planted on continuous land;
- Cooperative usually growing maize;
- Willingness to conduct the demonstration plot in partnership with RAB and its partners;
- The cooperative will plant maize in 2021 A;
- Individual farmers must be avoided;
- The cooperatives must not be selected in one district only, but in all the district under the focal RAB station.

These demonstration plots were managed by focal persons in the stations: Nyagatare, Ngoma, Rubilizi, Muhanga, Rubona, Nyamagabe, Ntendezi, Gakuta, Rwerere, Musanze, Gishwati, Tamira. In mid altitudes the harvest has been completed whereas the harvest still going on in high altitudes.

Fifteen maize hybrid varieties with superior traits were used in the demonstration plots. They comprised six hybrid varieties for mid altitudes, nine hybrid varieties for high altitudes, eight hybrid varieties official released and seven hybrid varieties submitted for official release (**Table 4**).

Table 4: Maize hybrid varieties used in demonstration plots in 2021A

No	Names	Ecology	Specific trait	Status
1	RHM104	MA	Drought tolerant	Officially released, under use by farmers
2	RHM1402	MA	Drought + MLN tolerant	Officially released, under use by farmers
3	RHM1407	MA	Drought + MLN tolerant	Officially released, under use by farmers
4	RHM1409	MA	Drought + MLN tolerant	Officially released, under use by farmers
5	RHMM1702	MA	Drought + MLN tolerant	Submitted for official release
6	RHMM1843	MA	Foliar disease resistance	Submitted for official release
7	RHMH1520	HA	Early maturity	Officially released, under seed production
8	RHMH1521	HA	Early maturity	Officially released, under use by farmers
9	RHMH1601	HA	Early maturity	Officially released, under use by farmers
10	RHMH1611	HA	Early maturity	Officially released, under seed production
11	RHMH1604	HA	Extra-early maturity	Submitted for official release
12	RHMH1706	HA	Extra-early maturity	Submitted for official release
13	RHMH1707	HA	Early maturity	Submitted for official release
14	RHMH1806	HA	Early maturity	Submitted for official release
15	RHMH1807	HA	Early maturity	Submitted for official release

Each maize farmers' cooperative received four varieties to be planted side by side with a spacing of 0.75 m between rows and 0.25 cm between stations. The plot size was made six rows of 6 meters length Kireequal to 28.125 m^2. Therefore, the four entries in each cooperative were planted on area equal to 112.5 m^2 (0.01125 ha). The total area planted with the demonstration trials with maize farmers' cooperatives was 14,400 m^2 equal to 1.44 ha comprising 512 plots. The total number of farmers in the cooperatives reached was 43,160 (**Tables 5-8**).

Table 5: Demonstration plots with maize farmers' cooperatives in Eastern Province

N	Sector	Coop	Men	Women	Total	Hybrids					
						RHMM 1843	RHMM 1702	RHM 104	RHM 1407	RHM 1402	RHM 1409
				Gatsibo							
1	Kageyo	COPROMAG	20	13	33	+	+	+	+		
2	Gitoki	COIRUGANZA	63	45	108	+	+	+	+		
3	Gitoki	KOAIG INDATWA	22	80	102	+	+	+	+		
4	Kiramuruzi	AMIZERO KABUGA	13	12	25	+	+	+	+		
5	Rugarama	COOPCUMA	184	96	280	+	+	+	+		
6	Kiziguro	COAMAKI	17	12	29	+	+	+	+		
7	Kiziguro	MBOMAFACO	108	86	194	+	+	+	+		
8	Murambi	DUTERIMBERE MURAMBI	22	26	48	+	+	+	+		
9	Remera	CAPRORE INTAMBWE	922	706	1,628	+	+	+	+		
10	Rugarama	COPEDUR	25	12	37	+	+	+	+		
11	Rwimbogo	KOAIRWI-INKOMEZAMIHIGO	171	368	539	+	+	+	+		
12	Ngarama	COOPAMCYA	41	6	47	+	+	+	+		
				Kayonza							
13	Nyamirama	DUFATE IYA MBERE MU MIHIGO	30	18	48			+	+	+	+
14	Mukarange	KARAMBO I	35	24	59			+	+	+	+
15	Gahini	TWITEZIMBERE NYABOMBE	22	38	60			+	+	+	+
16	Kabarondo	ABIZERANYE	29	39	68			+	+	+	+
17	Rukara	INTASIGWA	8	12	20			+	+	+	+
				Kirehe							
18	Gahara	COAIGA	1,502	844	2,346			+	+	+	+
19	Gatore	KODUIGA	562	168	730			+	+	+	+
20	Kirehe	KAKI	30	26	56			+	+	+	+
21	Nyarubuye	KOAISONYA	78	48	126			+	+	+	+
22	Mpanga	COVAMIS	214	116	330			+	+	+	+
				Ngoma							
23	Rurenge	SUBIZA	151	35	186			+	+	+	+
24	Kibungo	UBUMWE	100	44	144			+	+	+	+
25	Mutenderi	KOPAMUNYA	236	326	562			+	+	+	+
26	Gashanda	KOPAMU	46	42	88			+	+	+	+
27	Kazo	KOABIKA	46	44	90			+	+	+	+
				Nyagatare							
28	Karama	KOHIIKA	20	32	52		+		+	+	+
29	Karama	KOHUMUKA	38	11	49		+		+	+	+
30	Rukomo	RUDEMACO	19	11	30		+		+	+	+
31	Mukama	CODEPCUM	35	33	68		+		+	+	+
32	Mukama	DUKUNDISUKA	6	20	26		+		+	+	+
33	Tabagwe	KOABITADU	9	16	25		+		+	+	+
34	Matimba	KOBAM	719	369	1,088		+		+	+	+
35	Katabagemu	KOASOKA	26	14	40		+		+	+	+
36	Katabagemu	RRGC	90	8	98		+		+	+	+

Table 6: Demonstration plots in maize farmer cooperatives in Nyamagabe & Nyaruguru districts

N	Sector	Coop	Men	Women	Total	Hybrids						
						RHM 1520	RHM 1521	RHM 1601	RHM 1611	RHH 1807	RHM 1604	RHH 1806
					Burera							
37	Kinyababa	KOTUKI	31	2	33	+	+	+	+			
38	Nemba	COVMB	903	501	1,404	+	+	+	+			
39	Rugengabari	COOPACERU	29	6	35	+	+	+	+			
40	Butaro	DUHURIZEHAMWE MUGERA	23	17	40	+	+	+	+			
41	Rusarabwe	IHUTUDASIGARA MUSEBEYA	21	30	51	+	+	+	+			
					Gakenke							
42	Busengo	COPROSEBU	43	27	70	+		+	+	+		
43	Gakenke	COTUMU	448	674	1,122	+		+	+	+		
44	Gashenyi	ICYEREKEZO	63	80	143	+		+	+	+		
45	Mugunga	INTWARI MU BUHINZI	17	51	68	+		+	+	+		
46	Kivuruga	TWIYUBAKE KIVURUGA	244	96	340	+		+	+	+		
47	Janja	KOTWIMUJA	120	56	176	+		+	+	+		
					Gicumbi							
48	Kageyo	HUGUKA KAGEYO	208	166	374	+	+	+	+			
49	Rwamiko	TUNOZUBUHINZI RWAMIKO	24	12	36	+	+	+	+			
					Musanze							
50	Muko	AMAJYAMBERE KABERE	59	54	113	+		+	+		+	
51	Busogo	COPA	18	0	18	+		+	+		+	
52	Tumba	COVAMABA	1,983	793	2,776	+		+	+		+	
53	Muko	INDASHYIKIRWA	8	22	30	+		+	+		+	
54	Nkotsi	KANGUKA MUHINZI NKOTSI	19	9	28	+		+	+		+	
55	Gacaca	TWIGIRE GACACA	20	4	24	+		+	+		+	
56	Burega	KU MUYANZA	3,438	2,312	5,750	+		+	+		+	
57	Nyange	TWIGIRE MUHINZI NYANGE	33	10	43	+		+	+		+	
58	Kinigi	TWITEKUBUHINZI KINIGI	41	7	48	+		+	+		+	
59	Cyuve	TWIZAMURE	134	83	217	+		+	+		+	
60	Rwaza	TWONGERE UMUSARURO	204	173	377	+		+	+		+	
					Rulindo							
61	Buyoga	KORA UKIRE	983	844	1,827	+		+	+			+
62	Rukozo	KOCYACYIRU	103	29	132	+		+	+			+
63	Bushoki	TERIMBERE MUKOTO	18	13	31	+		+	+			+
64	Cyinzuzi	KOTEMURU	108	47	155	+		+	+			+
					Nyamagabe,	RHM 104	RHM 1402	RHM 1601	RHM 150			
65	Buruhukiro	TUJYE MU MUCYO	21	42	63	+	+	+	+			
66	Musebeya	KOTEMUMU	21	15	36	+	+	+	+			
67	Gatare	JYAMBERE MUHINZI RWONDO	57	10	67	+	+	+	+			
68	Kitabi	DUFATANYE NSHUTI	15	17	32	+	+	+	+			
69	Cyanika	KOACYA	23	28	51	+	+	+	+			
70	Tare	ABOGEZASUKA	26	27	53	+	+	+	+			
					Nyaruguru	RHM 104	RHM 1402	RHM 1601	RHM 150			
71	CyahindaNyagisozi	ABISHYIZEHAMWE URWONDYA	938	804	1,742							
72	Kibeho	DUTERIMBERE AGATOROVE	536	331	867	+	+	+	+			
73	Kibeho	JYAMBERE MUHINZI KIBEHO	215	123	338	+	+	+	+			
74	Ruramba	KOABW	50	91	141	+	+	+	+			
75	Ngera	KOPAIMU NGERA	394	236	630	+	+	+	+			
76	Kibeho	ABESAMIHIGO KIHEHO	121	124	245	+	+	+	+			

Table 7: Demonstration plots with maize farmers' cooperatives in Southern Province

N	Sector	Coop	Men	Women	Total	Hybrids				
						RHM 104	RHM 1402	RHM 1407	RHM 1409	RHM 1702
		Gisagara								
77	Muganza	KOABIMU	90	67	157	+	+	+	+	
78	Kibirizi	KOABIDU	370	673	1,043	+	+	+	+	
79	Save	ABAKORANAMURAVA	840	700	1,540	+	+	+	+	
80	Kigembe	KORWAMUKI	223	400	623	+	+	+		+
		Huye								
81	Tumba	KOAGIMA	193	448	641	+	+	+		+
82	Mukura	ABISUNGANYE AKARERA	75	126	201	+	+	+		+
83	Gishamvu	KOAMU	143	247	390	+	+	+		+
84	Simbi	ICYEREKEZO	119	145	264	+	+	+		+
85	Rusatira	TUZAMURANE RUVUNGIRANA	373	255	628	+	+	+		+
86	Rusatira	TUZAMURANE RUVUNGIRANA	373	255	628	+	+	+		+
		Kamonyi								
87	Gacurabwenge	KABIAKI	36	390	426	+	+	+	+	
88	Mugina	INDATWA ZA KAMONYI	702	486	1,188	+	+	+	+	
89	Karama	COAMALEKA	447	568	1,015	+	+	+	+	
90	Runda	ICYERECYEZO BIMBA	1	18	19	+	+	+	+	
		Muhanga								
91	Shyogwe	KIABR	300	560	860	+	+	+	+	
92	Mushishiro	UBUMWE	1	20	21	+	+	+	+	
93	Nyamabuye	KOPARWAMU	137	259	396	+	+	+	+	
94	Rongi	COIABNDI	95	61	156	+	+	+	+	
95	Cyeza	KORUBEHO	216	324	540	+	+	+	+	
96	Shyogwe	KOKAR	192	358	550	+	+	+	+	
		Ruhango								
97	Kinazi	ABIYUNZE	276	238	514	+	+	+	+	
98	Mbuye	COKUMBU	23	50	73	+	+	+	+	
99	Byimana	KOANYA	21	35	56	+	+	+	+	
100	Ruhango	UATA	191	263	454	+	+	+	+	
		Nyanza								
101	Busasamana	UBUSHAKEBWIZA	17	24	41	+	+	+	+	
102	Kigoma	ABAHUJINTEGA	201	234	435	+	+	+	+	
103	Mukingo	DUHUZIMBARAGA NYAMIGOGO	120	197	317	+	+	+	+	

Table 8: Demonstration plots with maize farmers' cooperatives in Western Province

N	Sector	Coop	Men	Women	Total	Hybrids											
						RHM 1520	RHM 1601	RHM 1611	RHH 1708	RHM 104	RHM 1402	RHM 1407	RHM 1409	RHH 1707	RHM 1706	RHH 1808	RHH 1807
		Karongi															
104	Gitesi	ABADAHIGWA	3	9	12	+	+	+	+								
105	Gishyita	IMBONI ZA MWUMVERO	82	110	192					+	+	+	+				
		Ngororero															
106	Kageyo	KOABU	31	5	36	+	+	+						+			
107	Hindiro	TUJYINAMA DUHINGA	19	12	31	+	+	+						+			
108	Ngororero	ZAMUKA MUHINZI NGORORERO	31	11	42	+	+	+						+			
109	Matyazo	ABAJYANAMA B'UBUHINZI	18	8	26	+	+	+						+			
		Nyamasheke															
110	Kanjongo	KODIKA	715	802	1,517					+	+	+	+				
111	Rangiro	COPIRA	240	264	504	+	+	+							+		
112	Macuba	KOHIMUMA	150	200	350	+	+	+							+		
113	Kangano	ICYEREKEZO	338	240	578					+	+	+	+				
		Nyabihu															
114	Rambura	KOAIBI	2	26	28	+	+	+						+			
115	Shyira	KOGIUMU	26	24	50	+	+	+						+			
116	Jomba	KOARU	24	52	76	+	+	+						+			
117	Mulinga	KOIBIMU	71	53	124	+	+	+	+								
118	Rurembo	KOAURU	61	7	68	+	+	+	+								
		Rubavu															
119	Mudende	CODAF	9	5	14	+	+	+	+								
120	Nyundo	KOAUNYU	33	21	54	+	+	+									+
121	Rugerero	BERWAN'UBUHINZI	13	8	21	+	+	+									+
122	Nyakiriba	TWUBAKEUBUHINZI	23	3	26	+	+	+								+	
123	Nyamyumba	TWITEZIMBERE	10	5	15	+	+	+								+	
124	Kanama	KOPDUWIKA	5	7	12	+	+	+								+	
		Rusizi															
125	Gihundwe	KOAIGA	13	41	54					+	+	+	+				
	Muganza	KODUSHARA	24	56	80					+	+	+	+				
		Rutsiro															
126	Nyabirasi	COABUNYA	1,146	464	1,610	+	+	+	+								
		TOTAL (all provinces)	**26,360**	**21,680**	**48,040**												

Demonstration plot with Farmers' Promotors

The demonstration plots with the Farmers' Promotors were conducted at sector level where 148 Sectors were selected in August and September 2021. Each sector planted one variety meaning that all the Farmers' Promotors

of a Sector planted one variety. Each Farmer Promotor planted a single plot of 10 m×10m (100m^2). A total 5285 demonstration plots, planted on area equal to 52.85 ha were conducted (**Tables 9-10**). The maize hybrid varieties used in demonstration plots were RHM104, RHM1402, RHM1407, and RHM1409 for mid altitudes, RHMH1520 and RHMH1601 for high altitudes.

Table 9: Demonstration plots with Farmers' Promoters in Northern, Southern, Western Provinces

N	Sector	Area planted per variety (ha)				
		Number of FPs	RHM 1520	RHM 1601	RHM 104	RHM 1407
	Burera					
1	Bungwe	26	0.26			
2	Cyeru	23		0.23		
3	Gahunga	39		0.39		
4	Gatebe	30		0.3		
5	Gitovu	23	0.23			
6	Kagogo	33		0.33		
7	Kinoni	28	0.28			
8	Kivuye	28		0.28		
9	Nemba	29		0.29		
10	Rugarama	34		0.34		
11	Rugengabari	32		0.32		
	Nyamagabe					
12	Buruhukiro	35		0.35		
13	Cyanika	45		0.45		
14	Gasaka	29		0.29		
15	Gatare	25		0.25		
16	Kamegeri	21	0.21			
17	Kibumbwe	23		0.23		
18	Kitabi	30		0.3		
19	Musebeya	38		0.38		
20	Mushubi	25	0.25			
21	Nkomane	35		0.35		
22	Uwinkingi	35		0.35		
	Nyaruguru					
	Cyahinda	25	0.25			
	Kibeho	22	0.22			
	Muganza	25		0.25		
	Munini	27	0.27			
	Ngera	21		0.21		
	Ngoma	32	0.32			
	Nyagisozi	21		0.21		
	Ruheru	27	0.27			
	Rusenge	25	0.25			
	Nyabihu					
	Jenda	40		0.4		
	Kintobo	31		0.31		
	Mukamira	35		0.35		
	Rugera	45		0.45		
	Shyira	31		0.31		

N	Sector	Area planted per variety (ha)				
		Number of FPs	RHM 1520	RHM 1601	RHM 104	RHM 1407
	Gakenke					
22	Busengo	38		0.38		
23	Coko	28	0.28			
24	Cyabingo	34		0.34		
25	Gakenke	46		0.46		
26	Gashenyi	38		0.38		
27	Kamubuga	36		0.36		
28	Kivuruga	28		0.28		
29	Mataba	27		0.27		
30	Minazi	24	0.24			
31	Mugunga	34		0.34		
32	Muhondo	40	0.4			
33	Nemba	32	0.32			
34	Ruli	30	0.3			
35	Rusasa	30		0.3		
	Huye					
36	Simbi	39			0.39	
	Kamonyi					
37	Karama	19				0.19
	Muhanga					
38	Muhanga	30				0.3
	Nyamasheke					
	Cyato	36		0.36		
	Gihombo	38			0.38	
	Kagano	50			0.50	
	Kanjongo	42			0.42	
	Karambi	46		0.46		
	Kirimbi	32			0.32	
	Macuba	53		0.53		
	Mahembe	31			0.31	
	Nyabitekeri	52			0.52	
	Rangiro	23		0.23		
	Shangi	33			0.33	
	Rubavu					
	Busasamana	49		0.49		
	Gisenyi	1			0.01	
	Kanzenze	21		0.21		
	Mudende	36		0.36		
	Nyundo	54			0.54	
	Rubavu	35			0.35	

Table 10: Demonstration plots with Farmers' Promotors in Eastern and Western Province

N	Sector	Area planted per variety (ha)						N	Sector	Area planted per variety (ha)						
		Number of FPs	RHM 104	RHM 1402	RHM 1407	RHM 1409	RHM 1601			Number of FPs	RHM 104	RHM 1402	RHM 1407	RHM 1409	RHM 1601	RHM 1520
	Bugesera								**Ngoma**							
1	Gashora	35	0.35					25	Gashanda	26				0.26		
2	Juru	33			0.33			26	Jarama	40			0.4			
3	Kamabuye	40		0.4				27	Karembo	26		0.26				
4	Mareba	52	0.52					28	Kibungo	31			0.31			
5	Mayange	35	0.35					29	Mugesera	35		0.35				
6	Musenyi	46			0.46			30	Murama	44				0.44		
7	Mwogo	25				0.25		31	Rukira	42		0.42				
8	Ngeruka	58			0.58			32	Rukumberi	26				0.26		
9	Ntarama	22				0.22		33	Sake	34			0.34			
10	Nyamata	47			0.47			34	Zaza	55		0.55				
11	Nyarugenge	39		0.39					**Kirehe**							
12	Rilima	44				0.44		35	Gahara	80			0.8			
13	Ruhuha	35	0.35					36	Gatore	44	0.44					
14	Rweru	39			0.39			37	Kigarama	56			0.56			
15	Shyara	20		0.2				38	Kigina	44		0.44				
	Gatsibo							39	Mahama	37				0.37		
16	Gitoki	57				0.57		40	Mushikiri	60			0.6			
17	Kabarore	25	0.25						**Kayonza**							
18	Kiramuruzi	39			0.39			41	Kabarondo	37			0.37			
19	Muhura	57				0.57		42	Mukarange	37			0.37			
20	Murambi	35			0.35			43	Mwiri	23	0.23					
21	Ngarama	51			0.51			44	Ndego	27			0.27			
22	Remera	43		0.43				45	Nyamirama	33			0.33			
23	Rugarama	54				0.54		46	Rwinkwavu	46		0.46				
24	Rwimbogo	39	0.39						**Rusizi**							
	Karongi								Gashonga	40		0.4				
	Bwishyura	46			0.46				Giheke	36					0.36	
	Gashari	32					0.32		Gihundwe	38			0.38			
	Gishyita	35		0.35					Gikundamvura	30		0.3				
	Murambi	36					0.36		Gitambi	27				0.27		
	Murundi	39					0.39		Kamembe	32			0.32			
	Rubengera	55			0.55				Mururu	34			0.34			
	Rugabano	44		0.44					Nkanka	28				0.28		
	Rugabano	44					0.44		Nkungu	40						0.4
	Ngororero								Nyakabuye	51			0.51			
	Gatumba	36					0.36		Nyakarenzo	30				0.3		
	Hindiro	31					0.31		Rwimbogo	26			0.26			
	Kabaya	42					0.42		**Rutsiro**							
	Muhanda	40					0.4		Boneza	28						0.28
	Muhororo	30					0.3		Kigeyo	38					0.38	
	Ndaro	33					0.33		Kivumu	45					0.45	
	Nyange	27					0.27		Mukura	53					0.53	
Total in country:		5,285 FPs; total area: 52.95ha							Murunda	28					0.28	

Backstopping 14 seed producers for certified seeds production using RAB maize hybrid varieties

Fourteen seed producers have undertaken certified seed production in the season using six RAB maize hybrid varieties (**Table 11**). They have planted approximately an area of 1,261 ha in the season 2021A.

Photo 1: RHMH1520 seed production, Bishenyi, with Rumbuka Seeds (left); Silk color of the parent SCH of RHM109, Nasho Irrigation Cooperative (NAICO) (right)

Photo 2: Leaf margin undulations and leaf angle of female plants with white silks and female plants with red silks (left); varietal difference in silk color (right)

Table 11: Seven maize hybrid varieties in seed production

N	Names	Type	Eco-logy	Growing altitudes	Specific trait	Grain texture	Seed produc-tion type	Planted by farmers ?
1	RHM 104	TWCH	MA	900-1800	Drought tolerant	Semi-dent	Certified	Yes
2	RHM 1402	TWCH	MA	900-1700	Drought +MLN tolerant	Semi-flint	Certified	Yes
3	RHM 1407	TWCH	MA	900-1700	Drought +MLN tolerant	Semi-dent	Certified	Yes
4	RHM 1409	TWCH	MA	900-1700	Drought + MLN tolerant	Semi-flint	Certified	Yes
5	RHMH 1520	TWCH	HA	1700-2600	Early	Semi-flint	Certified	Yes
6	RHMH 1601	TWCH	HA	1700-2700	Early	Semi-flint	Certified	Yes
7	RHMH 1611	TWCH	HA	1700-2800	Early	Semi-flint	Basic	Not yet

TWCH: Three Way Cross Hybrid; MA – Mid-altitude; HA – High altitude

They have been backstopped since the planting up the harvest, which through regular visits, networks, exchange visits, training and use of social media. However, there still some seed producers who planted late in the month of December 2020. They are currently experiencing some issues which may linked to interaction with the bad conditions and lead to discard seed production plots by the inspection while apparently, it is the interaction with environment (**Photo 1 and 2**).

2.1.2 Wheat

Farmer-managed trials

The activity has been conducted in form of on-farm technology adaptation trials using a participatory variety evaluation and selection approach. The objective has been to test for adaptability wheat varieties developed through research in terms of potential performance and general adaptability, and farmer's preferences as well. In this regard, seven wheat genotypes (including Gihundo as check) have been planted farmers' fields to evaluate their potential performance under appropriate crop management practices. These trials have been researcher-managed to ensure their performance as required and farmer-managed to make the selection process participatory (**Photo 3**).

Farmers from the surrounding areas and other stakeholders have been invited to view these varieties at either stages -milky or maturity stages- and select those they like best. The best selected varieties will be advanced to further evaluation stages for release process and subsequent commercial production. The genotypes under testing include the following: 113, 121, 109, 118, 104, 111, 116 and Gihundo as a check. The plot size per genotype varies depending on land availability.

Photo 3: Variety evaluation on farm, Gataraga, 2021A and a farmer field in Rwerere, Burera

Out of 17 trials expected by the end of financial year 2020-2021, 62 farmer-managed trials have been established across the country, especially in wheat growing areas including new sites of Nyagatare, as summarized in the **Table 12**.

Table 12: Farmer-managed trias per District

N	District	On-farm trials		N	District	On-farm trials	
		2021 A	2021 B			2021 A	2021 B
1	Gicumbi	2	4	6	Nyagatare	6	3
2	Burera	-	4	7	Rulindo	4	5
3	Nyabihu	1	-	8	Gakenke	1	1
4	Nyamagabe	1	-	9	Musanze	15	11
5	Nyaruguru	3	-	10	Ngororero	1	-
Total: 34 trials in 2021 A; 28 trials in 2021 B (62 trials in total)							

Sensitization of smallholder farmers to adopt improved wheat technologies

The major activity conducted to attact more farmers in adopting improved wheat technologies include the dissemination of improved wheat varieties among wheat growers across the country through the establishment of **demonstration plots** at strategic points (near the church, market place, crossroads, etc) to attract many more passers-by. The key objectives of the ctivity was to (1) make understand various stakeholders the importance of using improved varieties and crop management practices in increasing the standard of wheat production in Rwanda and in linking technology to the farmers, in a bid to specifically popularize the varieties among wheat farmers and other end-users; and (2) create demand for improved seed of the varieties.

The following steps were followed in carrying out such an activity
(1) Select an appropriate farm site in wheat growing areas of Rwanda;
(1) Solicit interest and active participation of farmer in establishment and management of field trials;
(2) Supply seed of the varieties to be evaluated and fertilizer and other necessary inputs;
(3) Use plot size of 4 m x 5 m, row spacing of 0.20 m, and hand-drilled seeds in sowing;
(4) Depending on available land provided by farmer, the number of varieties to be evaluated and amount of seeds available, grow 20-25 rows of each variety per plot per site;
(5) Ensure timely weed, pest and disease control by farmers;
(6) Apply fertilizer at recommended rates at planting and 4-6 weeks after planting;
(7) Erect appropriate signboard to attract passers-by;
(8) Organize field days to sensitize general public, farmers, local authorities and other stakeholders on the importance of improved varieties and modern agricultural practices in a bid to increase grain yield;
(9) Harvest, collect and compare grain yield data, share the obtained information with the stakeholders.

To make the wheat plots more visible in the fields and assist famers and other stakeholders to make their preferences/ choice, the first five varieties (Nyaruka, Gihundo, Majyambere, Reberaho, Cyumba) were planted in season 2021A and the other five varieties (Nyangufi, Kibatsi, Keza, Rengerabana and Mizero) were planted in the season 2021B. The number of sites selected in various Districts are summerized in the **Table 13**.

Table 13: Selected sites for demonstration plots per district

N	District	Demonstration plots		N	District	Demonstration plots	
		2021 A	2021 B			2021 A	2021 B
1	Gicumbi	7	7	7	Rulindo	12	6
2	Burera	9	4	8	Gakenke	2	1
3	Nyabihu	7	4	9	Musanze	23	11
4	Nyamagabe	2	6	10	Ngororero	3	-
5	Nyaruguru	6	7	11	Nyamasheke	1	-
6	Nyagatare	8	3	12	Muhanga	2	-
Total: 82 plots in season 2021 A; 49 plots in 2021B; total 131 plots							

The activity targeted individual farmers, farmer's associations and/or farmer's cooperatives such that more than 476 farmers, both men and women, representing over 86.5% of the adopters targeted (550) by the end of the year.

Dissemination of appropriate inputs including seeds and fertilizers

The awareness made for improved seed has been accompanied by the distribution of both improved variety seed and recommended types and rates of mineral fertilizers, namely, DAP (18-46-0) and urea (46-0-0), especially during the establishment of the demonstration plots and the on-farm trials in farmers' fields. The purpose of this activity has been to sensitize wheat farmers and highlight the importance of using recommended types and rates of mineral fertilizers at the right time is a key factor involved in increasing wheat productivity for smallholder wheat farmers. In 2021A, a total of 140 kg of seed was also disseminated among farmers of Gataraga innovation platform (IP) for further seed multiplication and resilience in quality seed. At the same time, more than 120kg of improved wheat seed of various commercial wheat varieties were distributed among different wheat farmers across the country for seed increase and popularization of improved wheat varieties. In both seasons 2021A and B, more than 350kg of seeds and 350kg of fertilizers has been distributed to farmers who participated in the establishment of both demo plots and on-farm trials in both seasons 2021A and B across the country. This achievement represents over 100% of the annual target that was 300kg.

Exchange field visits

The purpose of the exchange field visits was to share knowledge and views on wheat value chain and discuss the strategies aiming at increasing productivity and improving wheat market among wheat stakeholders of Rwanda.

The first field visit was organized on 29/01/2021 in the demonstration plots that were established in 2021A in Rwerere Sector, Burera District, when wheat was at late physiological maturity stage. At that time, the field tour involved 23 participants comprising several farmers surrounding the demo plots, Sector Agronomist, Socio-Economic Development Officer (SEDOs) at Cell level, and RAB staff. It was also an opportunity to appreciate the varieties they liked the most among the five commercial varieties that were planted in the plots. They ended up preferring all of them, namely Nyaruka, Gihundo, Majyambere, Reberaho, Cyumba, based on their agronomic performance compared with Musama variety that was in a closer farmer' field.

Photo 4: Wheat stakeholders in field visits, Rwerere Sector, Burera District, 2021A

Another important field visit was organized in a cooperative seed multiplication field located in Bungwe Sector, Burera District, and RAB Rwerere Research Station, early June 2021. The purpose was similar to the one mentioned above. The trip involved 25 participants including farmers, seed producers and cooperative members from INZIRAYUBUKIRE Cooperative (counting 308 members, whose 161 females and 147 males) based in Bungwe

Sector, Bungwe Sector Agronomist, Representative from Partners in Health Rwanda that financially and technical supports the Cooperative, and RAB staff.

The field visits were also the opportunity to distribute to the participants the extension materials mainly composed of leaflets on appropriate crop and postharvest management practices were distributed to the participants. Therefore, a total of two exchange field visits out of three that were planned for the fiscal year 2020/2021 were organized, representing 66.7% of the target. The failure to achieve them all three resulted from the COVID-19 pandemic impacts.

Training of wheat stakeholders

The training of wheat stakeholders mainly focused on appropriate use of wheat technologies and discuss key issues to wheat value chain. The first training was conducted on 29/01/2021during the field visit organized in Rwerere Sector. It involved 23 participants comprising several farmers surrounding the demo plots, Sector Agronomist, Socio-Economic Development Officer (SEDOs) at Cell level, and RAB staff. The second training was conducted on 2nd June 2021 during the field visit organized by INZIRAYUBUKIRE Cooperative to RAB Research Station. This one involved 25 participants including Cooperative Committee members and other few members, Representative from Partners in Health Rwanda and RAB staff.

Various topics including variety development, release and maintenance; wheat seed production and management; opportunities and challenges to wheat seed development in Rwanda, and seed business and marketing, were discussed among the participants. The discussions were also an opportunity to share knowledge, information and experience based on what the participants observe on the ground during the field tours.

The annual target was to train 50 stakeholders by the end of the year, and only 48 were trained, representing 96.5% of the target.

Photo 5: Training in of wheat stakeholders in the field, Rwerere Station, Rugezi site, June 2021

Radio talks and Rwanda Television show on wheat research and innovation

In October 2020, a radio talk on appropriate wheat crop management practices and the importance of using improved wheat varieties existing in Rwanda was developed and aired on RC Musanze by wheat staff. In February 2021, Rwanda television covered wheat research and innovation activities conducted in Rwerere Research Station and in farmers' fields through a participatory approach. The journalist was also interested in getting information on how RAB collaborates with other stakeholders in making a viable wheat value chain.

New Farmer Field Schools plots and or groups by FFS facilitators under Twigire Muhinzi approach

A total number of 345 demo plots and 85 FFS plots were established. A group of 4,323 farmer promoters, farmer facilitators and Socio Economic Development Officers (SEDOs) were trained on wheat crop management practices under TwigireMuhinzi approach.

2.1.3 Sorghum

Sorghum variety evaluation trials were planted in the season 2021 B so that all nurseries and trials are still in the field. Following activities were conducted in the financial year 2020-2021. These trials were:

a) Advanced yield trials on high yielding, short and early maturing lines comprising eight entries (I*K): I×K L2 (1), I×K L2 (2), I×K L6 (1), I×K L15 (1), I×K L15 (2), I×K L34 (1), I×K L35 (2), I×K L50 (2);

b) Advanced yield trials on high yielding, white grain, early maturing and highland sorghum lines (IS 9202*IS 21219) comprising five entries: IS×IS L8 (1), IS×IS L9 (2), IS×IS L12 (1), IS×IS L54 (1) and IS×IS L54 (2).

c) Advanced yield trials on high yielding, early maturing and vigorous sorghum lines (Amabanda × Mabereyingoma) are evaluated at Advanced yield trials comprising four entries: A×M L2 (1), A×M L3 (1), A×M L13 (1) and A×M L14 (1).

d) Advanced yield trials on high yielding, low tannin and early maturing sorghum lines (IS×SDL): comprising four entries: IS×SDL L13 (1), IS×SDL L52 (1), IS×SDL L59 (2), and IS×SDL L76 (2).

f) Preliminary yield trial (PYT) on high yielding, vigorous and early maturing sorghum lines (Kigufi*Mabereyingoma) comprising four entries: K × M L3 (1), K × M L40 (1*), K × M L37 (1) and K × M L40 (1).

Production of breeder and basic seeds

The breeder and basic seed production was undertaken on limited scale for Ikinyaruka, Kigufi, IS1219, IS8193, KAT369, SDL and IESV94027DL.

2.1.4 Rice

Rice is among current priority crops and has been strongly promoted in recent past. Rice production and yields have remarkably increased. Recent research on rice focused on variety development, farmer training, outreach and technology transfer. The major challenges for rice include new evolving rice diseases (sheath brown rot and sheath rot). We observed new strain of rice blast where some varieties (short grains) showed high susceptibility and others (long grains) are tolerant. This is an indicator of new strain evolution where short grain varieties were known to be tolerant to adverse conditions and diseases and long grains susceptible.

Preparation of two rice varieties for official release

Two new varieties namely Twigire with entry code RW-RCE21-01 and Ganza with entry RW-RCE 21-02 were proposed for future release with trading names of TETA 21- ML1 and TETA21-ML2. Two cooperatives of Rusizi and Kayonza districts are already demanding their official use and utilization. The descriptors of these two new varieties were developed and the varities will be submitted officially to the National Variety Release Committee in 2022A season.

Formation of breeding populations

The following parents KF190143, KF190213, KF190219, SR34590-HB3433-7-1-1 and SR35278-2-10-1-3 were used in introgressing desirable traits in local germplam. Like comprised long panicle, high number of spikelets per panicle and high yield. Ten populations were made: KF190213xWAT1395-B-24-2, KF190219x WAT1395-B-24-2, KF190143 x WAT1395-B-24-2, YUNKENG x RUMBUKA, TONGIL48xRGC 21, TONGIL48 x WAT1395-B-24-2, TONGIL48 x RUMBUKA, SR34590-HB3433-7-1-1 x RUMBUKA, SR35278-2-10-1-3 x WAT1395-B-24-2, BURYOHE x BASMATI 370. The F1 seeds were produced were subjected to the next generation using single seed descent methodology.

Trainings in rice growing techniques

A total of 1,300 farmers and frontline extension agents in rice including Farmers Field School facilitators and Farmer Promoters were trained in rice growing techniques.

Evaluation of KEFACI germplasm in observation trials

In Cyili, 55 varieties from KEFACI germplasm were tested. They were screened for rice yellow mottle virus diseases and exposed in hotpots of blast disease. Twenty varieties were selected and advanced to next generation. Varieties with superior characters, were used to improve local germplasm.

Outreach

To increase awareness about rice research, Rwanda Television was invited and visited the crossing block, several field trials and has produced a documentary that was aired during the television news (**Photo 6**). A film documentary was produced by Ministry of Agriculture in collaboration with Ministry of commerce in line of East Africa Rice conference where varieties in pipeline and the crossing block were presented and shown in video shooting.

Photo 6: Visit of crossing block by Rwanda Television

Demonstration plots

Thirty-six demonstration plots that included new rice varieties and varieties under cultivation were conducted 36 major rice growing schemes in Huye, Gisagara, Nyanza, Ruhango, Muhanga, Kamonyi, Gasabo, Kayonza,

Nyagatare, Kirehe, Ngoma and Bugesera (**Photo 7**). Each scheme has at least one demonstration plot which is often planted with several varieties (**Tables 14 and 15**).

Photo 7: Demonstration plots in Base (left) and Bugarama (right) rice schemes

Table 14: Demonstration plots in major rice scheme in 2020-2021

N	Rice scheme	Varieties
		Huye
1	Rwasave	TETA021-ML9, TETA021-ML1, TETA021-ML2, TETA021-ML3, TETA021-ML4, TETA 021-ML5, TETA021-ML6, TETA021-ML7, TETA021-ML8, Umutebo, Cyuzuzo, Gwiza
2	Mwogo	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, RAB30, Yun Keng
3	Umwaro	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, RAB30, Yun Keng
4	Umusizi	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, RAB30, Yun Keng
5	Rwamamba	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, KIRA, Yun Keng
		Gisagara
6	Migina-KOABINYA	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno,RAB30, Yun Keng
7	Ngiryi	Kibondo, Gwiza, Kageno, RAB30, Cyuzuzo, Muturage, BR, Yun Yin, Yun Keng
8	Mirayi	Umutebo, Gwiza Cyuzuzo, Muturage, BR, Kageno, KIRA, Yun Yin
9	Nyiramageni	Umutebo, Gwiza; Cyuzuzo, Muturage,BR,Kageno,RAB30, Kibondo, YunKeng, YunYin
10	Gatare	Umutebo, Gwiza, Cyuzuzo, Muturage, Kageno, Kibondo, RAB30, Yun Yin
11	Kabogobogo	Umutebo, Gwiza, Cyuzuzo, Muturage, Kibondo, Kageno, RAB30, Yun Yin
12	Ngiryi	Kibondo, Gwiza, Kageno, RAB30, Cyuzuzo, Muturage, BR, Yun Yin, Yun Keng
13	Mirayi	Umutebo,Gwiza,Cyuzuzo, Muturage,BR,Kageno, KIRA,Yun Yin
14	Nyiramageni	Umutebo,Gwiza,Cyuzuzo, Muturage,BR,Kageno,RAB30, Kibondo,YunKeng, YunYin
15	Gatare	Umutebo, Gwiza, Cyuzuzo, Muturage, Kageno, Kibondo, RAB30, Yun Yin
16	Kabogobogo	Umutebo, Gwiza, Cyuzuzo, Muturage, Kibondo, Kageno, RAB30, Yun Yin
17	Ngiryi	Kibondo, Gwiza, Kageno, RAB30, Cyuzuzo, Muturage, BR, Yun Yin, Yun Keng
18	Mirayi	TETA021-ML9, TETA021-ML1, TETA021-ML2, TETA021-ML3 TETA021-ML4, TETA021-ML5, TETA021-ML6, TETA021-ML7, TETA021-ML8
19	Nyiramageni	TETA021-ML3,TETA021-ML4, TETA021-ML5, TETA021-ML6, RAB45, RAB47, TETA021-ML8,TETA021-ML9
20	Nyakagezi	TETA021-ML9, TETA21-ML3, TETA021-ML4, TETA021-ML5, TETA021-ML6, TETA021-ML7 , RAB45, TETA021-ML8
		Nyanza
21	Nyarubogo	TETA021-ML9, TETA021-ML1, TETA021-ML2, TETA021-ML3, TETA021-ML4, TETA021-ML5 , TETA021-ML6, TETA021-ML7, TETA021-ML8
		Muhanga
22	Rugeramigozi I (KIABR)	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, RAB30, Yun Keng

23 Rugeramigozi II (KOKAR)	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, Kira, Yun Keng
	Kamonyi
24 CORIMU	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, Yun Yin
25 Mukunguli	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, Kira, Yun Keng
	Ruhango
26 Nyirakiyange	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, Kira, Yun keng, BR, Rumbuka
27 Rubuyenge	TETA021-ML9, TETA021-ML3, TETA021-ML4, TETA021-ML5, TETA021-ML6, TETA021-ML7, RAB45, TETA021-ML8
28 Nyarubogo	Umutebo,Gwiza, Cyuzuzo, Muturage,BR, Kageno, Kibondo, RAB30, YunYin, YunKeng
29 Budubi	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, RAB30, Yun Keng
30 Nyamigogo	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, Kibondo, RAB30, Yun, Yun Keng
31 Nyirakiyange	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, RAB30, Yun Keng
32 Base	Umutebo, Gwiza, Cyuzuzo, Muturage, BR, Kageno, RAB30, Yun Keng

Table 15: Demonstration plots in major rice scheme in 2020-2021 (continued)

No	Rice scheme	Varieties
		Kayonza
27	Kageyo	TETA021-ML1, TETA021-ML2, TETA021-ML3, TETA021-ML4, TETA021-ML5, TETA021-ML6, TETA021-ML7, TETA021-ML8, TETA021-ML9, TETA021-ML10, TETA021-ML11, TETA021-ML12
28	Gacaca	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin
		Nyagatare
29	P5	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin
30	P4	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin
31	Rwangingo	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin
		Kirehe
32	Isabane	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin
33	KOPRIKI	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin
		Ngoma
34	CORIMI	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin, Gwiza
		Bugesera
35	Rwabikwano	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin, Gwiza
		Gasabo
36	Kabuye	Gwiza, Jyambere, Fashingabo, Umutebo, Gacinya, Yun Yin

In the line of availing early generation seeds generation, we produced more than 300 kg of breeder seeds and at least 10 kg of every variety were availed to seed division for further multiplication of basic and certified seeds by private seed producers.

1.2 Banana Program

BXW control using BXW App

This activity is implemented under the framework of BMZ-funded project. Testing and evaluation of BXW App developed by 'Citizen Science to prevent the spread of Banana Xanthomonas wilt in Eastern and Central Africa' project supported by BMZ-Germany. The project works with 68 farmer promoters in Rulindo, Burera, Kayonza,

Gatsibo, Rubavu, Karongi, Muhanga and Gisagara. In the first 2 years of the project, more than 2,200 farmers were assisted to report on disease incidence and progress using BXW App. The success in access and use of BXW App which is now freely available at Google Store, interface in Kinyarwanda have promising potential for further scaling out of the digital extension messages and enlarging their focus and scale. Farmer promoters across 8 Districts are sharing information on how identify/ diagnose, control and prevent BXW in farmer's banana fields and provide agronomic practices on banana by using BXW application. By the end of 3rd year of the project, more than 4500 farmers including were registered into BXW application by farmers promoters and 4000 farmers farms were diagnosed.

Banana rehabilitation

Banana rehabilitation took place through providing technical support and visits to the selected by districts banana rehabilitation sites. A total of 10,669ha of banana fields was rehabilitated in 2021A and B (**Table 16**).

Table 16: Area of banana rehabilitated per district during FY 2020-2021

District	Area (ha)	District	Area (ha)	District	Area (ha)
EASTERN Province + Kigali City		SOUTHERN Province		WESTERN Province	
Bugesera	524	Nyanza	150	Rusizi	510.7
Kayonza	455	Huye	963	Nyamasheke	119.1
Nyagatare	373.1	Gisagara	1274	Ngororero	119
Ngoma	1351	Nyaruguru	12	Karongi	-
Kirehe	230	Nyamagabe	21	Rubavu	285
Gatsibo	192	Muhanga	3321	Nyabihu	79.6
Rwamagana	640	Kamonyi	23.6	Rutsiro	-
Kicukiro	8	Ruhango	17.9		
Sub-total	*3,773.1 ha*	*Sub-total*	*5,782.5*	*Sub-total*	*1,113.4*

Total National : 10,669 ha

Development and dissemination of extension material

Banana Program continued to distribute posters developed on new method for banana wilt control, how to differentiate banana xanthomonas wilt and fusarium wilt, and macro-propagation. Banana management book was re-edited and reprinted and included basic package on banana management practices, nutrient deficiencies and pests and diseases and their control. Separate brief modules on banana cultivation practices were developed and included in extension material for Tubura One Acre Fund and Agenda Agricole.

Support to banana seed production

Support in form of clean banana plant material delivery was given by RAB to districts. This has led to establish new mother gardens and new fields on 82.8 ha (equal to 82,800 plants (**Table 17**).

Table 17: New banana plantations established in the districts

District	Mother garden (ha)	New area (ha)	District	Mother garden (ha)	New area (ha)
SOUTHERN Province			WESTERN Province		
Nyanza	1		Rusizi	0.8	248
Huye	1.5		Nyamasheke	0.5	187
Gisagara	7		Ngororero		152
Nyaruguru	-		Karongi	-	
Nyamagabe	-		Rubavu		429
Muhanga	-	72	Nyabihu		16.3
Kamonyi	-		Rutsiro	-	
Ruhango	-				
Sub-total	9.5	72	*Sub-total*	*1.3*	*1,032.3*

Training of farmers, technical visits of banana farms

In FY 2020-2021, Banana Program has provided support in form of formal training of farmers groups (**Photo 8**) whenever it was possible under COVID-19 restrictions, technical visits, supply of training materials, and technical physical visits to banana farms. The support included advice on banana management practices, production of clean planting material, disease and pest identification and recommendations for its control. The total number of farmers advised, supported or trained was 2,441. This included 920 in East =920 (**Table 18**), 170 in West and 1,351 in South.

Photo 8: Meeting with farmers on banana trips control (left) and banana buyers in market (right)

New training topic was banana thrips, a new pest appeared at once in most of Rwandan districts and associated with sharp temperature increase in recent years which led to rapid population build-up. And we distributed to them the factsheet (**Photo 8**).

Table 18: Farmers trained in form of technical visits in Eastern Province

District	Number of trainees		
	Men	Women	Total
Bugesera	34	16	50
Kayonza	102	43	145
Nyagatare	71	41	112
Ngoma	96	58	154
Gatsibo	97	46	143
Rwamagana	74	32	106
Kirehe	87	62	149
Kicukiro	39	22	61
TOTAL	600	320	920

Pests and diseases control/ Banana trips control

Banana team staff visited and advised the farmers on banana trips control where the symptoms of banana trips attack are showing. A total of 5751ha were identified as affected by thrips (**Table 4**). The following recommendations were given for thrips control: - cut down the affected banana fruits and bury them to reduce the population of insects in the fields, Remove neglected plantations as these can serve as ground for trips to multiply; Apply proper sanitation techniques on infected plant residues and bunches; Immediately at flowering, covering of the bunch as it opens using the clear polythene bags, Spraying the pesticide (pyrethrum) starting just

after flowering on the young banana bunches in infected banana plantation, Avoid using the banana residues collected from the market and collection centers as manure or mulch to prevent the spread of disease. Sensitization meeting was organized during which the farmers have agreed on the control measures to use and action plan to combat thrips.

Table 19: Banana area affected by thrips in FY 2020-2021

N	District	Estimated area affected (Ha)
1	Kirehe	3000
2	Ngoma	2500
3	Kayonza	127
4	Bugesera	5
5	Kicukiro	4
6	Rwamagana	16
7	Gatsibo	99
8	Nyagatare	70
	TOTAL	5751.25

Photo 9: Vice Mayor launching the activity on banana trips control

Training on banana trips control was conducted in the affected field where control practices were demonstrated. We gave to the farmers the developed training material in form of booklets and factsheets). We also sensitized the banana bunches traders to buy the banana with symptoms of banana trips on the same price as the safe banana bunches. They refuse to buy them; otherwise they give the low price then the normal even below half. In Mushikiri Sector, Ngoma District, V/Mayor launch the banana trips control activity at District level. They attend this event all sectors agronomists from Ngoma District, local autorities from Nyinya cell, all Ubumwe cooperative members and journalists attended the event. The event was also published on social media (RTV, RBA, Izuba radio).

1.3 Pulses and Oil Crops Program

Common bean and soybean are important crops for both human consumption and animal feeds. Both commodities also establish symbiotic relationships with rhizobial bacteria and fix atmospheric nitrogen. Through

this symbiosis with rhizobia, the two crops play an important role in nitrogen cycling and in improving agricultural productivity. Although common beans and soybean offer potential solutions to prevalent food insecurity, malnutrition, and poverty in Rwanda, their productivity is still very low compared with their potentials. The average annual production in the country is far below the increasing demand for local consumption, export and processing. This is mainly due to lack of resilient varieties, poor soil fertility, climatic variability and limited skills of farmers on best agronomic practices. For these reasons, efforts have been made to develop and release new generation of better bean and soybean varieties, produce and avail adequate breeder and basic seeds of these commodities to enable access of adequate quantity and quality seeds to the smallholder farmers.

1.3.1 Soybean

Crossing, screening and performance evaluation trials

Soybean lines at various generations were evaluated in Rubona station in seasons A & B. Main traits included: resistance/ tolerance to pests and diseases, early maturity, logging, shattering and high yield. In addition to the segregating lines under evaluation in Rubona station, in season 2021 A 5 stable lines (S4243; S3301; S0107; S3348 and S3303) have been selected and advanced for yield performance evaluation in Rubona, Ngoma, Gashora and Nyagatare RAB stations. This trial was repeated in season 2021B to confirm their stability and adaptability before taking them to further evaluations.

Evaluation of new entries

In season 2021A, 20 new soybean varieties were introduced through a partnership with the soybean innovation Lab of Illinois University (**Photo 10**). Those varieties were planted in four RAB stations: Rubona, Gashora, Ngoma and Nyagatare. The trial was repeated in season 2021B with all the varieties to confirm their stability and adaptability in Rwandan conditions. The best performing ones will be advanced in On-farm trials in season 2022A. The picture below shows the performance of these varieties in Nyagatare station.

Photo 10: Adaptability trial of 20 new soybean lines, Nyagatare, 2021B

Evaluation of the best soybean plant spacing in farming systems of Rwanda

This study aims to determine optimum spacing for soybean in four RAB stations: Rubona in the granitic ridge AEZ, Gashora in the Bugesera AEZ, Ngoma in the eastern plateau & Nyagatare in the Eastern Savanna AEZ. These AEZs cover the major soybean growing areas of the country. In Rwanda two plant spacing (40 cm x 10 cm and 40 cm x 5 cm) are being used but there is no recommended planting density for soybean production in Rwanda. In this study we propose 4 more planting densities (50 cm x 5 cm; 45 cm x 5 cm; 30 cm x 10 cm; 25 cm x 10 cm), and will be applied to 2 soybean varieties namely RWSOY 20-1 and RWSOY 20-3. The plots size of 3m x 3m with 1m path between replications and 0.5 m between plots were used and the trial was laid down in randomized complete block design (RCBD). This study had started with the variety Peka 6 but with the release of the new varieties, we

decided to repeat it and shift from Peka 6 to the new varieties that are going to be widely disseminated in the country. The Variety RWSOY 20-1 is indeterminate thus taller while the variety RWSOY 20-3 is medium in height. So, the use of the two varieties in determining the right spacing forms a good representation of the remaining varieties. In 2021B, the study is ongoing in four RAB stations located in four agro-ecological zones (AEZ) of Rwanda: Rubona station located in the granitic ridge AEZ, Gashora in the Bugesera AEZ, Ngoma in the eastern plateau & Nyagatare in the Eastern Savanna AEZ. These AEZs cover the major soybean growing areas of the country. Data collected include: emergence count (%); days to flowering; days to podding; days to maturity; number of branches and pod load; height (cm); disease scoring; lodging; shattering; yield / plot (g); yield / ha (kg); 100 seeds weight and grain colour. Data analysis and report on this trial will be available after harvesting in July 2021. This study will be repeated in season 2022A to confirm the results before validation and recommendation.

On-Farm trials

In season 2021 A & B, 9 promising soybean varieties (TGX 2001-1DM; TGX 2001-10DM; TGX 2001-24DM; MAKSOY 4N; MAKSOY 2N; SC S1; TIKOLORE; NASOKO and SAGA) selected from 24 soybean varieties introduced in 2020 through the partnership with the Soybean Innovation Lab have been repeated to confirm their adaptability. Due to COVID-19 pandemic restrictions, we were not able to cover all agro-ecological zones as planned, and for that reason, we plan to repeat it again in order to get enough data before selecting best candidates for registration and future release. In addition to the above 9 varieties introduced, there are other 9 soybean lines (S2302; S3548; S1008-3-2; S2905; S0719-10-3; S2508-6-2; S0302-5-1; S0227; S02324) developed by RAB/soybean that are at national performance trials in Nyanza, Bugesera, Gatsibo and Nyagatare. These two trials will be repeated in season 2022A to select best candidates for future release. All the varieties received a uniform fertilization with DAP (100 kg ha^{-1}) and farmyard manure (10 t ha^{-1}).

Training and establishment of demonstration plots

To improve farmers' capacity and awareness of the new soybean varieties, a total of 203 demo plots have been established in season 2021 A & B as follows : 91 demo plots have been established in season 2021A in: Ngoma (18); Kirehe (1); Kayonza (20); Bugesera (6); Gisagara (5); Huye (5); Nyanza (5); Ruhango (5); Muhanga (5); Kamonyi (5); Nyagatare (11) and Gatsibo (5) and 112 demo plots have been established in season 2021B as follows: Huye (8); Nyamagabe (3), Nyaruguru (3), Nyanza (13); Gisagara (9); Rwamagana (8); Bugesera (10); Kayonza (11); Ngoma (10); Kirehe (11); Gatsibo (12) and Nyagatare (14) (**Photo 11**). In the same context soybean farmers and cooperative members across sites were trained on soybean best agronomic practices including the use of Rhizobium, DAP fertilizer, manure, line spacing, planting rates, weeding, pest and diseases management. At all the sites, farmers showed much interest in growing the new soybean varieties.

Photo 11: Demo plots in Gishari (left) and Muhazi (right)

Initiation of seed production trials in partnership with UR-CAVEM

A joint seed production at UR-Nyagatare campus started in 2021B season. A team led by RAB's Cereals and Pulses and Oil Crops Programs coordinators on recommendation from the Director General/RAB, visited UR-Nyagatare-campus in order to streamline and plan for initial activities that may be started during the 2021 season in line with the above-mentioned partnership. It was agreed that RAB support and technically assist UR-Nyagatare campus staff to set up a seed production trial in a bid to become professional/registered seed producers in the future. The campus has around 60 ha that may be used for seed production on various commodities with focus on soybean and hybrid maize. On the other hand, RAB's pulses and oil crops program recently released 8 new soybean varieties named RWASOY20-1, -2,-3,-4,-5,-6,-7,-8 and we are in the phase of seed increase and demo-plots set up for a smooth and quick adoption. For this end, it is paramount the some of these lines get produced in different locations across the country for farmers to get familiar with them in order to promote their use in near future (latest 2022 A). To start, UR-Nyagatare planted 3 varieties: RWSOY 20-3, RWSOY 20-5 and Peka 6 (**Photo 12**) and RAB provides technical backstopping.

Photo 12: Soybean in UR-CAVEM, Nyagatare campus

1.3.2 Bean

Bean research focused on development of bio-fortified with Iron and zinc varieties through variety evaluation, micronutrient analysis and conventional breeding for increased iron and zinc, multiple disease resistance, short cooking time, seed production and quality, training and outreach.

Development of bio-fortified beans

The objective of this activity was to develop bush and climbing bean populations with high mineral density (Fe and Zn), combining resistance to diseases, drought tolerance, and adaptation to low soil fertility for market and accepted by farmers in different AEZs. These varieties would improve iron intake and decrease the prevalence of iron deficiency among women and children, particularly, in farming communities where beans constitute principal staple food. The seeds from previous selections were used by crossing iron-rich material to adapted recipients in preferred market seed types and six sites (Rubona, Muhanga, Musanze, Rwerere, Ngoma and Nyagatare). Between July 2020 and May 2021, a total of 10.780 seeds were analyzed for micronutrients with the XRF machine set at Rubona. The selected seeds were multiplied.

Crosses & early variety development: During 2020/2021, a total of 719 crosses including 264 crosses of 90 combinations for bush parents and 455 crosses of 90 combinations of climbing parents were made in Rubona. Advancement from F1 to F2 seed is on-going where the best leads will be planted in F2 nursery in 2022A season. 180 segregating lines including 90 bush beans and 90 climbing beans are being advanced from F2 to F3 seeds at Rubona and 220 in F2 at Rwerere. 63 climbing segregating lines are being advanced from F3 generation to F4

seed during 2021B season in Rubona and 653 in F4 in Rwerere station. Best leads will be advanced to the next generation.

Intermediate variety development: A total of 220 lines including 116 bush and 104 climbers are being advanced from F3 nursery of 2021A season and generate F4 and F5 seed generation in 2021B and 2022 A seasons respectively. Other 447 lines including 220 bush and 227 climbers are being advanced from F4 nursery of 2021A season and generate F5 and F6/PYT seed generation in 2021B and 2022 A seasons, respectively. From 375 lines including 307 bush and 68 climbers, a total of 1104 mass selected lines including 190 climbers and 914 bush and 108 in F6 in Rwerere are being advanced (at Rubona and Rwerere respectively) from F5 nursery of 2021A season to F6/Preliminary Yield Trial and F7/Intermediate Yield Trial generation in 2021B and 2022 A seasons respectively.

Final variety development: Evaluation of preliminary yield trial of 146 lines (at Rubona) including 14 bush and 132 climbers and 118 climbing (at Rwerere) is on-going. Fe/Zn will be determined; best leads will be selected for 2022A evaluations. Evaluation of different sets of Intermediate Yield Trial of 554 lines including 303 bush and 251 climbers (Rubona) and 85 climbing lines (Rwerere) is ongoing. Fe/Zn will be determined, best leads will be selected for 2022A evaluations. Evaluation of AYT of 49 lines including 24 bush and 25 climbers (Rubona) and 25 climbers (Rwerere) is on-going. Fe/Zn will be determined, best leads will be selected for 2022A evaluations.

Test Genotype x Environment interactions: Multi-locational Yield Trial phase 1 evaluation of 48 lines included 16 bush and 32 climbers in 6 stations. Fe/Zn will be determined, best leads selected 2022A evaluations. Multi-location Yield Trial phase 2 of 17 lines included 10 bush and 7 climbers in on-station and on-farm trials. Fe/Zn will be determined, best leads selected for 2022A evaluations. Adaptability test of 13 lines including 6 bush and 7 climbers in on-station and on-farm trials is on-going. Fe/Zn content will be determined, best leads selected for 2022A evaluations. In 2021B season, 38 lines were introduced from CIAT for the regional nursery. The screening for adaptability is planned in 2022A season. Fe/Zn content will be determined and best leads selected for further evaluations.

Release of Biofortified Beans: Among the 19 new bean varieties recently released, 8 of them are high in iron and zinc content. These include RW BB181, RW BB 183, RW BB184, RW BB 186, RW CB 181 RW CB 184, RWCB 186 and RW CB 189. The other 11 including RW BB 182, RW BB 185, RW CB 185, RW CB 183, RW CB 182, RW CB 188, RW CB 1812, RW CB 1811, RW CB 191, RW CB 1810 and RW CB 187 are high yielding with good agronomic traits. Rwanda Agriculture and Animal Resources Development Board (RAB) intent to apply to National Variety Release Committee for registration of other 9 iron-rich varieties that are high yielding with other traits of interest. The nine (9) new elite lines include 4 bush (RWR 5055, RWR 5062, RWR 5064, RWR 5070) and 5 climbers (RWV 2425, MAC 71, RWV 6001, RWV 6008, RWV 5035) which were planted for distinctness uniformity and stability evaluation in on-station experiments. Data for characterization were recorded and DUS report will be developed. Application for registration and release is expected during 2022A season.

Seed Production

Seed of the newly released varieties were multiplied in all RAB stations in 2021A and B seasons. A total of 4,807kg of breeder and pre-basic seeds of different varieties were produced in 2021A and B seasons: in Rubona (1,130 kg), Rwerere (291kg of breeder seed and 1,462kg of pre-basic), Nyagatare (986kg of pre-basic seeds), Muhanga (30kg of pre-basic), Ngoma (908kg of pre-basic seeds).

Conventional breeding to improve bean protein content

The demand for beans is increasing in rural and urban areas, thus creating the need to increase the supply. Yield per hectare of beans has increased due to the developed and released varieties. Breeders must pay close attention to seed protein concentration and quality as increased yield in bean can be associated with decreased protein concentration and thus a less nutritious crop. Beans are legumes that fix atmospheric nitrogen to provide N to the current bean crop and the subsequent crop in rotation. Protein and yield in bean is closely related to the degree of biological nitrogen fixation (BNF) which is in part controlled by genetics and can be improved by breeding. In addition, a bean cultivar must have many other desirable attributes (stress tolerance, pest resistance, Fe & Zn content, seed size and color, etc.) to be chosen and grown by a farmer and thus impact livelihoods. Combining acceptable levels of high yield, protein, Fe & Zn content, and all other traits in a cultivar is a huge challenge for bean breeders and requires attention. This study aims to develop bean genotypes with high yield and high protein content through crossing. A total of 55 different genotypes are being selected for protein content test including crossings of locally bred lines and local collection landraces.

Improved postharvest handling to promote biofortified beans

This activity was conducted during 2020/2021 under the support of the AU-NARO project (1) Establishment of on-farm demonstration of crop management technologies and biofortified beans; (2) Morphological and molecular analysis of seed to determine their purity; (3) Assessment of common bean seed and grain for pests and pathogen contamination; and (4) Analysis of common bean grain to determine mycotoxin contamination.

On-farm demo of climate smart crop management (CM) and high yielding bio-fortified varieties

Despite COVID-19 challenge, on-farm demo fields were established in different districts of the Country, and were used to teach various agricultural techniques and technologies including new varieties and good agricultural practices. Sub-activities under this objective included multiplication of foundation seed, establishment and management of on-farm demonstrations; farmer field schools (FFSs), field days and the determination of the profitability and acceptability of CM practices and bio-fortified beans. With the support from African Union project, foundation seeds (2,404kg) including 430kg of RWR 2154, 490kg of RWR 2245, 475kg of RWV 1129, 601kg of MAC 44 and 408kg of RWV 2887 was multiplied by RAB stations. After identification of farmers who can receive the demonstration fields, establishment and management of on-farm demonstration fields was done by farmers under supervision of RAB researcher/extensionist staff and local government authority. Established demonstration fields provided the opportunity for promotion of the dissemination and adoption of bean based technologies. The demonstration plots served also as an opportunity to promote the consumption of bio-fortified beans by bean growers. Small sized farms were used. Demonstration fields were established in collaboration with adult farmers where the fields were prepared by farmers who are to learn by doing, experimentation, observation and reflection (**Photo 13**). The consumption of bio-fortified beans was promoted by providing high iron beans seed (50kg of RWR 2154) in school (APAGERWA NYANGE) to help change the perception of eating beans and promote good nutrition. The distributed seed was planted on 1 ha. The production was consumed by students and teachers at school while the selected seed was reproduced.

Photo 13: On farm demo plots and demonstration of crop management and bio-fortified beans

Development of promotional material

Two farmer's manual entitled: Imfashanyigisho kuburyo bwo kuzamura umusaruro w' ibishyimbo mu Rwanda; cyanecyane ibikungahaye kubutare bwa Feri (good agricultural practices); 2) GUFATA NEZA UMUSARURO W'IBISHYIMBO (on post-harvest handling technologies) were developed to facilitate understanding of the transmitted innovations. The manual on good agricultural practices covers: land preparation, planting, fertilization and pest and disease management were developed, while the manual on post-harvest handling technologies covers: harvesting, transporting, drying, threshing, cleaning, packaging, storage and insect pest management.

Radio outreach

A radio talk was given at RC Huye on bean cropping and season preparation in July 2020 where awareness of bifortified bean varieties and best agricultural practices were the focus. Among the audience, 30 liked the talk and reacted during the talk. Promoted bio-fortified beans include: RWR 2245, RWR 2154, MAC 44, RWV 1129 and RWV 2887. Other new high iron bean varieties to be promoted are: RW BB 184, RW BB 183, RW CB 181, and RW CB 186. Crop management technologies promoted include: Line planting and spacing, weeding, Earthing up, fertilizers application and staking techniques.

Demonstration for Pest management

A total of 481 demonstration fields were established in 3 bean production hubs where 462 demonstrations were established during 2021 A season and 19 demonstration plots were established in 2021B. All the demo fields were established by farmers/farmers' groups under supervision of trained FFS facilitators and extension agents from local governance using improved bio-fortified beans. The field day to promote the crop management technologies and high iron beans for improved health and nutrition of small holder farmers, share knowledge and experiences on bean-based technologies among the value chain actors is planned in the last week of June 2021.

Photo 14: Demo plot at Gisagara (left) and Farmer Field School in Northern bean hub (right)

Study of quality of common bean along the value chain

Some of the factors that affect the quality of beans from production to storage include pests and diseases in the field, timing of harvest, postharvest handling methods such as drying techniques, seed processing prior to storage and conditions of seed/grain storage. Ensuring high quality of seed and grain is critical for several reasons. To ascertain the quality of bean seed and grain at the different value chain levels, the following studies are being conducted: 1) Assess the physical purity of seed and grain. 2) Conduct morphological and molecular analyses to

determine the genetic purity of seed and grain; 3) Assess common bean seed and grain for insect pest and pathogen contamination; and 4) analyze common bean grain to determine the level of mycotoxin contamination. In the previous report, we reported the physical purity of seed and grain from sent to Italy for molecular analyses. This time, germination test of seed collected during a survey conducted under support of AU-NARO project, was performed to assess bean seed and grain for fungi contamination. Another set of sampled was prepared for determination of mycotoxin contamination.

A total of 374 samples were collected from farmers and traders during the baseline survey. During the survey, interviewees provided different quantity of samples; some gave few while other gave the needed sample of 1kg. The samples were divided into 6 different studies, sometimes with replications. From these samples depending on the sample size, the number of samples for different studies varied where 259 samples were selected for morphological characterization (Germination test), 115 selected for molecular characterization, 170 samples selected for mycotoxin study, 160 selected for fungal disease identification, 160 reserved for bacterial disease identification, and 169 selected for physical purity. Reference made to the expected result on determination of the genetic purity of seed and grain for at least 20 samples from selected hubs, we managed to select 115 samples, prepared and sent to Italy for molecular characterization.

Germination test of selected 259 samples of bean seed and grain was conducted using the National Genebank facilities located at RAB-Rubona to assess the effect of seed borne pathogens on seed germination. Among 259 selected samples for germination test, 174 samples representing 67% were observed to have the acceptable germination rate of 85% and above as per the Photo 15 below. This indicates the need for promoting seed and postharvest management technologies. Percentage of fungal infection diseases on collected bean samples was determined on selected 160 samples (the target was 150 samples) where the majority of seed 85 representing 53% was infected at less than 10% by fungal diseases while 75 samples had fungal infection rate varying between 10 and 47%. Sample purification for fungal diseases identification is completed. With the target of analysing 100 samples for determination of the level of mycotoxin contamination, selected 170 common bean grains were prepared.

Photo 15: Determination of percentage of seed affected by fungi with some samples isolated from collected samples for fungal diseases identification

AGRA project

Under AGRA funded project entitled: *Leapfrogging release and adoption of high yielding multiple stresses resilient bean, soybean and potato varieties to catalyse sustainable market-led seed industry in Rwanda,* some achievements have been made including: Conduct National Performance Trials and Multilocation Trials, harvest of National Performance Trials established in 2021A in Nyabihu, Ngoma and Nyagatare and Multilocation Trials established in Gicumbi, Burera, Musanze, Rubavu, Ngoma, Kirehe and Nyagatare.

New Multilocational Trials were established in 2021B in Musanze (2), Burera (2), Gakenke (2), Gicumbi(1), Ngoma (2) and Nyagatare (2). Also new 7 NPTs were stablished in Musanze and Burera Districts. Demonstration plots were also establish across different agro-ecological zones. Yield performance of new bean varieties was demonstrated under 114 demos established with farmer's cooperatives in 13 Districts: Burera, Gicumbi, Musanze, Gakenke, Rubavu, Nyabihu, Rutsiro, Bugesera, Ngoma, Kayonza, Kirehe, Nyagatare and Gatsibo. Also a total of 3.92 Mt of pre-basic seeds were produced in different RAB stations under AGRA support. Trainings to enhance the farmers/farmer groups were conducted as well. One training was conducted on seed production. Representatives of twenty-three (23) seed cooperatives / farmers' organizations were trained. Another training was conducted on climate advisory services on common bean.

Development of bean lines with multiple disease resistance using Marker Assisted Selection

This work aimed to strengthen national capacity for bean breeding via improvement of breeding efficiency with Marker Assisted Selection (MAS). Specific objectives were: 1) To introgress anthracnose and BCMV/BCMNV resistance genes into one market class bean variety through crosses (**Table 20**); 2) To characterize anthracnose races in three major common bean growing zones; and 3) To evaluate developed lines for anthracnose, Pythium Root Rot, BCMV and BCMNV resistance, yield and other agronomic traits in three major growing bean regions.

Table 20: Plant materials used for MAS selection

Common bean lines and crosses	Disease resistance	Targeted genes
BC4F6 (RWV3006 x G2333)	Anthracnose	Co-42 &Co-5
BC4F5 (RWV3006 x Mshindi)	BCMNV	I
BC4F4 (RWV 3006 x MCM5001)	BCMV/BCMNV	bc-12
BC4F6 (G2331 x RWR 719)	Pythium root rot	One gene from RWR 719 tagging PYAA19800 marker
BC4F1(RWV3006 x G2333) x BC4F1 (RWV3006 x Mshindi)	Anthracnose and BCMNV	Co-42 ,Co-5&bc-12 genes
BC4F1 (RWV 3006 x G2333) x BC4F1 (RWV 3006 x MCM 5001)	Anthracnose and BCMV/BCMNV	Co-42 ,Co-5&I genes

A total of 250 isolates were collected in the Northern and Eastern provinces, all from the most anthracnose hotspot areas. *DNA extraction and amplification:* Whatman FTA protocol was used for DNA extraction. DNA was extracted from young leaves collected from 2 weeks old plants on FTA cards. To get amplified genomic DNA, Polymerase Chain Reaction (PCR) was performed.

Isolation of anthracnose isolates: A total of 150 anthracnose isolates were identified. There is on-going single spore culture for further anthracnose isolates characterization. An evaluation of bean lines developed with anthracnose and BCMV/BCMNV resistance was done in different agro ecological zones of the country. Three hundred lines developed through a backcrossing program were evaluated for anthracnose, Pythium root rot and BCMV/BCMNV resistance at Nyagatare, Ngoma, Rwerere and Nyamagabe. Superior lines will be selected for evaluation in Preliminary Yield Trial in 2022A.

Marker Assisted Selection (MAS)

Marker assisted selection was used to select self-pollinated cross of RWV 3006 and Mshindi (BC4F4). **Photo 16** shows the image from PCR analysis, which allowed to select lines (L): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 17, 18, 20, 22, 23, 26, 27, 35 and 36 having SDB5 marker, tagging BC-12 gene L: 1bpmarker.The letter C- shows susceptible variety, and C+ shows resistant donor, Mshindi.

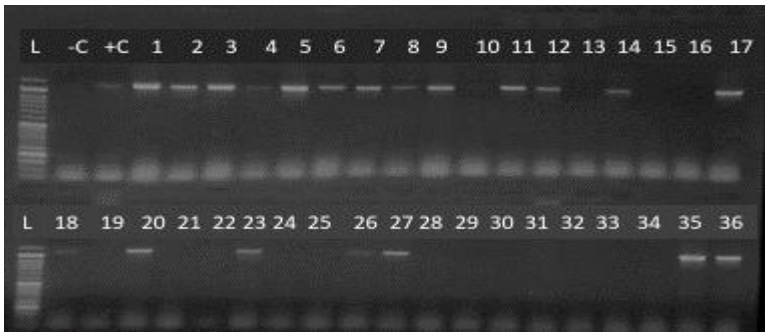

Photo 16: Image from PCR analysis serving to select self-pollinated BC4F4 (RWV3006xMshindi) plants

Rapid breeding for reduced cooking time and enhanced nutritional quality in bean

This activity aims to evaluate yield and adaptation of the parental lines; and to select the best parents to be used for future crossing. A total of 109 bush bean parental lines and 43 climbing bean parental lines were included in selection. As this activity is going on, best parents will be selected after harvest.

ECABREN project

This project has 3 objectives: 1) To implement bean corridor approach (targeted bean varieties and related products, respective off takers linked small holders, business and investments along the value chains, emerging issues etc.) and research contributions to respond to members of the bean corridors; 2) To evaluate promising lines of targeted market classes (Sugars, RM, Navy, red kidney) for climate change related stress resistance; and 3) To produce early generation seed. Activities were: Conduct multilocational evaluation (PYT, AYT, NPT) of selected and introduced breeding lines (red mottled, yellow, navy, sugar, RM, red kidney) for yield performance through the stage gate testing system (ECABYT). ECABYT group 2 trials were established in 6 sites in High and low altitudes. 21 bush lines were evaluated at Gashora, Ngoma and Nyagatare, while 39 climber lines were evaluated at Musanze, Rwerere and Ruhunde. In general, most of the lines performed well, selected lines will be advanced to AYT. Develop product concepts; define breeding programs priorities (**Table 21**); most preferred agronomic and nutrient traits, market classes, develop national breeding strategy through convening a bean multistakeholder meeting. Package and disseminate appropriate climate smart advisories to inform bean production in the corridors- PICSA to bean value chain actors. *Through Local NGOs:* Through the collaboration with local NGOs namely Caritas Kibungo, Caritas Kibuye, Caritas Butare and DERN, 9,690 farmers (64% women) were able to receive and use climate information service through DACA, WhatsApp and agricultural extension services.

Table 21: Product concepts developed

Product profile	Large red mottled	Medium red mottled	Medium red	Large red kidney	Large-medium Sugar	Medium White	Medium Yellow	Medium –small Yellow
Variety to replace		RWR 2245				RWV 3006	G2331	
Growth type	Climber	Bush	Bush	Bush	Climber	Climber	Climber	Bush
Target agro-ecology	low, mid-high altitude	low-mid altitude	low-mid altitude	low-mid altitude	low-mid altitude	low-mid altitude	low-mid altitude	low-mid altitude
Target market	National and East Africa	National, East Africa, India and Asia	National, East Africa,' India and Asia	National, Eat Africa, India and Asia	National and East Africa	National and East Africa	National ,East Africa, Oman, Australia	National ,East Africa, Oman, Australia
Yield potential	2.5-4.0 T/Ha	1.5-2.5 T/Ha	1.5-2.5 T/Ha	1.5-2.5 T/Ha	2.5-4.0 T/Ha	2.5-4.0 T/Ha	2.5-4.0 T/Ha	1.5-2.5 T/Ha
Maturity	95-115 DM	75-95 DM	75-95 DM	75-95 DM	75-95 DM	75-95 DM	75-95 DM	75-95 DM
Abiotic stresses	Drought tolerance	Drought tolerance	Drought tolerance	Drought tolerance	Drought tolerance	Drought tolerance	Drought tolerance	Drought tolerance
Diseases	Resistance/tolerance to BCMNV, RR & Anthracnose	Resistance/tolerance to BCMNV, RR& Anthracnose	Resistance/tolerance to BCMNV,RR & Anthracnose	Resistance/tolerance to BCMNV,RR &Anthracnose	Resistance/tolerance to BCMNV, RR & Anthracnose	Resistance/tolerance to BCMNV, RR& Anthracnose	Resistance/tolerance to BCMNV, RR& Anthracnose	Resistance/tolerance to BCMNV, RR & Anthracnose
Iron & zn	Fe: 75-100ppm; Zn:30-40 ppm	Fe:70-90ppm; Zn: 30-35 ppm	Fe:70-90ppm;Zn:30-35 ppm	Fe:70-90ppm; Zn:30-35 ppm	Fe:70-90ppm;Zn:30-35 ppm	Fe:70-90ppm; Zn:30-35 ppm	Fe:70-90ppm; Zn: 30-35 ppm	Fe: 70-90ppm;Zn:30-35 ppm

Through farmer cooperatives: Through 11 farmer cooperatives, a total of 1,949 farmers (56% women) were able to receive and use CIS in their beans production

Through Radio Huguka: The CIS4B team in Rwanda PABRA has been facilitating the design and choice of topics to be broadcast on radio and these talks are broadcasted twice during the week and rebroadcast on every Saturday. Feedback from listeners are captured and analyzed to reflect on people's level of access, understanding, use and changes as results of the program being aired on the radio.

112 listeners' club leaders have discussed with Radio Huguka journalist on different talk, shows on the use of climate information in beans production. However, due to covid-19 regulations in some regions, club members were not able to meet and discuss on the information received but were able to follow on their radio and mobile phones about the discussions and use of climate information.

1.4 Roots and Tubers Program

The Roots and Tubers Research Program covers potato, sweet potato and cassava commodities. The activities of Roots and Tubers Program during the fiscal year 2020/2021 have focused on (i) development of new varieties, (ii) development of new approaches of pests and diseases management, (iii) development of good agronomic practices; (iv) seed production, and (v) technologies dissemination.

1.4.1 Cassava

Cassava (*Manihot esculenta* Crantz) is the second and most important food crop in Rwanda after banana, occupying over 20% of the total cultivated land. It is among the seven prioritized crops for food self-reliance and commercialization. However, its production is severely threatened by the current epidemic of cassava brown

streak disease (CBSD) and cassava mosaic disease (CMD). The CBSD is caused by cassava brown streak virus (CBSV) and Ugandan cassava brown streak virus (UCBSV) of the genus Ipomovirus, family Potyviridae. The CMD is caused by cassava mosaic geminiviruses (CMGs), in the family Geminiviridae and genus Begomovirus. Both diseases are propagated via infected planting material as well as being transmitted by the whitefly vector: Bemisia tabaci, (Maruthi et al. 2005), by graft inoculation (Storey 1936) and by mechanical inoculation in herbaceous host plants (Ogwok et al. 2010; Mbanzibwa et al. 2009a). In addition to low potential yield varieties, poor seed systems and depending on the level pressure, the CBSD alone or in combination with CMD can cause up to 100% yield losses (Pariyo et al. 2015). They reduce plant growth, inhibit photosynthesis, the CBSD causes a dry brown necrotic rot in tuberous roots which causes spoilage and can lead to total crop loss. Thus cassava research aims to develop CBSD and CMD resistant varieties and enhance cassava seed systems.

Variety selection, taste evaluation and variety naming

The products profiling was conducted by involving farmers in participatory evaluation of 8 cassava clones tested at 4 multi-location sites, the selected clones we advanced to on-farm trials to assess their performance at farmers field conditions. Also a degustation (tasting) of Ugali for the new 8 cassava varieties was conducted for preparation of naming ceremony and documentation for official variety release. During degustation farmers reprentatives from cooperatives and progresstist farmers participated in the event. Among 8 new cassava varieties, 6 varieties were selected for variety naming ceremony and submission for official release and cataloging.

Photo 17: Degustation of new cassava varieties at RAB Rubona (left); Hon. State Minister in charge of Agriculture and Hon. Governor of Southern Province officiate the cassava variety naming ceremony

New varieties of cassava official released

During Fiscal year 2020/2021, either varieties submitted for official variety release. The 5 varieties were locally bred while 3 varieties were introduced for International Institute for Tropical Agriculture (IITA) (**Table 22**). After evaluation of the DUS/ descriptors and VCU test report, the variety release committee approved the release of NASE14 locally named Gikungu, NAROCASS1 locally named Buryohe, RWACASS1701 locally named Nsizebashonje, RWACASS1702 locally named Tebuka, RWACASS1703, Bulk 13 locally named Biseruka, Bulk 35 locally named Tegereza and MM96/8299 locally named Macadamia.

Table 22: Yield (t/ha) of released cassava varieties

Sites / Varieties	Gashora	Muhanga	Mututu	Rubona	Average yield (t/ha)	Yield range (t/ha)
Bulk 13	38.17	29.13	32.17	27.17	31.66	27.1 - 38.1

Bulk35	39.63	39.17	41.83	33.83	38.615	33.8 - 41.8
GAHENE/2	34	38.83	34	31.83	34.665	31.8 - 38.8
MH95/0414/1	30.67	24.33	30.67	25.63	27.825	25.6 - 30.6
NAROCASS1	37.17	36.5	37.17	36.83	36.9175	36.5 -37.1
NASE14	28.17	29.13	28.17	29.97	28.86	28.1 - 30
NDAMIRABANA/7	35.17	33.5	35.17	31.83	33.9175	31.8 -35.1
SE				*1.679*		
P. value				*<.001*		

Degeneration rate trials

The degeneration trial of eight varieties (Albert, KBH2006/026, Kibandameno, Mkumba, Nase14, Orera, Tajilika and TZ130) established to determine the level a given variety can degenerate mostly due viral diseases. This trial is conducted every year until all varieties degenerated completely (**Table 23**).

Table 23: Second year degeneration trial

No	Varieties	Yield t/ha	RCBSDi (%)	RCBSDs	CMDi (%)	CMDs
1	Albert	16.2	3.3	2.0	6.7	3.0
2	KBH2006/026	10.0	0.0	1.0	1.7	1.0
3	Kibandameno	10.0	3.3	1.3	45.0	3.0
4	Mkumba	15.7	3.3	1.3	0.0	1.0
5	Nase14	13.6	0.0	1.0	0.0	1.0
6	Orera	16.2	0.0	1.0	0.0	1.0
7	Tajilika	11.4	3.3	1.3	0.0	1.0
8	TZ130	12.7	6.7	2.0	0.0	1.0

Multi-location trial (GxE) of selected clones

The advanced trial of 13 clones was conducted at two contrasting agro-ecological zones and only six clones were selected for advancement to GxE trials (multilocation). In addition to the selected ones, the two introduced clones from 5CP project were added to make a set of 8 clones. The GxE trial was established at three agro-ecological zones. The preliminary observations at 3 months after planting (MAP) showed that all clones are free from CBSD and CMD visual symptoms (**Table 24**).

Table 24: Disease scoring on selected and introduced clones (CMD and CBSD scoring at 3 MAP)

Sites	Clones ID	3CMDi	3CMDs	CMDi%	3CBSDi	3CBSDs	CBSDi%
Rubona	RBN018-028	0	1	0	0	1	0
	RBN018-020	0	1	0	0	1	0
	RBN018-061	0	1	0	0	4	4
	OKHUMERERA	0	1	0	0	1	0
	RBN018-051	0	1	0	4	2	6
	RBN018-056	0	1	0	8	2	11
	F10-80-12	0	1	0	0	1	0
	RBN018-025	0	1	0	0	1	0
Mututu	RBN018-056	0	1	0	0	1	0
	RBN018-061	0	1	0	0	1	0

	RBN018-051	0	1	0	0	1	0
	RBN018-020	0	1	0	0	1	0
	RBN018-025	0	1	0	0	1	0
	OKHUMERERA	0	1	0	0	1	0
	RBN018-028	0	1	0	0	1	0
	F10-30-42	2	3	4	0	1	0
Gashora	RBN018-028	0	1	0	0	1	0
	RBN018-020	0	1	0	0	1	0
	RBN018-061	0	1	0	0	1	0
	OHKUMERERA	0	1	0	0	1	0
	RBN018-051	0	1	0	0	1	0
	RBN018-056	0	1	0	0	1	0
	F10-30-42	1	3	1	0	1	0
	RBN018-025	0	1	0	0	1	0

Advanced Yield Trials

A total of 21 clones were evaluated and planted in Advanced Yield Trial (AYT). Out of 21, a total of 13 clones were selected for multi-locational trial while 8 clones were subjected to seed multiplication to enable multi-locational trails in at least three sites. All selected clones were free from CMD and CBSD visual symptoms.

To note, among eight selected clones, two clones are fleshed orange with higher beta carotene content. These eight clones were selected for further evaluation step, but due to insufficient quantity of cuttings to be planted in at least three sites, they were multiplied to increase the number of cuttings for multi-locational trials, which will be established after field multiplication.

Table 25: Thirteen selected clones for advanced yield trial (AYT) clones

No	Clones	6CMDi (%)	6CMDs	6CBSDi (%)	6CBSDs	9CMDi (%)	9CMDs	9CBSDi (%)	9CBSDs
1	Control	0.0 ^{a}	1.0 ^{a}	14.3 ^{ab}	2.5 ^{de}	3.3 ^{a}	1.0 ^{a}	12.0 ^{ab}	2.5 ^{bc}
2	RBN018-011	0.0 ^{a}	1.0 ^{a}	2.1 ^{a}	1.5 ^{abc}	0.0 ^{a}	1.0 ^{a}	1.0 ^{a}	1.8 ^{ab}
3	RBN018-012	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}
4	RBN018-020	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}
5	RBN018-025	0.0 ^{a}	1.0 ^{a}	59.8 ^{c}	3.0 ^{e}	0.0 ^{a}	1.0 ^{a}	35.8 ^{ab}	3.0 ^{bcd}
6	RBN018-028	3.5 ^{b}	1.8 ^{b}	0.0 ^{a}	1.0 ^{a}	2.4 ^{a}	1.8 ^{b}	15.2 ^{ab}	2.0 ^{abc}
7	RBN018-032	15.0 ^{c}	3.0 ^{c}	50.0 ^{c}	2.0 ^{bcd}	7.5 ^{b}	3.0 ^{c}	50.0 ^{b}	2.0 ^{abc}
8	RBN018-033	0.0 ^{a}	1.0 ^{a}	34.2 ^{bc}	3.0 ^{e}	0.0 ^{a}	1.0 ^{a}	38.9 ^{ab}	4.3 ^{d}
9	RBN018-036	0.0 ^{a}	1.0 ^{a}	3.1 ^{ab}	1.3 ^{ab}	0.0 ^{a}	1.0 ^{a}	33.1 ^{ab}	2.3 ^{abc}
10	RBN018-051	1.0 ^{ab}	1.3 ^{ab}	0.0 ^{a}	1.0 ^{a}	1.0 ^{a}	1.3 ^{ab}	0.0 ^{a}	1.0 ^{a}
11	RBN018-054	1.3 ^{ab}	1.5 ^{ab}	2.5 ^{ab}	1.3 ^{ab}	1.3 ^{a}	1.5 ^{ab}	42.3 ^{ab}	2.5 ^{bc}
12	RBN018-056	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	10.4 ^{ab}	2.0 ^{abc}
13	RBN018-060	0.0 ^{a}	1.0 ^{a}	15.7 ^{ab}	2.3 ^{cde}	0.0 ^{a}	1.0 ^{a}	99.0 ^{c}	3.3 ^{cd}
14	RBN018-061	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	0.0 ^{a}	1.0 ^{a}	53.3 ^{b}	2.5 ^{bc}
	P Value	*<0.001*	*<0.001*	*0.002*	*<.001*	*0.039*	*<.001*	*0.002*	*<.001*
	LSD (α 0.05)	*2.7*	*0.5655*	*31.9*	*0.8414*	*4.2*	*0.5655*	45.2	*1.305*

Table 26: Eight clones selected for advanced yield trial (AYT)

No	Clones	CMDi	CMDs	CBSDi	CBSDs	Yield (t/ha)	Pulp colors
1	Yizaso/3	0	1	0	1	38.4	White
2	Yizaso/18	0	1	0	1	35.0	White
3	Mkombozi/2	0	1	0	1	35.0	White
4	IBA961089A	0	1	0	1	40.0	Orange
5	IBA141097/5	0	1	0	1	42.0	Orange
6	SHIBE/4	0	1	0	1	48.3	White
7	KALAWE/1	0	1	0	1	30.0	White
8	Mkombozi/3	0	1	0	1	56.0	White

Multi-locational trial and variety selection

The multi-location trial of 15 clones was conducted at three sites (Rubona, Mututu, and Gashora). The combined GxE analysis by AMMI and variety rankings using ASV and GSI, indicated ranks of varieties in following order and corresponded to the variety selected for subsequent variety testing with farmers (on-farm trials) and National Performance Trials (NPT) for variety release process: 1st. Mkumba, 2nd Kiroba, 3rd KBH2006/026, 4th EYOPE, 5th PWANI.

Table 27: GSI ranking for FRY and Root CBSD necrosis incidence (%)

	FRY (t/ha)						RCBSDi (%)					
Genotypes	Means	Rank	ASV	AVS Rank	GSI	GSI Rank	Means	Rank	ASV	AVS Rank	GSI	GSI Rank
ALBERT	19.25	4	4.149	10	14	8	38.29	10	7.56	5	15	8
EYOPE	13.68	12	1.597	4	16	9	25.37	9	9.35	6	15	9
KBH2002/066	11.53	14	3.282	8	22	12	41.48	11	9.49	7	18	12
KBH2006/026	8.33	15	4.325	11	26	15	0	1	10.69	9	10	3
KIBANDAMENO	15.59	9	7.105	14	23	13	98.49	15	16.78	13	28	14
KIROBA	14.14	11	1.117	1	12	5	16.02	5	4.72	2	7	2
KIZIMBANI	15.94	7	2.352	5	12	4	51.92	13	24.3	14	27	13
MKUMBA	18.33	5	1.225	3	8	1	16.71	6	2.21	1	7	1
NAROCAS1	29.28	1	4.422	12	13	6	8.1	3	14.15	11	14	6
NASE1	13.06	13	5.336	13	26	14	21.16	8	10.1	8	16	10
NASE14	15.92	8	1.195	2	10	3	48.6	12	5.75	3	15	7
ORERA	27.56	2	8.102	15	17	10	11.11	4	14.69	12	16	11
PWANI	14.56	10	3.489	9	19	11	21.16	7	6.88	4	11	4
TAJIRIKA	16.42	6	2.762	7	13	7	87.06	14	31.75	15	29	15
TZ130	26.83	3	2.61	6	9	2	2.2	2	11.9	10	12	5
LSD	6.434						45.75					
P Value	*<0.001*						*<.001*					

Table 28: GSI ranking for CMD incidence and severity at three months after planting

Genotypes	3CMDi (%)	3CMDs

	Means	Rank	ASV	AVSrank	GSI	GSIrank	Means	Rank	ASV	AVSRank	GSI	GSI Rank
ALBERT	8.8	13	3.1	1	14	7	3	13	3.4	1	14	8
EYOPE	9.6	14	3.2	2	16	9	2	12	9.4	3	15	10
KBH2002066	5.3	12	17.2	8	20	11	1	10	15.5	10	20	12
KBH2006026	2.4	7	22.9	11	18	10	1	4	13.8	5	9	1
KIBANDAMENO	45.1	15	240.7	15	30	15	5	15	14.7	9	24	13
KIROBA	4.8	11	47.9	14	25	14	2	11	20.7	14	25	14
KIZIMBANI	2.3	6	22.3	10	16	8	1	5	13.8	6	11	2
MKUMBA	1.4	2	10.0	4	6	2	1	1	17.8	11	12	4
NAROCAS1	2.9	8	29.6	13	21	12	1	8	9.7	4	12	5
NASE1	3.3	9	10.1	5	14	6	4	14	96.1	15	29	15
NASE14	1.9	4	15.6	7	11	4	1	6	13.8	7	13	6
ORERA	3.4	10	23.5	12	22	13	1	9	3.7	2	11	3
PWANI	1.5	3	10.4	6	9	3	1	2	17.8	12	14	7
TAJIRIKA	1.4	1	9.2	3	4	1	1	3	17.8	13	16	11
TZ130	2.3	5	22.1	9	14	5	1	7	13.8	8	15	9
LSD	5.7						1.7					
P Value	<0.001						<.001					

Table 29: GSI ranking for CBSD % incidence and severity at six months after planting

	6CBSDi (%)						6CBSDs					
	Means	Rank	ASV	AVS Rank	GSI	GSI Rank	Means	Rank	ASV	AVS Rank	GSI	GSI Rank
ALBERT	20.5	7	12.9	15	22	10	2	8	4.7	13	21	11
EYOPE	31.4	9	11.1	13	22	11	1	3	2.1	6	9	3
KBH2002066	64.6	12	6.1	10	22	12	2	10	1.0	4	14	8
KBH2006026	32.7	10	11.1	14	24	15	2	7	3.4	10	17	9
KIBANDAMENO	21.1	8	2.4	3	11	5	3	14	4.7	14	28	14
KIROBA	18.6	6	7.3	11	17	8	2	11	3.7	11	22	13
KIZIMBANI	71.6	13	4.9	9	22	13	4	15	8.9	15	30	15
MKUMBA	0.0	1	4.6	6	7	1	1	1	0.7	2	3	1
NAROCAS1	5.0	3	3.3	4	7	2	1	5	2.7	7	12	4
NASE1	82.6	15	1.8	2	17	9	3	12	0.5	1	13	6
NASE14	13.9	4	4.7	8	12	6	1	6	2.7	8	14	7
ORERA	77.2	14	1.8	1	15	7	3	13	1.5	5	18	10
PWANI	0.0	2	4.6	7	9	3	1	2	0.7	3	5	2
TAJIRIKA	62.5	11	9.9	12	23	14	2	9	4.6	12	21	12
TZ130	17.2	5	4.1	5	10	4	1	4	2.9	9	13	5
LSD	*21.3*						*0.7*					
P Value	*<0.001*						*<.001*					

Breeder and pre-basic seed multiplication

During this FY, cassava breeder and pre-basic seeds multiplication through the insect proof net screen houses (using stem node multiplication) to limit the early viral (CMD and CBSD) infection was conducted and a novel technology of rapid multiplication so called Semi autotrophic hydroponic (SAH) was introduced to support the

cassava seed multiplication. The pre-basic seed category and germplasm conservation conducted under insect proof net screen houses produced 44,206 plantlets of the 17clones. Also, a total of 15,618 plantlets from 46 accessions were multiplied and conserved in SAH.

Table 30: Pre-basic seed multiplication and breeder seed conservation under SAH at Rubona

No	Genotypes	N plantlets multiplied	No	Genotypes	N plantlets multiplied
1	PWANI	714	24	DSC 122	73
2	MKUMBA	588	25	DSC 269	25
3	OKHUMELELA	527	26	PERU 597	53
4	NAM-130	480	27	PERU 221	43
5	KLTZ-130	146	28	PERU 556	24
6	97/2205	300	29	DSC 202	50
7	2016B/185	722	30	NDAMIRABANA	438
8	2016B/504	342	31	GACYACYARI	408
9	2016B/521	994	32	NASE-3	20
10	I92/0057	252	33	MBAKUNGAHAZE	991
11	KBH/2006/18	360	34	GITAMISI	450
12	NASE-14	550	35	MM04/0016	340
13	MM96/4271	432	36	MM13/0024	516
14	2016B/087	783	37	MM16/0371	344
15	2016B/020	451	38	01/0040	543
16	98/0002	175	39	01/1206/75	532
17	KBH/2002/066	150	40	MM01/1457	58
18	MM98/3567	355	41	NYIRAMABUYE	268
19	MM96/5280	627	42	MM96/0735	244
20	MM16/O646	114	43	MM96/0669	190
21	PERU 226	27	44	MM96/8299	305
22	PERU 333	27	45	MM96/2134	300
23	PERU 315	19	46	BERERYINKUMI	268
	TOTAL		15618		

Table 31: Pre-basic seed multiplication under screen-houses

N	Varieties	N plantlets multiplied	N	Varieties	N plantlets multiplied
1	Albert	1016	10	NAM130	3908
2	Eyope	3201	11	NASE 1	1440
3	F10-30-R2	316	12	NASE 3	357
4	KBH/2002/066	5560	13	NASE 14	3863
5	KBH/2006/26	2209	14	Okhumelela	1657
6	Kibandameno	369	15	Orera	550
7	Kiroba	2827	16	Pwani	9325
8	Kizimbani	1555	17	Tajirika	777
9	Mkumba	1530	18	TZ-130	3746
	Total	44206			

Field multiplication for cassava basic seed production

The clean sites were established for basic seeds production. 814,380 cuttings of basic seeds were produced and distributed to selected cassava multipliers. The progressive farmers and multipliers were given seeds on the current approaches established by government of giving back the same quantity received (Kwitura approach). The selected varieties for basic seed multiplication were the most popular varieties with tolerance to CBSD and CMD including new varieties in pipeline for variety release.

Table 32: Basic seed cuttings of elite and new clones in pipeline for release multiplied

N	Clones	N cuttings multiplied as basic seeds	N	Clones	N cuttings multiplied as basic seeds
1	Mkumba	35000	11	Okhumerera	6200
2	NASE14	57630	12	NDAMIRABANA/7	150000
3	Eyope	21370	13	GAHENE/2	200000
4	TZ130	5900	14	NAROCAS1	182000
5	PWANI	35600	15	BULK13	4500
6	KBH2006/026	2400	16	BULK35	32000
7	NAM130	45450	17	SEMAK150139	12500
8	NASE1	1270	18	KIROBA	6160
9	ORERA1	200	19	KIZIMBANI	12200
10	KBH2002/066	4000		TOTAL	814,380

Demonstration trials and variety and technologies dissemination

In 2021A season, 160 demo plot were established while 112 demo plots we planted in 2021B season using TRICOT approach.

Table 33: 2021A Cassava demo plots

District	Sector	Number of plots	District	Sector	Number of plots
Bugesera	Rilima	20	Nyanza	Muyira	20
	Mayange	20		Kigoma	20
Kamonyi	Nyamiyaga	20	Ruhango	Ntongwe	20
	Rugalika	20		Kinazi	20

Quality declared seed of Cassava

The assessment is conducted every season by seed program with assistance from cassava staff. For the FY 2020-2021, a total of 34 cassava QDS multipliers were operational. They multiply released cassava varieties

1.4.2 Irish Potato

Potato is an important crop in Rwanda, grown for food security and income generation. The crop has been introduced in Rwanda at the beginning of the 19th century and is now being cultivated throughout the country,

particularly in the Northern Province (Birunga and Buberuka high lands agro ecological zones), Western Province (Birunga and Congo Nil Watershed Divine agro-ecological zones), and Southern Province (Congo Nil Watershed Divine agro-ecological zone), where rainfall and soil conditions are favourable. During this year, due to its importance, the crop was expanded to the Eastern Province of Rwanda. Since its introduction, its acreage, production and annual per capita consumption have increased with time, from 19,300 to 164,152 ha, 96,500 to 1.3 million tons and 8 to 145 kg, from 1961 to 2017, respectively. Potato covers 4% of total cultivated land per each growing season, but it provides 10% of total main crop production in Rwanda. Most of potato sector consists of small family farms that intercrop potato with beans and maize, and yields average is still low (around 10 tonnes/ha) compared to other countries such as The Netherlands and German that can reach up to 35 tonnes/ha. The main challenges causing this low potato productivity include small and fragmented potato production land, poor linkage of potato producers and markets, limited access to credit for agriculture inputs, shortage of appropriate post-harvest handling and processing technologies, inadequate supply of high quality seeds to farmers, low rate of fertilizer use and irrigation, pest and disease problems, and limited number of improved and high yielding potato varieties adapted to current biotic and abiotic stresses worsened by the current climate changes. In season 2020A, it was conducted various trials including (1) evaluation of Dutch hybrid potato clones, (2) Evaluation of direct transfer at farm level, (3) National performance trials of advanced potato clones, (4) performance evaluation of open pollinate clones, (5) performance evaluation of tetraploid bio-fortified potato clones, and (6) Performance evaluation of potato varieties in mid-altitude. The main objective of these trials was to identify the yields of various potato clones scattered in different breeding generations. In addition to research trials, the potato subprogram was involved in potato plantlets and mini-tubers production. All trials were properly conducted, data were collected and its entry is ongoing. With current situation below are some results from these trials.

Germplasm conservation

The very first step in variety development consists of conservation of the available germplasm and introduction of new genotypes that have shown performance for a given trait of interest (high yield, disease & pest resistance, farmer preferences in term of dry matter content, processing ability, dormancy period, etc) in other countries. During this year, two hundred and ninety (290) potato varieties/clones were conserved as Germplasm renewed after 6 to 8 months. In addition, in order to enrich potato germplasm, two introductions were sourced from the International Potato Centre (CIP), Lima, Peru.

Observation Trials (OT)

OTs consisted of 2020 potato clones from local breeding. OTs were conducted at Musanze and Rwerere Research Stations. Forty tubers were planted per plot per. The potato observation Trials were planted on 23/02/2021 and 25/02/2021 respectively in Kingi and Rwerere research stations.

Table 34: Tuber families of potato progenies planted at Kinigi, 2021B

N	Family	Number of clones	N	Family	Number of Clones
1	Cruza x CIP395112.6	14	9	KINIGI x RWANGUME	1
2	CIP395112.6 x Kinigi	3	10	PEKO x CIP395112.6	3
3	CIP395112.6 x Gikungu	5	11	PEKO x KINIGI	3
4	CIP395112.6 x CIP393077.159	9	12	PEKO x KINIGI	1
5	Gikungu x CIP393077.159	4	13	SARPOMELA OPEN	3
6	Gikungu x Kinigi	6	14	TWIHAZE x KINIGI	5
7	Gikungu x Rwangume	8	15	TWIHAZE x RWANG	5
8	Kinigi x CIP395112.6	7		TOTAL	77

The planting material originated from hand crossing between local adapted potato varieties (Rwangume, Kinigi and Gikungu) and CIP Potato genotypes. Vegetative data were collected at 75 days after planting. Those data include: Number of emerged plants/plot (NPE), Plant growth habit (PGH), Plant uniformity, Plant Vigor, Flowering degree, Disease scores (Late blight, Leaf miner, Potato viruses and Bacterial wilt). At harvest (end of June 2021), the following data: Number and weight of marketable tubers category I/plot (big size tubers), Number and weight of marketable tubers category II/plot (medium size tubers), Number and weight of non-marketable tubers/plot (small size) will be collected. Based on the both vegetative and harvesting data, the best genotypes will be selected for further breeding/ selection stages.

Preliminary yield trials of Diploid Bio-fortified potato clones

The objective of this experimental trial was (i) to assess the adaptability and acceptability of the diploid-biofortified potato cultivars under Rwanda agro-ecologies; (ii) to assess mineral concentrations as iron and zinc in cycle III selections of the diploid-biofortified clones under Rwanda agro-ecologies. The planting material included 18 diploid biofortfied potato clones: CIP306087.72, CIP306416.68, CIP306513.57, CIP306140.78, CIP306018.66, CIP306087.132, CIP306155.68, CIP306143.62, CIP306514.64, CIP306418.53, CIP306143.122, CIP306143.65, CIP306154.126, CIP306417.79, CIP306087.56, CIP306143.52, CIP306018.1, CIP306022.69, CIP306018.4 originating from CIP potato breeding program were planted for the purpose of preliminary yield trial of the genotypes in Rwandan agro-ecologies. Kirundo a tetraploid genotype was planted as the local check. Trials were established at two sites: Rwerere (2060 meters above sea level: masl) and Kinigi (2380 masl). The experiments were established in March 2021. The experiments were established in Random Complete Block Design (RCBD) at each site with three replications. The experimental plot consisted of four rows of 10 plants, which means 40 plants for each experimental plot. The rows were spaced 0.80 m apart and spacing within a row between tubers was 0.30 m. Vegetative data have been collected, while harvesting and data collection will be conducted before end of June 2021.

Advanced yield trials of Tetraploid Bio-fortified potato clones

Planting material comprised nine potato genotypes: CIP312507.311, CIP312621.069, CIP312682.042, CIP312721.038, CIP312721.169, CIP312725.048, CIP312725.057, CIP312735.253, CIP312764.013 from CIP Breeding program were planted. Field experiments were conducted at four sites: Rwerere (2060 masl), Kinigi (2380masl), Sigira (2347masl) and Tamira. The experiment was established in Random Complete Block Design (RCBD) with four replications. The experimental plot consisted of three rows of 10 plants, which means 30 plants for each experimental plot. The experiments were planted in May 2021, in late season 2021B due to the problem of breaking dormancy. No data were collected yet.

Multi-locational trials

During both 2021A &B seasons, seven clones and Kirundo as local check were established on RAB stations, located in four different agro ecological zones of Rwanda as follows: Musanze (Kinigi), Burera (Rwerere), Karongi (Gakuta) and Nyamagabe RAB Stations. Each of these 4 trials has another neighboring sister on-farm trial established, totalizing 8 MTs. These locations are the major research sites for RAB potato subprogram and known for their potato production. It is after one month that data collection is expected to begin, starting with trial establishment evaluation and other subsequent parameters.

National performance trials (NPTs)

During this year, five clones namely Kirundo 2018.58, Kinigi 2018.253, Kinigi 2018.150, Kinigi 2018.190, Kigega 2018.29 are tested against the local check (Kirundo). These six (6) clones were used to establish twelve (12) NPTs

across the country in the following districts locations: Burera 2, Musanze 1, Rulindo 1, Nyamagabe 2, Nyaruguru 1, Rwamagana 1, Kayonza 1, Ngoma 1, Rutsiro 1 and Karongi 1. All the above-mentioned trials were newly planted on farm and are being managed in collaboration with farmers in respective sites.

Agronomic Performance of Solynta Potato hybrids

The purpose of this activity was to evaluate diploid potato hybrids to assess their agronomic potential and disease resistance under Rwandan Agro-ecologies. The trial consists of 5 potato genotypes including three clones: 18RW001, 18RW005 &18RW006 and two varieties: Kinigi and Gikungu. The clones 18RW001, 18RW005 &18RW006 were planted as seedlings grown from True Potato Seeds from SOLYNTA company, Gikungu was planted as stem cuttings, while Kimigi was planted as minitubers. Both Kinigi and Gikungu are commonly potato varieties grown in Rwanda. They were planted on 06/10/2020 and harvested 17/02/2021. Harvesting data were recorded on the two midle rows. During the second season planted 15 March 2021 consisting of 5 genotypes: 18RW012, 18RW01, 18RW05 and the local checks Twihaze and Kirundo were planted as seedlings previously grown from the nursery. Vegatative and disease data were collected and the trial is still on going. Regarding tubers production, the genotype18R005 showed the highest number of tubers followed by check varieties Kinigi and Gikungu as well as the genotype 18R006. Only the genotype 18R001 performerd poorly for tubers production. Regarding fresh tuber yield the check varieties Gikungu (68.37t/ha) and Kinigi (68.12 t/ha) showed the highest fresh tuber yield number followed by the genotype 18R005 (16.01 t/ha). The genotype 18R006 (5.8 t/ha) and 18R001 (1.3t/ha) performed poorly for fresh tuber yield.

Demonstration plots (DPs) of varieties for future release

Both two growing seasons (2021A & B seasons), a total of 24 DPs were planted in 10 districts, following the potato growing agro-ecologies of Rwanda. Districts holding DPs are: Rwamagana, Ngoma, Kayonza, Musanze, Burera, Rulindo, Nyamagabe, Nyaruguru, Karongi and Rutsiro. DPs were established using the newly released potato varieties that are: Cyerekezo, Jyambere, Kirundo, Ndeze, Nkunganire, Seka and Twihaze.

Potato seed production: Tissue culture plantlets production and conservation

In Tissue Culture Laboratory of RAB/Musanze Station is used for maintenance and multiplication of two hundred and ninety (290) Irish Potato Varieties. 267 varieties, those are the varieties under research activities and 23 varieties are the varieties on mass propagation for mini tubers production and seed increase. The current report presents the annual situation from July 2020 to June 2021. The elements to be included are the annual weaned potato plantlets. During this year, a total number of tissue culture plantlets produced is 1,500,000 potato plantlets, representing 92.6% of the target. The most commonly cultured varieties Kinigi, Kirundo, Gikungu, Ndamira, which are most farmer-preferred.

Potato seed production: Minitubers production

The production of minitubers is realized using conventional screenhouses and aeroponics approaches. In total, RAB, Musanze station has 9 conventional screenhouses and 2 aeroponics. The capacity and productivity of these infrastructures are synthesized in the table below. A total of 1,699,463 mini tubers was produced, focusing on end-user preferred potato varieties that are Kinigi, Kirundo, Gikungu, Ndamira.

As shown in the table below, the quarter one doesn't have data because it didn't correspond with the harvesting period. Another point to consider is the low yields from aeroponic in comparison with the predicted ones. This is because of insufficient light inside aeroponic house caused by the darkness of the roof-sheets. The roof-sheets have been replaced and we hope in the next season, the yields will be good.

Table 35: Number of minitubers produced in 2020-2021

No	Varieties	Q1		Total Q1	Q2		Total Q2	Q3		Total Q3	Q4		Total Q4	Total
		Screen-houses	Aeropo-nic		Screen-houses	Aeropo-nic		Screen-houses	Aeropo-nic		Screen-houses	Aeropo-nic		
1	Cruza	66,661	-	66,661	-	-	-	-	-	-	-	-	-	66,661
2	Nkunganire	30,694	-	30,694	-	-	-	-	-	-	3,219	-	3,219	33,913
3	Ndeze	65,651	-	65,651	-	-	-	-	-	-	3,238	-	3,238	68,889
4	Izihirwe	24,521	-	24,521	-	-	-	30,722	-	30,722	-	-	-	55,243
5	Kazeneza	56,870	-	56,870	-	-	-	94,426	-	94,426	7,248	-	7,248	158,544
6	Kinigi	84,000	48,917	132,917	-	-	-	65,773	-	65,773	168,878	-	168,878	367,568
7	Gikungu	37,582	-	37,582	-	-	-	73,735	-	73,735	49,013	-	49,013	160,330
8	Kirundo	16,751	26,367	43,118	-	-	-	190,514	64,671	255,185	86,247	-	86,247	384,550
9	Gisubizo	26,308	-	26,308	-	-	-	-	-	-	6,568	-	6,568	32,876
10	Twihaze	29,584	-	29,584	-	-	-	49,409	30,825	80,234	37,504	-	37,504	147,322
11	Kigega	4,190	-	4,190	-	-	-	-	-	-	6,346	-	6,346	10,536
12	Mabondo	4,000	-	4,000	-	-	-	-	-	-	-	-	-	4,000
13	Ndamira	-	-	-	-	-	-	73,569	-	73,569	135,462	-	135,462	209,031
Total		446,812	75,284	522,096	-	-	-	578,148	95,496	673,644	503,723	-	503,723	1,699,463

Potato seed production: Direct transfer

In order to increase seed production, tissue culture plantlets which were not able to be accommodated in screenhouses were planted in direct transfer in various experimental fields of Musanze, Kinigi and Sigira. In direct transfer fields, a total of 1,603,163 tubers (**Table 36**) of pre-basic seed were produced.

Table 36: Number of tubers (pre-basic seed) produced from direct transfer of tissue culture plantlets

N	Varieties	Seed (# tubers)	Consumption	Total (# tubers)
1	NDAMIRA	313,528.00	0	313,528.00
2	NKUNGANIRE	231,289.00	0	231,289.00
3	GIKUNGU	336,789.00	0	336,789.00
4	TWIHAZE	131,693.00	0	131,693.00
5	KIRUNDO	311,864.00	0	311,864.00
6	CRUZA	278,000.00	0	278,000.00
	Total	1,603,163.00	0	1,603,163.00

Establishment of potato demonstration plots and on-site training of farmers

In the current situation where the country is facing low adoption of potato varieties and shortage of seed, farmers need to replace crop varieties with better-adapted ones to match rapidly the evolving seed demand. Therefore, the establishment of multiple potato demonstration plots of new potato cultivars to changing climate was aimed allowing farmers to have better choices among suitable potato varieties (**Photo 18**). The planting material consisted of eleven potato varieties: Kazeneza, Twihaze, Nkunganire, Izihirwe, Ndeze, Twigire, Seka, Cyerekezo, Ndamira, Gisubizo and Jyambere were given randomly to farmers. Those varieties were potato varieties which have been released in 2019 and 2020.

Photo 18: Plant vigor and disease score in Bugeshi/Rubavu district

Farmers hosting potato demonstration plots were previously selected by the potato facilitators participating in positive selection approach. Each famer was recommended to avail a plot of land with the size of 48 square meters (12mx4m). A visit of the plot was conducted at each farmer by RAB staff and CIP Potato staff to confirm or replace the plot based on accessibility, soil status and the crop rotation. Demonstration sites were planted in October 2020 for the season 2021A and in March 2021 for season 2021B in Gicumbi, Nyabihu and Nyamagabe Districts (**Table 37**).

Table 37: Number of farmers owning demonstration plots per district

District	Sector	Number of farmers
	Manyagiro	30
1. Gicumbi	Cyumba	20
	Mukamira	25
2. Nyabihu	Jenda	25
	Gatare	25
3. Nyamagabe	Buruhukiro	25
Total/season		150

At the same time, farmers hosting were trained on the seed production and potato crop management.

Challenges

The potato tissue culture multiplication was constrained by the shortage of consumables. The persisting challenge is related to the lack of tissue culture plastic containers (Barquette). These barquettes are used to accommodate tissue culture potato plantlets in the growth room. This is the reason why we are not attending the target we had been planned for year 2020 -2021. In case this problem perisists, the next growing season (2022A season) may be affected.

1.4.3 Sweet potato

Although many constraints due to Covid-19 pandemic, the sweetpotato sub program has focused on selection and advancement of new populations which were at different breeding stages. Pre-basic and basic seed have been produced in Rubona Tissue culture Laboratory (TC), screenhouses (SC), the 2 mobile net tunnels (MNT) and in nurseries. This production was coupled with modest dissemination through key Decentralised Vines Multipliers (DVMs) and other projects. 6 varieties have been selected for near future release. Many clones and advanced accessions have been selected and advanced to different breeding stages. In situ maintenance of selected sweetpotato and yam bean accessions was also part of the priority activities. The Sweetpotato sub-program has been supported by FoodSTART, BioInnovate and SweetGAINS projects.

Variety development

Under this output, the sweet potato sub program targeted to release at least 3 new white and orange fleshed sweet potato varieties. Out of many clones generated from 12 families (controlled and opened pollination crosses) and introduced sets from Mozambique, Ghana and Uganda, 205 clones have been selected and advanced to two preliminary yield trials. A set of 14 genotypes from Mozambique were planted in Multi-locational Yield Trials (MYT) for 2 consecutive seasons in 2 locations. Three out of the 14 Mozambique varieties named Jane, Cecelia and Melinda are the best high performing varieties across location with had high yields of 28.30, 22.25 and 20.40 tonnes/ha, respectively. In total, 105 accessions are being maintained in situ conservation. Two advanced yield trials and 2 multi-locational trials were conducted at locations. 6 genotypes have been selected for possible release after uniformity and distinctness tests by the homologation release committee. Data are being collected and will be analysed at the end of season 2021B. In total, 25 varieties were proposed for sweet potato catalogue.

Seed production

This output falls under early generation seeds (EGS) production approach which were used since 2018 to produce pre-basic and basic seed for Decentralised Vines Multipliers (DVMs). A total of 17 best bet high yielding Yellow and Orange Sweetpotato varieties (OFSP) are multiplied and maintained at TC Lab. Cacearpedo, Vita, Kabode, Terimbere (RW11-2560), Ndamirabana (RW11-2910) and Gihingumukungu varieties are the most OFSP varieties. Around 25000 pre-basic seeds were hardened from TC. 6 DVMs across districts received pre-basic seed sweetpotato. 7560 Basic and 1000 pre-basic seed were availed to Hinga Weze project to be distributed to pilot DVMs and districts. 6 DVMs out of 85 DVMs mapped were official registered by RISA and got their certificates as DVMs for year 2020.

Training on virus identification

A training on virus identification was organized and attended by 6 RAB staff. Sweet potato viruses screening and detection using NCM-ELISA kit was conducted this year aiming at detecting Sweet Potato virus diseases mainly Sweet Potato feathery mottle virus (SPFMV),Sweet Potato mild mottle virus (SPMMV), Sweet Potato Latent virus (SPLV), Sweet potato chlorotic flecks virus (SPCFV), sweet potato chlorotic stunt virus (SPCSV), Sweet potato mild speckling virus (SPMSV), sweet potato C6 virus (SPC6V), Sweet potato collusive virus former named as sweet potato caulimo-like-virus (SPCaLV), sweet potato virus G (SPVG) and cucumber mosaic virus (CMV) from sweet potato mother gardens and plant tissue culture laboratory from Rubona tissue culture, screen houses and nursery sampling.

BioInnovate project

Tissue culture plantlets were produced for market-preferred sweetpotato varieties that are Kabode, Vita and Ukerewe. During this reporting period, 8000 tissu culture plantlets were produced in laboratory. During hardening in screenhouse, 27500 early generation clean plantlets (pre-basic seed) were produced. Macro propagation has been a quick approach to quickly produce enough quantity of clean planting material and therefore to secure more mature vines for primary field multiplication. During season denoted "C" (dry season), the area under seed multiplication was 0.5 ha, where varieties Kabode, vita and Ukerewe were used. Expectedly, a good quantity of vines was produced and part of that was availed to field vine multipliers during 2020C season and 2021 A season. In total, 450,000 cuttings (basic) (*Kabode: 200,000; Vita: 200,000 and Ukerewe: 50,000 cuttings*) were produced from the swamp and 132,750 cuttings so far availed to farmers in various districts of Rwanda. Sweetpotato value chain actors were identified and data collected is to be loaded on the mobile app and therefore enable coordination of sweetpotato seed production. In addition, a study on "Investigation effects on tissue culture technology on sweetpotato production in Rwanda" is also being conducted by an MSc student, in order to assess the benefits of using clean seed versus non clean.

SweetGAINS project

Since July 2020, SweetGAINS project has focused on laboratory and screenhouse multiplication routine, planting of scarified seeds from Mozambique, Uganda as well as local bred seeds. Continued planting of selected high yielding genotypes for further Advanced yield and multilocation trials of best selected materials were planted in 3 locations (Rubona, Bugesera and Musanze). Curation and harmonizing data from different trials were completed to be uploaded to sweetpotatobase. Participation to different SweetGAINS virtual meetings was also part of activities conducted. Data are still under collection at different sites.

FoodSTART project

FoodSTART project aims at strengthening nutrition in Agri-Food Systems in East and Southern Africa through Root and Tuber Crops. In Rwanda, sweetpotato crop was selected to showcase in this objective. The project has rehabilitated the screenhouses with white anti-aphid's net. Some irrigation equipment's, lab equipment and some reagents have been provided to boost the pre-basic and basic seed production. A multiplication site of 0.6 hectares has been set up to Kigembe to support this initiative. FoodSTART intend to support 2000 households with OFSP varieties in 4 selected districts.

1.5 Horticulture Program

Production and dissemination of avocado, mango and citrus scions

Existing mother gardens of avocado, mango and citrus established at Rubona, Nyagatare Mahama, Kinigi and Bugarama RAB stations were regularly managed/maintained and they were used as sources of scions. The scions are normally used to develop new planting materials through grafting. In RAB maintained orchards, the targets number of scions was achieved. During the 2020/2021 fiscal year, 372,506 scions of avocado, 21,038 scions of mango and 34,499 scions of citrus were harvested and distributed to different beneficiaries including government projects like RAB/SAIP, NGOs (World Vision, Tubura, Caritas, Care International), private companies like Multiservice enterprises and individual farmers (**Table 38**).

In addition, RAB orchards/mother gardens alone cannot satisfy the high demand for scions as many stakeholders are involved in production of grafted seedlings. To overcome this, RAB have identified other stakeholders with clean mango, citrus and avocado orchards in position to supply scions.

Table 38: Quantity of avocado, citrus and mango scions produced at RAB stations in 2020/2021

Fruit species	Quantity of scions	RAB Station
Avocado	215,734	Rubona
	10,000	Muhanga (Mututu site)
	76,232	Nyagatare
	70,540	Musanze
Sub-total	*372,506*	
Citrus spp.	15,408	Rubona
	5,630	Nyagatare
Sub-total	*21,038*	
Mango	11,765	Rubona
	22,734	Nyagatare
Sub-total	*34,499*	
Total	***428,043***	

Training of Trainers (ToTs) on pineapple management and macro-propagation technique

A major problem for large scale commercial production of pineapple is the difficulty in obtaining uniform planting materials in large quantity due to low rate of multiplication by conventional methods and lack of high quality propagules. RAB has developed simple and cost-effective pineapple macro-propagation technique, one crown can produce from 13 to 15 plantlets per year which are uniform in size. Training of trainers (ToTs) on pineapple management and macro-propagation technique was done in pineapple growing areas: Nyamagabe and Gisagara. Two sectors per district were selected namely Musange and Cyanika sectors in Nyamagabe, and Gikonko and Nyanza sectors in Gisagara district. The sectors were selected based on the intensity of pineapple production. In addition, two cooperatives per sector were selected based on the farmer's needs and they were trained on macro-propagation technique as well as management of pineapple. Four farmer cooperatives were trained namely KOANYAMU and KOABOGI in Nyamagabe, and KOTWIHESE and KOKANYA in Gisagara district. A total 264 trainees including 142 females and 122 males were trained on macro propagation technique and management in Nyamagabe and Gisagara districts (**Table 39**).

Table 39: Cooperatives members trained on pineappkle macropropgation in Nyamagabe and Gisagara

District	Sector	Cooperative	Number of trainees		Total
			Females	Males	
Nyamagabe	Musange	KOANYAMU	32	18	50
	Cyanika	KOABOGI	40	32	72
Gisagara	Gikonko	KOTWIHESE	38	68	106
	Nyanza	KOKANYA	32	4	36
Total			142	122	264

Adaptability trials of new sweet and hot pepper varieties

Pepper, *Capsicum annuum* L., is the world's second most important Solanaceae vegetable after tomato. Hot peppers are pungent and mainly consumed as spices while sweet peppers are non-pungent and mainly used in soups and stews: also eaten raw on salads. In Rwanda, both hot and sweet peppers are mainly grown for cash and they play an important role in national economy (NISR, 2018; USAID, 2018). They are both grown for local consumption, however for the hot pepper most of the produce is exported to international markets. The

common varieties grown in Rwanda include Calfornia wonder for sweet pepper, and bird-eye, scotch bonnet, habanero for hot pepper. Despite the importance of these crops in terms of yield and income generation, their production and productivity is challenged by many factors such as lack of improved varieties, poor agronomic practices (including population density, fertilizer rates), biotic and abiotic stresses among others (Waweru et al., 2020). Thus, the current research was conducted with the objectives to test adaptability of introduced hot and sweet pepper varieties and identify the best performing pepper variety under Rwandan conditions. For hot pepper, adaptability experiments were carried out at four sites (Rubona, Rubilizi, Ntendezi and Nyagatare research stations, RAB) from November 2020 to June 2021. Five varieties of hot pepper introduced from World Vegetable Center (WVC) namely PP9852-170; PP9950-5197; PBC462; ICP18-7; HP 0117 were sown in seed beds. Healthy grown seedlings were were used. For sweet pepper, the experiment was carried out in two sites at Rubona and Nyagatare RAB research stations, from November 2020 to June 2021. Six varieties of sweet pepper introduced from WVC were evaluated including PPISPN8-2, PPISPN11-2, PP04142-20, ISPN11-4, PP0537-7019, PPISPN11-3. The seedlings were prepared in seed beds and later on transplanted in the main field. The design, plot size and plant spacing used was the same as the ones mentioned above for hot pepper.

All appropriate agronomic practices such as weeding, watering and hoeing were conducted uniformly at the nursery and field for both hot and sweet pepper. All data were recorded from the average of five selected plants from the central rows of each plot. The following parameters were measured; plant height (cm), days to 50% flowering, days to 50% maturity, number of fruits per plant, number of branches (primary), fruit length (cm), fruit diameter (cm), fruit weight/plant(g), total yield (t/ha). Both growth and yield data components were subjected to analysis of variance (ANOVA) and mean separation was carried out using Least Significant Difference (LSD) at $P<0.05$, SAS statistical software package. Data for Ntendezi and Nyagatare research station were not analysed as the experiments are still on-going.

There was significant difference ($P<0.05$) between hot pepper varieties in terms of plant height, fruit length and diameter at Rubona site. The tallest plant height was recorded from variety HP0117 (37.3) followed by ICP18-7 (35.3) and the shortest plant height was from variety PBC462 (21.3) in Table 3.1. Variety ICP18-7 had the longest fruits while the widest fruits were obtained from variety PP9950-5197. The difference in fruit length and diameter could be due to different dry matter partitioning ability of plants and inherited traits.

Table 40: Mean growth and yield of hot pepper varieties in 2021A and B at Rubona station, RAB

Varieties	Height (cm)	Fruit length(cm)	Fruit diameter (cm)	No. of fruits/plant	Yield/ plant(g)	Yield (t/ha)
PP9852-170	33.8±1.1a	7.4±0.2b	0.8±0.1b	97±12b	499±49a	18.5±1.8a
PP9950-5197	33.3±2.2a	5.9±0.1c	1.0±0.1a	80±10b	545±70a	20.2±2.6a
PBC462	21.3±1.3b	5.7±0.1c	0.6±0.1c	136±14a	342±41a	12.7±1.5a
ICP18-7	35.3±1.9a	8.2±0.2a	0.9±0.1b	90±9b	564±52a	20.9±1.9a
HP0117	37.3±2.1a	6.1±0.3b	0.8±0.1b	82±11b	508±75a	18.8±2.7a
CV	23.7	26.3	28.1	50.8	50.9	50.9
P	<.0001	<.0001	<.0001	0.0060	0.0741	0.0741
LSD	5.1	0.6	0.1	33	166.1	6.2

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD = least significant difference; CV = Coefficient of variation

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Pepper varieties differ in the ability to absorbed ample solar radiation that in turn influence the amount of photosynthetic assimilates accumulated in plant. Results indicated significant variation (P=0.0060) among the

varieties in regards to number of fruits per plant. Variety PBC462 had the highest number of fruits (136) while the least number of fruits per plant was recorded from variety PP9950-5197 (80). Yield per plant and yield per hectare did not differ significantly among the varieties. Variety ICP18-7 had relatively higher yields (20.9 t/ha) compared with other varieties (**Table 40**). This finding are supported by previous research that was carried at Rubona using the same varieties where by ICP18-7 had highest yield (Horticulture Annual report, 2019/2020).

At Rubilizi, hot pepper varieties did not show significant difference (P=0.8413) on days to 50 % flowering (Table 3.2). However, days to 50 % fruiting varied significantly (P=0.0140). The highest (49) days to 50 % maturity was recorded in variety PP9852-170 while the lowest (43). This indicated that variety ICP18-7, HP0117and PBC462 were early matured varieties while PP9852-170 and PP9950-5197 were late matured. Plant height, number of primary branches and fruit length were significantly (P<0.05) influenced due to varieties. ICP18-7 and HP0117 had the highest plant height and more primary branches compared to other varieties. This variation might be attributed to genetic make-up of the varieties and the growing climatic conditions. Though there were no significant influence oin total yield of pepper, the highest yield (26.9 t/ha) was recorded in variety ICP18-7 (**Table 41**).

Table 41: Phenology, growth and yield of hot pepper varieties in 2021A and at RAB Rubilizi

Varieties	50% flowering	50% fruiting	Height (cm)	Number of branches	Fruit length (cm)	Yield (t/ha)
PP9852-170	40±1.5a	49±1.0a	13.9±1.1b	6.0±0.2c	11.2±0.4b	19.7±1.2
PP9950-5197	40±1.0a	48±2.0a	14.9±1.4b	6.5±0.4bac	10.4±0.4b	19.5±0.3
PBC462	39±1.0a	43±0.7b	16.7±1.7ba	7.1±0.3ba	8.9±0.3c	23.8±3.9
ICP18-7	39±1.0a	43±0.7b	19.6±1.5a	7.3±0.4a	12.8±0.4a	26.9±1.3
HP0117	39±1.0a	44±1.7b	19.5±1.9a	7.3±0.2a	11.0±0.5b	21.1±2.0
CV	4.9	5.0	35.0	18.5	15.7	16.3
P value	0.8413	0.0140	0.0309	0.0231	<.0001	0.1418
LSD	3.5	4.1	4.3	0.9	1.2	6.6

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD = least significant difference; CV = Coefficient of variation

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At Rubona, there were significant (P<0.05) effect on plant height, fruit length and number of fruits per plant for sweet pepper (**Table 42**). Variety PP04142-20 was the tallest, with many and longest fruits compared to other varieties. Fruit diameter, yield per plant as well as yield per hectare were non-significant (P>0.05). Though there were significant difference, variety PPISPN11-2 yielded the most in comparison to other sweet pepper varieties.

Table 42: Mean growth and yield of sweet pepper varieties in 2021A and B at Rubona station, RAB

Varieties	Plant height	Fruit length	Fruit diameter	Number of fruits per plant	Yield per plant (g)	Yield (t/ha)
PPISPN 8-2	29.8±1.8b	8.2±1.0ba	3.9±1.1a	6.0±0.7b	393.5±49.1a	14.6±1.2a
PPISPN11-2	34.8±0.9a	7.2±2.0b	4.3±1.4a	6.0±0.7b	464.3±40.4a	17.2±0.3a
PP04142-20	35.6±1.3a	10.5±0.7a	2.6±1.7a	11.0±1.4a	349.3±41.6a	12.9±3.9a
ISPN11-4	25.3±1.0c	6.0±0.7b	4.2±1.5a	4.0±0.4b	423.8±40.3a	15.7±1.3a
PP0537-7019	28.5±0.9cb	4.3±1.7c	6.5±1.9a	6.0±0.9b	426.8±41.1a	15.8±2.0a
PPISPN11-3	34.1±1.0a	4.8±1.7cb	6.8±1.9a	5.0±0.5b	432.6±37.9a	16.0±2.0a
CV	16.4	25.8	32.0	56.4	42.8	16.3

P value	<.0001	0.0479	0.3529	<.0001	0.4958	0.4972
LSD	3.4	3.4	4.3	2.3	117.5	6.9

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD = least significant difference; CV = Coefficient of variation

The overall findings indicate that the introduced improved varieties are promising and could be appropriate for hot or sweet pepper production. However, further testing of the above mentioned varieties in different locations including the local checks is required.

Adaptability trials, response to organic and inorganic fertilizers and test of stevia sweetness

Stevia (*Stevia rebaudiana* Bertoni) is an herbaceous perennial plant of the Asteraceae family, originating from the north-east of Paraguay, where it grows wild in sandy soils. Dry leaves are the economic part of the stevia plant, with a high concentration of steviol glycosides, possible substitutes of synthetic sweeteners, which are many times sweeter than sugarcane and sugar beet but importantly without any calories. Stevia has many health benefiting plant-derived phyto-chemical compounds that help in controlling blood sugar, cholesterol and blood pressure. In addition to its use as natural sweetener, stevia extracts are further refined for use as table sugar. It can then be added in jam, yoghurt, ice creams, smoothies, deserts, chewing gum and sorbets and also to sweeten bitter medicines. Rwanda is able to achieve naturally high yields because of sustainable rainfalls, soil, climate conditions and ideal elevation (1400-2000m). It can be a potential source of foreign currency as it is exported as well as create employment opportunities for farmers as it is labour intensive. European regulatory bodies including the joint FAO/WHO Expert Committee on Food Additives (JECFA) and the European Food Safety Authority (EFSA) have now agreed that steviol glucoside is safe for all populations to consume and is a suitable sweetening option for diabetics. Effective from December 2nd, 2011, the EU has approved its use as a food additive. Due to the short time of stevia introduction as a new crop in Rwanda, there is no information available on nutrient requirement. The aim of the present work was to determine the type of fertilizer to be used for better yield for *S. rebaudiana*. Experiments were conducted during season 2021A and 2021B in Rubona and Ntendezi RAB research stations.

Table 43: Effect of different organic and inorganic fertilizers on growth and yield of S. rebaudiana in Rubona, means of season 2021A and B

Fertilizer type	Height	Stem internode	Leaf width	Yield (T/Ha)
Compost	40.52a	0.99ab	1.367a	3.389a
Cow dung	40.44a	1.095a	1.392a	4.028a
Pig manure	41.23a	1.075ab	1.445a	3.056a
Poultry manure	41.58a	1.04ab	1.323a	3.333a
NPK	42.2a	1.04ab	1.357a	3.667a
DAP	40.66a	0.987ab	1.305a	3.000a
Urea	42.46a	1.007ab	1.347a	4.111a
No fertilizer	39.76a	0.917b	1.323a	3.472a
CV (%)	12	24.8	31	29.8
P value	0.199	0.059	0.863	0.739
SE	0.781	0.04	0.0666	0.522
LSD	2.174	0.1113	0.1853	1.534

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD = least significant difference; CV = Coefficient of variation

Seedlings of commonly variety were raised in nursery bed and transplanted in experimental field at 45 days of age. Plant spacing of 20 cm between rows and plants was maintained and the crop was irrigated on need basis. Seven treatments included compost, cow dung; pig manure; poultry manure; recommended NPK; recommended DAP; recommended Urea and control (no fertilizer). Number of tillers, plant height weekly, internode length, leaf width and yield were collected at harvest.

At Rubona, both organic and inorganic fertilizers did not show significant (P = 0.199) effect on plant height compared to control (Table 4.1). Even though there was no significant effect on plant height, plants treated with urea fertilizer were the tallest 42.46 cm followed by poultry manure 41.58 cm while the minimum plant height was observed with control treatment. On the other hand, significant difference (P<0.05) occurred on growth of internodes between the fertilizers. Plants treated with organic fertilizers (with exemption of compost) developed longer internodes compared to plant treated with inorganic fertilizers and control. However, there was no varied effects on leaf width. Yield of fresh leaves per hectare during the period of harvest has shown no significant difference between the applied fertilizers (**Table 4.1**). The yield of the harvested fresh leaves of stevia treated with urea (100kg/ha) relatively high (4.11 t/ha) in comparison with other treatments. Number of tillers varied significantly (<.001) among the treatments. During the observation, urea played more dominant role in increasing number of tillers (21.73), poultry manure was the second (21.72) while control treatment (no fertilizer) showed minimum contribution in increasing number of stevia tillers (18.2) as shown in **Figure 1** and ***Table 44*.**

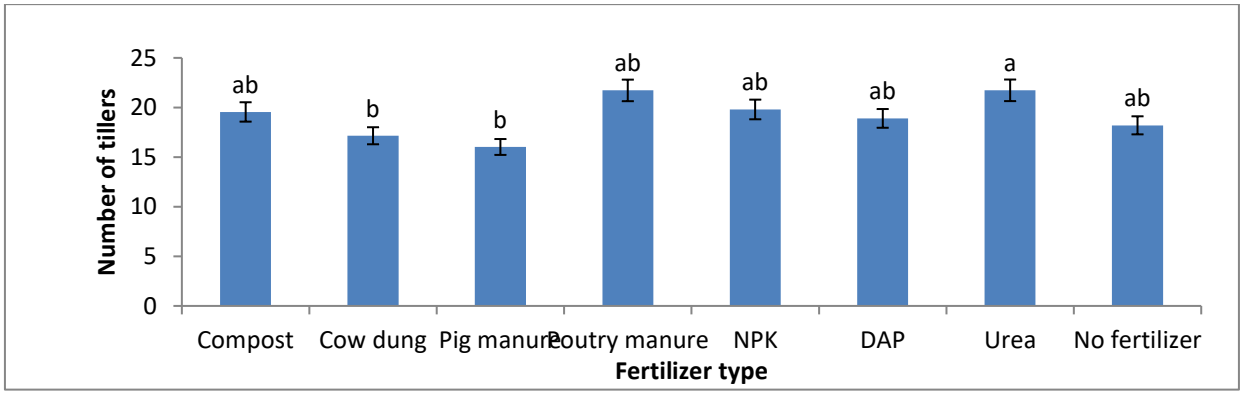

Photo 19: Effect of different organic and inorganic fertilizers on number of tillers in S. rebaudiana in Rubona station during season 2021A and B

At Ntendezi, there was no significant effect of fertilizer on plant height of stevia (**Table 43**). On the other hand, there was significant (P<.05) effects of the fertilizers on number of tillers and length on internodes. During the observation, poultry manure played more dominant role in increasing number of tillers (22.76), urea was the second (21.0) while control treatment (no fertilizer) showed minimum contribution in increasing number of stevia tillers (16.8). Leaf width was not significantly influenced by the different fertilizer application. Similar to Rubona site findings, yield/ha of fresh leaves was not significantly influenced by fertilizers effects. Stevia plants treated with poultry manure showed relatively higher yield of fresh leaves in comparison with other treatments (**Table 44**).

Table 44: Effect of different organic and inorganic fertilizers on growth and yield of S. rebaudiana in Ntendezi station during season 2021A and B

Fertilizer	Height (cm)	Number of Tillers	Number of stem internodes	Leaf diameter	Yield (T/Ha)
Compost	41.0 a	18.67ab	0.87ab	1.572a	3.413a
Cow dung	43.50a	19.30b	1.075a	1.492a	4.249a
Pig manure	42.67a	20.04b	1.055ab	1.475a	3.354a
Poultry manure	44.51a	22.76a	1.09ab	1.643a	4.744a
NPK	41.8 a	18.8ab	1.05ab	1.270a	3.623a
DAP	40.66a	18.9ab	0.871ab	1.200a	3.120a
Urea	41.46a	21.0a	1.126ab	1.236a	4.439a
No fertilizer	39.76a	16.8ab	0.943b	1.022a	3.524a
CV (%)	11	33.5	21.5	34	26.7
P	0.197	<.001	0.061	0.953	0.747
SE	0.783	0.889	0.05	0.0764	0.626
LSD	2.342	2.521	0.1223	0.1557	1.614

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD = least significant difference; CV = Coefficient of variation

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The findings, obtained in the present study, suggest that stevia may be grown using relatively inexpensive organic fertilizers because the use of synthetic chemical fertilizers did not result in significant higher yields in both sites. Among the organic fertilizer, poultry manure was relatively the best. The present results are for one season and therefore, there is need to repeat the study for another season in different locations in order to yield conclusive recommendations of the best fertilizer to use to enhance productivity of stevia.

Seed production for tamarillo, passion fruit and hot pepper

Good quality seed is one of the main factors that determines the success of a crop. In Rwanda, the unavailability of good seed for most of horticultural crops is a major problem to farmers due to the absence of good varieties, inadequate technology in seed production, poor quality control, postharvest seed handling, inadequate marketing and indifference to improved varieties. Horticultural crops such as Tamarillo, Passion fruit and Hot pepper have a major impact on potential crop yield and high income. However, many farmers save seeds from their own crops for the next planting. Some farmers buy mature fruits from the local market and use the seeds for planting. Existing commercial seed companies in Rwanda don't have Tamarillo and Passion fruit seeds and hybrid seed for hot peeper they have are very expensive to farmers. For the contribution to new Technological innovations developed for increased productivity and resilience of crops, clean planting materials of tamarillo, passion fruit and hot pepper had been produced through horticulture innovations.

Seed production plots were established in RAB for tamarillo (**Photo 19**) and hot pepper, while passion fruit seeds were produced by farmers' cooperatives through the training on seed production and follow up. During the fiscal year 2020-2021, a total of 36.7 kg of tamarillo seeds were produced in Rwerere, Gakuta and Tamira RAB stations. Hot pepper seed production was done in Rubilizi and Rubona stations with total 29.5 kg seeds produced. Produced seeds will be distributed in major production districts through cooperatives, NGOs, private companies, government organization as well as individual farmers. Through training and regular follow up, cooperatives in Rwamagana, Karongi and Ngororero produced a total of 41 kg passion fruit clean seeds.

Photo 20: Tamarillo fruits (left); seed production plot in Rwerere (center) and Hot pepper seed production in Rubilizi

Three fruit trees per household program

Malnutrition at household level is among the major challenges against which the government of Rwanda is putting more effort to achieve the sustainable development (MINAGRI, 2018). This malnutrition is mainly due to insufficiency of food and limited income among others. Insufficiency of food has been observed to be caused mainly by limited availability of quality planting material for some crops, inadequate knowledge on production techniques and limited awareness of nutritional and economic importance of some crops. On the other side, the limited income is mostly due to limited income generating activities and small land size per household. The major effects of malnutrition in Rwanda are stunting, infant mortality, low intellectual capacity and frequent family conflicts among others. Stunting rate remains at 38 %, which is high by international comparison; and 17.8 % of 6-23 month-old children do not meet the minimum acceptable diet (NISR, 2016). More than 20 % of Rwandan households are food insecure (NISR, 2015).

Though the government of Rwanda has made effort by promoting national-wide kitchen garden and fruit trees, there is still a long way to go as many households do not have even a single fruit tree due to many reasons as mentioned above. With appropriate promotion, the contribution of fruit trees to the livelihoods and health of Rwandan farmers and consumers could be substantially increased.

During the fiscal year 2019/2020, RAB together with other partners including RAB/SAIP, MINAGRI/RAB (Itorero Ingamburuzabukene), NAEB, Districts Reserve force, NGOs, private organizations and farmers produced in total 2,566,557 seedlings of different species of fruit trees including avocado, mango, orange, mandarin, lemon, passionfruit, tamarillo, papaya, and jack fruit. The seedlings were distributed to beneficiaries countrywide. In addition, a team of horticulture staff conducted regular follow up during the distribution, planting and after planting during the fiscal year 2020/2021. This was done to provide regular advice on crop maintenance (pruning, plant training, fertilization, pests and diseases control). Regular follow up is needed for further training of farmers and extension agents on fruit trees management especially for perennial fruits like avocado, mango, citrus species and jack fruit. This will contribute towards sustainability of the three fruit per household program.

1.6 Traditional Export Crops Program

2.6.1 Tea

Two research focused on tea clone evaluation and planting density trials at new tea planting sites of UNILEVER Tea Company LTD, in Kibeho and Munini, Nyaruguru District, since November 2018.

Evaluation of adaptability of new tea clones

A clonal trial was established in November 2018 at a new tea planting site of Unilever Tea Company LTD in Kibeho Sector, Nyaruguru, to test the adaptability of new tea clones and determine the most suited clones for the growing conditions of Rwanda. The study is conducted by RAB/Tea Sub-Program in collaboration with Unilever Tea Company LTD. The trial comprised four new accessions, namely clone UTK 9710342, UTK 401658A, Martim 1 and UTK 900244B that were introduced to Rwanda in 2016 along with clones currently used in commercial production of Rwanda, including TRFK 31/8, TRFK 6/8, BB 10 and TRFK 11/4. End results will guide tea growers in the area on best clones to plant in their fields. The experiment was set as a Randomized Complete Block Design (RCBD) with four replicates. Each net plot comprised 40 tea plants at a plant spacing of 1m x 0.70m. Data reported here consist of development/growth data collected at 10 and 20 months after planting, i.e. 2019/2020 and 2020/2021 respectively. Data included plant height, stem diameter, number of branches and leaves developed and canopy width (in 2020). Biomass from pruning or decentering at six months after planting was also measured as well as incidence of pests (mites and aphids) and weather dryness effect on clones were also assessed in 2020. Data from the trial were subjected to one-way analysis of variance (ANOVA) and mean separation of the treatment effects was done using the least significant difference (LSD). Fresh leaf (two and a bud) samples were collected in Munini tea field comprising the same clones. Ranges for macronutrient contents are also presented.

In 2019, clones UTK 9710342 and UTK 401658A recorded highest mean values of measured growth parameters **(Table 45)**. The rest of clones were almost in the same range, the local check TRFK 11/4 showing lowest values

Table 45: Effect of tea clones on growth and biomass, 2019/2020

Measurement	Clone								c.v. (%)	LSD (≤0.05)
	TRFK 31/8	TRFK 11/4	UTK 401658A	UTK 9710342	TRFK 6/8	UTK 900244B	Martim 1	BB10		
Plant height (cm)	49.8	41.9	53.3	48.1	44.9	48.6	50.0	45.9	9.6	ns
Stem girth (cm)	0.61	0.59	0.82	0.80	0.62	0.60	0.67	0.68	12.1	0.12
Number of leaves	40.3	36.8	58.9	60.7	44.3	44.7	42.1	45.9	19.0	13.1
Number of branches	4.9	4.5	5.7	5.8	5.4	5.1	4.4	5.3	11.0	0.83
Biomass (kg)	0.50	0.43	0.95	0.80	0.60	1.03	0.68	0.65	25.5	0.26

In 2020 (20-months), plant height, stem girth and canopy spread rate were measured as growth parameters. Stem diameter results were only significant (p≤0.05) of three variables (**Table 46**). Clone UTK 9710342 showed higher (p≤0.05) development of stem diameter (2.19 cm) followed by TRFK 6/8 (2.01 cm). The lowest value was for UTK 900244B (1.60 cm). Clone UTK 9710342 resulted in wider canopy (53.9%) followed by TRFK 31/8 (48.8 %) although not at a significant level. As observed in the previous report (2018), the results for the two periods are confirming the superiority of the tea clone UTK 9710342 with regard to establishment and development in Kibeho as compared to other clones. Assessment of pest severity (**Table 46**) showed that UTK 9710342 and TRFK 6/8 underwent highest level of mite attack scoring 2.13.

TRFK 6/8 is known for its high tea cup quality; being infested by mites at the same level as UTK 9710342 would be an indication of high quality of this clone as well. In fact, the survey (RAB, 2017) conducted in Rwanda tea plantations revealed that mite severity was highest in clonal teas as compared to lower tea quality stumps. Aphids were slightly severe in clones UTK 401658A and BB10 (1.38) whereas UTK 900244B was more affected by weather dryness than other clones.

Table 46: Effect of tea clones on mean values of agronomic/growth parameters of 2020/2021

Measurement[α]	Clone								c.v. (%)	LSD (≤0.05)
	TRFK 31/8	TRFK 11/4	UTK 401658A	UTK 9710342	TRFK 6/8	UTK 900244B	Martim 1	BB10		
Plant height (cm)	59.7	59.9	60.5	61.6	57.5	61.8	60.6	59.2	4.9	ns
Stem girth (cm)	1.98	1.85	1.92	2.19	2.01	1.60	1.89	1.99	7.5	0.21
Canopy spread rate (%)	48.8	44.9	43.0	53.9	42.1	43.5	38.1	42.4	13.9	ns
Mite severity	1.50	1.25	1.50	2.13	2.13	1.63	1.25	1.25	34.2	ns
Aphids severity	1.0	1.25	1.38	1.25	1.25	1.25	1.0	1.38	32.7	ns
Susceptibility to drought	1.38	1.5	1.5	1.5	1.5	2.0	1.25	1.43	42.9	ns

α: pest severity and Susceptibility to drought were scored following a scale from 1 to 5 from lowest severity and dryness effect (1) to highest severity and dryness effect (5)

Macronutrients were assayed in tea harvestable leaf (Two & a bud) from Munini tea field. The field comprised the same tea clones as in the experimental plots apart from clone Martim 1 that was replaced by clone TN 14/3. Ranges of macronutrients, viz. nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca) are summarized in **Table 47**. Although uppermost mature leaf is used as a diagnostic tool to assess the nutritional status of tea, there are also critical ranges for harvestable leaf. Particularly, harvested leaf nutrient content would give an indication on the nutrient amounts exported from the soil with the fresh tea leaf harvested. *It would therefore guide on the replenishment of nutrients through fertilizers.* This information will be available when yield data have been recorded from the plots.

Table 47: Nutrient content (%) in tea harvestable leaf (Two & a bud) of Munini (Unilever) tea field

Nutrient	Minimum[α]	Maximum	Mean	Normal value[#]
N (%)	4.09 (UTK 9710342)	4.92 (UTK 900244B)	4.41	4
P (%)	0.29 (BB10)	0.44 (UTK 900244B; TN 14/3)	0.36	0.35
K (%)	1.05 (UTK 9710342)	1.16 (TN 14/3; UTK 401658A)	1.11	2
Mg (%)	0.24 (UTK 9710342)	0.4 (UTK 401658A)	0.33	0.2
Ca (%)	0.41 (UTK 9710342)	0.5 (BB10)	0.46	0.4

α: Clones in the brackets were found in the category indicated (max. or min)
#: (Drinnan, 2008)

Leaf nutrient values (**Table 47**) show that leaf K content was low (<1.2%) for the site as compared to expected value (≥2%) whereas other nutrients were in good range for all clones except clone BB 10 that had low P (0.29%). Moreover, clone UTK 9710342 was found in the category of minimum leaf nutrients in general suggesting that it would be less requiring in terms of fertilizers as compared to other clones. Clone UTK 900244B was found in maximum category for N (4.92%) and P (0.44%) while Clone UTK 401658A (1.16%) recorded maximum values for K (1.16%) and Mg (0.4%). Although Munini site is some few km away from Kibeho site, the information given

here would be an indication of the nutritional status of Kibeho tea fields. At this stage of tea development in the trial it should be concluded that clone UTK 9710342 was showing best development and promising for high yield and quality. Other clones were ranked second with comparable performance indicating that other new clones are promising for good adaptability, particularly UTK 401658A.

Evaluation of effects of plant densities on tea growth

A trial on tea plant spacing was established at Kibeho (Nyaruguru) in November 2018 to evaluate plant population effects on growth, development, yields and quality of tea. It is testing five spacing or planting densities on clone UTK 9710342 and the local check TRFK 11/4. Spacing or plant densities under test were as follows: 1) 120cm x 80cm equivalent to 10,471 bushes ha^{-1}, 2) 120cm x 60cm or 13,889 bushes ha^{-1}, 3) 100cm x 70cm or 14,286 bushes ha^{-1}, 4) 80cm x 60cm or 20,800 bushes ha^{-1} and 5) 60cm x 60cm or 27,778 bushes ha^{-1}. The experimental design was a Randomized Complete Block Design (RCBD) under split plot arrangement, with clones as main plot and spacing as sub-treatment. Three replicates were considered. Yield data collection was expected to start when tea is two years old while measurement of growth parameters was done at 10 (2019/2020) and 20 (2020/2021) months. Data consisted of plant height (cm), stem diameter (cm), number of leaves and number of branches and the canopy width (2020/2021).

In 2019/2020, spacing 100cmx70cm recorded highest and significant ($p \leq 0.05$) values for leaf and branch development in clone UTK 9710342 (**Table 47**). High plant densities or closer spacing had lower values. There was no significance in measured variables for clone TRFK 11/4. It was observed, however, that wide spacing 120cmx80cm was slightly higher for plant height, stem girth and number of leaves for this clone. Considering spacing means, stem diameter was highest ($p \leq 0.05$) for 100cmx70cm and 120cmx80cm spacing. For other variables mean spacing was not significant. Comparison of clones showed that clone UTK 9710342 was highest for all measured variables but significant ($p \leq 0.05$) values were observed for number of leaves and branches. There was no interaction of space and clones indicating that at this young stage of development the tea plants were responding similarly.

Table 48: Effect of tea planting density on mean values of agronomic parameters (2019/2020)

Clone	Measured Variable	Spacing						LSD (0.05)			C.V. (%)
		60cm x60cm	120cm x80cm	120cm x60cm	80cm x60cm	100cm x 70cm	Mean clone	Clone	Spacing	Spac. x clone	
UTK 9710342	Plant height (cm)	56.9	56.3	56.9	56.9	64.8	58.4		ns		6.7
	Stem diameter (cm)	0.77	0.85	0.83	0.76	0.87	0.82		ns		8.3
	Number leaves	75.2	87.0	87.7	76.9	97.5	85		13.3		8.4
	Number branches	8.2	9.9	10.9	9.2	11.5	10		2.14		11.4
TRFK 11/4	Plant height (cm)	56	59.1	57	51.6	55	55.7		ns		6.9
	Stem diameter	0.68	0.88	0.84	0.64	0.86	0.78		ns		12.9
	Number leaves	65.2	81.0	77.7	52.7	68.4	69		ns		17.6
	Number branches	8.4	8.7	9.6	7.0	8.5	8.5		ns		16.7
Mean spacing	Plant height (cm)	56.4	57.7	57	54.3	59.9		ns	ns	ns	7.4
	Stem diameter (cm)	0.73	0.87	0.84	0.70	0.87		ns	0.12	ns	12.3
	Number leaves	70	84	83	65	83		10.3	ns	ns	17.5
	Number branches	8	9	10	8	10		1.3	ns	ns	18.5

In 2020/2021, plant height, stem girth and canopy width were measured (**Table 49**). Considering mean spacing values of variables, 120cmx80cm spacing recorded highest (p≤0.05) stem diameter (2.27 cm) followed by 100cmx70cm (2.18 cm) whereas canopy spread rate was highest (p≤0.05) with closer spacing 60cm x 60cm (74.9%) followed by 80cm x 60cm (61.5%). Mean plant height was not significant. Within clones, 60cm x 60cm spacing recorded significant highest values of canopy spread rate for both clones and followed by 80cm x 60cm. Stem diameter response was significantly highest for 100cmx70cm (2.3 cm) in clone UTK 9710342 and highest for 120cmx80cm (2.3 cm) in clone TRFK 11/4. It was lowest for closer planting (60cm x 60cm and 80cm x 60cm**)** in both clones. Plant height was significant for clone TRFK 11/4 and highest for 120cmx80cm spacing. Comparison of mean clonal values revealed superiority of UTK 9710342 over TRFK 11/4. There was clone and spacing interaction for Canopy spread rate (%) and Plant height (cm) suggesting that the extent of spacing response for these two growth parameters depends on clone.

Table 49: Effect of tea planting density on mean values of agronomic parameters (2020/2021)

Clone	Measured Variable	Spacing						LSD (0.05)			C.V. (%)
		60cm x60cm	120cm x80cm	120cmx 60cm	80cm x60cm	100cm x70cm	Mean clone	Clone	Spacing.	Spac.x clone	
UTK 9710342	Plant height (cm)	59.6	61	61.9	62.8	65.5	62.2		ns		5.3
	Stem diameter (cm)	1.9	2.2	2.0	2.0	2.3	2.1		0.2		5.2
	Canopy spread rate (%)	77.6	45	40	72.0	59.5	58.8		9.6		8.7
TRFK 11/4	Plant height (cm)	55.5	61.0	57.9	54.8	53.7	56.6		3.7		3.5
	Stem diameter (cm)	1.8	2.3	2.0	1.8	2.1	2.0		0.29		7.8
	Canopy spread rate (%)	72.1	43.8	38.8	50.9	38.6	48.8		15.7		17.1
Mean spacing	Plant height (cm)	57.6	61.0	59.9	58.8	59.6		2.1	ns	4.8	4.7
	Stem diameter (cm)	1.85	2.27	2.00	1.91	2.18		ns	0.16	ns	6.5
	Canopy spread rate (%)	74.9	44.4	39.4	61.5	49		5.4	8.5	12.0	13.0

At this stage of the trial and considering above results it can be concluded that best planting densities were 100cm x 70cm and 120cm x 80cm. The fastest development of canopy observed in higher planting densities was logical as tea plants in these plots were advantaged by their very closeness. When clones are considered separately, 100cm x 70cm spacing was showed promising for clone UTK 9710342 while 120cm x 80cm spacing could be best for clone TRFK 11/4. Nevertheless, present results are only indicators as the best spacing will be ultimately determined by the yield and the influence of the spacing on soils and the crop. The two studies have been replicated in other tea planting environments since 2019/2020 fiscal year: experimental sites are located in Rulindo (clonal and spacing trials), Karongi (Clonal trial) and Nyamasheke (clonal and spacing trials) districts. 2020/2021Data including plant height, stem diameter, number of branches and leaves developed, canopy width and incidence of pests (mites and aphids) and weather dryness effect on clones were also collected. They were under analysis at preparation of this report.

1.6.2 Coffee

Climate change is putting coffee production and the livelihoods of coffee farmers and their families around the world at risk. Changes in temperature and rainfall patterns, as well as extreme weather events, can impact production cycles and negatively affect coffee production. In order to develop a strategic approach that responds effectively to climate change and its effects on coffee production, coffee research and technology transfer is underway through the public and private partnership. The goal of the initiative is to develop a strategic approach to climate change that is based on practical experiences and effective collaboration (**Table 50**).

Table 50: Direct and indirect effects of extreme or unusual weather events on Coffee arabica

Climate hazard	Impact	Adaptation options
- High temperature	- Increased Pests and diseases	- Varietal resistance - Integrated pests and disease management (IPM)
- Heavy rain, hail, strong winds	- Soil erosion, landslides, subsidence, wash-away of agrochemical applications	- Integrated soil fertility management - Protective covers (cover crops and mulching
- Intermittent and - unseasonal rain	- Possible increase of some diseases	- Varietal resistance Integrated pest and disease management
- Prolonged rain	- Increased humidity may favor some fungal diseases; may increase some insect pests such as Coffee Berry Borer	- Integrated pests and disease management (IPM)
- Prolonged drought	- Stressed trees - more susceptible to some pests	- Breeding for drought resistance - Irrigation

Variety breeding

Significant evidences reports that current coffee varieties will not tolerate the environmental threats of the 21st century, changing climate, and new disease and insects (WCR 2016). This creates a potentially disastrous decline in supply in the coming decades. The best hope for sustaining the supply of high-quality coffee in the 21st century is to focus on making the coffee plant more resilient. The creation of new, highly adaptable varieties, supported by a vibrant new seed sector, will result in major global productivity and quality gains. The study was conducted through the national performance trials consisting of 40 f1 hybrids and 28 new fixed varieties. The hybrids were developed by WCR and RAB. Plant materials were evaluated for growth and quality characteristics in three different locations. Statistical analysis consisted of AMMI, AMMI stability value (ASV) path analysis and general and specific combining abilities (GCA and SCA). From the AMMI analysis and ASV 10 best performers recorded a cherry yield per tree higher than 3 kg/tree and the overall quality scores above 85%. Best performing varieties include Paraneima, IPR103, IPR 107, Batian, Geisha, Top 5 best performers for hybrids included tall hybrids such as Geisha La Luisa X16691, Geisha HERBAZU X16691, Jackson X6A, Harrar X5A, Geisha La Luisa x 4877. Twenty four months after crop establishment the varieties and hybrids already recorded high yield cherries per tree (**Tables 51, 52**).

Table 51: Top 5 best performers within NPT involving fixed varieties

Variety ID	Cherries yield (gr)/tree	Stature	Disease reaction		Overall quality scores (%)
			CLR	CBD	

1	Parainema	4,551	Dwarf	R	MS	84.6
2	IPR 103	3,756	Dwarf	MR	MS	85.8
3	IPR 107	3,378	Dwarf	R	MR	85.2
4	Batian	3,538	Dwarf	MS	MR	86.9
5	Geisha	3,250	Dwarf	MS	MS	88.4
				CLR – CBD -		

Table 52: Top 5 best performance F1 hybrids

	Hybrid ID	Cherries yield (kg)/tree	Stature	Disease reaction		Overall quality score (%)
				CLR	CBD	
1	Geisha La Luisa X16691	4,390	Dwarf	HR	R	90.
2	Geisha HERBAZU X16691	3,970	Dwarf	HR	R	85
3	Jackson X6A	3,710	Dwarf	MR	R	87
4	Harrar X5A	3,557	Dwarf	R	MR	95
5	Geisha La Luisa x 4877	3,250	Dwarf	R	R	82

The path analysis revealed high correlation between stem diameter, number of nodes per branch, number of cherries per tree, bean size, weight of 100 beans and overall cherry yield for both hybrids and varietal trials, and, hence the direct and indirect effects of cause variables on effect variables. The GCA effects of parents and SCA effects of crosses were significant ($P < 0.01$) for stem diameter, number of nodes per branch, number of cherries per tree, bean size, weight of 100 beans, cherry yield per tree, rust and coffee berry disease scores. This indicates that improvement programmes should be directed towards selection of superior parents (Fasahat et al.2016). Crosses exhibiting high SCA effects would produce desirable transgressive segregants in advanced generations (Reyes 2019). Performance trials exhibited good candidates for direct release for both F1 hybrids and fixed varieties. However, for hybrids, it will be necessary to put in place a sustainable strategy for mass multiplication of planting materials either through clonal propagation and exploitation of the male sterility. Hybrids with positive SCA are valuable genetic resources for further breeding investigations.

Coffee pests and diseases surveillance and monitoring: *Development of IPM package*

Rwandan coffee is threatened by a range of pest and diseases. Many of them cause minor damage and limited effect on yield and quality. However, some can be very serious indeed and can have a major impact not only on individual farmers but on the whole coffee export earnings. These are coffee berry disease (CBD), coffee leaf rust (CLR), antestia bug and coffee berry borer. Farmers need to be aware of these pests/diseases and to control them at early stage to prevent losses. Therefore, coffee pests and disease surveillance program was designed to monitor all key coffee production areas. Research on mitigation and control of coffee pests and diseases complements the surveillance program, and results are being shared within coffee value chain.

Spatial distribution of Coffee Berry Disease (CBD) in Rwanda

Rwanda's economy depends largely on Agriculture and coffee plant playing a considerable role for export earnings. Coffee is used to be Rwanda's top export product and thus main source of foreign exchange income.

The production of coffee has drastically declined in the last decade due to mainly diseases and pests. With the regards of existing climate change effects, Coffee Berry Disease (CBD) caused by *Colletotrichum kahawae* is becoming a potential threat to coffee sector productivity, not only in Rwanda but also in the whole east Africa countries. In Rwanda, little information on this disease is needed especially its distribution and spread across the country as well as its long term management strategies. It is in this context that a survey was conducted in the coffee growing regions with the following objectives: (i) To determine incidence, severity and prevalence of CBD, and (ii) To investigate the characteristics of C. kahawae. The survey covered the major coffee growing regions in Rwanda Rulindo, Gakenke and Gicumbi; Huye, Nyamagabe, Gisagara Gatsibo, Rwamagana, Ngoma, Kirehe, Rubavu, Rutsiro, Nyamasheke. In each district CBD assessment was taken in 3 randomly selected plots of at least 40x40m/plot at intervals of 1km. The three parameters were assessed :

Disease severity: 10 trees per plot were randomly selected on two diagonal lines by moving in **''X''** fashion within the plot and each tree was divided into 3 strata of branches (top, middle and bottom). From which stratum two branches were selected to calculate disease severity. CBD damaged and healthy berries were counted and then percentage of diseased berries over total counted berries calculated. Disease severity was rated using standard disease scales of 0-6; where, 0: 0%, 1: ≤ 2%, 2: 2-5%, 3:6-10%, 4: 11-50%, 5: 51-99% and 6: ≥ 99% of diseased berries (Mohammed *et al*. 2015). Then the score was changed into Percentage Severity Index (PSI) for the analysis using the formula of Wheeler: PSI= [Sum of numerical rating / (Number of plant rated x maximum score of the scale)] X 100

Disease incidence: Visual assessment of 10 trees per field were randomly taken and diagnosed for presence and absence of the disease on each tree. Thereafter disease incidence was calculated as: (Number of diseased trees / Total observed trees) x 100. **Disease prevalence** was determined as the proportion (%) of total field assessed for each district.

Incidence and severity of CBD: A total of 39 fields were surveyed in thirteen districts of Rwanda. The results show that the Mean incidence ranged from 33.3 % in Kirehe fields to 100% in Gatsibo. The overall mean incidence at district level was 73,6% within the surveyed areas (**Table 53**). Like disease incidence, severity of CBD in the fields was also. Mean severity ranged from 24.5% in Kirehe fields to 141.1% in Gatsibo. The overall mean severity at district level was 69.1% within the surveyed areas (**Table 53**).

Generally, this level of disease intensity might have explained by using of only one variety which is Arabica and crop management practices in the surveyed areas. The spread and scale of epidemics was suggested to be due to the use of a limited number of varieties and the predominant self-fertility of *C. arabica* and uniform cultural practices over a long period.

The importance of CBD might also be judged by lack of knowledge of farmers because they confuse it with coffee dieback. Therefore, the use of improved variety with high level of resistance to CBD is a long term management in Arabica coffee production in Rwanda.

Prevalence of CBD: The computed prevalence of CBD was 100% in each of the surveyed district with an overall mean of 100%. Therefore, given the importance of CBD in Rwanda, the breeding program must make available an improved variety with a high level of resistance to CBD which could be a long term solution in Arabica coffee production in Rwanda. The table below summarized data from the surveyed areas.

Table 53: Mean incidence, severity and prevalence of CBD in surveyed areas during the end of 2019 B

District	Altitude (masl)	Incidence (%)	Severity (%)	Disease prevalence (%)
Gatsibo	1629-1841	100	141.1	100
Ngoma	1400-1650	60	27.8	100
Kirehe	1477-1552	33.3	24.5	100
Rwamagana	1437-1624	63.3	46.1	100
Huye	1677-1720	70	87.8	100
Nyamagabe	1875-1972	60	47.8	100
Gisagara	1677-1723	90	97.2	100
Gicumbi	1755-1842	70	46.1	100
Gakenke	1459-1804	96.7	124.4	100
Rulindo	1725-2049	70	67.2	100
Rubavu	1472-1630	93.3	66.7	100
Rutsiro	1619-1875	80	75.6	100
Nyamasheke	1733-1807	70	46.1	100

Morphological characterization of *Colletotrichum kahawae*

A major threat to the production of Coffea Arabica in Rwanda is the coffee berry disease (CBD), caused by the fungus *Colletotrichum kahawae*. Crop losses can reach more than 50% if no control measures are applied. The characterization of *C. kahawae* diversity is ongoing at morpho-cultural level conducted in plant pathology laboratory located in Rubona. The main objective of this study is to investigate the diversity of the Colletotrichum isolated from different major coffee growing regions in Rwanda. In this study, the appearance of the mycelium, colony color and growth rate are being evaluated. The studies revealed 30 Colletotrichum isolates grouped into four different colors (**Photo 20**).

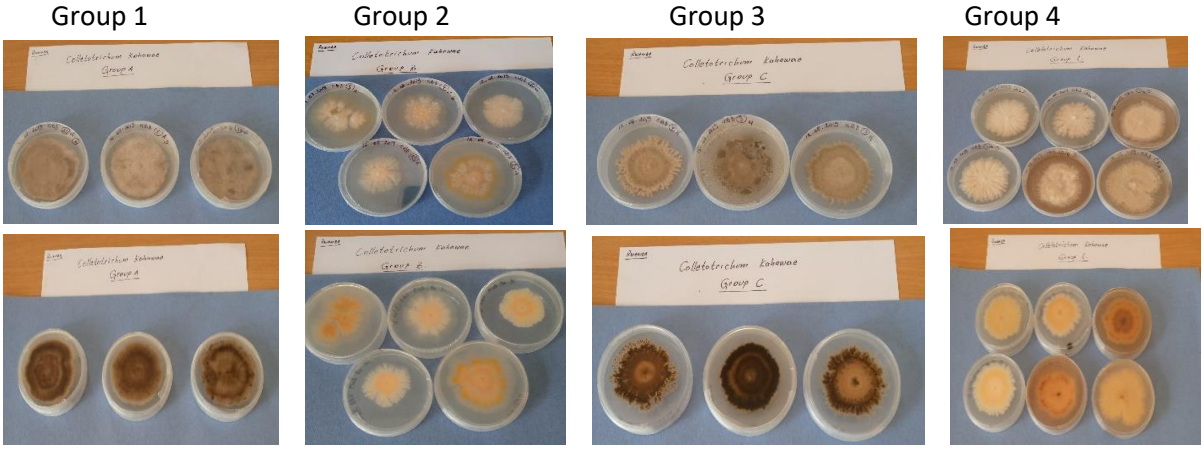

Photo 21: Morphological characterization of C. kahawae

Morphological data show that the disease was the most abundant in the Northern Rwanda compared to other regions. This may reflect preference of the CBD pathogen for cooler high elevation area.

Integrated Soil Fertility Management

Characterization of soil spatial variability for major coffee sites: To optimize nutrient application, soil sampled were collected in major coffee sites. In this study 25 samples were collected in various agro-ecological zones. Data were analyzed using the principal component analysis (PCA) and geostatistical methods (variograms and degree of spatial dependence) based on hypothetical intrinsic stationarity assumptions to study the spatial

variability of soil properties. Seven Principal components (PC) were obtained accounting for the 83.9% of total variability. According to the first three components, much variability across the study sites was observed on soil acidity variables such pH (PC1=78.0%), EC (PC1=69%), CEC (PC1=81.8%). Variability was also observed on macronutrients such as K (PC1=71.1%) and P (PC2=57.8%) as well as microelements such as Ca (PC1=83.1%), Mg (PC1=78.6%), B (PC=83.7%), S (PC2=73.9%), and Na (PC3=74.9%). For physical properties much variability was observed for S and (PC2= -92.8%), and clay (PC2=90.7%) contents of samples. The spatial dependence of all chemical properties in this study was classified as strong or moderate indicating variability of chemical and physical properties across the study sites. This study revealed different nutrient levels and soil structure in various geographical locations, evidencing the needs to develop site specific soil management strategies and fertilizer recommendations. Potential fertilizer recommendations were developed (**Table 54**). The recommendations will be validated through crops response trials that are expected in the quarter 1, 2021/2022. All the surveyed sites presented following nutrient status in the top soil: very Low pH, very Low Phosphorus, Very Low Potassium, Very Low Calcium, Very Low Magnesium, Low Sulphur in this, Very Low Manganese, Very Low Boron, Very Low Copper >Low Zinc >Low C.E.C >Low Total Nitrogen >Very Low Calcium.>Very Low Magnesium %.>Very High Hydrogen. In all the surveyed sites, following rates of 22.6.12 +3S +B +Zn and lime were suggested (**Table 54**).

Table 54: Potential fertilizer recommendations for specific sites

N	Site	NPK 22-6-12+3S+B+Zn		Lime	
		Kg/ha	g/tree	Kg/ha	g/tree
1	Gisuma, Kamuhozi	590	395	2100	1400
2	Gisuma, Gahinga (plot)	510	340	5000	3335
3	Gisuma, Gahinga	650	435	3500	2335
4	Gisuma, Murinzi	520	345	3700	2465
5	Gashonga, Nyamutarama	420	280	900	600
6	Gashonga, Raango	600	400	1900	1265
7	Gashonga, Gatare	550	365	4500	3000
8	Gashonga, Muti	410	275	3000	2000
9	Gakenke, Karambi	470	315	1400	935
10	Gakenke, Ngogo	580	385	1600	1065
11	Kayonza, Nyarunazi	510	340	3400	2265
12	Kayonza, Rwakabamba	500	335	1100	735
13	Kayonza, Agahiza	530	355	2100	1400
14	Gicumbi, Mayogi 1	470	315	2000	1335
15	Gicumbi, Mayogi 2	450	300	3300	2200
16	Gicumbi,Mayogi, Gikumba	490	325	2600	1735
17	Huye, Nyakizu 1	500	335	500	335
18	Huye, Nyakizu 2	560	375	300	200
19	Huye, Nyakizu 3	600	400	900	600
20	Huye, Nyakizu 4	600	400	500	335

Introduction of foliar fertilizers in coffee farming systems

Application of foliar fertilizers is a rapid way to fix nutrient deficiencies. The current study aimed to investigate the use of Rokohumin as a foliar fertilizer for coffee. Rokohumin is a nutritional cocktail of amino acids, peptides, humic acids, macro and micronutrients that was developed to be used as a foliar fertilizer for the supplementary nutrition of coffee to prevent or control the occurrence of macro-and micronutrient deficiencies. Organic coffee cultivation is more sustainable and profitable and use of foliar fertilizers would help to develop organic coffee in Rwanda. Multi-locational trials were established in January 2021 in Rwamagana, Rulindo, and Huye. Rokohumin (2.5l/ha), N22P6K12 (500kg/ha), organic manure (37.5t/ha) and a control with no fertilizers were applied as

treatments. While REML model of analysis of variance showed no significant difference between the treatments on plant vigor (Table 20) and growth traits, significant differences were obtained in yield and quality: Application of Rokohumin and NPK produced significantly higher yields than treatments with organic manure only and control. Therefore, Rokohumin may be recommended as foliar fertilizer for coffee. Rokohumin may also be recommended for use as a supplement to inorganic fertilizer. Further studies would determine optimal application rates and frequency to maximize profitability from this organic product.

Multi-locational trials were established in January 2021 in four different locations representing diverse agro-ecologies where coffee is grown (**Table 55**). Despite its small size Rwanda has large diversity in terms of agro-ecology due to large variability in elevation and the East-West rainfall gradient. According to the FAO, about 40% of land is classified as high erosion risk and requires soil retention measures, while only 23% is risk free from erosion. About 75% of soil is highly degraded. As for soil quality, a large proportion of land (>70%) suffers from soil acidity (pH< 4.5) often with aluminum toxicity. As expected, pH is lowest in the wetter western part of the country where soils have weathered more. SOM is generally lower in the (dryer) eastern part of the country. It is highest in wetter and cooler (high elevation) areas in the west and in the low lying peat land areas in the south. Low pH (acidic soils) negatively influences availability and uptake of several essential nutrients and also restricts root growth and access to water and nutrients, leading to low productivity. Therefore testing the efficacy of the product in such diversified conditions will enable us to draw concise conclusions and recommendation on site specific product performance and stability/consistence across the environments.

Table 55: Physical description of the study sites

Type of trial	Province	Distrct	Altitude (masl)	Agro-ecological characteristics			
				AE Zone	Soil	Mean annual rainfall (mm/year)	Mean annual temperature (° C)
On-farm	East	Rwamagana	1500	Eastern Plateau	Oxisols	950	20-21
On-farm	North	Rulindo	1700	Kivu lakeside	Oxisols	1200	17-19
On-station	South	Huye (Rubona)	1,700	Central Plateau	Oxisols	1200	18-20

In a bid to draw meaningful conclusion of the efficacy of the product, assessment will be done on vegetative, yield and quality characteristics. The environmental impact will be assessed by analysis of potential residues in the final product (cup quality).

Plant Vigor: Crop vigor is considered as a combination of 3 factors: the foliage density, the foliage overall color and the hardiness of the plant, which is a synonym of rusticity characterized by the fact the plant looks strong, have a good stem diameter and a good number of branches.

Yield and quality characteristics: Crop yield is a response to a number of agronomic practices and environmental factors but more primarily crop response to fertilizer application. Yield and yield characters were evaluated mainly by measuring number of cherries per tree (effect of fertilizer on fruit maturation) cherry yield per tree, parchment yield per tree, weight of 100 grain (density) and quality characters (overall scores (**Table 56**).

Table 56: Vigor rating associated with different fertilizer applications

Replications	Tree #	Rubona				Rwamagana				Rulindo			
		ROKO	NPK	Control	Manure	ROKO	NPK	Control	Manure	ROKO	NPK	Control	Manure
1	1	4.0	4.0	2.0	4.0	5.0	4.0	2.0	3.0	4.0	4.0	4.0	3.0
1	2	4.0	5.0	2.0	4.0	5.0	5.0	2.0	4.0	5.0	5.0	3.0	5.0
1	3	4.0	4.0	3.0	4.0	4.0	4.0	2.0	4.0	4.0	4.0	3.0	4.0
1	4	5.0	4.0	3.0	4.0	4.0	4.0	3.0	5.0	5.0	4.0	3.0	5.0
2	1	4.0	4.0	4.0	3.0	5.0	4.0	4.0	3.0	5.0	4.0	4.0	3.0
2	2	4.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0
2	3	4.0	5.0	4.0	3.0	4.0	4.0	4.0	4.0	3.0	4.0	5.0	4.0
2	4	4.0	5.0	3.0	4.0	4.0	5.0	4.0	4.0	4.0	5.0	4.0	4.0
3	1	5.0	5.0	3.0	4.0	5.0	4.0	3.0	4.0	5.0	4.0	3.0	4.0
3	2	4.0	5.0	3.0	4.0	4.0	5.0	2.0	4.0	4.0	5.0	2.0	5.0
3	3	5.0	5.0	4.0	3.0	5.0	4.0	2.0	3.0	5.0	4.0	2.0	3.0
3	4	4.0	4.0	3.0	3.0	4.0	4.0	3.0	2.0	5.0	5.0	5.0	4.0

1= low vigor (>50% yellowing)
2= medium to low vigor (30-50% yellowing). The plants miss some of his leaves and a discoloration appear on some leaves,
3= medium vigor (20-30 % Yellowing). The plant has a normal amount and green color of the leaves.
4= medium to high vigor (10-20%) Yellowing. The plant has a dark-green for the leaves and the density of the leaves is good.
5= high vigor (>10%). The foliage density seems high and the leaves have a dark-green color.

For the present study, more vigorous and less yellowing coffee plants were obtained in the plots treated with NPK and Rokohumin as compared to plots treated with organic manure and control plots. The high performance of NPK and foliar application of Rokohumin is attributed to that both type of formulations ease the plant fertilizer uptake (Jolly 1986) compared to organic manure which has a slow nutrient release potential. These suggestions corroborate with Adeniyan et al. (2016) who demonstrated that a combination of broadcast and band applications coupled with foliar applications optimized nutrient uptake by crops in low fertile soils.

Effect on fruit development: Fruit development is the key aspect in the developmental stages of coffee as the extent of fruit set in terms of amount and density is a reliable determinant of yield potential. Fruit set is generally affected by environmental factors such as heavy rains both during flower expansion and at anthesis, mineral nutrition and sudden temperature drops. Flower expansion and anthesisis will determine the amount of seed set, number of glomules, number of fruits (cherries) per plan and the overall yield per tree and subsequent extrapolations. The number of nodes per branch, cherries per node are highly correlated with crop yield. Several techniques were developed to predict yielding potential based on (1) a visual estimation of the number of fruits per lateral summed across all laterals per plant, and (2) an average fruit dry mass derived from the random harvest of 50 fruits per plant (Idol et al.2019). The number of cherries per plant is determined by the bearing potential (number of nodes per branch and number of cherries per nodes for the laterals).

The analysis of variance did not reveal any significant effect of fertilizers on the bearing potential neither within location nor between locations (no significant interaction between treatments and trial locations i.e. all the treatment performed similarly for the number of nodes per branch and number of green cherries per node (**Table 57**).

Table 57: Mean square estimates of number of the average number of nodes per branches per branch and average number of cherries per node (numbers between blankets represent p-values)

Source of variation	d.f.	Nodes per branches	Cherries per node
Site	1	218.425 (<0.001)	8.505 (0.045)
Replication	2	3.031 (0.333)	2.832 (0.247)
Replication x Site	2	0.179 (0.934)	0.097 (0.951)
Treatment	3	0.437 (0.918)	2.782 (0.251)
Site xTreatment	3	0.967 (0.777)	3.408 (0.177)
Residual	24	2.633	1.908
Total	35		
C.V		11.2	11.1

The lack of significant effect is attributed to phenological stages of the crop which is primarily decided on the flowering initiation. The optimization of coffee fertilizer programmes requires the application at both stages of the generative process of the growth i.e after flowering to enable fruit set and fruit development and at the maturation (**Figure 2**).

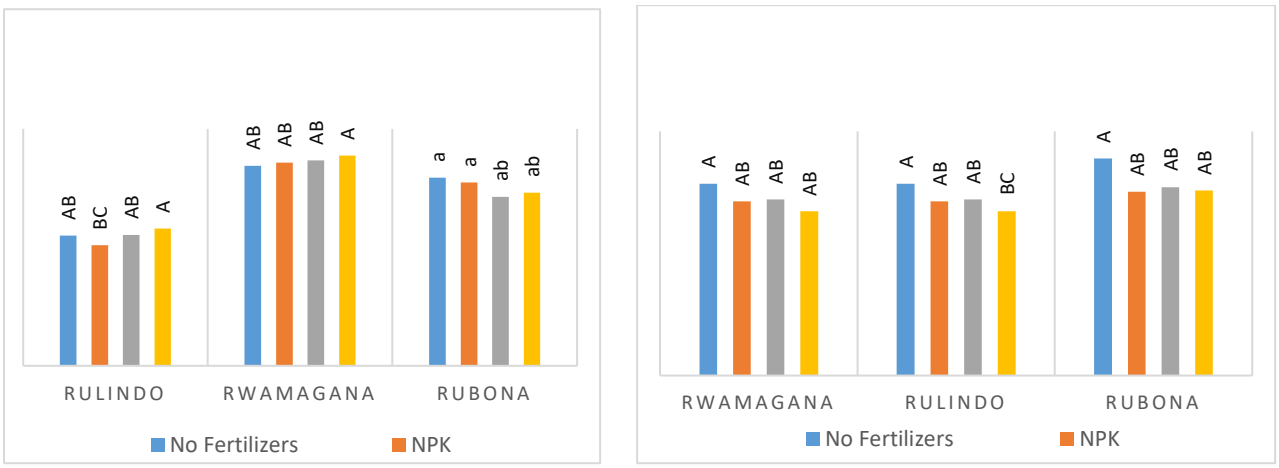

Photo 22: Average number of nodes per branch (left) and number of cherries per node

Effect on fruit maturation and subsequent yield parameters: The components of coffee cherry yield can be described in 4 points (1) yield per ha, (2) Yield per tree, (3) number of cherries per tree, (4) weight beans/cherry.

The cherry density is a function on the effect of nutrient uptake during the maturation stage of the fruit development. The nutrient use efficiency will have implication of grain filling of photo assimilates and consequently grain weight and subsequent grain yield.

The analysis of variance following a REML procedure (table 2) revealed significant difference between different treatments (fertilizer type) for all the yield and quality parameters i.e weight of 100 cherries (P=0.01), weight of 100 parchment beans (P<0.001), cherry yield per tree (P<0.001), plot yield (P<0.001),) and overall quality scores

(P<0.001). The interaction between fertilizer type and site or site specific performance was not significant (**Table 58, Figure 3, 4**).

Table 58: Mean square estimates for yield and quality parameters (numbers in blankets represent P-value or significant differences

Source of variation	d.f.	Weight of 100 beans (cher-ries)	Weight of 100 beans (parchment)	Yield/ tree	Plot yield	Quality scores
Site	1	0.202 (0.714)*	0.202 (0.714)	154457 (0.004)	2471315 (0.004)	0.2 (0.913)
Rep	2	1.182 (0.461)	1.182 (0.461)	16514 (0.301)	264228 (0.301)	33.03 (0.173)
Rep.Site	2	3.312 (0.141)	3.312 (0.141)	39601(0.007)	633616 (0.0077)	32.68 (0.176)
Treatment	3	192.097 (0.01)	192.097(0.001)	1759076 (0.001)	28145214 (0.001)	277.28 (0.001)
Site.Treatment	3	0.329 (0.874)	0.329 (0.874)	7983 (0.602)	127732 (0.602)	40.04 (0.112)
Residual	12	1.431	1.431	12415	198643	16.2
Total	23					
* P value in brackets						

At least the effect of one treatment was significantly different from other treatments for beans density, yield per tree and quality scores. Interaction between treatments and trial locations was not significant for all the parameters meaning there was no specific environmental influence on the fertilizer use efficiency.

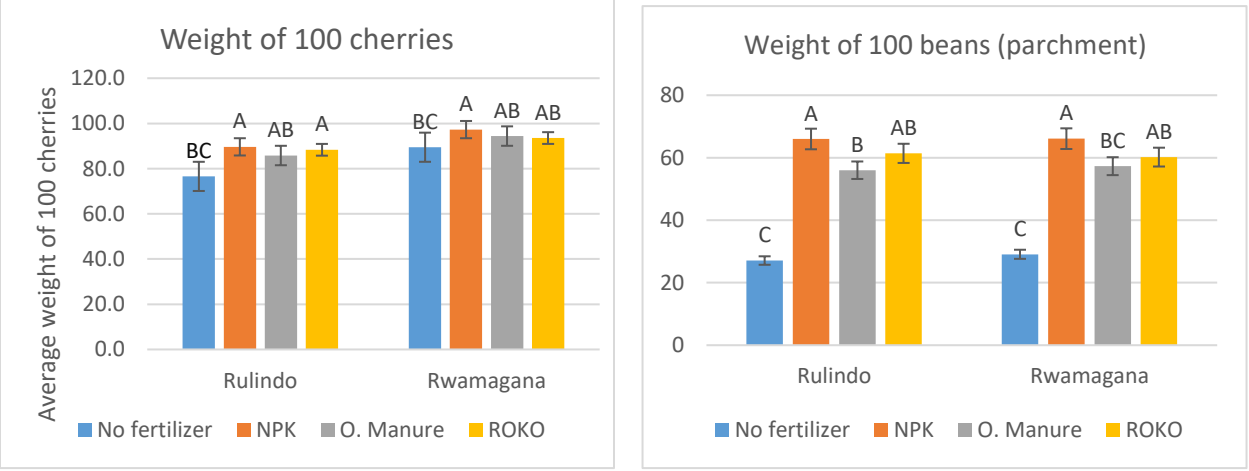

Photo 23: Average weight of 100 cherries (left) and parchments

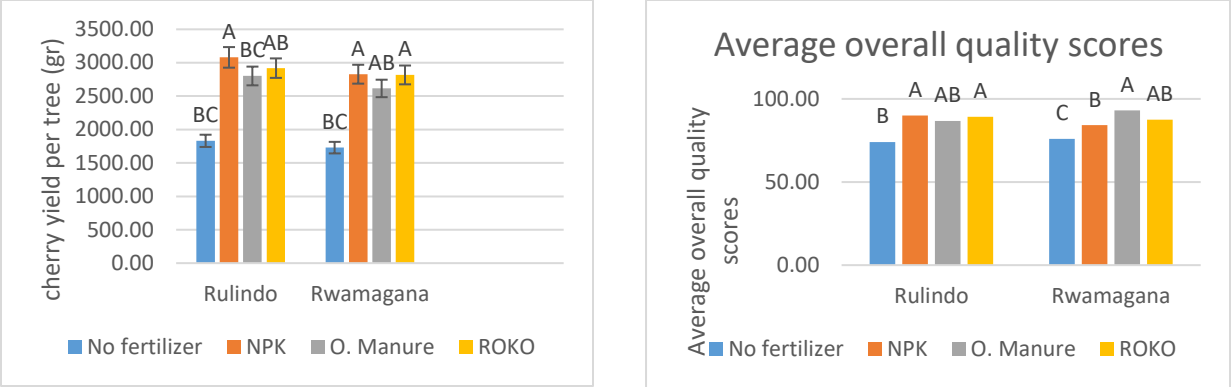

Photo 24: Average cherry yield per tree (left) and quality evaluation

The existence of a significant difference between treatment means that there is a least one fertilizer type that performed well compared to the rest of fertilizer in a specific trial location where the lack of significant different interaction between fertilizer types and trial locations indicate that there was no wide performance rather the performance was site-specific. This means that significantly different effects of fertilizers were obtained within-trial locations rather than between trial locations.

For yield components, all the tree fertilizer types performed well, and in most of the cases, and effect of Rokohumin was statistically similar to the effect of NPK and slightly different or equal to the effect of manure. Control treatment recorded the lowest yield components. Nutrients are required for both the vegetative growth of coffee trees and the production of high-quality beans and hence nutrient imbalances can affect the coffee quality. Several reports have revealed that the balance between the soil nutrients was well correlated with coffee quality attributes. The nutrient balance should have been improved in treatments consisting of NPK and Rokumin in comparison to organic manure and treatment. Nutrient balance in organic manure is common in most fertilizer programs as a nutrient are slowly released. Foliar nutrients are absorbed directly by the plant leaves, which is the goal of fertilization, to begin with. It also increases the rate of photosynthesis and thereby also stimulates the absorption of nutrients by plant roots. In general, the supply of nutrients via the roots is restricted under low rainfall and low pH soils because of the negative effect of drought and salinity on nutrient availability. The efficacy of foliar fertilization has several times been reported higher than that of soil fertilizer application in these situations. The reasons for this are because of the supply of the required nutrient directly to the location of demand in the leaves and its relatively quick absorption. In regards to the above statements, the efficacy of Rokohum as a foliar spray was revealed to have an effect on plant vigor, yield, and quality parameters similar to inorganic fertilization (NPK) from statistical perspectives. The efficacy was even higher than that of soil organic fertilization. This is an indication that Rokohum is potentially an efficient foliar fertilizer in coffee farming systems. Due to the nature of organic fertilizers, it would be better to use Rokohumin as a supplement to inorganic fertilizer to maximize the fertilizer use efficiency. However, more investigations are needed to add value to the current findings. The efficacy can be improved through the combination of Rokohumin with other sources of nutrients i.e inorganic fertilizers (NPK). A more exhaustive deep dive is needed to investigate crop response to varied application rates and frequency of applications.

Coffee seed production

Lack of a coffee seed sector is among major constraints to improve future coffee quality. Major coffee varieties are shown in **Table 59**. The other set of hybrids in shown in **Table 60**.

Table 59: National performance trials: List and origin of varieties

VARIETY NAME	PROVIDER	IP RIGHT	BREEDER	HABIT	TYPE
AB3	Indonesia	Public domain	ICCRI	Tall	Line
BATIAN	Kenya	Registered in UPOV	CRI	Tall	Multiline
BLP10	Indonesia	Other	ICCRI	Tall	Line
BP432A*	Indonesia	Other	ICCRI	Tall	Line
CATIGUA MG2	Brazil	Registered in UPOV	Embrapa	Dwarf	Line
CATUAI V IAC144	Brazil	Public domain	Embrapa	Dwarf	Line
CENTROAMERICANO	Central America	Other	Promecafe	Dwarf	F1 hybrid
COL1	Colombia	Registered in UPOV	Cenicafe	Dwarf	Line
COL2	Colombia	Registered in UPOV	Cenicafe	Dwarf	Line
COL3	Colombia	Registered in UPOV	Cenicafe	Dwarf	Line
COL4	Colombia	Registered in UPOV	Cenicafe	Dwarf	Line
COL5	Colombia	Registered in UPOV	Cenicafe	Dwarf	Line
EC15	Central America	UPOV registration in process	CIRAD-ECOM	Dwarf	F1 hybrid
GEISHA	Panama	Public domain	F. Serracin	Tall	Line
IPR103	Brazil	Public domain	Embrapa	Dwarf	Line
IPR107	Brazil	Public domain	Embrapa	Dwarf	Line
K7	Kenya	Registered in UPOV	CRI	Tall	Line
KARTILA 1	Indonesia	Other	ICCRI	Dwarf	Line
LEMPIRA	Honduras	Other	IHCAFE	Dwarf	Line
MARSELLESA	Central America	Registered in UPOV	CIRAD-ECOM	Dwarf	Line
MUNDO MAYA	Central America	Registered in UPOV	CIRAD-ECOM	Dwarf	F1 hybrid
MUNDO NOVO 379/19	Brazil	Public domain	IAC	Tall	Line
ORO AZTECA	Mexico	Registered in UPOV	INIFAP	Dwarf	Line
PACAMARA	El Salvador	Public domain	ISIC	Dwarf	Line
PARAINEMA	Honduras	Other	IHCAFE	Dwarf	Line
PARAISO	Brazil	Registered in UPOV	Embrapa	Dwarf	Line
RUIRU 11	Kenya	Registered in UPOV	CRI	Dwarf	Complex hybrid
S4808	India	Other	CCRI	Dwarf	Line
S795	India	Other	CCRI	Tall	Line
SL28	Kenya	Registered in UPOV	CRI	Tall	Line
SLN5B	India	National Bureau of Plant Genetic Resources India	CCRI	Tall	Population
SLN6	India	National Bureau of Plant Genetic Resources India	CCRi	Tall	Population

For new plants, most farmers either produce then 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. Many nurseries are in remote areas and use local and old varieties of poor health status, which do not take into consideration genetic traceability or even variety name.

Table 60: List of F1 hybrids under multi-locational trials

First Batch, all with dwarf stature					Second, with dwarf stature				
N	Hybrids	Female	Male	Origin	N	Hybrids	Female	Male	Origin
1	Harrar X Ruiru 11	Harrar	Ruiru 11	RAB	1	W020B	Obata	4602	WCR
2	W100B	Obata	GeishaHERBAZU	WCR	2	W030B	Obata	4679	WCR
3	W11-la	Iapar 59	4550	WCR	3	W040B	Obata	4863	WCR
4	W14-la	Iapar 59	4863	WCR	4	W070B	Obata	16691	WCR
5	W15-la	Iapar 59	4873	WCR	5	W100B	Obata	GeishaHERBAZU	WCR
6	W19-la	Iapar 59	Geisha LaLuisa	WCR	6	W12-LA	Iapar 59	4602	WCR
7	W20-la	Iapar 59	GeishaHERBAZU	WCR	7	W16-LA	Iapar 59	4877	WCR
8	W29MA	Marsellesa	Geisha a Luisa	WCR	8	W21MA	Marsellesa	4550	WCR
9	W30MA	Marsellesa	GeishaHERBAZU	WCR	9	W22MA	Marsellesa	4602	WCR
10	W050B	Obata	4873	WCR	10	W24MA	Marsellesa	4863	WCR
11	W060B	Obata	4877	WCR	11	W26MA	Marsellesa	4877	WCR
12	BM139x5A	BM139	5A	RAB	12	BM139xCatimor	BM139	Catimor	WCR
13	BM139x6A	BM139	6A	RAB	13	JacksonxRuiru11	Jackson	Ruiru 11	RAB
14	W33GL	Geisha La Luisa	4679	WCR	14	Harrar x Ruiru11	Harrar	Ruiru 11	RAB
15	W37GL	Geisha La Luisa	16691	WCR					
16	W38GL	Geisha La Luisa	16728	WCR					
17	W40H	GeishaHERBAZU	4602	WCR					
18	W42H	GeishaHERBAZU	4863	WCR					
Second batch, with tall stature									
No	Hybrids	Female	Male	Origin	No	Hybrids	Female	Male	Origin
15	W31GL	Geisha La Luisa	4550	WCR	21	W45H	Geisha HERBAZU	16691	WCR
16	W32GL	Geisha La Luisa	4602	WCR	22	BM139x5A	BM139	5A	RAB
17	W35GL	Geisha La Luisa	4873	WCR	23	BM139x6A	BM139	6A	RAB
18	W36GL	Geisha La Luisa	4877	WCR	24	BM139xBatian	BM139	Batian	RAB
19	W41H	GeishaHERBAZU	4679	WCR	25	JacksonX6A	Jackson	6A	RAB
20	W44H	GeishaHERBAZU	4877	WCR	26	Harrarx5A	Harrar	5A	RAB

To this end 2.5 tons of RABC 15 (modern variety) and 0.5 t of BM139 and Jackson (traditional varieties) were produced and distributed to farmers through the partnership with coffee washing station managers. The amount of genetically clean seeds is equivalent to around 9,000,000 seedlings and can plant at least 3200 ha of land. However, seed producers do not have the needed tools to identify and trace varieties as they move from seed gardens to nurseries, from nurseries to farmer fields. This matters because different varieties do different things. And if farmers don't know or can't trust what they have, they are exposed to huge risk.

Coffee soil survey

Coffee soil survey was conducted in major coffee growing areas and aimed to characterize major nutrients and soil physical properties to map relative suitability of the current soils for coffee (**Table 61**), where red color indicates low nutrient level, yellow – moderate nutrient level, and green normal nutrient level and blue for unusually high, possibly outlier level of nutrients

Table 61: Results from the soil survey (Soil Physical properties in various agroecological zones of Rwanda)

Field Name	pH	*EC (Salts)	P	K	Ca	Mg	S	Na	Fr	Mn	B	Cu	Zn	C.E.C	*Total N	OM	*C/N ratio	Ca %	Mg %	K %	Na % (ESP)	Other Bases %	H	Ca: Mg
		uS/cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	Meq /100g	%	%		%	%	%	%	%	%	
Gisuma Kamuhozi	4.64	35.5	1.92	81.5	668	209	41.5	23.6	89.7	36.2	0.13	2.95	0.54	13.6	0.20	3.56	10.3	24.6	12.8	1.54	0.75	8.12	52.2	1.92
GisumaGahinga Coopplot	4.53	111	8.51	42.4	1790	325	18.3	22.2	109	96.3	0.80	7.58	3.65	31.8	0.19	4.87	14.9	28.1	8.51	0.34	0.30	8.34	54.4	3.30
GisumaGahinga CoopOffic	4.38	93.3	4.01	310	671	148	270	34.7	87.6	153	0.35	3.43	5.07	16.3	0.13	2.46	11.0	20.6	7.57	4.88	0.93	8.64	57.4	2.72
Gisuma Murinzi	4.43	46.4	2.15	78.9	1070	198	33.8	18.0	114	74.6	0.52	4.53	2.27	20.8	0.23	4.72	11.9	25.8	7.95	0.97	0.38	8.54	56.4	3.24
Gashonga Nyamutarama	3.86	88.1	2.23	56.1	78.7	17.0	21.9	15.2	86.7	23.6	0.31	1.66	0.31	3.11	0.23	6.64	16.8	12.6	4.55	4.62	2.12	9.68	66.4	2.78
Gashonga Rango	4.13	79.4	6.57	174	227	49.9	197	22.9	58.9	20.7	0.46	1.66	0.24	7.37	0.16	3.27	11.9	15.4	5.64	6.06	1.35	9.14	62.4	2.73
Gashonga Gatare	4.78	29.1	91.8	136	2400	332	18.6	24.4	198	28.2	0.30	2.45	2.58	35.6	0.19	4.27	13.1	33.7	7.77	0.98	0.30	7.84	49.4	4.34
Gashonga Muti	4.43	99.9	3.16	603	346	75.8	85.6	15.1	105	66.4	0.28	2.87	0.56	11.3	0.24	5.48	13.3	15.3	5.57	13.6	0.58	8.54	56.4	2.74
Hingakawa Karambi	4.29	27.4	1.86	86.9	275	35.3	17.9	24.1	232	3.58	0.72	0.49	0.31	6.24	0.20	5.65	16.4	22.0	4.71	3.57	1.68	8.82	59.2	4.67
Hingakawa Ngogo	4.45	26.3	7.45	107	425	44.4	19.6	21.7	289	7.36	0.29	0.99	1.51	8.07	0.16	3.73	13.6	26.3	4.59	3.40	1.17	8.50	56.0	5.74
TUK Nyarunazi	4.50	37.7	6.87	102	1010	216	16.5	24.2	182	21.6	0.41	2.56	0.35	19.7	0.20	4.89	14.2	25.6	9.13	1.33	0.53	8.40	55.0	2.81
TUK Rwakabanda	4.96	55.5	4.21	175	540	73.4	11.4	14.9	187	16.5	0.16	1.31	0.54	8.19	0.21	5.16	14.3	33.0	7.47	5.48	0.79	7.48	45.8	4.41
TUK Agahiza	4.79	28.1	1.41	51.3	1040	209	15.5	21.5	80.2	25.9	0.53	2.40	0.24	16.7	0.18	4.61	14.9	31.2	10.4	0.79	0.56	7.82	49.2	2.99
Mayogi Kabare 1	4.27	24.4	4.00	60.0	431	79.1	15.5	14.4	155	20.3	0.28	0.89	0.30	9.61	0.22	5.62	14.9	22.4	6.86	1.60	0.65	8.86	59.6	3.27
Mayogi Kabare 2	4.82	48.8	7.16	493	1070	314	13.6	14.5	177	8.06	0.24	0.57	0.35	21.3	0.23	6.04	15.3	25.1	12.3	5.94	0.30	7.76	48.6	2.04
Mayogi Rudogo	6.65	49.7	18.6	334	1170	252	13.3	29.2	220	68.8	0.34	1.81	1.59	9.93	0.16	3.15	11.4	58.9	21.2	8.63	1.28	4.75	5.25	2.79
Mayogi Gikumba	4.89	17.3	3.62	383	907	314	18.4	31.6	94.2	12.6	0.78	2.98	0.65	18.3	0.20	5.38	15.6	24.8	14.3	5.36	0.75	7.62	47.2	1.73
Nyampinga CWS	4.52	19.3	3.75	32.9	136	11.8	25.5	17.2	129	2.54	0.077	1.58	0.21	2.53	0.20	5.05	14.7	26.9	3.89	3.33	2.95	8.36	54.6	6.92
Nyampinga Nyakizu	4.22	24.1	3.80	10.7	43.9	9.64	29.0	15.7	140	0.86	0.083	0.60	< 0.20	1.30	0.17	3.97	13.6	16.9	6.18	2.11	5.25	8.96	60.6	2.73
Nyampinga Uwimpundu	4.20	37.6	5.03	35.7	152	31.4	20.4	21.4	186	3.39	0.13	2.06	0.36	4.02	0.15	3.22	12.5	18.9	6.51	2.28	2.31	9.00	61.0	2.90
Nyampinga Ruhinga	4.36	26.2	4.33	47.9	52.0	12.9	23.7	24.1	132	2.27	0.28	1.24	< 0.20	1.78	0.18	3.17	10.2	14.6	6.06	6.92	5.90	8.68	57.8	2.42
Kunda Ikawa yacu Kamina	4.71	12.0	1.80	70.2	444	86.1	12.7	27.5	303	4.28	0.15	0.85	0.66	7.85	0.18	3.19	10.3	28.3	9.14	2.29	1.52	7.98	50.8	3.09

Field Name	pH	*EC (Salts)	P	K	Ca	Mg	S	Na	Fr	Mn	B	Cu	Zn	C.E.C	*Total Nitrogen	OM	*C/N ratio	Ca %	Mg %	K %	Na % (ESP)	Other Bases %	Hydrogen %	Ca:Mg Ratio
		uS/cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	Meq /100g	%	%		%	%	%	%	%	%	%
Gisuma Kamuhozi	4.64	35.5	1.92	81.5	668	209	41.5	23.6	89.7	36.2	0.13	2.95	0.54	13.6	0.20	3.56	10.3	24.6	12.8	1.54	0.75	8.12	52.2	1.92
Gisuma Gahinga Coop plot	4.53	111	8.51	42.4	1790	325	18.3	22.2	109	96.3	0.80	7.58	3.65	31.8	0.19	4.87	14.9	28.1	8.51	0.34	0.30	8.34	54.4	3.30
Gisuma Gahinga Coop Office	4.38	93.3	4.01	310	671	148	270	34.7	87.6	153	0.35	3.43	5.07	16.3	0.13	2.46	11.0	20.6	7.57	4.88	0.93	8.64	57.4	2.72
Gisuma Murinzi	4.43	46.4	2.15	78.9	1070	198	33.8	18.0	114	74.6	0.52	4.53	2.27	20.8	0.23	4.72	11.9	25.8	7.95	0.97	0.38	8.54	56.4	3.24
Gashonga Nyamutarama	3.86	88.1	2.23	56.1	78.7	17.0	21.9	15.2	86.7	23.6	0.31	1.66	0.31	3.11	0.23	6.64	16.8	12.6	4.55	4.62	2.12	9.68	66.4	2.78
Gashonga Rango	4.13	79.4	6.57	174	227	49.9	197	22.9	58.9	20.7	0.46	1.66	0.24	7.37	0.16	3.27	11.9	15.4	5.64	6.06	1.35	9.14	62.4	2.73
Gashonga Gatare	4.78	29.1	91.8	136	2400	332	18.6	24.4	198	28.2	0.30	2.45	2.58	35.6	0.19	4.27	13.1	33.7	7.77	0.98	0.30	7.84	49.4	4.34
Gashonga Muti	4.43	99.9	3.16	603	346	75.8	85.6	15.1	105	66.4	0.28	2.87	0.56	11.3	0.24	5.48	13.3	15.3	5.57	13.6	0.58	8.54	56.4	2.74
Hingakawa Karambi	4.29	27.4	1.86	86.9	275	35.3	17.9	24.1	232	3.58	0.72	0.49	0.31	6.24	0.20	5.65	16.4	22.0	4.71	3.57	1.68	8.82	59.2	4.67
Hingakawa Ngogo	4.45	26.3	7.45	107	425	44.4	19.6	21.7	289	7.36	0.29	0.99	1.51	8.07	0.16	3.73	13.6	26.3	4.59	3.40	1.17	8.50	56.0	5.74
TUK Nyarunazi	4.50	37.7	6.87	102	1010	216	16.5	24.2	182	21.6	0.41	2.56	0.35	19.7	0.20	4.89	14.2	25.6	9.13	1.33	0.53	8.40	55.0	2.81

TUK Rwakabanda	4.96	55.5	4.21	175	540	73.4	11.4	14.9	187	16.5	0.16	1.31	0.54	8.19	0.21	5.16	14.3	33.0	7.47	5.48	0.79	7.48	45.8	4.41
TUK Agahiza	4.79	28.1	1.41	51.3	1040	209	15.5	21.5	80.2	25.9	0.53	2.40	0.24	16.7	0.18	4.61	14.9	31.2	10.4	0.79	0.56	7.82	49.2	2.99
Mayogi Kabare 1	4.27	24.4	4.00	60.0	431	79.1	15.5	14.4	155	20.3	0.28	0.89	0.30	9.61	0.22	5.62	14.9	22.4	6.86	1.60	0.65	8.86	59.6	3.27
Mayogi Kabare 2	4.82	48.8	7.16	493	1070	314	13.6	14.5	177	8.06	0.24	0.57	0.35	21.3	0.23	6.04	15.3	25.1	12.3	5.94	0.30	7.76	48.6	2.04
Mayogi Rudogo	6.65	49.7	18.6	334	1170	252	13.3	29.2	220	68.8	0.34	1.81	1.59	9.93	0.16	3.15	11.4	58.9	21.2	8.63	1.28	4.75	5.25	2.79
Mayogi Gikumba	4.89	17.3	3.62	383	907	314	18.4	31.6	94.2	12.6	0.78	2.98	0.65	18.3	0.20	5.38	15.6	24.8	14.3	5.36	0.75	7.62	47.2	1.73
Nyampinga CWS	4.52	19.3	3.75	32.9	136	11.8	25.5	17.2	129	2.54	0.077	1.58	0.21	2.53	0.20	5.05	14.7	26.9	3.89	3.33	2.95	8.36	54.6	6.92
Nyampinga Nyakizu	4.22	24.1	3.80	10.7	43.9	9.64	29.0	15.7	140	0.86	0.083	0.60	< 0.20	1.30	0.17	3.97	13.6	16.9	6.18	2.11	5.25	8.96	60.6	2.73
Nyampinga Uwimpundu	4.20	37.6	5.03	35.7	152	31.4	20.4	21.4	186	3.39	0.13	2.06	0.36	4.02	0.15	3.22	12.5	18.9	6.51	2.28	2.31	9.00	61.0	2.90
Nyampinga Ruhinga	4.36	26.2	4.33	47.9	52.0	12.9	23.7	24.1	132	2.27	0.28	1.24	< 0.20	1.78	0.18	3.17	10.2	14.6	6.06	6.92	5.90	8.68	57.8	2.42
Kunda Ikawa yacu Kamina	4.71	12.0	1.80	70.2	444	86.1	12.7	27.5	303	4.28	0.15	0.85	0.66	7.85	0.18	3.19	10.3	28.3	9.14	2.29	1.52	7.98	50.8	3.09

1.7 Crop Protection Program

The Crop Protection research focuses on management of major pests and diseases affecting priority crops. Under conditions of ongoing climate change, there is unprecedented pest and disease pressure due to the effects of climate change. Program promotes sustainable crop protection practices for increased agricultural productivity. During the fiscal year 2020 -2021, the crop protection's activities were the following:

- Development of technologies for pests and diseases management,
- Development of extension materials and production of guidelines for pests and diseases management,
- Conduct Mobilization campaigns on pests' management through radio programs and spot,
- Development of technical materials to be used during surveys and carry out seasonal survey for pests' presence and their identification for different crops,
- Trainings of frontline extension agents on management of major pests & disease and on Pesticides safe use & handling,
- Running and providing advice to farmers through Plant Clinics,
- Backstopping of plant doctors for effectiveness of plant clinics,
- Linking of plant clinics to FFS and TwigireMuhinzi Groups

Bio-efficacy trials against FAW

Different tests were conducted to evaluate the effectiveness of new or existing pesticides against insect pests. Trials on evaluation of pesticides for FAW management in Gasabo and Bugesera districts were established. The effectiveness was conducted on two new insecticides such as Ruruka 70% WDG, FWAFIX82% WDG and Radiant 120 SC.

Bio-efficacy trials against thrips in pastures of Nyagatare and Gatsibo district

A recent outbreak of aphids in eastern province of Rwanda has prompted RAB management and Gatsibo and Nyagatare District representatives to conduct a baseline study to know the causes of the problem, the status of farms and knowledge of dairy farmers on the problem. A Survey and observation methods were used in the study. The results indicated that the majority of aphid's outbreak was in Gatsibo (Rwimbogo sector) with 93.2% of surveyed farms (139); while only 6.8% were the farms (10) suspecting to hold the aphids in Nyagatare district (Matimba and Rwimiyaga sectors). The number of suspected farms (reported before) with aphids was reduced from 167 to 139 in Gatsibo district due to some dairy farms allocated and dedicated to crops plantation. While considering the incidence of aphids in farms, we realized that the total affected areas was 300ha and 100.4ha in Gatsibo and Nyagatare, respectively. 98.2% of farms were natural while only 1.8% were planted farms. In addition, 96.4% of surveyed farms were classified as overgrazed and 3.6% as not managed. According to the general observations done in pastures, the present insects were aphids which colonized different species in pasture (ex: *Hyparrhenia* sp (Umukenke), *Sporobolus* spp (Imitsina), *Brachiaria* (Ivubwe). The pastures showed yellowish, reddening, and drying as symptoms.

The insects were present in 56.4% of surveyed farms. Dairy farmers reported that the insects can be seen in other crops such as beans, ground nuts, maize, millet, Napier grass and Paspalum. The dairy farmers indicated that, despite the high incidence level of aphids, there was no control measures against the insects. A frequency of 93% dairy farmers indicated that they did nothing to tackle the outbreak. The outbreak had yielded the negative effects on the milk production and weight loss of animals. It needs a more practical management practice. In Rwanda, there is no management strategies to control aphids. There is therefore a need to develop a natural safe product

for the management of the above pasture pests. In the present study, the EWC+ as a new organic product on the market was evaluated for their effects on the mortality in laboratory and their effectiveness in reducing aphid's population in open pastures. In laboratory conditions, the results revealed that EWC+ could kill 100% of aphids when 2-4ml are used. However, when the product is used in pastures, it could reduce at 85% the population of aphids when 4ml/20 litres of water are used. When the product is applied for the second time, it can also reduce the population of aphids at 82%. Pyrethrum EWC+ was a very effective product and can be used in pastures against aphids. The efficacy of Pyrethrum EWC+ increased with the time of exposure. It was a very effective against aphids at doses equal to or higher than 3ml/20l of water. The effectiveness of Pyrethrum EWC+ increased with dosage. The numbers of insects in treated plots with liquid soap were found to be numerically the highest in all observations (**Photo 23**). This is not a conclusive study (conducted in two weeks), there is a need for a detailed and comprehensive study.

Photo 25: Laboratory test on the management of aphids

Bio-efficacy trials against storage insect pests

Diatomaceous Earth insecticide was tested against Maize, Beans, Wheat and Sorghum grains to control main stored grain insect pests of these crops (**Photo 24**). The main objective of the study was to evaluate the efficacy of Diatomaceous Earth insecticide applied at different dosages on Maize, Beans, Wheat and Sorghum grains to control main stored grain insect pests of these crops; and to determine the accurate application dose (screening dosage) for an accurate control and protection of stored grains. The studies were conducted in the laboratory (controlled conditions) and in storehouse/warehouse (non-controlled conditions). The trials were laid out in a Completely Randomized Design with doses ranging from 1.1-1.5g/500 of bean grains. However, for maize, sorghum and whaeta grains the doses ranged from 2.2-4.0g/500 g of grains. There was also untreated grains as negative control and treated grains with superskana as positive control. The observations consisted of adult's mortality, grains damage, live and dead insects after emergence. The results indicated that Diatomaceous earth was a very effective alternative to the existing substances in stored-grain protection at doses equal to or higher than 2.0g/ for bean grains and at doses equal to or higher than 4.0g/ 500g for maize, sorghum, and wheat grain. These doses require further evaluation

in terms of safety for the consumer and residues on stored products. The number of insects (dead and live) in storehouse and percent grain damage and grains weight loss in treated grains were found to be numerically the lowest in all observation times. The grain damage decreased with increase of Diatomaceous earth dosage. The recommended dose could be 2g/500g for bean grains and 4.0g/ 500g for maize, sorghum, and wheat grains. The killing capacity of Diatomaceous earth inert dust was low, especially, in small treated grains such as sorghum and wheat. Diatomaceous earth is effective against maize weevil and bean weevil but higher doses and/or longer exposures are needed to obtain 100% adult kill. The presence of storage insects in treated grains with Diatomaceous earth underline the need for a more integrated approach for maize weevil and bean weevil management in storage facilities especially hygiene and sanitation practices by reducing or eliminating the source of infestation.

Photo 26: Laboratory trials on the management of stored insect pests

Comparing sex pheromone lures at capturing fall armyworm moths (*Spodoptera frugiperda*) in maize fields

The American origin - Fall Army Worm (FAW, *Spodoptera frugiperda*) has been a fast-spreading invasive pest of maize in Africa and Asia. In other regions, the moths are migratory and affect maize seasonally. Therefore, monitoring is crucial for early detection of invasions, forecasting population appearance in the cropping cycle, as well as for decision making for pest management interventions. Several types of commercial sex pheromones lures and traps are in use depending on the region and monitoring purpose, therein limiting comparability among studies. A constant, slow, but sufficient release of pheromones is desirable. We here-with assessed moth captures by traps laced with 9 different lures of the fall armyworm sex pheromone (**Photo 25**). Our results from 9 field trials in southern Rwanda in October and November 2020 revealed that traps with PheroBio and Russel IPM lure well-captured fall armyworm over time, and Trece lures also to an acceptable level. In contrast, PPI CAR and PheroBank lures, regardless of the type, were of relatively low attractiveness, although their capture rates remained relatively stable. The lures and traps captured an about 1/4 proportion other noctuid moths (Trece lures even up to 40%). This can lead to potential misinterpretation by unexperienced users. As for the PPI CAR and PheroBank lures, it can be concluded that a higher attractiveness would be desirable, whereas duration of pheromone release and specificity to fall armyworm seem good. It is to be noted that the captured moths are currently at a taxonomist for final verification, and subsequently data may still slightly change.

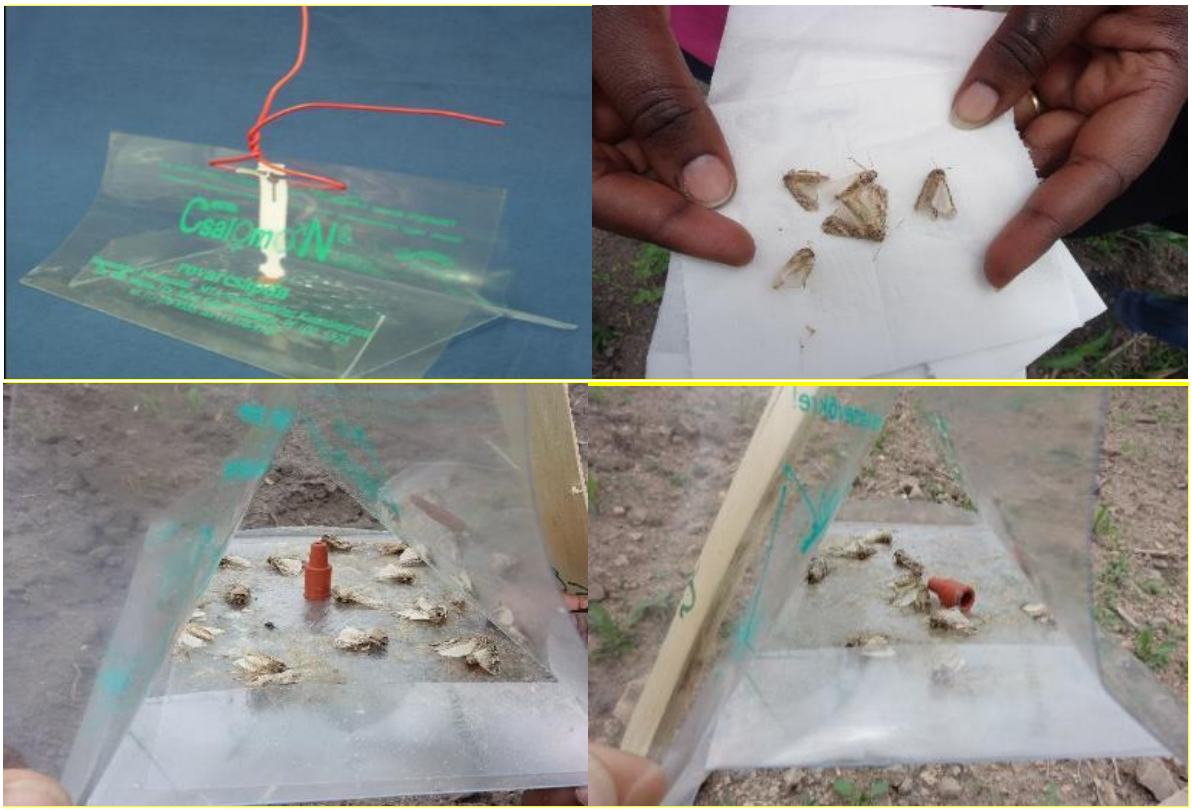

Photo 27: Pheromones traps for the management of Fall Army Worm (FAW)

Development of extension material and guidelines for pests and diseases management

Extension materials on management of millepede, thrips, mango mealybug, crickets, Desert Locusts, were developed, printed and several copies were distributed to farmers across the country. Additionally, more than 10 pest management decision guides & factsheets were revised and updated in collaboration with Plantwise.

Mobilization campaigns on pests' management through radio programs and spot

Mobilization campaigns were conducted to manage Fall Armyworm in collaboration with Hinga Weze project in Nyabihu, Ngororero, Rutsiro, Nyamasheke, Karongi, Nyamagabe, Ngoma, Kayonza, Gatsibo and Bugesera districts. During this campaign, 2,356 farmers (329 youths, 1,072 males and 975 females) were reached and 586.2ha of maize covered (**Photo 26, 27**). In addition, Radio talks on banana Thrips, Mango mealybug and Millipedes management were aired on RBA and B&B Umwezi radios.

Photo 28: Extension workers demonstrating to farmers how to prepare pesticides in controlling FAW (right) and Extension workers introducing to farmers FAW and other pests and how to control them efficiently (left)

Photo 29: Demonstration of how to mix pesticides with water in the sprayer before application (right) and Different partners including RAB, CABI, local authorities participated in the campaign (left)

Seasonal survey for pests' presence and their identification for different crops

For this activity, technical materials (questionnaires, protocols) were developed and used during surveys. Four surveillances were conducted on Red thrips in Banana plantation, aphids affecting pastures in Nyagatare and Gatsibo districts, Mango mealy bugs in East, South & Western parts of the country and another surveillance on major pests that are found in exportation commodities in collaboration with RICA in the aim of updating national pests list. In addition, more than 30 field visits were conducted in different parts of the country. These field visits were mainly focusing on assessment of pest/aphids in pasture/farms in Nyagatare & Gatsibo districts, red thrips in Banana plantation, assessment of viruses in hot peper in Bugesera district, Millipede assessment in Kamonyi, Muhanga, Ruhango, Huye, Gatsibo & Nyagatare districts, caterpillars in bean in Nyanza, and regular follow up on FAW in almost all maize fields during A, B & C season. Advice to manage all the mentioned insect pests were provided to farmers (**Photos 28-32**).

Photo 30: The Crop Protection team detecting millepedes in Kamonyi

Photo 31: Millipedes' Symptoms on different crops

Photo 32: Aphids on grasses and its natural enemy (coccinellid on the right)

Photo 33: Mango mealybugs detection

Photo 34: Bunches infested by rust thrips at Mushikiri, Kirehe (left) and meeting with farmers on rust banana thrips control (right)

Trainings of frontline extension agents on management of pests, diseases and safe use of pesticides

In collaboration with CABI, we trained 17 RAB technical staff for FAW management. In partnership with ICIPE, we trained more than 200 extension agents that are expected to train 50 farmers each, making it a total of 1,000 farmers. Both training took place in Bugesera. In addition, up to 600 frontline extension workers, mainly through ToT were trained (**Photo 34**).

Photo 35: Training of trainers on the management of Fall Army Worm (Nkongwa idasanzwe)

Running and providing advice to farmers through Plant Clinics (PCs)

The following strategies have been adopted to increase farmer knowledge on pests and diseases: Running of 15 Plant Clinics (PCs) was achieved through linking them with Farmer groups such as FFS and Twigire Muhinzi; Backstopping of 40 plant doctors on how to conduct and run plant clinics; and linking of plant clinics to FFS and TwigireMuhinzi Groups. Through this activity, 20 groups of farmers were linked with 20 PCs.

Regular field visit is the recommended way to manage insect pests and diseases. While the current management option is through pesticides use, the integrated pest management is necessary for a better, safe, economic, and environmental friendly's management of insect pests and diseases. The need of local leaders in the management of insect and diseases especially timely reporting of any new outbreak of the pests.

1.8 Plant and Microbial Biotechnology Program

Plant and Microbial Biotechnology research aims to improve crops mushroom production and develop sustainable disease management using modern biotechnological methods. Main activities were training in genetic engineering, establishment of plant genetic engineering and containment facilities, introduce and test Modern technologies, establish demonstration plots for tissue culture derived plants, training of farmers on mushrooms production technologies, and establish demonstration plots to showcase mushrooms production technologies.

1.8.1 Plant tissue culture

Tissue culture is a technique of cultivating an explant under aseptic conditions on a defined artificial medium to get substantial number of planting materials in a short period of time and small place. Conventional plant propagation has risk of transmitting diseases and produces very few propagules. RAB has established facilities for plant tissue culture at Rubona, and Musanze RAB stations where tissue culture unit focused on (1) Development and optimization of protocols for in vitro propagation of Passion fruits and Coffee hybrids, (2) Development and optimization of protocols for in vitro conservation of Cassava, Sweet Potatoes and Banana, (3) Development and optimization of protocols for in vitro propagation of Passion fruit and Tamarillo, (4) In vitro production of Coffee, Cassava, Banana and Sweet potatoes disease free planting materials, (5) Establishment of demo-plots for banana tissue culture derived plants.

Development and optimization of protocols for in vitro propagation of Passion fruits and Coffee

One experiment was conducted and aimed at developing protocol of three varieties of Coffee (Mibirizi 87, 92 and 93) through embryogenesis techniques. The coffee media was supplemented with 2.25mg^{l-}, 3mg^{l}, 4mg^{l}, 4.5mg^{l} of Benzylaminopurine (BAP). Sterilization of leaf discs was performed using bleach disinfectant (Jik) at 25% for 20 minutes and ethanol at 70% at one minute. The incubated in dark room for callus and embryos development. Up to now no callus or embryo is developed and the experiment is still on going and waiting the results.

Development and optimization of protocols for in vitro crop conservation

In vitro conservation of Cassava, Sweet Potatoes and Banana (3 varieties per each crop) was initiated. Media composition depended on crop, but all media were deprived with growth regulators for slow growth keeping. Non-use of growth regulators reduced the growth and increased time from inoculation to sub-culturing for all tested crops (**Photo 35**). Next will be testing effects of conservative sugars.

Photo 36: Conservation of Sweet Potatoes (left), Cassava (Middle) and Banana (right) cultured on media with no growth regulators.

Development and optimization of protocols for in vitro propagation of Passion fruit and Tamarillo

The passion fruit experiment was conducted through embryogenesis approach. MS medium supplement with 2.25mg^{l-}, 3mg^{l}, 4mg^{l}, 4.5mg^{l} of Benzylaminopurine (BAP) was used. Sterilization of leaf discs was performed using bleach disinfectant (Jik) at 25% for 20 minutes and ethanol at 70% at one minute. The incubation was carried out in the dark room to stimulate callus and embryos development. This experiment passion fruit is still ongoing. The tamarillo experiment was conducted using embryogenesis technique. Leaf discs were collected and washed thoroughly under running tap water for 20minutes, then followed by the second tap water mixed with liquid soap washing before the actual disinfestation under the aseptic cabinet Lamina flow. Initiation media was made of three different types of sugars as followed: Fructose (15, 20 and 25 mg/L), Saccharose (15, 20 and 25mg/L) and normal table sugar with 15, 20, and 25 mg/L. This experiment is still ongoing but there is a promising results (**Photo 36**).

Photo 37: Embryogenesis of Tamarillo, callus development (Middle), embryos developed (Right).

In vitro production of Coffee, Cassava, Banana and Sweet potatoes disease free planting materials

Tissue culture laboratories have produced a considerable number of plantlets (**Table 62**).

Table 62: Production of plantlets under Rubona station Tissue culture labs July 2020- July 2021

Crop	Target 2020/21	Plantlets produced in tissue culture lab
Coffee	6,000	8, 386
Banana	6,000	7, 375
Sweet potato	12,000	9,760
Cassava	12,000	14, 203
Potato	1,600,000	1,481,033

A total of 290 potato varieties were multiplied at Musanze lab (167 local breeds, 100 CIP clones and 23 are released clones under mass multiplication).

Establishing demo-plots for banana

On farm demonstration plots were established in Huye, Gisagara and Nyanza Districts, where more than 100 farmers benefited banana clean planting material from Rubona lab (**Photo 37**).

Photo 38: Distribution of in vitro plantlets to farmers at Gisagara district

1.8.2 Rhizobium laboratory

Bio-fertilizer production

Since 1980, research on bio-fertilisers in Rwanda focused on rhizobium production. Use of 400g of efficient Rhizobium strain provided soybean yield increase equivalent to 100kg/ha urea application. Thus, research aims to identify local microbial bacteria or fungi which are able to enrich soil with nitrogen, phosphorus and organic matter to sustain crop yields. In this perspective, the laboratory of microbiology was established for mass production of inoculants based on demand.

Identification and authentication of rhizobium isolates

Five rhizobium isolates from bean (NAR1, NAR2, NAR3, NAR4 and NAR5) and soybean (NAR54, NAR59, NAR62, NAR64 and NAR66) were identified (**Table 63**). All isolates were gramnegative and rod shaped. Morphological characteristics of the isolates such as acid/alkali production for rhizobium isolates showed that all isolates turned yeast extract mannitol agar (YEMA) medium containing Bromothymol blue (BTB) from green to yellow colour (**Photo 38**). Growth assessment of these isolates revealed that they have fast or intermediate growth and they have made the reaction on YEMA and BTB media.

Table 63: Characteristics of the soybean and bean rhizobium isolates used

Entry	Altitude	Longitude	Latitude	Sub-family	Growth rate	CR YMA*	BTB YMA**
54	1783m	E 029°48’35,6"	S 02°05’55.1’’	Soybean	Fast	Non Absorbent	Fully Absorbent
59	1783m	E 029°48’35,6"	S 02°05’55.1’’	Soybean	Intermediate	Non Absorbent	Non-Reactive
62	1783m	E 029°48’35,6"	S 02°05’55.1’’	Soybean	Intermediate	Non Absorbent	Non-Reactive
64	1783m	E 029°48’35,6"	S 02°05’55.1’’	Soybean	Fast	Non Absorbent	Fully Absorbent
66	1601m	E 030°31’13,1"	S 01°55’59.7’’	Soybean	Fast	Non Absorbent	Fully Absorbent

16	1730m	E 029°50'13,1"	S 02°01'52,0"	Bean	Intermediate	Non Absorbent	Non-Reactive
42	2050m	E 029°44'00.1"	S 01°25'46.2''	Bean	Fast	Non Absorbent	Fully Absorbent
92	1991m	E 029°44'03,4"	S 01°25'51,1"	Bean	Fast	Non Absorbent	Fully Absorbent
113	1691m	E 029°50'46,2"	S 02°00'07,0"	Bean	Intermediate	Non Absorbent	Non-Reactive
114	1658m	E 029°51'10,7"	S 02°00'55,1"	Bean	Fast	Non Absorbent	Fully Absorbent

*RC YEMA: Congo Red yeast extract mannitol agar, **BTB YEMA Bromothymol blue yeast extract mannitol agar

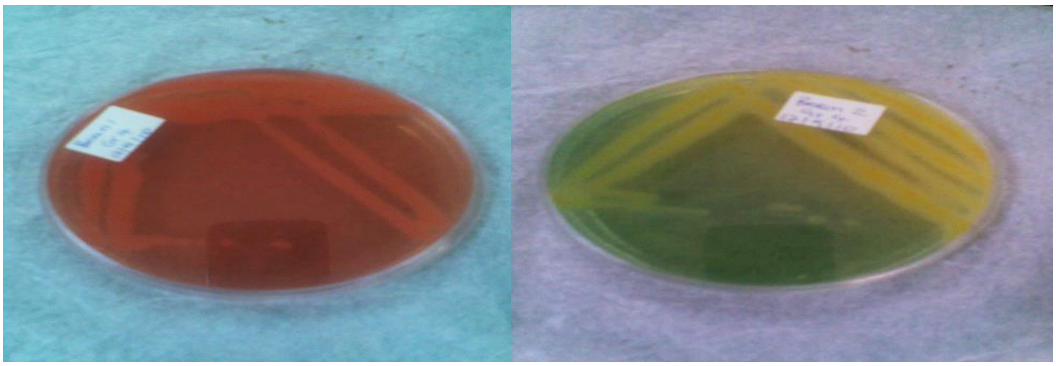

Photo 39: Bean and soybean isolates growing on YEMA Congo Red and BTB.

Evaluation of potential of local rhizobium isolates in agro-ecological zones of Rwanda

Trials with 5 rhizobium isolates (NAR1, NAR2, NAR3, NAR4 and NAR5) for bean (MAC2245) and 5 isolates (NAR54, NAR59, NAR62, NAR64 and NAR66) for soybean (RWASOY20-3) were established at Nyagatare, Ngoma and Gashora sites to test their effect on crop yield. Progress results showed that all tested isolates were able to infect the roots of bean and soybean and form noodles in both, greenhouse and field (**Photo 39**). Further work will assess their potential for improving bean and soybean yield.

Photo 40: Rhizobium isolates assessed for nodulation in greenhouse and field conditions.

Mass production of Rhizobium

Mass production of rhizobium inoculants for bean and soybean, known as CIAT889 and Spain, was done on demand from RAB Seed Unit and farmers. About 7,314 packets of inoculants of soybean were produced; among them 6,127 packets were distributed through season 2021A and B.

1.8.3 Mushroom laboratory

Mushroom production

Mushroom laboratory at RAB focuses on oyster mushroom (*Pleyrotus ostreatus*) production, establishment of demo plots; training of stakeholders in mushroom value chain, production and distribution of mushroom spawn and tubes, and conducting research. Mushroom lab is conducting research on production development protocol for new mushroom species (*Pleurotus erengi*, *Pleurotus auricularia*, and *Ganoderma lucidum)*. Their spawn production is still at laboratory stage (**Photo 40**). Many mushroom tubes are using cotton seed hulls which are very expensive and unavailable. Ongoing trials aim to identify an alternative substrate.

Photo 41: Production of spawn in the laboratory

Training of stakeholders in mushroom value chain

Different stakeholders of mushroom production value chain were trained to increase their knowledge and skills and raising their awareness on the JUNCAO technology. In this regard, 500 farmers were trained on mushroom cultivation (**Photo 41**). Participants have learned theory of mushroom industry, planting and fruiting management, and harvesting. These trainings in mushroom production were conducted in different districts and supported by SAIP project. After training, many farmers are able to produce mushroom tubes themselves.

Photo 42: Training of farmers (left) and district focal persons of SAIP project (right)

Production and distribution of mushroom spawn and tubes

Mushroom laboratory is one of the leading producers of mushroom tubers serving as seed material for farmers involved in mushroom production. A total of 90,960 mushrooms tubes were produced and distributed in different districts of Rwanda in collaboration of China Rwanda Agriculture Demonstration center (CRATDC) (**Photo 42**).

Photo 43: Mushoom spawn and tubes production by the farmers (left) and in the CRATDC (Right) (left)

Demonstration plots to promote mushrooms production technologies

On station and farm demonstration plots (**Photo 43**) to increase the awareness on mushroom production opportunity and also to help farmers to get knowledge and skills were established using Farmer field schools.

Photo 44: Demonstration plots of mushroom production

1.8.4 Plant pathology

The plant pathology unit conducts research on crop diseases. Recent activities included beans and banana disease diagnostic. The studies conducted were (1) To characterize anthracnose races in three major common bean growing zones, (2) Identification of seed borne pathogens in common bean value chain, and (3) Microbial identification of unknown banana disease reported in Eastern zone.

Characterization of anthracnose races in three major common bean growing zones

Samples were collected in the northern and eastern agricultural zones of Rwanda, in the main anthracnose hotspot areas. Potato Dextrose Agar (PDA) and Marthur media were prepared following the International Center

for Tropical Agriculture (CIAT) protocol. Small portions of bean pods and leaves with anthracnose symptoms were plated on both media and incubated upside down to grow at the temperature of 24°C, then incubated for 5 days. Through this study, 150 anthracnose isolates were identified, and a single spore culture for further anthracnose isolates characterization is on-going.

Evaluate common bean seed samples for presence of seed borne pathogens

Bean seeds were collected in major bean producing districts of Rwanda. Seeds were surfaced sterilized in 3% sodium hypo chloride for 10 minutes then 70% ethanol for 3 minutes and rinsed in several changes of sterile distilled water and letting dry for a short while on sterile filter paper in a laminar flow cabinet. The Petri dishes containing bean samples were incubated for 7 days at 20-22°C. After incubation, fungi were grown out of the seeds and have been isolated on Potato Dextrose Agar (PDA) which was prepared according to manufacturers' instruction as described by Marcenaro and Valkonen (2016). Specific and selective media have been used to isolate pure cultures of fungi of seed-borne in common bean. After isolation, identification of fungal colonies was carried out a visual observation in Petri dishes. Through this study, 45 families of fungal pure cultures of seed borne diseases of common bean have been identified (**Photo 44**).

Photo 45: Seed born fungi in seeds of common beans (left to right: seed born fungal in beans at early stage, seed born fungi in beans at advanced stage and pure culture of seed born fungi of common bean).

The activities conducted provided results from visual observation, growth and colony appearance. More characterization based on color, colony size, type of mycelium, fruiting bodies, and others are needed. These characterizations with microscopic identification, and morphology of the isolated fungal strains are recommended prior the molecular characterization.

Microbial identification of unknown banana disease reported in Eastern zone

Visual assessment of unknown banana disease and sample collection have been conducted in Eastern province, Ngoma district. Samples were collected on each part of the crop (stems, fruits and leaves). (**Photo 45**).

Photo 46: Samples of affected banana stems, fruits and leaves

Both leaves and stem samples were prepared and plated on PDA medium for fungal isolation and on Nutrient agar for both fungal and bacteria. The shell of banana fruit was removed and the infected browning part was plated on PDA medium, and another part was treated using water, mortar and pestle to make serial dilutions for bacteria isolation on the nutrient agar medium. Petri dishes containing cultures were incubated on 25°C for 7 days. Fungal was only found on leaves and fruits samples. Bacteria was found on all collected samples from leaves, stem and fruits. The pure cultures (**Photo 46**) of Bacteria and fungal isolates were isolated and further characterization is planned in next fiscal year.

Photo 47: Pure cultures of bacterial and fungal isolates from leaves, stem, and fruits of infected banana

1.8.5 Molecular Biology

The molecular biology unit has conducted research activities aimed at (1) enveloping a protocol for cleaning crop virus diseases and (2) identification of status of crop diseases.

Development a protocol for cleaning cassava virus diseases

Cassava production in Rwanda is severely threatened by the current epidemic of cassava brown streak disease (CBSD) and cassava mosaic disease (CMD). Both diseases are propagated via infected planting material. Therefore, an experiment was conducted to clean the infected planting material and eliminate CBSD and CMD infections

using meristem culture combined with heat treatment (thermotherapy) in 2 improved cassava varieties namely Cyizere and Mushedire. Leaf samples from cassava were collected for CBSVs detection. PCR detection was perfomed after first strand cDNA synthesis. These leaf samples showed amplifications for single and coïnfections of CBSVs with Mbazibwa primer pair (**Photo 47**).

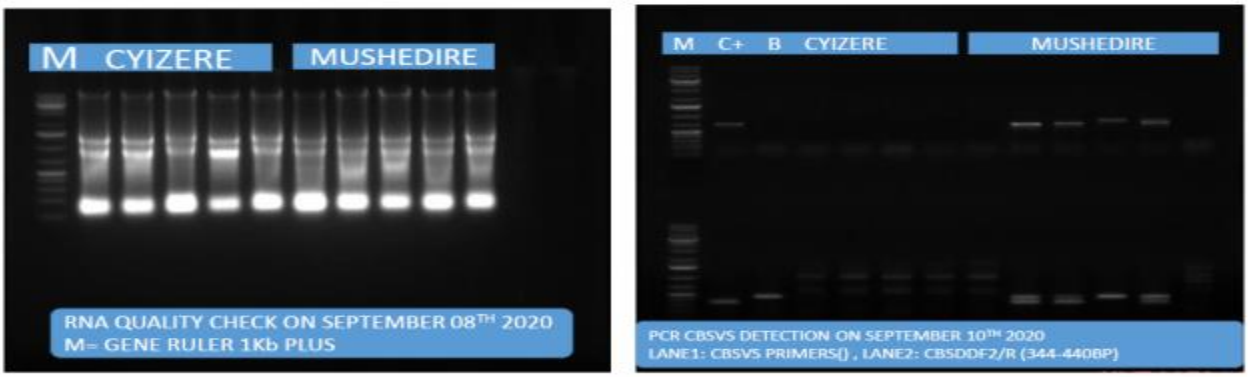

Photo 48: Gel Picture for RNA Quality check and CBSVs amplicons amplification

Thermotherapy: Five cassava stakes from each variety with its negative controls were harvested at Rubona. These stakes were subjected in thermotherapy chamber for 5 weeks (**Photo 48**).

Photo 49: Cassava stakes disinfected and established on heat therapy

Within 5 weeks, stakes subjected on heat therapy, were sprouted under 16 hours of light and 8 hours of darkness. Following Morgan Ferguson's manual, young sprouts were disinfected with 70% ethanol and commercial bleach. Under stereo microscope, the meristem tip were isolated and cultured on the regeneration full murashige and skoog medium supplimented with phytohormones and kept in darkness for 15 days. Callus was formed within 15 days and took 10 days to elongate under the light conditions. Young elongated embryos were grown to produce rooted shoots (**Photo 49**). This study has provided good results for cleaning cassava material from viruses. Further experiments will be conducted to improve this protocol.

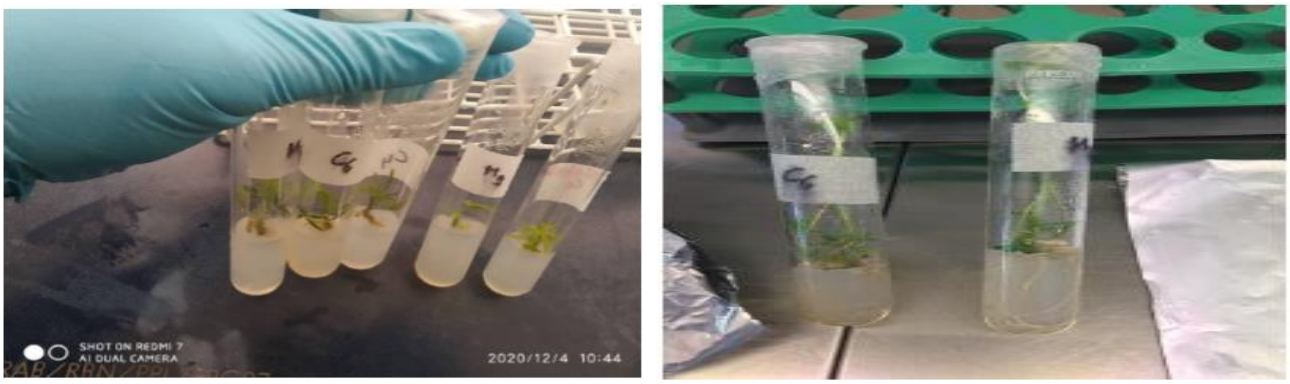

Photo 50: Full grown shoots with internodes

Monitoring of viral diseases in cassava confined field trial

Cassava brown streak virus (CBSV) and Ugandan cassava brown streak virus (UCBSV): 58 transgenic cassava leaf samples were collected in the confined field trial established at Rubona RAB station three months after planting (3MAP) using herbarium method and pressed to preserve the nucleic acid integrity. A total nucleic acids were extracted following CTAB (Cetyl trimethyl ammonium bromide) method for RNA extraction (Modified from Lodhi *et al.,* 1994 & Xu *et al.,* 2010). After RNA Integrity and purity and quality check, first strand cDNA was synthesized on forty-two 42 samples following manufacturer's instructions (New England Biolabs Protoscript II first strand cDNA synthesis kit) by denaturing RNA/oligo dT (23) VN at 42°C of reverse transcriptase 20 units as final concentration. A CBSVs PCR detection was performed following manufacturer's instructions (New England Biolabs, onetaq standard buffer pack) at 51°C as annealing temperature of Mbazibwa primer pair (CBSDDF2/CBSDDDR) and 0.2 µM as final concentration.

Cassava Mosaic Begomoviruses infections indexing: Fifty-eight young and tender cassava leaf samples were collected from confined field trial at Rubona station with 4 months after planting (4MAP) using paper bags and kept at -20°C. DNA was extracted following Dellaporta et al. with some modifications (1983). After DNA integrity, purity and quality check, a PCR test was performed for cassava mosaic begomoviruses (African Cassava Mosaic virus-ACMV and East Africa Cassava Mosaic Virus-EACMV) detection. The results from this analysis revealed that no *Cassava brown streak virus* and Cassava Mosaic virus were detected in the sampled plants. The samples analysed are described in **Table 64**. RNA and DNA were successfully extracted and all samples analyzed shown that there is no virus. This trial must be continuously monitored and indexed from all cassava viral infections.

Table 64: Description of analysed samples

RNA samples	DNA samples
1-5: TH16-T2XR2-82	1-5: TH16-T2XR2-34
6-10: TH16-R1XT2-222	6-10: TH16-T2XR2-82
11-15: TH16-R1XT2-182	11-15: TH16-R1XT2-222
16-20: TH16-T2XR2-34	16-20: TME14-WT
21-24: TH16-T2XR1-35	21-25: TH16-T2XR1-33
25-29: TME14-WT	26-30: TH16-R1XT2-189
30-34: TH16-T2XR1-33	31-34: TH16-T2XR1-35
39-46: CYIZERE	35-58: CYIZERE

1.9 Crop Intensification Program

Crop Intensification Program is implemented through close collaboration of 12 RAB stations (Ntendezi, Nyamagabe, Gakuta, Gishwati, Tamira, Musanze, Rwerere, Rubilizi, Rubona, Nyagatare, Ngoma and Muhanga) and all 30 districts. The key players in this collaboration are Farmer Promoters (elected at village level), SEDOs (Socio-economic development officers working as permanent staff at cell level), sector and district agronomists working under supervision of the District Directors of Agriculture. These leaders are guiding the community to implement the major agriculture activities, decide on crops, priorities and mainstream the various investments and support through project and different partner activities. The CIP is focused to promote modern farming of major and storable food crops which play key role in country's food security: maize, beans, wheat, potato, cassava, rice and soybean. A total of **17,005 demo plots** were established in **2021A** and **15,388 demo plots** were established in season **2021B** (**Table 65**). The most demonstrated crop was maize in season A and beans in season B. Detailed number of demo plots per district and province in 2021A and B season is shown in **Table 66**.

Table 65: Summary of demo plots per crops at country level

Crop	*# of Demo plots season 2021A*	*# of Demo plots season 2021B*
Maize	13687	3619
Beans	2103	8258
Soybean	108	697
Banana	31	222
Rice	64	81
Cassava	253	639
Irish potato	600	970
Wheat	55	270
Vegetables	104	632
Total	**17005**	**15388**

Crop Intensification Program has concentrated on seasonal activities as season launching, establishment of demonstration plots for good agronomic practices, chemical fertilizer use and best varieties for each crop, trainings through Twigire Muhinzi initiative, distribution of agricultural input in form of annual crop seeds, mainly, maize, and chemical fertilizers, supply of lime where appropriate, seasonal follow up of consolidated land areas, progress of planting and harvest. A total of 16,317 and 17,210 FPs were trained during season A and B (**Table 66**). More than 30,000 Twigire Muhinzi groups were formed and 178,222 and 265,738 farmers were reached through these groups in season A and B, respectively (**Table 66**).

In **2021 A**, a total of **814,137 Ha** were planted under land consolidation, which is **59.6%** of the total cultivated area. In **2021 B**, a total of **551,366 Ha** was planted in land consolidated sites, which was **40.4%** of the total cultivated land. While crops differed and depended on district and agro-ecological conditions, as well as farmer community decision, the main crops in land consolidated sites where most of agricultural input was applied were maize, beans, wheat, rice, Irish potato, cassava, soybean and vegetables. A total of **58,375 tonnes** of mineral fertilizer and **11,418 tonnes** of lime was applied in land consolidated sites.

The details on crops planted versus planned targets are shown per district and province in **Tables 67** and **68** below. The input use details are shown in **Table 69**.

Table 66: Number of demo plots, farmer promoter trainings, TwigireMuhinzi groups and farmers reached per district and season (A+B)

		Training of Farmer Promoters				Number of demo plots				TwigireMuhinzi (TM) groups									
		2021A		2021B		2021A		2021B		2021A					2021B				
	District	Target	# people trained	Target	# people trained	Target	# demo-plots established	Target	# demo-plots established	# TM groups formed	# farmers in TM groups		# farmers reached through TM groups		# TM groups formed	# farmers in TM groups		# farmers reached through TM groups	
											Male	Female	Male	Female		Male	Female	Male	Female
1	Kirehe	698	653	~~758~~	~~713~~	572	861	454	846	163	1228	1680	1228	1680	1631	16791	17297	17636	25252
2	Ngoma	567	543	~~587~~	~~529~~	454	755	524	376	435	3511	5041	3511	5041	450	3334	4576	3334	4576
3	Kayonza	496	448	~~533~~	~~466~~	386	590	436	371	0	0	0	0	0	504	5511	6244	5511	6250
4	Gatsibo	716	678	~~750~~	~~688~~	577	664	572	474	1379	12434	9851	12434	9851	1159	13204	9058	10764	6045
5	Nyagatare	783	687	~~806~~	~~729~~	555	656	577	698	0	0	0	0	0	1231	12364	9826	8779	7393
6	Rwamagana	588	541	~~591~~	~~524~~	436	265	555	520	0	0	0	0	0	1106	8658	11035	8112	10112
7	Bugesera	658	642	~~730~~	~~667~~	524	864	386	596	1053	8442	8114	8442	8114	2516	13819	15590	10702	9750
8	Nyarugenge	143	135	~~157~~	~~145~~	111	259	123	170	209	979	1961	979	1961	45	400	359	126	297
9	Gasabo	374	348	~~360~~	~~335~~	268	309	111	255	299	2072	2790	2072	2790	223	1967	1833	2488	3203
10	Kicukiro	169	152	~~177~~	~~156~~	123	141	268	96	160	888	1659	888	1659	9	81	98	98	179
11	Gicumbi	807	776	~~874~~	~~835~~	605	709	605	789	434	3213	2259	3213	2259	960	6923	6479	7494	6848
12	Burera	713	676	~~753~~	~~697~~	541	703	589	531	719	7287	5519	7287	5519	979	10345	9726	8761	8238
13	Musanze	575	537	~~615~~	~~547~~	411	302	411	334	0	0	0	0	0	0	0	0	0	0
14	Gakenke	790	759	~~881~~	~~810~~	589	435	541	395	0	0	0	0	0	0	0	0	0	0
15	Rulindo	649	610	~~724~~	~~664~~	476	236	476	299	0	0	0	0	0	0	0	0	0	0
16	Nyabihu	520	499	~~617~~	~~599~~	395	700	396	581	1343	15431	12124	15431	12124	1454	16604	14774	9172	9461
17	Rubavu	536	525	~~598~~	~~572~~	401	722	456	615	764	5862	6943	5862	6943	553	5176	5830	4725	5561
18	Ngororero	541	526	~~608~~	~~580~~	408	460	317	517	2732		23873		23873	2269	20635	21271	15999	17755
19	Rutsiro	498	475	~~618~~	~~595~~	409	409	512	823	420	2906	3969	2906	3969	2817	10112	15352	13743	21232
20	Karongi	655	609	~~671~~	~~640~~	505	472	318	594	2385	9511	10931	9511	10931	3869	37758	37037	21902	21856
21	Nyamasheke	683	627	~~733~~	~~716~~	538	759	503	733	2088	1370	895	1370	895	547	9185	5753	17899	12630
22	Rusizi	720	708	~~766~~	~~725~~	582	472	493	750	1299	683	606	683	606	1751	10446	9752	11740	5585
23	Kamonyi	410	386	~~436~~	~~384~~	300	395	300	295	1152	6854	7768	6854	7768	658	5835	5162	5645	5050
24	Muhanga	435	415	~~439~~	~~411~~	318	491	582	326	1419	9325	12319	9325	12319	712	4473	6299	3999	6360
25	Ruhango	614	593	~~706~~	~~653~~	512	806	538	651	913	8192	8058	8192	8058	960	9348	10904	10322	11411
26	Nyanza	501	466	~~555~~	~~511~~	396	500	395	416	1104	27401	9093	27401	9093	1188	9475	10111	6344	7210
27	Huye	625	599	~~655~~	~~588~~	493	588	401	672	1032	7799	8551	7799	8551	1029	8293	10842	8352	11136
28	Gisagara	625	593	~~663~~	~~581~~	503	578	505	621	1605	14159	13935	14159	13935	1052	10308	9829	13055	26849
29	Nyamagabe	685	668	~~757~~	~~711~~	523	1011	409	920	2959	23371	17911	23371	17911	2208	20993	20673	8286	15463
30	Nyaruguru	418	443	~~485~~	~~439~~	317	893	408	10	2097	9568	11972	9568	11972	10	50	150	21	36
TOTAL		**17,192**	**16,317**	**18,603**	**17,210**	**13,228**	**17,005**	**13,228**	**13,161**	**15,274**	**28,163**	**187,822**	**182,486**	**187,822**	**31,890**	**272,088**	**275,860**	**235,009**	**265,738**

Table 67: Targets and Planted area for main CIP crops in 2021 A and B in Northern and Western Provinces

Northern Province

	Season 2020A													Season 2020B											
	Target (ha)						Planted (ha)							Target (ha)						Planted (ha)						
District	Maize	Beans	Potato	Wheat	Cassava	Vegetables	Maize	Beans	Potato	Wheat	Cassava	Vegetables	**Total**	Maize	Beans	Potato	Wheat	Vegetables	Cassava	Maize	Beans	Potato	Wheat	Cassava	Veg	**Total**
Burera	14500	6745	7000	3500	-	-	14139	7499	7049	3487	-	-	**32173**	500	13810	7000	7000	-	-	944	13813	6710	6498	-	89	**27965**
Musanze	7360	3176	3100	800	-	-	7360	3185	3102	800	-	-	**14447**	640	8766	3970	1060	-	-	640	8766	3970	1060	-	-	**14436**
Gakenke	15524	4396		263	203.5	-	15680	4415		219	132	-	**20447**	2218	15260		234	-	68	2301	15925		632	100	-	**18958**
Rulindo	6346	18641	1138	103	15	-	6300	18688	1139	103	15	-	**26245**	418	16092	921	1047	-	-	424	16099	931	1047	-	-	**18501**
Gicumbi	5294	20686	6997	1764	159.5	200	5522	21278	6289	1450	150	235	**34923**	1503	8722	5711	4150	100	104	1831	10934	5597	3797	106	**121**	**22386**
							Total planted (ha) in 2021A (ha)						**128,235**							**Total planted in 2021B (ha)**						**102,246**

Western Province

	Season 2021A																Season 2021B														
	Target (ha)								Planted (ha)								Target (ha)								Planted (ha)							
District	Maize	Beans	Potato	Wheat	Cassava	Veg	Rice	Soy	Maize	Beans	Potato	Wheat	Cassava	Veg	Rice	Soy	Total	Maize	Beans	Potato	Wheat	Veg	Cassava	Rice	Soy	Maize	Bean	Potato	Wheat	Cassava	Veg	Rice	Soy	Total
Nyabihu	4989	12179	11076	297	-	250	-	-	4989	12149	10076	297	-	250	-	-	**27761**	5076	4084	11255	4732	110	-	-	-	5059	3975	9165	3326	-	91	-	-	**21616**
Rubavu	3000	5275	5550	-	-	-	-	-	2986	5523	5570	-	-	-	-	-	**14079**	2900	4925	4450	-	466	-	-	-	2934	4861	4445	-	-	452	-	-	**12240**
Rutsiro	5316	8337	6610	-	715	50	-	-	5319	8381	6611	-	715	71	-	-	**21096**	3385	6750	5492	1050	31	-	-	-	3753	6771	4937	1060	-	31	-	-	**16435**
Karongi	5220	12200	2000	-	1250	-	-	-	5365	12609	2034	-	1297	-	-	-	**21305**	150	16368	1000	-	-	1250	-	-	190	16529	1040	-	1310	-	-	-	**19069**
Ngororero	5991	7500	6023	270	3050	113	-	-	5991	7500	5879	270	2591	99	-	-	**22330**	**2790**	6558	5777	2772	42	1471	-	-	3816	6561	4591	2267	1213	38	-	-	**18486**
Nyamasheke	12304	13654	-	-	12120	-	400	1155	12306	13064	-	-	12144	-	400	1157	**39071**	329	11310	-	-	-	1375	400	1192	329	11006	-	-	1375	-	366	1192	**14268**
Rusizi	9700	7500	-	-	8000	-	1414	460	9700	7500	-	-	8007	-	1414	460	**27081**	186	13118	-	-	-	-	1414	922	186	13118	-	-	-	-	1414	922	**15640**
									Total planted in 2021A (ha)								**172,723**									**Total planted in 2021B (ha)**								**117,754**

Table 68: Targets and Planted area for main CIP crops in 2021A and B in Southern, Eastern and Kigali City Provinces

Southern Province

	Season 2021A													Season 2021B														
	Target (ha)						Planted (ha)							Target (ha)								Planted (ha)								
District	Maize	Beans	Rice	Soybean	Cassava	Potato	Maize	Beans	Rice	Soy	Cassava	Potato	Total	Maize	Beans	Rice	Soy	Cassava	Veg	Potato	Wheat	Maize	Beans	Rice	Soy	Cassava	Veg	Potato	Wheat	**Total**
Muhanga	3700	15450	257	350	1575	-	3701	22654	222	437	1816	-	**28830**	1950	15450	257	350	1575	-	-	-	1016	9643	1365	303	1365	-	-	-	**13692**
Ruhango	1100	10000	480	125	8250	-	1187	11975	516	159	10107	-	**23944**	900	9055	480	125	8250	-	-	-	963	7148	6724	99	6724	-	-	-	**21658**
Kamonyi	4100	15000	563	200	3025	-	4,157	17875	563	201	5919	-	**28715**	670	14000	563	0	3025	-	-	-	863	13991	188	0	188	-	-	-	**15230**
Nyanza	3700	28840	1000	300	6900	-	3961	29475	1180	311	7046	-	**41973**	750	15000	700	160	6900	-	-	-	780	15045	747	160	6838	-	-	-	**23570**
Huye	4268	25466	2728	130	3850	-	4312	25695	2728	148	3871	-	**36754**	1230	7649	1364	80	3850	249	-	-	1231	7680	1364	81	3865	225	-	-	**14446**
Gisagara	7200	26623		546	1796	-	7229	27013		560	1848	-	**36650**	150	10843	1245	-	-	-	-	-	152	11189	1327	-		-	-	-	**12668**
Nyaruguru	6500	28800	4900	-	-	4900	7052	31114	-	-	-	5358	**43524**	1865	8440	-	-	-	-	8350	12791	2112	8119	-	-	-	-	7939	12406	**30576**
Nyamagabe	10767	10610	1022 8	-	1609	10228	10879	11981	-	-	1466	10371	**34697**	900.0	10000	-	-	1920	-	3300	7015	566	10638	-	-	1908	-	3742	6814	**23668**
							Total planted in 2021A (ha)						**275087**									**Total planted in 2021B (ha)**								**155508**

Eastern Province

	Season 2021A													Season 2021B													
	Target (ha)						Planted (ha)							Target (ha)						Planted (ha)							
District	Maize	Beans	Rice	Soybean	Cassava	Veg.	Maize	Beans	Rice	Soybean	Cassava	Veg.	Total	Maize	Beans	Rice	Soy	Cassava	Veg.	Maize	Beans	Rice	Soy	Cassava	Veg	Total
Nyagatare	23684	13030	1250	200	250	1900	23718	13069	1540	282	218.5	-	**38828**	12270	22180	2250	150	-	-	12544	22196	1718	38	-	-	**36496**
Gatsibo	15907	1337	1291	100	492	300	17271	3479	1291	197	460	186	**22884**	777	13430	1291	400	360	-	773	13477	1291	346	299	-	**16186**
Kirehe	25000	9189	816	266	800	-	24817	10011	816	278.5	760	150	**36833**	1272	25152	816	534	15	-	1646	24312	816	514	11	-	**27299**
Ngoma	21243	21066	1244	60	1500	221	21279	21241	1244	71	1474	60	**45369**	-	21434	1244	60	-	-	-	20910	1244	40	-	-	**22194**
Kayonza	9042	17078	1619	272	1819	250	7074	13796	1479	135	779	203	**23466**	3330	15290	1626	391	763	-	2599	14742	1626	220	542	-	**19729**
Rwamagana	16453	14900	315	610	1100	350	16471	15264	280	559	1063	351	**33988**	535	16600	513	30	-	810	756	16590	478	61	-	533	**18418**
Bugesera	8500	21823	1000	200	1000	454	9313	21992	1001	222	980	398	**33906**	8500	23132	703	220	-	1500	7786	23411	667	200	-	782	**32846**
							Total planted in 2021A (ha)						**235274**							**Total planted in 2021B (ha)**						**`173168**

Kigali City Province

	Season 2021A												Season 2021B											
	Target (ha)						Planted (ha)						Target (ha)						Planted (ha)						
District	Maize	Beans	Rice	Soybean	Cassava	Veg.	Maize	Beans	Rice	Soybean	Veg.	**Total**	Maize	Beans	Rice	Cassava	Soybean	Veg.	Maize	Rice	Beans	Soybean	Cassava	Veg	**Total**
Gasabo	870	114	260	-	-	-	900	146	258	-	-	**1304**	114	870	200	-	-	423	131	280	903	-	-	334	**1648**
Kicukiro	450	245	36	6	-	200	484	446	58	6	204	**1198**	122	466	69	-	80	120	123	42	462	80	-	82	**789**
Nyarugenge	100	150	4	2	-	60	100	150	4	2	60	**316**	50	150	4	-	-	60	50	4	150	-		49	**253**
							Total planted in 2021A (ha)					**2818**							**Total planted in 2021B (ha)**						**2690**

Table 69: Mineral fertilizer use in FY 2020-2021

	Western Province										
	Annual target (tonnes)					Applied (tonnes)					
District	DAP	Urea	NPK	Blends	Lime	DAP	Urea	NPK	Blends	Lime	**Total**
Nyabihu	899	458	3685	-	-	971	586	5186	-	-	**6743**
Rubavu	949	438	3008	-	-	949	437.6	3008	-	-	**4395**
Rutsiro	680	368	482	2.9	-	652	357	475	0.9	1050	**1485**
Karongi	750	340	188	68	2275	930	609	266	64	2919 (travertine)	**1869**
Ngororero	1033	454	507	-	-	989	474	444	-	-	**1907**
Nyamasheke	1012	705	975	-	-	1126	846	685	-	-	**2657**
Rusizi	807	800	901	-	3000	1111	1091	941	-	3030	**3143**
Total											**21199**

	Eastern Province											
	Annual target (tonnes)						Applied (tonnes)					
District	DAP	Urea	NPK	Blends	Lime	Total	DAP	Urea	NPK	Blends	Lime	**Total**
Nyagatare	830	760	195	377	-		1495	1244	105	540	-	**3384**
Gatsibo	585	491	390	142	-		659	716	410	113	-	**1898**
Kirehe	707	470	96	-	-		664	412	91	-	-	**1167**
Ngoma	1088	677	156	-	-		1043	608	135	-	-	**1786**
Kayonza	516	461	415	-	-		390	295	364	-	-	**1049**
Rwamagana	895	517	326	-	-		1096	726	401	48	-	**2271**
Bugesera	505	291	270	-	-		219	476	213	64	-	**972**
Total												**12527**

	Northern and Kigali Provinces										
	Annual target (tonnes)					Applied (tonnes)					
District	DAP	Urea	NPK	Blends	Lime	DAP	Urea	NPK	Blends	Lime	**Total**
Burera	697	166	775	223	-	697	166	775	223	1083	**1861**
Musanze	2131	756	2360	386	-	2131	756	2360	386	-	**5633**
Gakenke	1497	754	132	-	-	1497	754	132	-	-	**2383**
Rulindo	908	853	420	203	-	908	853	420	203	-	**2384**
Gicumbi	398	196	559	-	1765	563	288	519	-	1112	**1370**
Gasabo	86	83	102	-	-	159	167	92	22	-	**440**
Kicukiro	67	49	22	-	-	122	72	28	-	-	**222**
Nyarugenge	35	44	24	-	-	24	27	18	-	-	**69**
Total											**14362**

	Southern Province										
	Annual target (tonnes)					Applied (tonnes)					
District	DAP	Urea	NPK	Blends	Lime	DAP	Urea	NPK	Blends	Lime	**Total**
Muhanga	226	149	116	0.4	-	226	149	116	0.3	-	**491**
Ruhango	155	142	179	11.1	-	210	202	142	12.5	-	**567**
Kamonyi	272	364	236	54.2	-	272	364	236	54.2	-	**926**
Nyanza	260	231	198	24	1125	260	231	198	24	1125	**713**
Huye	315	239	373	98	1099	315	239	373	98	1099	**1025**
Gisagara	482	265	178	730	314	482	265	178	730	314	**1655**
Nyaruguru	848	737	118	21	?	848	737	118	21	?	**1724**
Nyamagabe	1178	958	785	265	?	1178	958	785	265	?	**3186**
Total											**10287**

II. LIVESTOCK RESEARCH AND TECHNOLOGY TRANSFER DEPARTMENT

Animal agriculture has contributed up 14% of the agricultural GDP and about 3.5% to the national GDP (NISR, 2020). Major policy and investments have been put in place to raise livestock productivity through adoption of improved breeds via the national programmes of Artificial Insemination and One Cow per poor family. These programmes encourage producers of crossbred animals by focusing on genetic improvement to meet current market and consumption demand. During the year 2020/2021, the department of Animal resources innovations and technology transfer continued with pursuit on improving the Animal Genetic in order to identify genotypes of animals, health of animals and forages that increase land and animal productivity.

2.1 Ruminant program

The ruminant program activities aimed to produce of forage seeds for improved animal feed resources; Conduct campaign to increase awareness on improved forages cultivation; Train dairy/beef, goats and sheep farmers on general husbandry (e.g. animal housing sanitation, disease prevention and management, feeds and feeding); Establish improved forages at different available niches to improve ruminant feeding; Map and to characterize nutritional content of available crop residues and agri-industrial by products; Establish hydroponic fodder technology in IDP model villages; Evaluate multiple ovulation and embryo transfer (MOET); Establish elite local goats breeding stock; and Establish Inyambo cattle breeding association for genetic resources conservation and use. All these deliverables were achieved regardless the challenges of COVID-19 pandemic.

Evaluation of growth performance of steer genotypes fed on *Chloris gayana* and *Panicum coloratum* supplemented with Leucaena leaf meal and molasses

The feeding trial was conducted at Mirama (Nyagatare research station) of Rwanda Agriculture and Animal Resources Development Board (RAB). The aim was to evaluate growth performance of steer genotypes fed on *Chloris gayana* and *Panicum coloratum* supplemented with Leucaena leaf meal and molasses. The dietary treatments were two different roughages: *Panicum coloratum* or *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 significance 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.

Evaluation of milk yield from dairy cows fed on Brachiaria hybrid cv. Mulato II and Rhodes grass (*Chloris gayana*)

Eight (Ankole × Jersey) crossbred cows (605±11 days of age and 203±35 kg live weight) were selected and divided into two groups of four. Four cows were randomly assigned to each dietary treatment in a completely randomised block design. Fortnight days for feed adaptation were allotted to individual cows. After adaptation period of 14 days, individual animals were measured to the nearest 100 g using mechanical Weigh Bridge (PORTEE 1000 kg, 2x1 m, B.C, 188021, RAPPORT). The animals from each group was ear tagged, randomly assigned to one of the two dietary treatments. Animals were put individual pens in a housed built for cows in the station and partitioned for stall feeding. ALBENDOZOLE (10 mL/10 kg body weight) and acaricide (Norotraz 12.5% E.C- Effective Concentration, 2 mL/1 L of water; twice/week) were used to control endo and ecto-parasites, respectively. Individual pens were cleaned every morning. Basal diets were hay of *Brachiaria* hybrid cv. Mulato II and Rhodes grass (*Chloris gayana*) harvested at Nyagatare RAB station where they were established without fertiliser application. The soil type of the plots was sandy clay with nitrogen and carbon content of 0.2±0.4% and 1.2±0.5%, respectively. These grasses were harvested after 90 days of establishment at a height of 15 cm from the ground. The hay was chopped (10 cm length) using forage chopper (Mild steel, 7 HP of power, electric motor/diesel engine, BrazAfric Ltd) before feeding. The hay was fed with commercial dairy concentrate supplements (2 kg/day). Grass hay, water, and mineral block were provided *ad libitum*. Daily feed offers and refusals were weighed, recorded and sampled at 9:00 h and 15:00 h for a period of 12 weeks. Feed sampling was done twice a week for a period of 12 weeks. Daily feed dry matter (DM), organic matter (OM), crude protein (CP), metabolisable energy (ME), calcium (Ca) and phosphorus (P) intake were calculated as the difference between feed offer and refusal corrected for the respective contents in the original samples. Feed conversion ratio (FCR) was calculated as the slope of the linear regressions of cumulative nutrient (DM, OM and CP) intakes on milk production. Milking was done twice daily, in the morning and in the evening for 12 weeks. Samples of feed offered and refusal were collected daily. Samples of feeds were taken and analysed for chemical composition. Results showed that Mulato II increased milk at 37% while dry matter intake (DMI) increase up to 9% o and Body weight gain increased up to 63% over *Chloris gayana*.

Evaluation of growth, feed intake and conversion ratio of improved goats fed Brachiaria grass and Napier grass mixed with or without Leucaena leaf meal

This study assessed the growth and feed intake performances of Galla goats and their crosses with local goats fed on Brachiaria grass cultivar Mulato II and Napier grass mixed with Leucaena leaf meal. Twenty-four Galla goats and 24 crossbred goats were selected and divided into four groups of three goats for each genotype and put in a partitioned house for goats' stall feeding. Goats from each group were identified using ear tags, randomised and then allotted one of the dietary treatments. Feed rations used as treatments were hay of Mulato II, silage of Napier grass, Mulato II, ML (67% Mulato + 33% Leucaena leaf meal) and NL (67% Napier grass + 33% Leucaena leaf meal). Individual goat weights were taken on a weekly basis. Feed samples of each diet were collected every week and analysed for nutritive values. The chemical composition of feed showed significant differences ($P<0.05$) among diets. Absolute and relative nutrient intakes showed that Galla goat had a higher DM intake of NL compared to other diets and in crossbreds. Galla goats had a higher feed conversion ratio for DM from Napier and NL diets. Mulato II increased body weight up to 29% and 47% over Napier grass in crossbreds and pure Galla goats, respectively. The findings suggest that Mulato II could be a better feed resource for growing goats. Further studies should be conducted by increasing the levels of Leucaena leaf-meal in the diets and determine nitrogen retention and quality of meat under the same feeding regime.

Evaluation of multiple ovulation and embryo transfer (MOET)

For the MOET, there was embryo searching through the flushing and then embryos collection after flushing (Figure 1). After the embryos collection, 15 recipient cows of RAB station received 6 fresh embryos and 9 frozen embryos. The PD has shown that 7 out 15 cows were pregnant. This shows that the conception rate is estimated at 47%. The target was to attain to a conception rate of 30%.

Photo 51*: Flushing and embryos collection after flushing (A), Embryo searching (B)*

Prevalence of sub-clinical mastitis, pathogen distribution and antimicrobial sensitivity in selected districts

Bovine mastitis is one of the most prevalent and economically costly disease in dairy cattle occurring worldwide, Subclinical mastitis (SCM) in Rwanda remains significant problem facing dairy cattle development. This study aimed at assessing the prevalence of SCM and related risk factors, isolate causative pathogens, and test their antimicrobial sensitivity, for dairy cows in intensive and semi-intensive production systems in selected Districts of Rwanda. A total of 5,725 lactating cows from 1030 farms of varying sizes were included in the study. California Mastitis Test (CMT) was used to screen cows and scored on 0 to 3 scale, and a questionnaire was administered to collect cow information. Positive quarters were milk sampled for bacteriological analysis. Disk diffusion assay was used in evaluating antimicrobial susceptibility test. The overall SCM prevalence at cow level was found to be 65.6% (3,755/5,725). Out of 22,439 quarters (5,725 cows) examined, 8,941 (39.8%) had subclinical mastitis. The common bacteria found was coagulase negative staphylococcus *(*52%) followed by *Staphylococcus aureus* (18.6 %). Less common bacteriological findings were Streptococcus species (9%), Bacillus species (8.8%) and Coliform species (8.3%) and contamination (3.3%). Above 50 % of isolated pathogens were resistant to penicillin and streptomycin but susceptible to gentamicin. This is the first study to include a large number of cows and demonstrated that SCM is highly prevalent in dairy cows in Rwanda. Majority of causative bacteria were contagious in nature and resistant to penicillin, the most widely used antibiotic, therefore mastitis control program needs to be prioritized accordingly.

Establishment of elite goats breeding stock and inyambo cattle breeding association for genetic resources conservation and use

Fifty goats of pure Galla breeds have been procured and evaluated for their adaptation, and 100 local goats were purchased. Currently, 100 elite local goats and 399 exotic goats breeding stock are under evaluation at Nyagatare RAB station. Furthermore, a private organisation for Inyambo conservation registration has been submitted, official registration still pending. Meanwhile, 15 Inyambo cattle have been purchased from RAB by the private organisation and the MoU to use the animal properly has been signed between RAB and the organisation.

Forage planting

The target was to plant 2,500 ha of improved forage species via RDDP project. Forage planting campaigns started in season 2021A in Nyagatare, Rwamagana, Gatsibo, Kayonza, Rusizi, Nyamasheke, Rulindo and Gakenke with 808 farmers involved in Quarter 1, and Nyagatare, Rwamagana, Gatsibo, Kayonza, Rusize, Nyamasheke, Musanze, Rulindo, Gakanke, Nyanza, Ruhango, Muhanga, Kamonyi, Nyaruguru and Gakenke in Quarter 2 with 1,306 farmers involved. In season 2021B, the forage campaigns were conducted in Musanze, Rusizi, Nyamasheke, Nyagatare and Gatsibo with 1,010 farmers involved (Photo 53). In all forage campaigns, an agreement with seed beneficiaries was made to pass on forage seeds that farmers had acquired from RAB or RDDP to other farmers to enabled enough forage seed for the community. The total area of improved forage reached 3,991.3 ha against 2,500 ha planned. Besides forage campaigns, radio talks and livestock farmer field schools were also used.

Photo 52: New forage fields at 3 months after planting in Gisagara

A number of seasonal forage launches were organised in different districts (Photo 54) where districts officials and farmers participated.

Photo 53 : Launching of forage planting in Nyanza (left), Ruhango (center), and Muhanga (right)

Training on forage conservation

Biomass of fodder produced was mainly based on *Chloris gayana* and *Brachiaria* for hay making (Photo 54). Around 58 tonnes of grass hay baled were produced at RAB Nyagatare. A practical trainings and demonstration sessions for forage conservation technologies were organised with the support of RDDP in Kayonza, Huye, Nyanza, Rubavu, Nyabihu, Rutsiro district and Muhanga (Photo 61), where facilitators, farmers in LFFS groups, sector

veterinaries and Girinka beneficiaries were involved. At least 17 LFFS group with 498 LFFS group members, 175 facilitators, 62 private farmers and sector veterinaries were trained, and 18 silage bags (9,000 kg of ensiled Napier grass), 1 silo pit (2,000 kg of ensiled Napier grass) and 19 hay bales were produced by the participants during the training.

Photo 54: Grass drying for Hay at RAB Nyagatare (left) and training on hay making using the wood hay baler (center and right)

To prepare for June-September 2021 dry season, a campaign was organised in collaboration with RDDP to encourage farmers to conserve surplus forage (hay and silage) and crop residues (Photo 54) in order to copy with the dry season.

Photo 55: Training of forage conservation/ silage

Furthermore, training on improving crop residues nutritionally was conducted. This was through the demonstration on the urea straw treatment and finally seal up in the sheeting to avoid spoilage through oxidation (Photo 57).

Photo 56: Urea straw treatment

Training of smallholder farmers on management of ET cows

Farmers training on management of Embryo Transfer born cows was conducted in Musanze (Photo …) and focused on use of acaricide to prevent cows against tick borne diseases. Also, farmers were reiterated to put cows in the livestock insurance scheme, which is a joint initiative of MINAGRI in partnership with insurance companies. In addition, vaccination of all calves against Theileriosis was conducted during the training.

Photo 57: MOET trainers and farmers

Photo 58: Calve born from Embryo transfer

Establishment of hydroponic fodders

Eight hydroponic fodders have been produced in Nyanza and Muhanga. The fodders are being fed to cattle at farm level in Nyanza district (9 dairy farms) while in Muhanga are being fed to cattle in the common shed.

Photo 59: Hydroponic fodder at Nyanza farm

During the implementation of forage planting, scarcity of seeds was a challenge because some forage planted required to use vegetative materials which need a specific transport like truck to carry a lot Napier grass cuttings or splits of Brachiaria grass. Other challenges were the availability of funds, as well as restricted movement due to COVID-19 pandemic, which has hampered gatherings at farm level during the training of farmers or farm visits. Irregard to challenges, including COVID-19 pandemic and limited funding, the annual planned targets under Ruminant programme were achieved. Furthermore, forage planting and feed conservation have become a habit, especially during the cropping and dry seasons. This has allowed a smooth implementation and achievement of the target. Though we managed to evaluate and get a number of hectares under forage crops, we hope that it is not exhaustive because there are other farmers mobilised through radio talks who might have planted forage and yet was not reported. Therefore, thorough engagement of extension officers at sector and cell level could help to get accuracy information on land under improved forages, feed conservation and other animal husbandry activities.

2.2 National Artificial Insemination 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 Development (ARD). The National Genetic Improvement Center (NAGIC) Division of ARD implemented, monitored and supervised bovine genetic improvement activities, which are here reported for the fiscal year 2020-2021. The key activities focused on bull management bulls (at Rubona 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.

Bull management

Rubona Bull station hosts a team of around 11 best bulls selected to produce semen in order to ensure fast dissemination of superior genetics and faster genetic improvement and conservation of local breeds. In the fiscal year 2020/2021, 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. 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 bull center and trained on semen production.

Photo 60: Holstein-Friesian bull (left), Jersey Bulls (center) and Inyambo (right)

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 2020/2021 a total of 121,124 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 10,000 semen doses and 200 embryos and 5000 doses trough Heifer International. To improve quality of semen used in country, RAB conducts 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 (104,595L from Rubilizi Plant and 81,345 from Rubona Plant). All bovine artificial insemination inputs were availed to stakeholders.

Bovine artificial insemination and capacity building

Bovine Artificial insemination (AI) is the best and safe mean of cattle reproduction. With AI, the dissemination of superior genetics is faster; access of best bulls is ensured and reproductive diseases are prevented. Most of farmers and Girinka beneficiaries cannot keep good bulls for breeding. Thus, the AI is the only option to breed their cows. RAB coordinates the bovine AI and identification of AI born calves across the country. In the 2020-2021 fiscal year, a total of 110.232 cows were inseminated and 49,840 calves born on AI were identified. This was due to significant efforts invested in availing liquid nitrogen; training of more inseminators; availing different

inputs to technicians and training of farmers via RDDP project and other partners such as Send a Cow, Heifer International Rwanda, Jersey Island, Bothar and MSAADA.

Photo 61: Capacity building of artificial insemination stakeholders

To improve AI success rate, RAB and partners organized training for new AI technicians on cattle artificial insemination and reproductive management to improve skills of inseminators. During the reporting year, a total of 260 veterinarian technicians were trained on bovine artificial insemination technique, PD, semen and liquid nitrogen handling. The target for AI in 2020-2021 was 106,942. A total of 110,332 cows were inseminated across the country. This improvement was due to significant efforts invested in production and supply of liquid nitrogen used to conserve the semen training of more inseminators; availing different inputs to technicians on time such us semen , gloves, sleeves, and hormone and training of farmers via RDDP project and other partners such as Send a Cow, Heifer International Rwanda, Jersey Island and RCVD. Number of AI calves born as annual targets was 40,159. In fact, after AI activity, a total of 49,840 calves were born. This improvement on registration of calves born is a result of the significant presence of inseminators in the field. The recording of calves born is done at the same time when Inseminators are in the field for insemination. It is done at the same time. Our partners (RDDP, Heifer International, Send a Cow, MSAADA, Districts, etc) supported in different ways to achieve this targe.

2.3 Veterinary services program

2.3.1 Veterinary laboratory

Veterinary diagnostic laboratory at RAB aims to (i) develop policies and strategies for the control and eventual eradication of transboundary animal diseases and pests; develop and coordinate implementation of transboundary animal disease (TAD) programmes; (iii) In collaboration with other countries, to progressively control and eventually eradicate transboundary animal diseases which are devastating to livestock as well as human health; (iv) To monitor, evaluate and devise the most cost effective methods of controlling the most important health and socio-economic transboundary animal diseases; (v) To prepare and implement emergency preparedness and response plans for dangerous emerging transboundary animal diseases; and (vi) Control and eradication of transboundary animal diseases in specific areas alongside the regional and international obligations. TAD diagnosis is generally a function of the national veterinary diagnostic laboratory. Many of these laboratories have biocontainment facilities, which allow them to work with highly contagious or controlled agents, such as Foot-and-mouth disease virus. Suspect cases submitted to a state or regional laboratories are forwarded to the national laboratory for diagnosis and /or confirmation. In the event of an outbreak, the national laboratory provides extensive laboratory support service for the confirmation of the disease.

2.3.2 Animal disease surveillance

One of the integral functions of the national laboratory is disease surveillance, both active and passive. This involves the diagnosis of samples submitted to the veterinary diagnostic laboratory and those collected during active surveillance. This is specified in the OIE (World Organization for Animal Health) International Animal Health Code, which states that a country can only be considered free of a disease if that country has a surveillance programme for that disease. The code provides specific guidelines for certain diseases, such as FMD, CBPP, blue tongue and rinderpest. If a country wishes to apply for OIE certification as being free from these diseases, the results of surveillance testing must be supplied to the OIE. These OIE surveillance requirements carry important trade implications, as the OIE was designated in the Sanitary and Phytosanitary (SPS) Agreement of the World Trade Organization as the standard setting organization for animal health. The veterinary diagnostic laboratory system serves as the cornerstone for surveillance by performing the testing necessary to determine the status of targeted animal populations. Active surveillance programmes, such as those for newly eradicated diseases, for example rinderpest in sub-Saharan Africa, involves a statistically determined sampling of a population of animals. Passive disease surveillance generally involves taking receipt of clinically affected animals and/or tissues to determine the cause. Testing for active surveillance programmes requires the establishment of protocols and personnel dedicated to processing diagnostic laboratories. State and regional laboratories interact directly with veterinary practitioners and animal owners to provide the interpretation and application of test results to the disease scenario. National laboratories provide national veterinary authorities, such as state veterinary services with expertise in testing for control/surveillance programmes. Veterinary diagnostic laboratories also provide expertise in the understanding of pathogenesis, diagnosis, biology, epidemiology and prevalence of diseases.

Provision of trainings and capacity development

National veterinary diagnostic laboratories are involved in the organization of training and capacity development programmes in areas of basic laboratory skills, biosecurity principles, surveillance and monitoring in other to equip the much needed manpower in states and private laboratories. They usually identify the needs of the participating laboratories, and organize these trainings in collaboration with international agencies like OIE/FAO in other to strengthen the capacity of laboratories for effective disease surveillance. Most national veterinary diagnostic laboratories also train middle manpower in skills required to support research and diagnostic activities, these range from short term to long term trainings that award certificates. Consultation for transboundary animal diseases, animal surveillance, animal disease monitoring, import/export testing, consultation and interpretation of diagnostic results, research as animal disease control and well as quality assurance activities. Laboratory personnel provide expertise in the development of eradication programmes, in addition to the interpretation of test results for clinical cases. Participation in quality assurance and proficiency testing is increasing and many countries are pursuing laboratory accreditation. As veterinary diagnostic laboratories maintain and improve their expertise in animal disease diagnosis, they provide veterinary services with the diagnostic capability that allows the country to respond to transboundary animal disease incursions and to endemic disease concerns. These laboratories also provide the capability for surveillance testing which enables a country to meet the OIE requirements for freedom from a particular disease and to certify that this freedom is maintained. During this fiscal year July 2020-June 2021, based on performance contract the activities below were done such as: Central veterinary laboratory has the capacity of testing different diseases and endemic diseases caused by different microorganisms, the main diseases are: Brucellosis, Mastitis, FMD, RFV, PPR, ASF, Rabies, Avian influenza, Newcastle disease, CBPP, Tick and Born Diseases, Helminthes.

Table 70: Samples of transboundary and endemic animal diseases analyzed

Disease	Number of samples	Disease	Number of samples	Disease	Number of samples
Brucellosis	>18,500	RVF	1,100	Swine erysipelas	268
CBPP	1,321	Mastitis	1,717	Rabies	2
PPR	1,600	Tick borne diseases	208	NCD	1,750
FMD	1,826	Helminthes	189	Drug residue	642

Photo 62: Blood sample collection from goats in Kayonza for PPR (left) and pigs in Rubavu for Swine erysipelas surveillance (right)

Photo 63: Blood sample collection from chicks imported from Belgium during the control of avian influenza

2.4 Monogastric animal program

Poultry and pig farming in Rwanda has experienced progressive growth in the last 5 years. With the aim of diversifying the economy, the Government of Rwanda has given priority to the poultry and piggery value chains due to their potential to promote inclusive growth, market and competitiveness as well as resilience to climate change.

Photo 64:

The current populations of Monogastrics in Rwanda are: 5,306,254 Poultry; 688,788 Rabbits and 1,385,769 Pigs (NISR, 2019); the meat production are 37,351MT poultry meat; 23,137MT pork meat and 9248 MT rabbit meat. The current consumption per person per year equal to 14.06Kg for meat and 0.66kg for eggs. In addition, the current production of eggs is equal to 7972 MT. The flocks are a mixture of exotic, local and crossbreed. Exotic breeds for the various species were introduced by NGOs and public authorities via agencies and research stations or directly to farmers to improve the local breeds. The production systems used for small stocks are extensive, semi intensive and intensive, with the extensive being predominant. The innovations and extension methods wer used in improving pig and poultry productivity.

Farmer Field Schools on maize and soybean

Lack of domestically sourced feed forces companies to import the feed ingredients from outside. The project “ENABEL /PRISM” aims to support the animal feeds value chain by developing a reliable and sustainable supply of locally produced soybean and maize for feed companies. Training of trainers was organized in Rwamagana and Huye for 72 farmer cooperatives from Rwamagana, Kayonza, Ngoma and others from Kamonyi and Gisagara on soybean (36) and maize (36). FFS facilitators were expected to organize, facilitate and train farmer field school groups at village level. Quality seeds and pesticides were supplied to the trainee cooperatives besides RAB technical assistance. From RAB side, a total of 9 Trainer staff were trained on maize and soybean.

The Training of Trainers (ToT) on maize and soybean aims to put in place qualified farmer field school (FFS) facilitators who will coordinate, organize, facilitate, and train FFS groups at village level for maize and soybean. The training included **participatory norm setting and leveling of expectations, formation of host teams and their functions, leadership and activity schedule, gap analysis and schedule, field visits.** ToT participants on soybean chose to establish ToT plots on performance of various soybean genotypes (10 varieties) and the use of fertilizers while maize participants established both varietal comparison (6 hybrid maize) and effect of different fertilizers (DAP, DAP + Urea, NPK, cereals, Amidas + Urea). Soybean seeds have been mixed with Rhizobium before sowing. Field activities included field selection prior to planting, cultivation and levelling, manure transport to the field, plots delimitation and sowing according to the field layout.

Photo 65: Saison 2021A Mineral fertilizer application in field (left); and soybean seeds mix with Rhizobium in Rwamagana ToT plot (right)

Agro-Ecosystem Analysis (AESA) is extension approach to evaluate field situation with pests, natural enemies, soil conditions, plant health, climatic factors and growing healthy crop. Regular field visits should be done up to harvesting: Four AESAs were done in the season 2021A and three AESA in season 2021B. The trainees observed and recorded data, then discussed in small groups and thereafter each small group presented data to the whole group to share the findings and discuss them before validation.

Photo 66: Data collection in the field plot of soybean and maize at Huye and Rwamagana

Photo 67: AESA presentation during the season 2021A in Rwamagana (left) and Gisagara (right)

Training topics were: historical background of FFS; the facilitator: qualities and defects; How to make Maize and Soybean crop calendar; Basic concept of FFS, Fundamental elements of FFS; Seed preparation; Land preparation and good agronomic practices on both maize and soybeans, Parts of maize and soybean plant and their functions; Agro-Ecosystem Analysis (AESA) and how to conduct it; Soybean and maize pests, diseases and their management; Formation of farmer Field School groups; Soil fertility management; Manure and fertilizer use.

Sites under maize and soybean production

The team has selected 8 sites for maize and 7 for soybean technical support. Seeds and pesticides were provided to the cooperatives involved. A total of 4176kg maize and 8,960 kg soybean seeds were distributed (Table 4).

Table 71: Sites under Maize and soybean production

Province	District	Sector	Site	Area (ha)	Crop of choice
SOUTH	GISAGARA	Gishubi	Muyinza	30	Soya
		Ndora/ Kibirizi/Muganza	Kibugazi	75	Maize
	KAMONYI	Rukoma/ Karama	Gikoro	85	Maize
EAST	NGOMA	Jarama	Jarama	100	Maize
		Kazo	Kagarama	80	Soya
	KIREHE	Nyamugari	Kabeza	100	Maize
		Mahama	mwoga	80	Soya
	KAYONZA	Gahini	Buyanja	55	Maize
	RWAMAGANA	Muyumbu	Hirwa 35A	150	Maize
		Musha	Kagarama	10	Soya

	GATSIBO	Remera	Kanyonyomba	110	Maize
		Gatsibo	Nyagahanga	7	Soybean
		Gitoki	Cyabusheshe	4	Soybean
	NYAGATARE	Rukomo	Cyabayaga	20	Soya
		Mimuli	Nyabugogo	20	Maize

The team went regularly to different Districts for monitoring and following up soybean and Maize Field Activities. They gave advice for different aspects of integrated crop management such as planting techniques, pests and diseases managements, top dressing for maize, etc.

Photo 68: Status of maize field at Kamonyi/Gikoro site

The objective of the ToT was to produce skilled FFS facilitators who will be able to establish, organize and conduct FFS groups in their living and achieve higher yields of maize and soybean. Farmers were interested to get new skills, and to learn about FFS learning by doing, which retains knowledge by themselves and make it easier to teach the other farmers. Besides, fodder-related LFFS on Soybean and Maize trainings were conducted in Kamonyi, Gisagara, Rwamagana, Ngoma and Kayonza.

Training of Livestock farmer field school facilitators on Chicken and Pig production

The training of LFFS facilitators was conducted in Rubavu, Rusizi, Muhanga; Rwamagana and Bugesera, Rulindo and Musanze for chickens and Rubavu, Rusizi, Muhanga, Gisagara, Nyamagabe, Rwamagana, Bugesera, Rulindo and Gicumbi for pigs. A total of 22 Master trainers were engaged in this training: 6 females, and 16 males. A team of trainers was composed by RAB staff, Zamura Company, Uzima chicken Ltd as well as University of Rwanda/CAVM campus). The training aimed to deliver updated knowledge and develop skills in livestock feeding and rearing which would lead to develop profitable, resilient and sustainable livestock farms through the farmer field schools and farmer business schools approach. Training activities consisted in delivery of learning modules to future Farmer Field School Facilitators; Election of leading committee during the training; Host Team formation; Regulations setting; Levelling of expectations; Gap analysis, preparation before arrival of broiler and layers chicks and follow up of chicks received and brooding of broilers and layers; poultry and pig management within group of LFFS formed by facilitators; Training on finishing stage of broilers and growing stage of layers; Different breed of poultry; Chicken diseases and tratment; Laying and hatching of eggs; Provide technical assistance on management of chicks received and on group of farmers formed; Assess the group of famers formed; Assess the poultry house which will use as learning poultry house; Assess the pig pen which will use as learning pig pen; Participation in

distribution of bicycle to 16 facilitators in poultry and 9 facilitators in pig; To train LFFS facilitators in pig farming techniques and L-FFS methodology.

Awareness meeting about ENABEL project

In August 2020, a meeting about ENABEL project was organized for SARO, DARO, Directors of Agriculture and MINAGRI staffs of 10 districts (Rwamagana, Muhanga, Bugesera, Gisagara, Gicumbi, Rulindo, Musanze, Rusizi, Nyamagabe and Rubavu). Project focal person introduced the planned activities on Livestock Farmer Field School (L-FFS). Participants have selected the criteria and facilitators. A total of 213 facilitators were selected - 118 for poultry & 95 persons for pigs.

Training of poultry facilitators at sites

Training sessions of poultry facilitators were conducted at each of 7 sites (Rubavu, Rusizi, Musanze, Rulindo, Muhanga, Bugesera and Rwamagana), where all facilitators met at the farm of the elected host farmer facilitator to follow up the training. At each site, trainings were conducted in 2 sessions: first to deliver the basic knowledge, and second to practice. The trainings used participatory approach whereby participants worked in small groups, plenary session, and group discussion. The first training module included participant's introduction, election of lead committee, host heam formation and regulations setting, leveling of expectations and gap analysis. Facilitators have been trained on LFFS history, LFFS methodology, LFFS concepts, principles, organization and implementation. Livestock FFS shares the same key principles as other types of FFS: Learning by doing; Farmer-led learning activities; Learning from mistakes; Learn how to learn; Problem-posing/problem-solving; The farmer's field is the learning ground ; Extension workers are facilitators, not teachers; Unity is strength; Every FFS is unique; Systematic training process.

The Gap analysis on Poultry problems revealed gaps and possible solutions after group discussion. The gaps were ranked: 1) Lack of poultry products market; 2) Limited knowledge of the consumers on nutritious importance of the poultry products; 3) Insufficient capital; 4) Lack of poultry post-harvest factory Expensive poultry feeds; 5) Insufficient and expensive poultry feed; 6) Expensive and unavailability of chicks; 7) Limited knowledge in poultry management; 8) Limited Veterinary Technicians; 9) Expensive poultry drugs and supplements; 10) Lack of poultry materials; 11) Limited knowledge in poultry management; 12) Insufficient capital.

Preparation before arrival of broiler chicks and follow up of chicks received started 48 hours before arrival of chicks with disinfection of the housing; Set up the brooder box about 48 hours before the arrival of chicks; Bedding for chicks (needs to be absorbent)**;** A heat source was vitally important (Charcoal heater for poultry)**;** Set up of drinkers and feeders**;** Once chicks arrived, they were introduced to the brooding area, to water and feeds by the facilitators**;** Adjustment of feed as chicks developed**;** Doing LESA every day.

Photo 69 : Arrival of broiler chicks (left) and Chicks introduced to the brooding area (right)

Livestock Ecosystem Analysis (LESA) includes the understanding and reflection on different components of livestock ecosystem, their relationships and interdependence with holistic appreciation of the system as a whole. LESA aims to enhance farmers' observational, analytical and decision-making skills; to teach how observation relates to farm management; to introduce the concept of an ecosystem; to enhance understanding of the tropic levels in an ecosystem.

Photo 70: Layers introduced to the brooding area (left) and Layers on the 3rd day (right)

The second session of Poultry Facilitators Training (ToT) was held at Host farmer site. Training topics were about growing and finishing stages for both broilers and layers: good quality chicks; good quality of feed and proper feeding; proper ventilation and how is it advantages for all stages; How to maintain good litter and how it is good to maintain it and to check; biosecurity and possible ways of achieving it; when to switch from chick feed to grower/ finisher feed for layer; and factors affecting feed intake. The facilitators leaned how important Feed Conversion Ratios. It helps farmer to know how much amount of feed will be required in the growth cycle of animals and how to dose it. The facilitators participated in identification of contributing factors for chicken diseases and each of them explained how any factor could be origin of the diseases. Similar trainings were done in parallel at Rusizi, Muhanga, Rwamagana, Bugesera, Rulindo and Musanze.

Pig FFS

The ToT training of pig FFS was organized in 9 districts namely Gisagara, Rwamagana, Nyamagabe, Bugesera, Gicumbi, Rulindo, Rubavu, Rusizi and Muhanga for 95 future LFFS facilitators. At **Gisagara site**, 17 facilitators from Nyamagabe and 13 from Gisagara were invited. The Master Trainers came from RAB and UR. The training followed the LFFS methodology whereby the trainees were given opportunity to discover the topics. These facilitators were grouped into small groups known as Host farmers. For every topic, there was group work, presentations and discussions. The facilitators were organized into L-FFS school with the name "IMBANZABIGWIMUKWESA IMIHIGO" and elected leaders. Six host teams were formed. Training topics included: L-FFS principles; LESA; Groups creation; Problem identification; Pairwise ranking of the problems; Solutions identification; Course programs development; Pigs breeding and reproduction; Biosecurity and diseases; Pigs nutrition and feeding; Group dynamics. Master Trainers worked hand in hand with the District Livestock Officer of Gisagara district and the Sector Livestock Officer of Save sector.

Photo 71: Presentation of group work by Facilitators (left), Master Trainers giving technical courses (right)

At **Rwamagana site**, 20 pig facilitators including 7 from Rwamagana, 7 from Bugesera and 6 from Muhanga were trained for the first round on the LFFS. Pig Facilitators from each district gave the status of the selection of farmers after the first session and a summary of what they learnt during the first session. Farmers were organized in host teams. The following topics have been covered: pig housing/piggery unit; standard of the piggery unit; construction materials of the piggery unit; right place of the piggery unit; making decision on the direction before construction; ifferent compartiments of the piggery; hygiene and desinfection of the piggery; problem ranking regarding pig farming in Bugesera, Muhanga and Rwamagana districts; feed formulation using box method. Exercises on feed formulations have been given to the participants so that in the third session participants can be able to make concentrates using four types of ingredients.

Photo 72: Prioritization of pig farming problems and presentation by facilitators in Gicumbi

At **Gicumbi site**, training covered different topics related to the general management of pigs including Livestock Farmer Field School approach for Pigs, terminology, and LFFS operation. Key principles of LFFS, formation of L-FFS, selection criteria for facilitators, selection of group members, L-FFS Curriculum, Learning program, Adult learning process, How to conduct Livestock-Ecosystem Analysis (LESA), How to conduct different experiments in Pig Farmer Field School, Biosecurity in Pig farming system, Farmer preparations for receiving pigs in his farm, Pig houses construction and it's different sizes depending on breeds and objectives of rearing. During this period also the team of Master trainers highlighted the qualities of a good facilitator, Role of facilitator and facilitation techniques, formation of host teams/sub-group and regulations setting, TOT courses introduction (Presentation of the Curriculum to the participants), outline the output expected by facilitators from these LFFS training sessions (In sub-groups), what is Livestock (pig) extension, role of LFFS in extension and LFFS principles, adult learning, characteristics of adult learning, comparison between the Adult learning and teaching , and adult learning principles, Livestock (pig) problem analysis and ranking, identifying potential solution (Group discussion) and principles of reception of pigs. In the second session of training, the facilitators have done summary on last courses and presentation on pig breeds. The facilitators also followed the pig nutrition courses, how to formulate the ration of pig for different categories of pigs.

At **Rusizi site**, training focused on delivery of knowledge about Livestock Ecosytem Analysis (LESA), Pig infrastructures, Feeds and animal nutrition, and LFFS group sustainability.The classs was composed by 9 trainees with one female and eight male with limited youth member. Both theoretical and practical sessions exercise were used in participatory manner. The training was participative and characterized by group discussions, plenary sessions, presentation and working in LESA and Host teams. Recapitulation before next session was initiated and daily report by Host Team and Daily records in class book of all conducted activities. The trainees have received equipment for LFFS Groups such as sheetings, jerricans, bassins, wheel barrows; six pigs for learning (five gilts and one boar). First and second LESA were carried out by Host teams and presented. Courses were delivered on Pig house construction, feeds and feeding for piggery; Review on LFFS Methodology and gap analysis. Learning Methodology was applied using plenary, discussion, group working, Host team formation, plenary presentation, Group dynamics and practical session. Farmers were taught about value based holistic community development.

Photo 73: Pens prepared for reception of Pigs

In conclusion, Concrete Pig pens were recommended. It was important to ensure value based Holistic Community Development are inclusive in topics for pig LFFS sustainability; it is essential to focus on Social capital, financial capital, Human capital and Skills development in LFFS group. It is good to finalizing preparation of Pig pens while waiting to receive Learning pigs for LFFS groups. It was recommended that the Facilitators continue activity of selecting group members to form two FFS groups; to monitor five Gilts in gestation and one Boer by Host Farmer; to prepare Plan of pig insurance of received pigs; to form LFFS group starting by Selection of group members and forming two groups with average of 25 pig farmers; to ensure closer follow up to Facilitators during group formation and preparation of pens, anf to conduct regular ToT Sessions on Pig production.

Livestock research proposals

Research proposals on alternative source of protein, calcium and energy for poultry and piggery were developed, reviewed and approved for financing by ENABEL project. They aim to enhance chicken and pig productivity; nutrition to improve availability of small stock feed resources, and breeding to provide better genetic resources and conservation of local breed to fight genetic erosion. This research will be undertaken as a participatory action research (PAR) on-farm and on station. RAB and ENABEL organized this research workshop with University of Rwanda and Private sector. Scientists from RAB, UR and other stakeholders developed 14 research proposals (9 research proposals on feeds, feeding and 4 in breeding and one in health) of chickens and pig. Ten Presentations were successfully done and suggestions were given to presenters how to improve the research methodology, budget, time frame and target groups.

Table 72: Presented research proposal on the Workshop on research review

No	Title of research proposal	Responsible	Comments
1	Growth & production performance of chi-cken fed on starter & grower broiler mash supplemented with graded levels of Azolla	Gaspard Uwimana	To work with private feed plants; To clearly mention the objectives; To show how cost effective of the project; To use available ponds to produce Azolla
2	The determination of different methods for conservation and transportation of boar fresh semen in Rwanda	Shyaka Innocent	To improve budget and include all needs and mention; To work with UR for certification for animal welfare; To consider parameters to be evaluated; To consider some factors like mana-gement at farmers after insemination; Distance from centers to farms. To add other key staff to the team.

3	Evaluation of the effect of black soldier fly's maggot meal on growth performance of broilers in Rwanda	Remy Titien	To test on one-day old chick; to use R software in data analysis; Site criteria to be mentioned; Selected category of farmers to work with SHF, MF and Large farmers; to improve Meat Quality assessment methodology; to add Drying and Packaging of Maggots; to improve budgeting; to work with Zamura Feeds; to select Zamura beneficiaries (Broiler chicken farmers); to add 100% BSF Maggots in treatment; to add Head of Dpt AP /UR as Co Team
4	Introducing chicken-silkworm integrated farming for food security and livelihood improvement in Rwanda	Amandin Rutayisire	The committee suggested working with various feed millers and reviewing some statistical analysis.
5	Investigation for technological processes of obtaining fillers for the use of limestone as calcium source in poultry and pigs	Jules Mutabazi	To work with partners to help conduct the research On station trials before dissemination to farmers
6	Effect of brooding system on chicken productivity	Aline Kayitesi	Suggested to work with private sector experience (Zamura and Avi Farm Solution); To add other provinces in the area of study for better result on different zones; To add equipment to collect more data
7	Assessment of production of day old chicks,functionning and capacity of hatcheries in Rwanda	Safari Syrvestre	To add cost benefit analysis of hatcharies
8	Evaluation of growth performance of pigs fed hydroponic green fodder supplement.	Remy Titien	Add a Private Partner: Uruhimbi; Cooperative in Gicumbi; Removal of first objective and improve objectives; Add Hypothesis; Improve budgeting; Ensure Barley Seeds availability
9	Effect of essential amino acid on performance growth of pre-layers and Layers fed on concentrate feed	Nathan Ndayambaje	DDG suggested to rework on the objective and the title of the research proposal and to work with the private company deal with animal feed.
10	Study on pig performance evaluation based Sweet potato Silage diets in Rwanda	Remy Titien	Add Private partner: Rwanda Pig Association; Remove1st objective, improve objectives; Add Hypothesis; Improve budgeting; Harmonise the plan
11	Effect of different feed diets on swine reproductive performances in Rwanda	Ferdinand	To improve the methodology; Improved proposal will be presented on next presentation session in January 2021, after establishment of monogastric research center.
12	Determine the burden & level of exposure to Total Aflatoxins and Aflatoxin B1 conta-mination in eggs, meat (muscles, kidney and liver) and chicken litter (droppings) for backyard and commercial layers in urban and peri-urban areas of Kigali city.	David KIIZA	He should discuss with Zamura, Avi farm for more improvements
13	Enhancing indigenous chicken productivity through Breeding and Nutrition Management	Dr.Claire D'Andre Hirwa	The presentation was postponed due to the monogastric research center, which is not ready now. The research proposal could be presented next year in January
14	Improvement of poultry production thru artificial insemination technology	Dr. Richard Habimana	The presentation was postponed due to the monogastric research center, which is not ready now. The research proposal could be presented next year in January.

Evaluate the effect of black soldier fly's maggot meal on growth of broilers (ongoing research)

Insects have been identified as potential alternatives to the conventional protein sources in livestock feed. This study aims to determine nutritional chemical composition of maggots' meal; evaluate effect of maggots' meals on Broiler performance both growth rate and meat quality; to assess cost benefit analysis maggots' meals-based rations; and to determine farmer's perceptions on insect feeding and main challenges on poultry farming and to ensure production in quantity and quality of Maggots meals from BSF reared on different organic substrates with their life stage growth requirements. Five diets

were used (Table…). One-day old chicks will be fed with starter feed up to 14th day. From there we fed diet with maggot with adaptation period of 1 week.

Table 73: Diets used in the experiment from 2 weeks after birth (finisher feeds)

Ingredients	**Quantity**				
Diet	To/0%maggot	T1/25%maggot	T2/50%maggot	T3/75%maggot	T4/100%maggot
Whole maize	23	23	23	23	23
Soybean	20.6	15.45	10.3	5.15	0
Cotton seed cake	4.4	4.4	4.4	4.4	4.4
Wheat pollard	1.2	1.2	1.2	1.2	1.2
Wheat bran	3.6	3.6	3.6	3.6	3.6
Yellow lime	1.6	1.6	1.6	1.6	1.6
Premix	0.2	0.2	0.2	0.2	0.2
Lysine	0.1	0.1	0.1	0.1	0.1
Methionine	0.1	0.1	0.1	0.1	0.1
Monocalcium phosphate	1	1	1	1	1
Salt	0.2	0.2	0.2	0.2	0.2
Maggots meal	0	5.15	10.3	15.45	20.6
Tot	**56**	**56**	**56**	**56**	**56**

This research is ongoing at Muhanga, broilers have completed one production cycle, and data on broiler growth were collected and are currently being analysed. Samlpes were taken to determine nutritional chemical composition of maggots' diets. Rwamagana farmers from FFS groups were interviewed to define perceptions about insect feed. Data are currently being cleared and will be analysed. Samples of BSF were taken to laboratory test for chemical composition, salmonella and aflatoxins, and the results show they are free from both, Salmonella and aflatoxins.

Photo 74: Black soldier samples

Evaluation of growth performance of pigs fed with supplement of hydroponic green fodder

Feeding trial was prepared in Rusizi, Gihundwe with 30 weaned pigs of crossbreed (Pietrain and Landrace) fed with concentrates as basic diet and hydroponic barley fodder as supplement. The diet selected is hydroponic barley fodder (HBF) harvested after six days of growth and concentrate feeds (basal diet). The basal diet includes ground corn, soybean, white salt, limestone, vitamin premix, L-Lysine, dicalcium phosphate and Fat plus hydroponic barley fodder.

Pig performance evaluation with sweet potato silage diets

This study aims to evaluate of growth performance of pigs fed on sweet potato silage diets at Muhanga District – Nyamabuye Sector through assessment of nutritive quality of the sweet potato silage; growth performance of piglets feeding different levels of supplement of sweet potato silage, to assess cost benefit analysis of sweet potato silage meals-based rations. The research was set at Muhanga District, Nyamabuye sector, where a sweet potato silage unit was established. Crossbreed pigs (Pietrain and Landrace) were fed with concentrate and sweet potato silage mix: 100% Concentrate, 85% concentrates and 15% SPS, 70% concentrates and 30% SPS, 55% concentrates and 45% SPS (Table…).

To make sweetpotato silage, chopped leaves, vines and roots are combined with Napier or other grass and wheat bran in correct proportions. Molasses is added to the mixture to aid in fermentation and to increase the nutrient content. The fermentation process takes 30 days. Silage made from sweetpotato vines and non-commercial roots provide an excellent low cost feed for pigs, Feeding sweetpotato roots to pigs offers a good opportunity to convert an undesirable and often unmarketable crop into a high-value commodity. The sweet potato silage can be produced and harvested within 30 days.

Table 74: Ingredients for feed formulation

Diet component	%	Quantity per pig (kg/day)	Quantity for 90 days per pig	Quantity for 40 pigs
Ground corn	70.67	1.41	127	5,080
Soybean	24.8	0.5	45	1,800
Fat source	1.8	0.036	3.24	129.6
Dicalcium P.	0.84	0.017	1.53	61.2
Limestone	0.7	0.014	1.26	50.4
White salt	0.84	0.017	1.53	61.2
Vitamines	0.2	0.004	0.36	14.4
L-Lysine	0.15	0.003	0.27	10.8

All preparative steps have been completed. The study will continue in the next fiscal year when the results will be reported.

Formulation of swine diets for Grower and Lactating pigs

Age-specific diets were formulated and will be tested further for piglets and lactating sows. Nutrients used in formulating piglet and lactating diets are shown in Table 29 and 30.

Table 75: Nutrient requirements of piglets (second age of life)

Physiologic stage	Live weight (Kg)	Age interval (days)	Digestible Energy (Kcal)	Crude Protein (g)	Lysine (g)	Methionine +Cystine (g)	Calcium (g)	Phosphorus (g)	NaCl (g)
Piglet (2nd age)	10-25	40-70	3300	190	11	6.5	10.5	7.5	3

Table 76: Nutrient requirements of lactating sow

Physiologic stage	Live weight (Kg)	Age interval (days)	Digestible Energy (Kcal)	Crude Protein (g)	Lysine (g)	Methionine +Cystine (g)	Calcium (g)	Phosphorus (g)	NaCl (g)
Lactating	60-100	>210	3000	140	6	3.3	8	5.5	3

Rations were formulated on a 1 Kg basis, particularly where cost per kg of diet ingredients was to be determined. The final feed formulation (Tables 33 and 34) include percentage of inclusion, nutrient values for each ingredient, contribution of the mixture, requirements of the pigs and, finally the price per Kg of concentrate produced. Based on ingredient price in Rwanda nowadays, this formula is balanced and expensive due to the high level of protein requirements (383.43 RwF/Kg of concentrate).

Table 77: Feed formulation for piglets "10-25 Kg live weight"-Second age

Ingredients	%	Quantity (kg)	DE (Kcal)	CP (g)	Lysine (g)	M+C (g)	Ca (g)	P (g)	NaCl (g)	UP (RwF)	TP (RwF)
Maize	28.8	0.288	1008	27.936	0.8352	1.2384	0.0576	0.7776	0	170	48.96
Wheat bran	12.3	0.123	300.12	18.696	0.5166	0.4551	0.3813	1.2423	0	240	29.52
Rice bran	20.5	0.205	680.6	27.265	1.1275	1.148	0.287	3.198	0	150	30.75
Soybean meal	16.4	0.164	688.8	60.68	3.858	1.886	0.41	0.984	0	650	106.6
Fish meal	13	0.13	400.4	66.17	0.975	0.481	7.15	3.38	0	1000	130
Molasses	4	0.04	101.2	1.36	0.008	0.016	0.064	0.012	0	25	1
Bone meal	3.2	0.032	0		0	0	11.2	4.96	0	200	6.4
L-Lysine HCl	0.5	0.005	0	0	3.99	0	0	0	0	1800	9
NaCl	0.3	0.003	0	0	0	0	0	0	3	400	1.2
Pig Premix	1	0.01								2000	20
Contributions	100	1	3179.1	202.11	11.31	5.22	19.55	14.55	3		383.43
Requirement			3300	190	11	6.5	10.5	7.5	3		

DE=Digestible Energy (Kcal), CP=Crude Protein (g), M+C=Methionine + Cystine (g), Ca=Calcium (g), P=Phosphorous, NaCl=Mineral salt (g), UP=Unit Price, PT= Total Price. Pig premix includes vitamins and oligoelements.

Table 78: Feed formula for lactating sow

Ingredients	Quantity (kg)	DE (Kcal)	CP (g)	Lysine (g)	M+C (g)	Ca (g)	P (g)	NaCl (g)	UP (RwF)	TP (RwF)
Maize	0.29	1030	25	0.841	1.305	0.058	0.7	0	170	49.3
Maize bran	0.23	938.4	2.323	0.062	0.083	0.007	0.053	0	150	34.5
Sunflower cake	0.284	852	94.9	3.35	3.81	0.065	0.324	0	150	42.6
Wheat bran	0.142	346	22	0.5	0.5	0.44	1.43	0	240	34.08
Limestone	0.004	0	0	0	0	1.5	0	0	100	0.43
Bone meal	0.016	0	0.45	0	0	5.3	2.4	0	200	3.22
NaCl	0.003	0	0	0	0	0	0	3	400	1.2
Pig premix	0.01								2000	20

DE=Digestible Energy (Kcal), CP=Crude Protein (g), M+C=Methionine + Cystine (g), Ca=Calcium (g), P=Phosphorous, NaCl=Mineral salt (g), UP=Unit Price, PT= Total Price

Based on ingredients prices in Rwanda nowadays, this formula is balanced and very cheap as compared to the pig feed prices in Gorilla feed company (305RwF/Kg). If a pig farmer uses this formula, he will gain about 120 RwF per Kg of concentrate.

Success stories

S

My name is MUKASHEFU Elyse; I am a poultry farmer and poultry facilitator from Musanze District, Gataraga sector, Rubindi cell and Kaberege Village. Tel: 0784477452

I started the business of rearing chickens in 2015; I started with 2500 layer chicks from Agrotech Company. In 2017 because the disasters caused by the rain all my flock of 5800 layers died and from that time I stopped rearing chickens and start putting my farm in the rent for other poultry farmers like Uzima Chickens, Zamura, Easy hatch. The first time I heard for the ENABEL Project, I have just started the business. Selection team (district and sector

vet) supplied me with at least 200 broiler chicks. I was so happy and felt motivated to start the business of rearing chickens. I thank so much the ENABEL project and RAB for selecting me as one of poultry facilitator in Musanze District. After validation of all facilitators in our districts three of us were selected as facilitators who fulfill some conditions to be qualified as Host farmers to host the training process, considering the different criteria to fulfill for being considered as host farmer, my farm was selected as the best place where all trainings and experiments should be taken. I thank ENABEL project for the trainings provided and the knowledge gain from different courses or lessons learnt in rearing chickens (Broilers, Layers and Dual purpose). I thank ENABEL Project for all preparations from the beginning up to now. They gave as all materials needed during the training period including Litter, Charcoals, Feeders, Drinkers, Jerricans, Feeds, Vaccines, Drugs, Chicks, Books and Pens, Thermometers, weighing scales,…). I thank ENABEL Project as the host farmer; the project has made me to be known as a poultry farmer in Musanze district and especially in my sector (Gataraga sector). Before the ENABEL project I tried the business but I was not known from anywhere. But in our days everybody in sector knows my name as a modern poultry farmer. With the ENABEL projects I am now fearless, determined and have the courage to raise more chickens. From the trainings I know how to take decision in all the business involved in. From today I am having three groups of poultry farmers where two groups are composed by 30 members and one group by 30 members. All these small poultry farmers are learning how to rear chickens as business through following the Livestock farmer Field School (L-FFS) approach. At my farm I am now rearing 1189 Layers chickens and 600 Broiler chickens, and I will not give up. I am targeting to have at least 10000 or more chickens at my farm. We thank so much the ENABEL Project, RAB, Musanze District and all Master trainers for considering us and selecting us to attend the trainings as Facilitator.

SUCCESS STORY OF LFFS FACILITATOR FROM RULINDO

I am HABYARIMANA Mathieu, LFFS poultry facilitator candidate located in Mbogo sector in Rulindo District

I was about to leave to be poultry farmer, due to big loss I have experienced in June 2020 during Covid-19. I spent 12 years of experience as poultry farmer. I have lost more than 1500 chicks among 1800 chicks I had.

During that period, I stopped poultry business for 6 months and I restarted in December 2020 where I procured 1200-day-old chicks and I started brooding, the same problem occur where I lost 100 chicks. After brooding, the grower's period started and during that period I have experienced to an unknown disease, which destroyed at least 380 and it remain only 820 growers, which was in three poultry houses among seven poultry houses I have.

Basing on that I was suggesting leaving poultry business and change into other business because I have experienced big losses within short period. In due time, ENABEL project came with solution where we have gained knowledge on poultry breeding through LFFS approach where I have chosen to be among poultry facilitators and a group of LFFS master trainers trained us on proper brooding technique, feeding management and general poultry management. This training was done in participatory approach and we have learnt by doing. We have found that, there were some errors we did during our poultry breeding and we have discovered during discussion and we corrected it during training. After one session, we have assigned to form the group of farmer through LFFS approach where we will gain together proper poultry breeding. I have 26 poultry farmers joined and form a LFFS group where we discuss and discover some important information related to poultry breeding. By joining as poultry farmers, we will have full participation to set the price of our poultry products basing on cost of production.

Distribution of bicycles to facilitators

In order to facilitate the facilitators in poultry and pig in the Districts under ENABEL operational area, the project delivered bicycles, which will help with their daily activities as facilitators. After receiving bicycles, the facilitators in both commodities appreciated the gifts.

Photo 75: Reception of bicycles by LFFS facilitators in pig and poultry in Rulindo

Small stock project

In the framework of building good foundation of livestock production and enhance animal products trade and consumption, a project aiming at reduction of food insecurity, reduction of malnutrition through provision of animal source protein (ASF). Generation of household income, provision of manure for increased agricultural productivity was funded, in order to increase income of youth and vulnerable women groups in local areas by creating job to unemployed youth and women, the project intituled: "Small stock project" was develop and modernize the small animal industry in Rwanda. The project was implemented by earmarked funds at the districts level in the country and was implemented in different steps which are selection of beneficiaries, training of beneficiaries, construction of shelters, procurement and distribution of small stock for breeding, procurement of animal feeds, veterinary drugs. In collaboration with the district staff the RAB team provide the technical specification at each steps during implementation of the project Fiscal year 2020/2021.

RAB organized an awareness meeting of project with aim of having common understanding on the implementation process of the project. The meeting was conducted through WebEx due to Covid-19 pandemic because the face-to-face meeting were restricted. The meeting was led by DDG-ARR&TT of RAB and attended by RAB staff, which are the HoD ARR&TT, Head of Monogastric program and all staff of Monogastric program, in MINAGRI a staff in charge of livestock, and at all six districts it was attended by all Directors of Agriculture Resources and DAROs. The meeting was successful and the team agreed on recommendation to improve the technical specifications, the implementation process and selected sectors where the project will work which are Gisagara: seven sectors, Nyaruguru: five sectors, Nyamagabe: five sectors, Karongi: four sectors, Gicumbi: four sectors and Burera: eight sectors. The minutes was taken and letters was submitted to the Mayors of the six district to inform them about the new implementation process of the project.

Technical specifications used by six districts were prepared by RAB monogastric team and submitted it to the concerned districts. Developed technical specification were guidance to the districts during selections of groups, preparation of tender contract to suppliers of chickens and pig (including male and pregnant pig), drugs, feeds, constructions materials and all need to use in the chickens and pig managements. A model copy of announcement calling groups to submit projects to the district was developed and distributed to the seven Districts (Annex 1).

Selection of beneficiaries in all district was done after receiving the project submitted by groups at the district level. Prior the district distributed an announcement at each sector level calling youth and women group or other group that are willing to rear chickens and pigs to prepare project detailing the type of species they want to rear and their participation including the site of constructing animal shed.

Table 79: Small stock distributed during FY 2020-2021

District Number	Pigs	Chicken
Gicumbi	130	3800
Burera	220	6000
Karongi	280	6800
Gisagara	110	7000
Nyaruguru	230	6800
Nyamagabe	1050	0
Remained in last FY 2019-2020	666	7891
Total	2686	38291

Field visit of pre-selected groups (women and youth groups)

Training of beneficiaries was done in each sector, where the groups were located to reduce the journey of beneficiaries to the site of training. Beneficiaries received training according to the species they will rear in separate rooms. In general, the training was based on general management including construction of chicken and pig houses measurement and recommended standards, feeding, breeding especially for pigs and heath management including diseases prevention, which are the vaccination calendar for chickens and other related activities for diseases control. The trainings were successfully done for all groups members after each presentation of trainer beneficiaries participated with question for more clarification on the topics.

Photo 76: Gisagara District Animal Resources Officer giving an opening introduction of small stock project and project management to the beneficiaries

Photo 77: Training of beneficiaries on Chicken (left) and pig management (right)

Training of small stock beneficiaries was successful achieved for all beneficiaries of 11 groups for pig production and 7 groups for chicken productions. Regular monitoring and follow up was done during construction of shelters and distribution of small stock to help them to reach their targets.

Construction of chickens and pig houses: The groups did cnstruction of chickens and pigs houses, the team of the sector level composed of sector animal resources officers, and the land manager monitored the process of construction. Different measurements were given to the groups to be respected during construction, for chickens an open house for deep liter system were suggested with 200m^2 (10m x 20m) and 8.75m^2 for each pig to make 96.25 m^2 for the whole piggery of ten pigs. Most of the groups respected recommended standard and received the construction funds on their accounts.

Photo 78: Pig and chickens houses construction by the group participation for both women and youth

Distribution of chickens and pigs: Distribution of small stocks were done progressively starting by groups that were ready than others, the overall distribution is at 100% for the current situation. Distribution of chickens and pigs the planned target (**Table 3**). The district authorities and RAB team gave them encouragement remarks, advice to work hard, to work as a group and increase saving. They also promised to the groups their availability at any time of need for assistance.

Photo 79: Received pig by group even delivered few days after reaching the group

Groups receiving chickens (Sasso and Laye

The implementation of small stock project to support youth and women group was done successfully in all distict on time as planned. The aim of small stock project 2020-2021 is to create new job for youth and women was achieved successfully, where the target of distribution small stock was done and this will increase income of groups and enhance livehoods of beneficiaries. It is recommended to continue regular follow up of groups to help them to reach their goals.

Capacity building in pig artificial insemination

To increase good quality pigs for meat production, pig artificial insemination practice needs to be disseminated. UR-CAVM Busogo and Gasabo CPPA Kisaro AI center were used for training. Musanze station in collaboration with Monogastric program have organized training session for sector vets and private vets to acquire skills on pig AI practice. Besides, one staff from RAB and one sector vet from Nyamasheke district and UR Student have attended the training. The training focused on the following topics: Synchronization of sows and gilts (in 3 rounds); Theory sessions on artificial insemination and pig production and general management; Preparations of semen to be used (collection, processing, storage); Conduct artificial insemination practical sessions. A total of 30 vets from Gasabo, Musanze, Rubavu and Nyamasheke were trained.

Synchronization of sows and gilts: To ensure that all sows and gilts are ready to be inseminated at fixed schedules, specific reproductive hormones were used to synchronize the estrous heat of all sows and gilts identified. During estrous synchronization, a protocol two hormones (Regumate porcine, PMSG) was followed in this training. Of all 26 sows and gilts treated with hormones to synchronize heats, 23 have shown signs of heats and the failure of those 3 were due to farmers who missed some days on distribution of hormones.

Photo 80: Preparation for synchronization of sows

Theory sessions on artificial insemination and pig production and general management

It was one-day session where they have covered different modules in order to have enough skills on pig artificial insemination and pig farming in general. The topics covered include: Pig artificial insemination theory (background, Current status, Heat detection, collection, processing & storage of semen, and Steps of AI); Pig production and general management; Synchronization protocols and its success stories.

Preparation of semen to be used (collection, processing and storage)

Pig semen is used while fresh and could be used from day of collection till day 6 on condition it is stored at 17^0C. During this training, semen was collected from one Boar at Org. CPPA Kisaro and UR-CAVM Busogo AI centers. Normally the boars used for collection of semen can be maintained for at least two years from the period of production. The trainees have experienced the whole process of collection, processing and storage of fresh boar semen.

Artificial insemination practical sessions

At the due dates of estrous heats following synchronization of sows and gilts were inseminated. During this training, a total of 17 sows and 6 gilts from 8 farms showered estrous heats and were inseminated starting from 14-15 November 2019 for Gasabo and 28- 30 September 2019 for Musanze and Rubavu. Pigs from Gasabo were inseminated with Pietrain semen while those from Musanze and Rubavu were inseminated with Landrace semen. Each trainee practiced the heat detection assessment, cervix penetration and action of insemination at least two times.

Photo 81: Trainees learning AI technology

2.5 Veterinary Services Program

The Veterinary Services program plays a key role in animal resources department through Planning and executing Veterinary Services research and technology transfer activities, to ensure mentorship for scientists in animal health and laboratory analysis; to establish and maintain effective collaboration with other stakeholders (researchers…), locally, regionally and internationally; to coordinate and facilitate demand articulation, planning, implementation and reporting of veterinary service delivery, disease diagnostics, and animal quarantine services at the national level; Establishing, updating and implementing human resource and infrastructure development plans for public veterinary service delivery and disease diagnostics; Advising RAB and relevant authorities on Veterinary services policies and regulations, and any other duties assigned by RAB authorities. The key activities were on transboundary pest control; control of zoonotic diseases, PPR vaccination campaign;

Control of Transboundary animal diseases

During 2020/21, we conducted vaccination activities for different animal disease prevention including lumpy skin disease (LSD), Black quarter and anthrax (BQ), peste des petit ruminants (PPR), Foot and Mouth Disease (FMD) in high risk areas were vaccinated, these areas include districts bordering Tanzania and Uganda; and among these are; Kirehe, Kayonza, Gatsibo and Nyagatare districts.

Control of zoonotic diseases

Rwanda has had different zoonotic diseases incidences of which some have become endemic and pose a big threat to the public. These include Brucellosis, Rift Valley Fever, Rabies and cysticercosis. During this FY 2020-2021 we conducted vaccination campaign in Districts located alongside, Umuvumba, Akagera and Nyabarongo rivers and their effluents, We conducted also vaccination against rabies as well as brucellosis for young female cattle (4-11months).

PPR vaccination campaign

Pest des Petits Ruminants (PPR), also known as sheep and Goat plaque, is a highly contagious animal disease affecting small ruminants. Once introduced, the virus can infect up to 90 percent of an animal heard, and the disease kills anywhere from 30 to 70 infected animals. Symptoms of the disease are high fever, oral discharge, severe diarrhea sometimes mixed with blood, breathing difficulties with coughing, wounds in the mouth, cracked and dry nostrils, sudden death (in 5-10 days) among others. The PPR virus does not infect humans. Today, more than 70 countries are affected including neighboring countries; therefore, we are at high risk of contracting the disease if prevention measures are not strengthened, and thus we started the vaccination program in high-risk zones. Given the above background - The Rwanda Agriculture and Animal Resources Development Board (RAB) in collabotion with Districts has launched a campaign to vaccinate Peste des Petits Ruminants (Sheep and Goats). The campaign was done in 13 districts: Gisagara, Nyaruguru, Bugesera, Nyamagabe, Nyagatare, Kirehe, Kayonza, Gatsibo, Gicumbi, Rusizi, Huye, Gisagara, Ngoma on 7th September 2020, whereby 470,678 sheep and goats have been vaccinated.

Photo 82: PPR Vaccination campaign in Bugesera District

Rift Valley Fever Vaccination Campaign

Rift Valley Fever (RVF) is caused by a zoonotic arbovirus that is endemic to Eastern and Southern Africa. It has also been reported in West and North Africa, Madagascar and the Arabian Peninsula. The virus is transmitted by mosquitoes and humans may also be infected with RVF while handling blood or other animal body fluids. The disease affects cattle, sheep, goats, several rodents, wild ruminants, buffaloes, antelopes, among others. RVF virus regularly circulates in endemic areas between wild ruminants and haematophagous mosquitoes. The disease is usually unapparent in wild species of animals due to their lower susceptibility. Certain Aedes species act as reservoirs for RVF virus during inter-epidemic periods. Increased precipitation or flooding in dry areas leads to an explosive hatching of mosquito eggs, many of which harbour RVF virus. The disease is characterized by a high fever lasting 24–96 hours, nasal discharge and excessive salivation, anorexia, weakness, bloody/fetid diarrhoea, bloody in natural cavities, fall in milk yield, abortion rate which may reach 85% in the herd. There is not any specific treatment for RVF.

Photo 83: Vaccination campaign against RVF in Ruhango District

Table 80: Vaccination Progress report from July 2020 to 30 June 2021

District	BQ	Brucellosis	FMD	LSD	RVF	Rabies	PPR
Bugesera	15,523	1,049	N/A	18,500	17,400	429	55,106
Burera	32,507	3,484	N/A	40,084	12,729	116	N/A

Gakenke	31,047	3,500	N/A	50,955	27,150	213	N/A
Gasabo	3,766	3,097	N/A	3,988	15,161	800	N/A
Gatsibo	12,734	1,681	16,417	25,426	13,399	133	32,071
Gicumbi	33,527	4,386	N/A	61,021	19,016	18	35,878
Gisagara	30,315	1,391	N/A	26,768	13,607	107	37,965
Huye	26,820	2,823	N/A	21,837	6,089	410	24,457
Kamonyi	27,529	2,247	N/A	33,334	25,024	319	N/A
Karongi	19,991	947	N/A	25,533	7,353	330	N/A
Kayonza	21,170	1,211	77,213	16,183	16,532	232	56,576
Kicukiro	4,010	424	N/A	3,814	3,461	434	N/A
Kirehe	17,118	1,291	25,917	21,335	25,272	176	50,773
Muhanga	22,107	715	N/A	19,741	10,000	312	N/A
Musanze	21,689	2,925	N/A	14,660	6,300	306	N/A
Ngoma	16,736	1,289	N/A	13,876	11,953	181	35,582
Ngororero	9,538	758	N/A	21,915	5,691	116	N/A
Nyabihu	32,207	3,464	N/A	29,791	6,950	198	N/A
Nyagatare	33,908	971	37,128	38,366	20,969	84	60,031
Nyamagabe	18,855	3,542	N/A	18,865	7,902	297	20,897
Nyamasheke	17,210	4,138	N/A	18,236	N/A	317	N/A
Nyanza	15,198	1,847	N/A	15,198	8,452	N/A	19,472
Nyarugenge	1,209	51	N/A	3,404	3,029	293	N/A
Nyaruguru	12,304	1,117	N/A	14,809	8,206	149	19,758
Rubavu	17,256	1,132	N/A	20,260	3,270	142	N/A
Ruhango	12,446	2,506	N/A	22,376	16,731	91	N/A
Rulindo	30,983	1,623	N/A	31,221	27,393	133	N/A
Rusizi	15,161	860	N/A	15,161	N/A	249	29,783
Rutsiro	19,113	1,750	N/A	31,780	N/A	261	N/A
Rwamagana	21,023	2,540	N/A	21,023	10,500	100	N/A
Achievement	**593,000**	**58,759**	**156,675**	**699,460**	**349,539**	**6,946**	**478,349**
Annual Target	**592,187**	**52,728**	**120,000**	**692,402**	**365,040**	**9,500**	**400,000**
Percentage	**100**	**111**	**131**	**101**	**96**	**73**	**120**

The presence of RVF in Rwanda was confirmed in 2013, and regular vaccination campaigns started therefore. This fiscal year 2021-2021, Rwanda Agriculture and Animal Resources Development Board (RAB) plans to vaccinate more than 365,000 animals, especially in districts bordering Akagera and Nyabarongo rivers. Containing the disease is effective through vaccinating susceptible animals in risk zone, controlling animal movements (extension of disease), maintaining hygiene in slaughterhouses, draining standing water to eliminate or reduce vectors, building the capacity of farm personnel, and clinical management of RVF cases.

Control of animal movement for Animal and animal products

Control of animal movement is one of the control measures put in place by veterinary services to control transboundary animal diseases and is mandated to issue out permission to allow movement of following animal, as well as import and export of farm equipment.

Table 81: Permits issued for FY 2020/2021

Permit Category	Item	Permits issued	Total Quantity
EXPORT	Pets	158	104 Dogs and 54 Cats
	Day Old Chicks	48	688,173 Chicks
	Hides &Skin	122	2,902,181 Kg ; 613,229 Pcs
	Hatching eggs	28	346,496 Eggs
	Biological samples	9	
	Consumable eggs	16	15,778 Eggs
	Insects	1	5 African Queen Butterfly
	Live fish	1	40 Kg
	Breeding cattle	3	122 cows
IMPORT	Pets	148	99 Dogs and 39 Cats
	Day Old Chicks	69	873,819 Chicks
	Hides &Skin	4	12,500 Kg, 8,500 Pcs
	Hatching eggs	70	1,798,927 Eggs
	Bovine	5	22,957 Doses
	Porcine		12 Straws
	Live animal- Pigs	2	12 Pigs
	Goat		60 Galla Goats
	Farm accessories	52	
TRANSIT	Pets	8	8 Dogs
INTERNAL MOVEMENT	Cattle	130	3,208 cows
	Pigs		28 pigs
	Poultry		5,700 chicken
	Sheep		1 sheep
Non Objection letters	Letters		48 letters
TOTAL		**796 Permits issued, 48 No objection letters**	

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

An update on the distribution of Glossina (tsetse flies) at the wildlife-human-livestock interface of Akagera National Park, Rwanda

Glossina (tsetse flies) biologically transmit trypanosomes that infect both humans and animals. Knowledge of their distribution patterns is a key element to better understand the transmission dynamics of trypanosomosis. Tsetse distribution in Rwanda has not been well enough documented, and little is known on their current distribution. This study determined the current spatial distribution, abundance, diversity, and seasonal variations of tsetse flies in and around the Akagera National Park. A longitudinal stratified sampling following the seasons was used. Biconical traps were deployed in 55 sites for 6 consecutive days of each study, from May 2018 to June 2019 and emptied every 48 h. Flies were identified using FAO keys, and the number of flies per trap day (FTD) was used to determine the apparent density. Pearson chi-square ($\chi 2$) and parametrical tests (t-test and ANOVA) were used to determine the variations between the variables.

The significance ($p < 0.05$) at 95% confidence interval was considered. Logistic regression was used to determine the association between tsetse occurrence and the associated predictors.

A total of 39,516 tsetse flies were collected, of which 73.4 and 26.6% were from inside Akagera NP and the interface area, respectively. Female flies accounted for 61.3 while 38.7% were males. Two species were identified, i.e. *G. pallidipes* [$n = 29{,}121$, 7.4 flies/trap/day (FTD)] and *G. morsitans centralis* ($n = 10{,}395$; 2.6 FTD). The statistical difference in numbers was significant between the two species ($p = 0.000$). The flies were more abundant during the wet season (15.8 FTD) than the dry season (4.2 FTD). Large numbers of flies were trapped around the swamp areas (69.1 FTD) inside the park and in Nyagatare District (11.2 FTD) at the interface. *Glossina morsitans* was 0.218 times less likely to occur outside the park. The chance of co-existing between the two species reduced outside the protected area (0.021 times). The occurrence of *Glossina* seems to be limited to the protected Akagera NP and a narrow band of its surrounding areas. This finding will be crucial to design appropriate control strategies. *Glossina pallidipes* was found in higher numbers and therefore is conceivably the most important vector of trypanosomosis. Regional coordinated control and regular monitoring of *Glossina* distribution are recommended.

Identify Trypanosoma species circulating in cattle, their diversity and distribution around the Akagera National Park. Rwanda

African Trypanosomiases threaten both humans and animals. The diseases occur in poor and vulnerable settings of Africa. Trypanosomes are transmitted by tsetse and other biting flies. In Rwanda, the endemic area is mainly around the tsetse-infested Akagera National Park (NP). The study aimed to identify Trypanosoma species circulating in cattle, their diversity and distribution around the Akagera NP. A cross sectional study was carried out in four districts, where 1,037 cattle blood samples were collected. The presence of trypanosomes was determined by microscopy, immunological rapid test VerY Diag and PCR coupled with High Resolution Melt (HRM) analysis. The overall prevalence was 5.6%, 7.1% and 18.7% by thin smear, Buffy coat technique and PCR/HRM respectively. Microscopy showed a low sensitivity while a low specificity was shown by the VerY Diag. Trypanosoma (T.) congolense was found at a prevalence of 10.7%, T. vivax 5.2%, T. brucei brucei 2% and T. evansi 0.7% by PCR/HRM. The non-pathogenic T. theileri was also detected. No human-infective T. brucei rhodesiense was detected. There was no statistical significance between the mean PCV of infected and non-infected animals ($p>0.162$). Our study sheds light on the diversity of animal infective trypanosomes around the Akagera NP, including both pathogenic and non-pathogenic trypanosomes. The PCV estimation is not always an indication of trypanosome infection and the mechanical transmission should not be overlooked. Prevention and control activities should target mainly areas around Akagera NP. AAT impact assessment on cattle production and

information on the use of trypanocides are needed to help policy makers prioritise target areas and optimize intervention strategies. Ultimately, these studies will allow Rwanda to advance in the Progressive Control Pathway (PCP) to reduce or eliminate the burden of AAT.

2.6 Aquaculture and Fisheries Program

2.6.1 Capture Fisheries

Capture fishery is artisanal or small-scale where fishers are organized into cooperatives. Fishing is an important for communities neighboring the Lakes. Currently, a total of 36 cooperatives operate on lake Kivu fishing zones in Karongi, Nyamasheke, Rusizi, and Rubavu districts, with 1,349 members along with 973 Males and 376 females. The remaining 25 lakes from 4 following Fishing Zones: *Bugesera* (9 lakes Bugesera Districts), *Gisaka* (3 lakes, Nasho, and *Nothern* are counting 2,130 cooperative members along with 488 females, 1,505 males, and 241 among them are youth more to that there are 10 more lakes located in the Akagera National Park and fishing activities are managed by Akagera National Park.

In Rwanda fishing activities are regulated by the Ministerial order Nº 001/11.30 of 11/12/2020. In order to ensure a sustainable fish production, the following measures were adopted:

- Licensing Fishing Activities (Renewable on annual basis after each biological break) for the protection and exploitation of lakes and reservoirs,
- Adopting a 2-month biological Break in each fishing zones,
- Fight against Illegal Unregulated and Unreported (IUU) fishing activities in RWANDAN Lakes,
- Environmental Protection by promoting the use of selective fishing nets and environmentally friendly,
- Licensing the trading of Fishing Equipment.

The key fish species contributing to capture production are *Limnothrissa miodon*, *Haplochromis spp.*, Oreochromis niloticus, *Clarius gariepinus*, *Protopterus aethiopicus*, and *Cyprinus carpio*. Fishing activities are undertaken through the cooperatives of fishermen. The landed capture production in 2020/2021 FY was **39,269 MT.**

Awareness Campaign

Meeting with fishers were conducted in Western Province (Rubavu, Rutsiro, Karongi, Nyamasheke, and Rusizi), in Eastern and Northern Provinces (Bugesera, Gisaka, Nasho, Muhazi, and Northern Fishing Zone)in collaboration with MINAGRI, RAB, Districts and Police Marine to raise awareness about new Ministerial order regulating aquaculture and Fisheries. Awareness campaign through Radio, TV, and News Paper to fight against illegal fishing, illegal trading in Eastern, Northern, and Western Lakes was conducted.

Lake surveillance to Control Illegal Fishers

Regular sensitization meetings and visits were carried out in different fishing zones for increased production in lakes. Lake surveillance was reinforced to control illegal fishers and guide fishing cooperatives to increase fish production from Rwanda. Regular surveillance and monitoring of fishing activities were done with Police Marine, Army Marine, and Cooperative Union, different poachers and equipment were seized: 1,109 Kaningini; 368 poaching boats; 169 supernets; 142 poachers as reported to Police and Army Marine stations.

Regular patrol was done in Lake Kivu in the districts of Rubavu, Rutsiro, Karongi Nyamasheke, and Rusizi to fight poaching in the lake.

Table 82: Results of surveillance during the biological break on Lake Kivu

Districts	Rubavu	Rutsiro	Karongi	Nyamasheke	Rusizi	Total
Kaningini	27	190	55	01	120	**392**
Supernet	16	42	16	01	17	**91**
Boats	19	55	17	01	33	**125**
Poachers	03	28	28	0	33	**89**
Seized fish	357kgs	85kgs	55	---	45kgs	**542kgs**

Inspection of markets and landing sites

During the field visit, Inspection was done on the following landing sites and markets across the five districts of Western Provinces. Due to the current Covid-19 Pandemic restriction, the inspection was not well done in Rusizi and Nyamasheke. In Bwishyura Sector (Karongi): 55kg of fresh isambaza were seized from Donatha Nyirarukundo and Mukeshimana: They have denounced the individuals who sold the isambaza to them. The seized products were distributed to people who suffer from malnutrition. During that activity, we held a gathering to sensitize about the usefulness and the duration of the biological break. In Rutsiro, the landing sites of Kabacuba, Cyimbiri, and Gashingamutwe were inspected and the market of Nkora was also inspected: there were no fishing products or illegal fishing activities noticed. The landing site of Kiraga/Rubavu was inspected and no illegal activities were noticed. While inspecting the Gisenyi market/RUbavu, 30kg of isambaza fresh were seized; 35kg of isambaza fresh were also seized in the Mbugangari market. In the Kiziba market and in Mahoko market, 10kg were seized. In Rushangara / Nyamyumba, 5kg were seized.

Inspection of fishing cooperatives

In order to reinforce the good practice of fishing in Lake Kivu, an inspection session has been implemented in collaboration with the fishers' cooperatives unions and different sectors authorities in districts bordering with the lake. The outcome of this inspection will allow us to issue new fishing permits. The inspection of fishing gears carried out 36 cooperatives operating in the districts Karongi, Rutsiro, Rubavu, Nyamasheke, and Rusizi. Among which 35 were fulfilling all the requirements to be issued a fishing license.

Photo 84: Kanigini illegal nets seized (left) and poachers captured (right) during Kivu lake Surveillance

2.6.2 Aquaculture

For 2020/2021 FY the government of Rwanda through the Ministry of Agriculture and Animal Resources implemented by the Rwanda Agriculture and Animal Resources Development Board to promote fish farming in ponds in order to improve the productivity of abandoned fish ponds. The main objective has been to provide technical assistance in pond management of existing fish ponds in the country, coop. management & organization under a RARICO contract of promoting fish farming in ponds and manage properly Rwandan lakes. In addition to that fingerlings and fish feed has been provided to 96 farms. The achieved aquaculture production is mainly from

cage fish farming, dams, and few ponds since most ponds were stocked starting from the end of December, and harvesting will be in next year. A production of **2,395 MT** was achieved. The total fish production achieved for this fiscal year was **41,664 MT.**

Technical Assistance

Training of RARICO field staff, assistant field technicians and field coaching

A total of 45 field staffs of RARICO that were providing technical assistance to 96 fish farmers located in 26 districts were given a refresher training on fish pond construction and its preparation before stocking/restocking; water quality management; Fish pond stocking or restocking; Fish feeding; Fish sampling (Fish Control); Protection against Predators; Sex reversal, Daily Fish farm record keeping & Harvesting System; Linkage to market and financial institutions

A total of 98 assistant field technicians from 96 farms and all provinces (81males and 18 females) were trained on different subjects such as Site selection and preparation; Fish pond construction and its preparation before stocking/restocking; Water quality management; Fish pond stocking or restocking; Fish feeding & integrated fish farming with rabbits or hens; Fish sampling (Fish Control) fight against Predators; Linkage to market and financial institutions. A total of 209 Cooperative Leaders from allprovinces (178 males, 27 females and 4 youth) have been trained on same topics.

A total of 8,725 fish farmers were coached at farm sites through theory and direct practices They were coached on pond construction and management, cooperative management and book recording, fingerling transportation d conditioning, and access to finance.

Provision of training materials, water testing and farm equipment

Training materials were developed and distributed on fish farming, cooperative management, access to finance, and preparation of cooperative action plan. Besides, 96 water testing kits were supplied to fish cooperatives, which included thermometer, Secchi disk, Alkalimeter, and Oxymeter. Besides, Nursey nets, graders, electronic scales and fishing nets were supplied.

Production harvested during the rehabilitation period

During the rehabilitation period of fish ponds, as described in the below table, 13,579Kgs of fish were harvested (5,481Kgs sold while 7,498Kg consumed by farmers' families).

Table 83: Fish production

s/n	Province	Harvested (Kg)	Sold (Kg)	Value of sold fish (Frw)	Unsold (Kg)
1	Northern	2,403	1,490	3,659,250	913
2	Southern	3,416	975	2,083,250	2,441
3	Western	2,900	127	317,500	2,773
4	Eastern	2,188	1,168	2,506,500	1,020
5	Kigali City	2,072	1,721	3,993,000	351

6	Total	13,579	5,481	11,397,500	7,498

Follow up of fish hatcheries and fish farms in Rwanda

The capacity for fingerling production relies mostly on private hatcheries, where RAB monitors their production capacity. A total of 9 hatcheries and 1 fish feed factory were inspected: Fine Fish Ltd has capacity of 150,000 Tilapia fingerlings/Month; Fingers Fish Farm Ltd has capacity of 300,000 Tilapia fingerlings/Month; Fre Fish Ltd has a capacity of 250,000 Tilapia fingerlings/Month; Rwafil Ltd has capacity of 100,000 Tilapia fingerlings/Month; Aquatic Ltd has capacity of 10,000 Tilapia fingerlings/Month; Kivu Tilapia Ltd has capacity of 100,000 Tilapia fingerlings/Month; Kungabu has capacity of 20,000 Tilapia fingerlings/Month; Rwasave - 2500 catfish fingerlings/Month; Lakeside fish farm ltd - 300,000 Tilapia fingerlings/Month; Huye Feed was visited and has capacity for 200 tons of feed per month (they can produce 40% CP, 35% CP, 30% CP, and 25% CP). A production of 27,320,149 fingerlings could be potentially achieved from 9 hatcheries monthly.

Facilitation of new investors in Cage Fish Farming

During this fiscal year 13 investors have been facilitated in technical analysis of submitted business plans, in site identification, visit, and administrative procedures of getting required licenses to start a fish farm in Rwanda.

Table 84. Facilitated new investors in Cage Fish Farmers

No	Name of the company	Lake	Location/District
1	Fish farming forces Ltd	Muhazi	Gicumbi
2	Build'ones Ltd	Kivu	Nyamasheke
3	Aquahort Export Ltd	Kivu	Karongi
4	Tropical Fresh Harvest Ltd	Muhazi	Rwamagana
5	Chanelmic Farms Ltd	Kivu	Rutsiro
6	Eastern Fishing Business Services Ltd	Muhazi	Gatsibo
7	Kivu Fresh Fish Farm Ltd	Muhazi	Rwamagana
8	Umuvumu Family Ltd	Kivu	Nyamasheke
9	Fish Taste Farming Company Ltd	Muhazi	Gatsibo
10	E&M Tilapia Farm Ltd	Kivu	Nyamasheke
11	SOCOPO Ltd	Kivu	Rutsiro
12	Nature and Fisheries Ltd	Muhazi	Rwamagana
13	Twizeric Farms Ltd	Kivu	Rutsiro

Kigembe Fingerlings production and Stocked in Ponds, Dams, and Lakes

Restocking of water bodies is one of the strategy used in capture fisheries for stock enhancement where depletion of stock of specific species have been observed. The bellow table indicates that the total number of 182,625 fingerlings was stocked in 6 dams, 40,000 stocked in 6 ponds and 40,000 stocked in 4 in lakes.

Table 85. Restocking of Fish Ponds, Dams and Lakes during 2020 2021 FY

№	Months	Fingerlings produced orsupplied	Stocking Location

		Produced, Tilapia	Produced, catfish	Supplied fingerlings	
1	July	45,004	0	10,000	Muhazi lake
				4,000	Musenyi Modal Farm
2	August	32,309	0	4,000	Ngwinondebe coop.
				4,000	Abizeranyemubikorwa coop.
				4,000	Duharanire indyo nziza coop.
				10,000	Muhazi lake
3	September	90,400	0	0	
4	October	95989	3000	4,000	Tubehoneza coop.
				40,000	Rugeramigozi dam
5	November	131200	3000	50,000	Tuyakoreshe gakondo (dam)
				10,000	Mugesera lake
6	December	47,000	5000	10,000	Rwabicuma dam
				20,000	Ntyazo ponds
7	January	91,500	10000	12,625	Tuyasaranganye Agasasa (dam)
				20,000	Kibuza dam
8	February	121,200	30,000	0	
9	March	108,800	0	40,000	Cyili dam
10	April	76,421	0	10,000	Cyohoha lake
				10,000	Cyili dam
11	May	83,000	5000	0	
Total		**922,823**	**56,000**	**262,625**	

Production of Black soldier fly (*Hermetia illucens)* as live fish feed for aquaculture farming

Black Soldier Fly Larvae (BSFL) uses organic waste to produce nutritive biomass rich in proteins. This study evaluated the potential of farming BSFL as an alternative protein source for fish feed. The methodology used was to produce these BSF by installing two treatments where the production of larvae in T_1 eggs were hatched in brewer's waste bought from factory that manufacturing beer (Skol) while for T_2 the eggs were dispersed over the waste containing fruits and vegetable (Banana peels, oranges, pineapples and avocados, and watermelons. The all eggs collected were incubated in five basins (5 replicate groups) for each type of feed or treatment. Through using different feeding rates, the effect of the substrates used on the mean larval weight over time showed varied response of BSFL growth. BSFL larvae grew more rapidly on brewery waste as compared to the larvae fed on fruits mixed with vegetable (Banana peels, oranges, pineapples and avocados, and watermelons). The analysis of prepupae fed on both brewer's and vegetable mixed with fruit waste showed sufficient crude protein content to enable usage in fish feed formulation.

A comparative study on evaluating the growth response of Nile Tilapia Fish (*Oreochromis niloticus)* fed on three different commercial diets

A 90-day long experiment was carried out to evaluate three commercial Tilapia feeds. Two types were available locallt and one was imported from Israel. Feed from Aquahort (located in Masoro), Huye feed and RANAAN Fish Feed (designated as treatment_T_1 T_2 and T_3 respectively) on the growth of Nile Tilapia. At the beginning, the fish were fed twice daily at 8% of their body weight, which was gradually reduced to 6 and 5%.Water temperature was 20.0°C- 26°C, pH 6.8 - 8.5, DO 5 - 11.55 mg/1 and transparency or Secchi depth of 20-25cm. The mean weight gain

of fish was significantly (P<0.05) higher with RANAAN fish feed followed by Huye feed, then Aquahort. The specific growth rate (SGR) ranged between 2.62 and 3.08, feed conversion ratio (FCR) values between 1.56 and 2.00 with treatment T_1 showing the lowest FCR. The survival of fish varied between 87.4 and 91.3%. The significantly (P<0.05) higher fish production (kg/ha/90 days) and lowest profit (Kg/ha/90 days) was observes with use of RAANAN followed by Huye feed and Aquahort feed, respectively. For fish growth performance, feed from Israel, RAANAN feed is the best but the high cost of this imported feed causes low profit. Therefore, this feed could not be considered as a recommended feed for large scale production of tilapia fish. The farmers have to organize aquaculture by using feed from our available industries.

Comparative Growth Performance of new Introduced Strain of Nile Tilapia (*Oreochromis Niloticus*) with the existed stocked at Kigembe fish farm

A comparative study on growth of fry introduced from Kivu Tilapia Fish (KTF) farm and the existing strain of Nile tilapia (*Oreochromis niloticus*) at Kigembe fish farm was performed. The trials were conducted in six hapas placed in one pond for a period of 145days. The study carried out was to evaluate the growth performance and feed utilization for those different strains of Nile tilapia (*Oreochromis niloticus*). Fishes were fed supplementary feed 40% of protein level from animal feed factory located at Sovu in Huye District. After 145 days the results show that for new introduced Nile Tilapia from KTF farm, the mean final weight and weight gain, differed significantly (P<0.001) compared to existed one. Data show that the high final weight was obtained in Nile Tilapia from KTF farm (22.13 g/fish), while the existed Nile Tilapia exhibited the final weight of 17.86g/fish. Similarly, weight gain exhibited the same trend. However, specific growth rate (SGR) and survival rate did not show a significant (P>0.05) difference between those two tilapia strains. The introduced Tilapia from KTF farm (28.12g feed/fish) had higher feed intake but lower FCR (1.27). It is worth mentioning that was more efficient in feed utilization and protein turn over than the existed Tilapia. This is because higher growth performance and less FCR values were observed in introduced Nile Tilapia fish. From this study, the crossing between those two different strains while selecting for fast growth and lower FCR, we expect to greatly improve the performance of resultant progeny. Therefore, exploitation of the genetic variation within those different strains through selective breeding can help to improve growth performance of the Kigembe strain. The offspring from crossing when distributed to fish farmers will greatly improve the productivity and consequently have a positive impact on the livelihoods of the farmers.

Revalorization of fish ponds in Rwanda

A total of 925,94m2 ponds were rehabilitated; 949 ponds restocked; 24,245.6kg of fish feed was supplied. Training materials were supplied to 141 farmers. A total of 209 farmers were trained on pond management, and 980 were trained in fish separation, sexing and harvesting.

A total of 136 ponds with area of 11,309m2 belonging to 21 cooperatives were stocked with 445,235 fingerlings were supplied in Northern province; 229 ponds with of 129,799 m2 belonging to 16 cooperatives were stocked with 519,196 m2 were supplied in West; 23 cooperatives with 255 m2 area were supplied with 882,365 fingerlings in Southern province.

Table 86: Fingerlings supplied

Province	Number of fish cooperatives	Number of ponds	Pond area, m2	Number of fingerlings supplied
Northern	21	136	111,309	345,999

Western	16	229	129,799	519,196
Southern	30	220	220,591	647,904
East	19	215	203,144	533,586
Kigali	10	103	106,976	364,923
Total	96	978	771,819	2,265,672

Fish Feed distribution

A total of 23,440kg of fish feed were supplied to a total of 88 cooperatives across the country (3,574kg to 21 fish cooperatives in Northern province; 4,118 kg to 16 coopertives in Western province; 5,560kg to 19 cooperatives in Eastern province; and 6,927 kg to 32 fish cooperatives in Southern Province).

Table 87: Fish production production 2020/2021 FY (by 15th June 2021)

Province	Q1	Q2	Q3	Q4	Total
A. Capture fisheries production					
Eastern	1,403,442	1,292,506	1,916,514	912,002	5,524,464
Southern	30,050	50,830	101,611	39,675	222,166
Western	1,497,471	6,681,444	5,555,474	10,289,929	24,024,318
Northern	2,116,800	2,407,290	2,631,779	2,120,746	9,276,614
Kigali City	35,440	41,385	84,961	59,700	221,486
Total	***5,083,203***	***10,473,455***	***10,290,339***	***13,422,052***	***39,269,048***
Production (tonnes)	5,083	10,473	10,290	13,422	39,269
B. Cages					
Rwamagana	113,998	547,983	111,717	215,809	989,507
Kayonza	10,249	20,192	30,293	28,034	88,768
Bugesera	-	-	800	5,000	5,800
All East	124,247	568,175	142,810	248,843	1,084,075
Rubavu	18,753	24,429	45,526	38,268	126,976
Karongi	102,156	1,800	7,770	5,153	116,879
Rusizi	55,753	55,429	55,526	58,268	224,976
All West	176,662	81,658	108,822	101,689	468,831
Burera	163,133	112,150	111,301	96,700	483,284
Gicumbi	1,350	1,350	1,350	1,240	5,290
Musanze	700	1,200	1,610	-	3,510
All North	165,183	114,700	114,261	97,940	492,084

Kigali City	725	1,211	250	-	2,186
TOTAL	**466,817**	**765,744**	**366,143**	**448,472**	**2,047,176**
C. Ponds and Dams					
Gatsibo	-	*7,533*	*4,448*	*3,266*	*15,246*
Kirehe	*2,680*	*0*	*0*	*0*	*2,680*
Rwamagana	2,184	3,457	3,595	3,848	13,084
Kayonza	72,137	68,471	120,499	51,891	312,998
Bugesera		440			440
East	**77,001**	**79,901**	**128,542**	**59,005**	**344,618**
Gisagara	885.5	1287	346	801	3,320
South	885.5	1287	346	801	3,320
Kigali City			***170***	-	170
Total	**77,887**	**81,188**	**128,888**	**59,806**	**347,938**
Total B and C	**544,704**	**846,932**	**495,031**	**508,278**	**2,395**
Targeted production	**975,000**	**975,000**	**975,000**	**975,000**	**3,900,000**
Total A,B and C	**549,787**	**857,405**	**505,321**	**521,700**	**41,664**

Table 88: Fingerlings production in hatcheries

District	Name of Hatchery	Q1	Q2	Q3	Q4	TOTAL
Gatsibo	**Rafson Company**	112,400	82000	142000	180000	516,400
Kayonza	**La Flamine, Rwafil**	276,000	210,000	628,200	788,240	1,902,440
Bugesera	**Lakeside**	758,000	568000	756400	841000	2,923,400
East		**4,202,400**	**2,323,509**	**3,581,500**	**4,242,380**	**4,349,789**
Nyanza	**Dufatanye coop**	72400	36526	322357	58847	490,130
Huye	**Rwasave**	106,000	300,000	200,143	100,253	706,396
Gisagara	**Kigembe Fish center**	167,713	285,189	361,500	164,421	978,823
All South		240,113	321,715	683,857	223,268	1,468,953
Rubavu	**Fine fish**	60,000	80,428	60,386	40,932	241,746
Nyamashek e	**Kungabu**	34,939	-	-	-	34,939
Rusizi	**Kivu Tilapia**	1,140,000	977,069	1,982,166	1,951,936	6,051,171
All West		**1,234,939**	**1,057,497**	**2,042,552**	**1,992,868**	**6,327,856**
Gasabo	**Fine fish**	1,309,250	1,012,001	1,319,300	1,533,000	5,173,551

Kigali City		1,309,250	1,012,001	1,319,300	1,533,000	5,173,551
TOTAL		**6,986,702**	**4,714,722**	**7,627,209**	**7,991,516**	**27,320,149**

2.7 Commercial Insects Program

RAB Commercial insects program conducts research and development on kee keeping and sericulture. It aims to promote value chains of sericulture and bee products.

2.7.1 Bee keeping

Training of beekeepers around Nyungwe zone

Nyamagabe, Nyaruguru, Nyamasheke and Rusizi beekeepers were trained in colony multiplication and apiary management. Five members from each of 28 Cooperatives learned beekeeping including biology of honey bees, conditions for the place to start an apiary, first operations when entering an apiary, how to use top bar hives and log hives in order to increase honey and wax production, bee diseases monitoring and management for round one, and bee suits making with local material, field visits and practical activities in the apiary, inspection of hives, transfer of bees from traditional to modern hives, how to mark a queen, how to plan or monitor weekly activities and how to strengthen a bee colony by following the bee calendar, how to use refractometer, monitoring of bee diseases and pests. Out of 140 trainees, 21% were women and 79% men. The training was tailored provide investment alternative to modern expensive Langstroth hives with low cost top bar hives. The trainees were able to make 6 low cost top bars using locally available materials and 2 hive stands that play a key role in Apiary Management.

Photo 85: Beekeepers from COPAM explaining proper use of smoke (left) and COATUM transferring bees from log to modern hive (right)

Bee keepers from 14 cooperaties received training on how to make wax and top bar hives using local material. Local authorities were advocated and have availed good building for appropriate honey storage. Cooperatives from Dusabane and COATUM received new bee suits from the apiary to enable them to work with their aggressive bee colonies. The program has supplied bee food to help to minimize bee colony loss along with the training organized on improved bee management.

Photo 86: Beekeepers from COPAM learn how to make wax foundation sheets (left) and Dusabane and COATUM cooperatives receive bee suits from the Apiary Ltd (right)

Bee calendar development

Bee calendar was developed after conducting the bee forage exercise (**Figure 1**). It will be printed and disseminated to bee keepers to help to follow up the major steps in bee management.

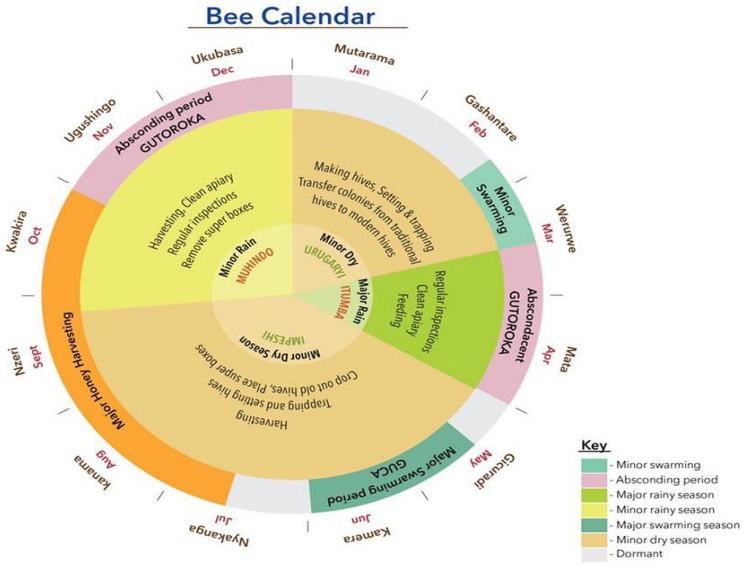

Figure 1: Bee calendar

Increasing number of bee colonies

Bee colony multiplication refers to the creation of new colonies with a young mated queen, brood and bees. RAB helps beekeepers to expand their colonies and increase bee the population to boost the production of honey and its by-products. Colony multiplication effectively controls natural swarming and keeps a check on the aggressiveness of the bees. This procedure allows beekeepers to start a new colony and is considered an important aspect of good bee management. Experts from RAB oorganized beekeeping training for beekeepers to gain proficiency in bee colony multiplication. A total of 210 bee colonies were produced in 12 cooperatives in Rusizi and Nyamasheke, while 250 bee colonies were strengthened by feeding them by pollen supplement.

Construction of Honey Collection Center and supply of bee equipment

One Honey Collection Center was built in Kirehe through REMA project's fund and bee equipment was supplied for 100 bee hives, bee suits and other bee equipment for production and processing. Besides, World vision Rwanda in their core project availed 200 hives to beekeepers in Nyamasheke and Rusizi at the end of April 2021. Four Honey Collection Centers were equipped with honey processing equipment in Nyamasheke (Kagano, Macuba, Karengera and Impashyi HCCs). Api-organic Rwanda established a small factory in Rwamagana to produce modern hives at lower price and by using market system approach with the target to produce 1 million bee hives in 4 years to be given to beekeepers though credit contracts. Now, they were able to produce 200 hives.

Development of high quality queens with comparing local honeybee responses Karl Jenter and Doolittle grafting queen rearing methods

There exist different methods for queen rearing. This study aimed to compare honeybee response to Doolittle method and the Karl Jenter and cup kit queen rearing techniques; to identify and evaluate effectiveness of two technologies of queen rearing in langstroth hives; and to compare the number of queen bees produced per hive and per technology applied. Queen rearing is a process of raising honeybee queens that uses an existing with queen or with queen colony. It encourages the reproduction of queens with characteristics that help bees to succeed in specific climatic and geographic conditions. Several methods exist which are applied in rearing queens: Karl Jenter method uses frame consisting of a box like construction with openings for 110 plastic cells, a compartment the queen is replaced in and two lids (front and back).The front lid is removed to expose the queen compartment and the cells where she is expected to place her eggs. The back lid exposes the backsides of the cell cups, which should hold the young developing larva. In addition one needs cup holders, which are fastened to frame bars, cell protectors, and of course the plastic cells to fit the cage for the queen to lay in. This method allows to raise up to 110 queens at one time.

Doolittle method involves grafting of the young larvae from the worker cells into artificial queen cell cups. It is quick, cheap, reliable, and it can be applied for mass production of queens. It is currently employed by commercial beekeepers worldwide.


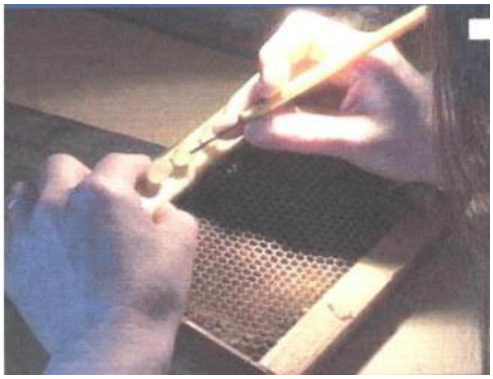

Photo 87: Grafting of larva and closing the frame holding larva (left); Queen rearing frame with the cell holder (right)

The study was conducted in 5 sites located in 5 districts – Huye, RUbavu, Rusizi, Burera, Kirehe and Nyagatare - during the peak flowering season when surplus forage is available at the station. Seven Langstroth hives with strong colonies were selected for colony splitting. Another seven empty Langstroth hives were prepared for the splitting program. Queens were raised through natural fertilization. During the reporting year, among two tested methods, only Doolittle method was successful (Table…), while the use of Karl Jenter method did not produce good results, because queens failed to lay eggs.

Table 89: Queen rearing results with Doolittle method

District	Cooperative	Number of grafted queens	Queens accepted		Queens catched	
			Number	%	Number	%
Huye	COPABUHU	30	12	40	9	30
Rusizi	UNICOPARU	30	8	26.66	7	23.33
Burera	UNICOPAVU	30	13	43.33	8	26.66
Rubavu	UNICOAPIGI	30	16	53.33	15	50
Rubavu	COABUMUCYA	30	10	33.33	6	20
Kirehe	COPAKI	30	17	56.66	11	36.66
Nyagatare	COPAKI	30	9	30	7	23.33

Out of 210 of grafted queens in all cooperatives, the rate of queens accepted was 27 to 40% and hatched queens were from 23 to 50%. The recommended period of raising queens is when the weather is warm. Among the cooperatives, UNICOAPIGI (Rubavu) has achieved the highest rate of hatched queens (50%) with 53.33% accepted queens. With Karl Jenter method queens failed to lay eggs in cell box. Doolittle grafting queen rearing method is recommended for use in Rwanda.

2.7.2 Sericulture

Current mulberry plantation in Rwanda is about 950 ha and the total production of Cocoons is only 30,436 kg per year, which is very low. China and India produce up to 1000 kgs of cocoons per ha per year. Sericulture research aims to develop high yielding and disease resistant of both silkworm breeds and mulberry varieties; and to develop appropriate sericulture technologies.

Evaluation of 4 mulberry varieties

The evaluation trial with 4 varieties (Diamond (control), Kanva, RSC-2, and Thailand) was carried out at RAB Rubona. **Leaf moisture content and moisture retention capacity**: Mulberry varieties varied in moisture content and moisture retention capacity. Moisture content was significantly higher in tender (88.00 %), medium (75.10%) and coarse (70.40%) leaves of RSC-2 and lower in leaves of Kanva (60.20%, 54.70%, and 57.16%, respectively). Moisture retention capacity was the highest in tender, medium and coarse leaves of RSC-2 (71.50%, 69.04%, 67.90%, respectively) and the lowest in Kanva (58.20%, 56.40%, 54.70%) (**Table 90**). Thus, RSC-2 was the best in moisture content and retention.

Table 90: Moisture content and moisture retention capacity of different mulberry varieties

Mulberry variety	Leaf maturity	Moisture content (%)	
		In fresh leaf	In leaves at 6 hours after harvest
RSC-2	Tender	88.00	71.50
	Medium	75.10	69.04
	Coarse	70.40	67.90
Thailand	Tender	80.10	68.16
	Medium	70.41	65.19
	Coarse	68.03	65.61
Diamond	Tender	76.72	62.26
	Medium	64.77	60.84
	Coarse	63.16	59.78
Kanva	Tender	60.20	58.20
	Medium	54.70	56.40
	Coarse	57.16	54.70

Characterization of 12 performing silkworm breeds

The aim of this study was to evaluate quantitative characteristics of silkworm germplasm. The experiment was conducted in the Laboratory of Genetics and breeding of silkworm, RAB-Rubona station. Twelve silkworm breeds (B2(m), B2(L), B3, B4, Luc, Demon, Progress, KN, Rub-1, Rub-2, C and J) were evaluated for daily fresh larval weight, survival rate, larval duration at 5^{th} instar stage, fresh pupal weight, cocoon weight, cocoon shell weight, and cocoon-shell ratio (including sex: female and male) were determined. Females were bigger in size as compared to males in cocoon weight (Female: 2.27 g > Male: 1.94 g), Pupal weight (Female: 1.80 g > Male: 1.50 g), shell weight

(Female: 473.8 mg > Male: 469.4 mg), but smaller for cocoon shell ratio (Female: 19.3 % > Male: 22.6 %). Demon, Progress and E-08 produced higher cocoon weight for both female, above 2.5 g and male (> 2.1 g). Similar trends were observed in pupal weight and shell weight (Table 4), where Demon, Progress, E-08, B2 (M), and Luc were highly ranked, while KN, C and Rub-2 recorded the lowest values.

Table 91: Cocoon, pupal and shell weight and shell ratio of 12 silkworm breeds

	Larval duration	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
SD	0.821	0.322	0.181	0.284	0.119	56.85	60.27	0.911	1.729

Maintenance of mulberry plantation

This mulberry plantation is used as mother garder to source the cuttings, which can be rooted to become saplings for dissemination to farmers. The mulberry variety used to produce saplings in the nursery was Diamond. More than 200,000 mulberry cuttings were planted for the production of saplings. These saplings were distributed in Southern province (Huye, Nyamagabe, Gisagara, and Nyaruguru).

Maintenance of 40 silkworm breeds and silkworm hybrids eggs production

During this fiscal year (2020-2021), 40 silkworm breeds were maintained and 200 boxes of hybrid eggs were produced and distributed (**Photo 99**).


Photo 88: Incubation of silk worms (left) and silkworm larvae (right)

Establishment of on-farm trials

To introduce new mulberry varieties to farmers, three on farm trials were established in Nyanza, Ruhango and Kamonyi with aim to evaluate performance of mulberry variety Diamond under farmers' management conditions. The maximum number of sprouted cutting (7.22), average number of sprouts per cutting (4.11), length of longest sprout after 7 months (0.5 m), diameter of thickest sprout (0.43cm), internodes (5 cm), number of leaves on new shoots (10.67), shoot sprouting percentage (87%), fresh weight of shoot (38.23gm), dry weight of shoot (9.77gm), root percentage (60.11), number of primary root (10.78), secondary root (42.55), length of longest root (12.00cm), fresh weight of root (9.27gm), dry weight of root (2.48gm) were recorded. On the other hand, the minimum sprouting cutting (6.00), average number of sprouts per cutting (2.89), length of longest sprout (6.38cm), diameter of thickest sprout (0.32cm), number of leaves on new shoots (8.22), shoot percentage (60.22%), fresh weight of shoot (33.15gm), dry weight of shoot (9.07gm), root percentage (51.67%), number of primary root (7.11), secondary root (38.78), length of longest root (11.44cm), fresh weight of root (7.25gm), dry weight of root (2.01g) was observed. These preliminary data show that Diamond variety performs well and the evaluation will continue.

III. LAND HUSBANDRY IRRIGATION & TECHNOGOLY TRANSFER DEPARTMENT

Land Husbandry Irrigation Innovations and Technology Transfer (LII&TT) Department activities focused on :

(i) Operation Maintenance and Management of irrigation scheme under HoReCo services provision;
(ii) Water management and Capacity building (WAMCAB);
(iii) Small Scale Irrigation Technology (SSIT);
(iv) Soil and plant analytical laboratory and CARAVAN Project mapping soil fertility in Nyabihu District;
(v) Integrated soil fertility Management (ISFM);
(vi) Irrigation schemes development;
(vii) Export Target Irrigation (ETI).

The rehabilitation of **irrigation** infrastructures damaged by heavy rains and flooding was done following flooding situation that occurred in Rwanda in season B, 2020 many irrigation and water harvesting infrastructure were destroyed including roads, houses, dam etc. The rehabilitation of Cyabayaga was initiated to reduce the risk of

siltation of Cyabayaga dam located in Nyagatare District to serve around 400 Hectares of rice. Due to siltation of main canal and the dyke, the technical team visited the site and conclusion were made on what need to be done to solve this problem. Rehabilitation works of Cyabayaga infrastructure was started. On the other hand, RAB rehabilitated infrastructures for Bwera, Rwabiharamba, Kajevuba and Gashora Dams and also sediments and infrastructures were rehabilitated in Mukunguli Marsland. Farmers in irrigation schemes under HoReCo were provided with training and quality and cost effective inputs (seeds, fertilizers, pesticides, irrigation equipment etc.) and linked to the potential markets. This resulted in improved operation and maintenance of irrigation schemes; increased water fees collection and community works; improved proper water resource management; improved proper irrigation activities and improved agricultural practices.

Integrated soil fertility Management program has implemented establishment of radical and progressive terraces, soil survey, soil erosion risk maps preparation, soil characterization of developed land husbandry schemes, establishment of Public Private Partnership of program for results (PforR), trial on balanced fertilizers for crop yield, and fertilizer product efficacy trials. Through **CARAVAN project**, a Cooperation Agreement between RAB and OCP-Foundation was signed to establish a partnership between the Parties and to contribute to the development of the agricultural sector in Rwanda based on technical cooperation for soil fertility management and development of crop specific fertilization was signed. Soil samples from different areas were collected and analysed.

The **mechanization** activities focused on promotion of farm machinery in different farming, building capacity in agricultural mechanization. The main achievement was expansion of land tilled with farm machinery, planting, crop treatment, demonstration and training, engagement of youth in agricultural mechanization through training with Export Targeted Modern Irrigated Agricultural (**ETI**) Project financed by EXIM Bank of India. Other project activities were Irrigation Development (7000 Ha), Farm Mechanization- Centre Of Excellence, Food Processing Units (Value Addition), Solar Power Plant, Capacity Building Component and Project Management Consultancy.

3.1 Irrigation

Rehabilitation of irrigation infrastructure damaged by heavy rains and flooding

After 2020B flooding, many irrigation and water harvesting infrastructures were destroyed: roads, houses and dams.

Cyabayaga: The rehabilitation of Cyabayaga was done to reduce siltation of Cyabayaga dam (Nyagatare) to serve 600 Hectares of rice. Due to siltation of main canal and the dyke, technical visit was done, then rehabilitation focused construction of diversion weir of 25 m width and 1.5 m height of weir; construction of two wing dykes on the weir against floods; creation of 4 km of main irrigation canal from the weir to existing canal; construction of two silts trap along the main canal (**Photo 100**).

Photo 89: Temporary River deviation to allow the construction

Bwera, Rwabiharamba, Kajevuba, Gashora dams and Mukunguli marchland: After flooding in 2020B and descruction of roads, houses, dams and irrigation infrastructure, RAB rehabilitated Rwabiharamba, Kajevuba and Gashora Dams, as well as Mukunguli Marsland. In Nyagatare, Bwera dam was damaged and water harvesting was affected. Bwera dyke located in Rwimiyaga sector serves as the main source of water for cattle, while cattle keeping is the main activity there. Moreover, Bwera dam collects runoff from its watershed and helps in flood control while providing water during the dry season. All of these dams were repaired.

Photo 90: Bwera (left) and Rwabiharamba (right) dams under rehabilitation

Rwabiharamba Dam: The dam was destroyed by a heavy rain occurred between February to May 2020, the existing spillway was overturned by the water which was passing under the spillway, the water washing away of the spillway and the bridge. The team from RAB and contractor visited the site and decided to start as quick as possible due to the importance of the dyke in water storage which supply drinking water to around 25,000 cattle in the dry period. Due to the damage of the existing spillway at 100 % including the bridge which facilitate the crossing of the dyke by vehicles and complicity of its rehabilitation a decision was made to make new spillway, a demolition for the damaged spillway with a deep cut was also made and felt the cut area in the dyke by a good compaction of good soil and rebuilt the spillway on the existing location. The work will be composed by the earth work and civil work for demolition and construction of new spillway to accommodate the probable flood whereby

the existing was 3m wide and 1.5 m deep but a new one will be 4m wide and 1.75m deep. The Rwabiharamba dam was rebuilt for a length around 120 m, bottom width of 35 and the top width is 6 m and the depth of 8 m, the profiles of rehabilitated dyke are attached here. Dam and spillway construction were completed.

Kajevuba Dam: The dam was destroyed by a heavy rain occurred between February to May 2020, the existing spillway was located in the middle of the dam, which was completely damaged as water pass under the structure. The dam irrigates the rice and vegetable at the downstream of the marshland. Dam and spillway construction were completed.

Photo 91: Dam and spillway construction at Kajevuba Dam (left) and Gashora (right)

Gashora: The rehabilitation of Gashora included demolition of damaged dyke and re-embankment of anti-flood dyke near the bridge on 211.4 m ; demolition of damaged dyke and re-embankment of anti-flood dyke downstream the bridge on 493m ; Demolition of damaged dyke and re-embankment of dyke where lined irrigation canal is constructed on 1684 m ; Construction of wing wall in RCC on bridge and rehabilitation of main lined irrigation canal where was demolished by flood. The rehabilitation was fully completed.

Photo 92: Repaired channel in Busogwe (left) and repaired dam in Jabana (right)

Mukunguli marchland : Rehabilitation work focused on excavation of Mukunguli River on 4038 m with 140, 392 m3 of sandy soil to be excavated and packed at 9 m from the minor bed of the river to form the Major bed of the river; Rehabilitation of the main diversion weir with construction of wing wall of 60 m length in RCC and reconstruction of gabions ; shifting and lining of the irrigation canal on 190 m where destroyed by the floods ; construction of the embankment, gabions and aqueduct structure passing across Mukunguli river; and construction of gabion on Mukunguli river bank to restore where destroyed by floods (Photo …). The work was fully completed.

Photo 93: Excavation of Mukunguli River (left) and construction for gabions (right)

Irrigation scheme operation and management under HoReCo ervice provision and OMMIS project

Identification of irrigation schemes for HoReCo support: A total of 65 irrigation schemes were supported by HoReCo in 2020-2021 with a total area of 10,330ha, which were located in 18 districts: Kamonyi, Gisagara, Huye, Ruhango, Nyanza, Nyamagabe, Nyaruguru, Rulindo, Gakenke, Kicukiro, Gasabo, Rwamagana, Ngoma, Bugesera, Kirehe, Nyagatare, Kayonza, Nyamasheke through OMMIS project (Operation, Maintenance and Management of Irrigation Schemes Project). Additionally, 17 schemes were added within the same districts to expand the work and conduct similar activities as the initial planning was not enough.

Photo 94. Rice in maturity stage in Mwura Agatare (left) and pest control at Rwasave (right)

Assessment of the identified irrigation schemes: Assessment emphasized on farmers' organization (Cooperative and WUOs), production and productivity, irrigation activities, operation and maintenance of irrigation structures, legal existence of farmers'organizations (Cooperatives and WUOs), administration and management of farmers' organizations, collaboration with local leaders, production and markets, irrigation activities, operation and maintenance of irrigation structures, legal existence of farmers' organizations (Cooperatives and WUAs), administration and management of farmers' organizations.

Photo 95: Rehabilitation of irrigation channels in Bishenyi marshland (left) and community work in Rufuka (right)

Photo 96: Deviation of Base river in Gashenyi sheme (left) and Irrigation in Nyagatare (right)

Elaboration of methodology and strategies: Inception report was already submitted and validated in this Q1 and assignment execution strategies and methodologies to be followed were put in place. Baseline was done in all irrigation schemes in order to assess the situation of the farmers associated in WUOs and Cooperatives and the general status of the schemes. This was done to identify the problems related to the irrigation schemes.

Photo 97: Matimba irrigation scheme with French beans (left) and Ngoma 22 irrigation scheme (right)

Development, validation and production of training modules : The seven (7) modules to be developed are "Operation and maintenance of irrigation infrastructures, Cooperatives and WUOs administration, Conflict management, Best Agricultural Practices, Horticulture, Soil Conservation, Financial management &Audit'' with addition of one (1) module of post-harvest which is the commitment of HoReCo to be established. The implementation of this activity was planned to be done in Q2.

Training of the Scheme Farmer Promoters (SFPs) : From the baseline of **501** Scheme Farmer Promoters (**SFPs)** trained, the training of new SFPs was planned to be done by using class training where **517 Scheme Farmer Promoters** (SFPs) will be trained. The training was planned to be done in Q3&Q4. Besides, 27 farmers including cooperative leaders, zone leaders and group representatives of Busogwe irrigation scheme were trained on cooperative administration and financial management, cooperative leaders' responsabilities for irrigation scheme sustainability. A total of 119 leaders on cooperatives and WUOs managements, Financial management and audit, respondability of a leader and fight against aflotoxin in Nyarububa scheme. Other farmers were trained using demonstration plots and trial plots: 329 farmers trained on GAP, use of quality seeds, chemical application and spacing. The developed modules for the previous contracts were « Operation and maintenance of irrigation infrastructures, Coops&WUOs administration, Conflict management, Best Agricultural Practices, Horticulture, Soil Conservation and Finacial management &Audit. Seven training modules were updated.

Photo 98: Meeting with participants in Kamonyi (left) and community work in Gisagara-Ruvungirana scheme (right)

To increase crop productivity, yield targers were established for each crop based on the existing baseline data (**Table 92**).

. Table 92: Agricultural production & Productivity Targets

Crop		Average Baseline Yield (MT/Ha)	Target Yield (MT/Ha)
Food crops	Rice	4.5	6.5
	Maize	4.6	5
	Bush Beans	1.6	2
	Climbing beans	2.1	3
	Soybean	1.6	2.5
	Ground nuts	0.9	1.2
	Irish potatoes	26	34
	Chia seed	0.5	1
Vegetables	Tomato	31	40
	Egg plants	15	27
	Cabbages	29	42
	Carrots	12	18
	Amaranth	16	22
	Beet	13	17
	Onion	18	25
	Sweet pepper	13	16
	Garden peas	2	3
	Cucumber	18	24
	Courgette	14	25
	French bean	12	18
Fruits	Watermelon	29	36

Facilitate cooperatives in registration process: The OMMIS Project/HoReCo is currently managing 83 cooperatives where up to now, 80 Cooperatives have got the final certificate from Rwanda Cooperative Agency (RCA). From the annual targeted of 11 cooperatives to be helped in registration process for final certicate, only 3 cooperatives remaining (KODUKWIMU-Mushishito, KOGARU-Rusuri and TUZAMURANE-RUVUNGIRANA). The implementation of this activity was done at 96.38%. Additionally, from the baseline of 15WUOs that should be in place among those new schemes, the process was in place to install another WUO in Rubuyenge but the action was constrained by covid-19 effects. Tuyakwizehose Rusuri and Twuzuzanye Kilimbi have got the temporary certificate from District and proceed for the final certificate, Abadacogora for Rwabashyashya (Merged 2 WUOs) has deposited the documents, while Aratugobotse Rugende and Twitekubikorwa remezo Kamiranzovu have got temporary certificate from RGB.

Facilitate WUOs in registration process : OMMIS Project/HoReCo is now managing 67 Water Users Organizations (WUOs) where up to now, 19 WUOs have got the final certificate from RGB, 20 WUOs submitted their documents in RGB requesting the final certificate, 7 WUOs have got the provisional certificate from RGB, 16 WUOs have the district collaboration letter for further process to get final registration certificate from RGB while 5 WUOs are in formation stage (Tuyabungabunge-Rubuyenge, Tuzamurane-Gashenyi, Tuyasaranganyeneza-Gitinga, Tuyiteho-Kavunja, Tuyabungabunge-Kibuza). From the annual target of 12 WUOs to be helped to have at least the District

collaboration letter, the process was delayed by COVID-19. The implementation of this activity was done at 58.33% in Q1. Additionally, 20 cooperatives in new schemes have already registered except, UDC (Unity for Development Cooperative) known as CNF (Conseil National des Femmes) which willing to add rice on their allowed crops to be grown and it is being helped to perform this action even if the action was delayed by the COVID-19 effects.

Establishing FFS demonstration plots for every 20Ha : The mandate of HoReCo is to establish at least one demo plots within 20Ha, the annual target of 554 demo plots to be established and 471 demo plots were put in place and this has achieved from the assured commitment and willing of our technicians to disseminate the knowledge and technics to respective farmers. Farmers were committed to provide plots 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, chemicals and timely application of inputs.

Number of farmers trained using demonstration plots : The field exchange visits have further focuses on the established of demonstration plots for farmer learning and experimentation, thereby providing an opportunity for them to observe the benefits of new crop varieties, quick win of good agriculture practices (GAPs), timely use of agricultural inputs and natural resource management. The plots are managed by farmers and lead by SFPs in help of HoReCo Scheme managers who all use them to provide direct training to farmers according to stage of crops and the target of that FFS. From the annual target of 15,061 farmers to be trained on demo-plots, 7,917 farmers in different irrigation schemes have trained on established demo-plots. The implementation of this activity from the annual target was done at 52.6%.

Photo 99: Rice trial (left), maize demo plot (center) and beans (right) in Nasho 1 irrigation scheme

Daily proximity coaching of farmers on good agricultural practices : The daily proximity coaching of farmers is the dissemination of knowegde and skills to transform subsistence agriculture into a modern (commercial) farming through cooperatives, WUOs, individual farmers coaching on daily basis either by using FFS demonstration plots as a simple tools of learning by doing and daily assistance of farmers in agricultural activities where farmers were benefiting different farming skills (GAP), practical practices where the adoption of good agriculture practices is at good rate. From the baseline of **27,281 farmers** whom were adopted GAP with the annual target of achieving **49,443 farmers** (100%) farmers, the implementation of this activity was done, the average number of farmers applying GAPs was at 89.7% (40,345 farmers) in this Q1. In addition, farmers were grouped in groups in their respective irrigation schemes where **1084 saving groups** are presented and **56,396,040 Rwf** is cumulative savings of those groups to build their capacity.

Photo 100: Vegetables grown in Bahimba scheme

Facilitate cooperatives in registration process: The Cooperatives of Agatorove and Nyagisenyi Rufigiza (after merging seven (7) cooperatives working in Nyagisenyi Rufigiza scheme) were cooperatives targeted to be supported in Q4. Both Cooperatives have been supported to organise all documents where **KOABIGA** (Koperative y'Abahinzi Bahuje Intego ba Gasabo) have already received the final certificate from RCA and for Agatorove's cooperative (**DUTERIMBERE-KIBEHO**) we still waiting the final certificate from RCA where all required documents have deposited. The implementation of this activity was at 100%.

Establishing FFS demonstration plots within every 20Ha: The target of HoReCo is to establish at least one demo plots within 20Ha, from the baseline of **404** demonstration plots, the annual target of 280 demo plots and from the target of **70** demo plot to be established in this Q4, **296** demo plots have been established and obviously the demo-plots put in place were exceeded the targeted ones due to the assured commitment and willing of our technicians to spleed the knowledge and technics to our farmers. Farmers were 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.

Photo 101: Coaching in rice demo plots in Nyamigogo (left) and Nyagisenyi Rufigiza (right) irrigation schemes

Study tours: The field exchange visits were conducted in different irrigation schemes in aim of exchanging skills and knowledge among farmers and to change and update in quick way farmers'mindsets. In fact, as defined in

action plan HoReCo should help farmers to conduct one (1) field exchange and one (1) study tour and 74 field exchanges have done within the schemes where farmers visited different plots to learn from its' performances.

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. This define all agricultural activities planned to be done and precised time and dates those activities will be performed in aim of organizing and preparing the performance of the production. The implementation of this activity was at 100% but it was not applicable in Q4.

Supporting the cooperatives in market negotiationDuring season 2020 A, 54 farming contracts were negotiated and signed with different buyers. The negotiated markets include vegetables buying companies, 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 2020B others are taken by farmers for home consumption and some vegetables have taken at local markets. Some negotiated markets were 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: Average participation of farmers in community work was increased where from the baseline of 76.5% with target was to achieving 100% of farmers attending community works in their respective schemes, the participation of farmers in community works was at 89.4%. The farmers' ownership spirit was changing day to day and through mobilization approach, maintenance of irrigation schemes was being done at good proportion. Eventhough average of farmers attending community work was at 89.4% in this Q4, some irrigation schemes are no longer doing community works like GFI Nyagatare and LUX DEV regulary, the community works were done in some urgent activities like cleaning at pumping stations and this activity was constrained by covid-19 effects with heavy rains occured. The total number of farmers participated in community works was 167,358 and worked on 1462.809 km with the community work value of 125,547,315 Rwf.

Photo 102: Community work in Ruhango, near Base (left) and repair of damage at Base scheme (right)

Support WUOs committees to collect water fee: Actually water fee is collected after harvesting and selling the produce. In fact, in that season 2020C covering Q4, we have targeted to collect **62,518,988Frw** and the water fee collected was **39,048,977 Frw**, the remaining water fees were charged by coop. organization and wait to be deposited on WUO's accounts.

Mobilize WUOs to rehabilitate damaged infrastructures: Some hydraulic infrastructures were damaged due to heavy rain which has caused erosion on catchment side. The lightly damaged irrigation infrastructures were reabiritated and maintained by WUOs through community work and by using water fee collected where 170,893,585 **Rwf** used to repair damaged and destroyed irrigation infrastructures in six districts. Most of damaged irrigation infrastructures are water diversion weirs, Main streams, canal bridges, secondary and tertiary irrigation and drainage channels, water falls, roads etc. The average implementation of this activity was achieved at 88.7%. There are some cases where destroyed infrastrucuture beyond the capability of WUOs and farmers like in Rumira-urukingu, Nyakagezi, Nyakanyeri and Kigaga Kabogobogo in Gisagara, the case of Nyagisenyi Rufigiza resulted small culverts across the road, damaged Umwaro's DAM etc, desitruction of dyke in Rurambi and Gashora resulted to the flooding, therefore, non-functioning infrastructures hindering the production activities to achive the objective of increasing the production and productivity but resulting also to farmers' losses.

Coaching farmers' organizations to fill all recommended books: Cooperatives and WUOs have 8 main recommended books, and all 49 cooperatives and 48 water users' organization have been coached how timely to fill those books. The implementation of this activity was at 100% in Q4. Due to changing of committees and coming of new persons in committees that need the continuous follow up and continuous coaching.

Support WUOs committees to collect water fee: Actually water fee is collected after harvesting and selling the produce. In fact, in most of these new irrigation schemes, some WUOs were new and the way of collecting water fees was not appropriately understandable but the mobilization was ongoing. From the targeted water fees of 1,715,300rwf, the collected money was 1,207,207 rwf.

Facilitate cooperatives in market negotiation and sseasonal production and financial reports: A total of 17 farming contracts were negotiated and signed with different buyers in season 2020B. The negotiated markets include vegetables buying companies and industries buying rice and maize. Most of them are namely Izere services&Trading Co. Ltd, Big Seller, Green growth co.ltd, AIF, Gikonko Rice Mill, Kinazi Rice etc. Some negotiated markets were seasonal and others are annual based markets where the buyer sign contract on annual basis or seasonal basis. Besides, farmer cooperatives were trained on writing seasonal production and financial reports.

Challenges: The main challenges were the following: presence of more than one cooperatives with legal personality in the same irrigation scheme this resulting mostly in conflicts of interest and mismanagement of the scheme for instance Mushishito (3coops), Kanyegenyege (5 coops) need to be merged in one with collaboration with RCA; Necessary arrangements have been made to maximize the crop production but in all irrigation schemes, farmers were still facing a problem of shortage of postharvest facilities (warehouses, storages etc.); High erosion from unprotected catchment area in different irrigation schemes is still a big challenge and this resulted to the decrease of farmland production and productivity and losses to our farmers from their investments; Some irrigation infrastructures were destroyed by erosion as well as mass movement and farmers' organization capacity for rehabilitation was too less comparing to the damaged infrastructures, but the simply damaged infrastructures have been rehabilitated.

Lessons *learnt / best practices :* The best farming techniques taught to the farmers through FFS demonstration plots and Farmer to Farmer coaching have led to good results of changing farmers' mindsets as well as increase of production; Creation of ownership spirit of farmers through mobilization towards community works for operation and maintenance of irrigation infrastructures has been successfully conducted to good results of maintening irrigation infrastructures in respective schemes; Initiation of Income Generating Activities such as

establishment of Credit and Lending Groups (Ibimina) also contributed to changing of farmers midset and build the capacity of farmers in terms of money; Organizations of different DISCs and SISCs meetings have been resulted to better collaboration with local authorities; Ability and willing to invest in agriculture from lessons of FFS productions.

3.2 Mobilization by HoReCo on erosion control

HoReCo, after looking the incidence of erosion from the catchment areas and from hills surrounding different irrigation schemes and based on the experienced destruction of crops grown in different irrigation schemes under HoReCo management and other marshlands, HoReCo decided to start the mobilization of erosion control on those hills and in different areas that shows to be the source of erosion by creation of ditches, water retions holes with different startegies to reduce the water flow pressure and favorise the water infritration in soil where this mobilization has started in Ruhango District on 12th August 2020. The action of general community works has done on areas surrounding Base scheme but the action has continued in Huye, Gisagara, Nyamagabe, Nyaruguru and Kamonyi districts as it is shown down in **Table 93** below.

Table 93: Community work outputs in the irrigation schemes

SCHEME	DISTRICT	DATES	NUMBER OF PARTICIPANTS	AREA PREPARED (ha)	VALUE OF THE WORK (Rwf)	ORGANISERS
Base I&II	Ruhango	12/8/2020	2,500	7	1,000,000	HoReCo and different districts Leaders
		1/9/2020	500	1.2	700,000	
Ruvungirana	Huye - Gisagara	20/08/2020	3,500	4.5	4,400,000	
Bishenyi	Kamonyi	3/9/2020	645	4.5	1,090,000	
Muzirantwago	Nyamagabe	28/08/2020	550	2.5	700,000	
Agatobwe	Nyaruguru	28/08/2020	740	3.5	1,480,000	
TOTAL			8,435	23.2	9,370,000	

3.3 Water Management and Capacity building under JICA (WABCAB)

The WAMCAB project started in March 2019, and it aims to increase capacity for water management in in Gisagara, Ngoma and Rwamagana through building support system to IWUO; enhance its management, implement operation and management (O&M); improve water and farm management. The target model sites were Bugugu, Gashara, Cyimpima and Cyaruhogo (Rwamagana) ; Ngoma 22 (both marshland and hillside) and Mwambu (Ngoma) ; Ngiryi and Nyabuyogera (Gisagara). The responsibility for Operation and Maintenance (O&M) of the developed irrigation schemes has been transferred from the Government to Irrigation Water Users Organization (IWUO) under decentralization and Irrigation Management Transfer (IMT) policy. The Government of Rwanda (GoR) requested the "Project for Water Management and Capacity Building (WAMCAB)" with the purpose of sustainable management of irrigation schemes by IWUO. The key activities under the project were the following :

Baseline survey was performed, and **Improvement Plan & Training Plan** (IP&TP) was prepared and approved by the Joint Coordinating Committee (JCC). The next activities were reorganization/formation of IWUOs, preparation of various packages of training for strengthening IWUOs, financial management, basic civil work, farm roads repair, farm management, etc.

IWUO management is currently poor. The existing IWUO policy has been investigated, and bottlenecks analyzed. Recommendations for improvement were made to improve IWUO performance. Under COVID-19 restrictions, WAMCAB has been steadily implemented. In line with the IP&TP, as one of the remote activities, WAMCAB has started **Radio Training Program** (Audio Training) associated with each output of the Project, and **Webinars** lead by a Japanese Professor. Radio program aims to raise the awareness towards WAMCAB and share know-how / skills of irrigation water management and irrigated agriculture with more beneficiaries in a wider coverage through mass media. A total of five radio trainings with different themes were broadcasted from March until April 2021.


Photo 103: WAMCAB Core C/Ps and national staff recording for Radio Training Program in a studio

WAMCAB has conducted webinars that are lectures using video conference to C/Ps and TF members. Two webinars namely "**The role of government in PIM**" and "**Irrigation water management**" have been conducted by Prof. SATOH, a Japanese expert in charge of support for IMT promotion. Participants attended webinar lectures from Rubirizi station, Rwamagana, Ngoma and Gisagara Districts.

Gisagara : Following the **discussion with Task Force members** strongly suggested the consideration/inclusion of Nyiramageni irrigation scheme as one of the targeted model sites of WAMCAB since it is the downstream of Ngiryi irrigation scheme, so that the water management of both Ngiryi and Nyiramageni schemes could be the same as they have a single source of water to avoid the conflicts related to water management and distribution that might occur. Thus, Nyiramageni was agreed as a satellite scheme of Ngiryi for the time being, while an official request from Gisagara District to RAB and approval at the JCC meeting will be followed.

Gisagara : supplementary survey in Ngiryi and Nyabuyogera Schemes : WAMCAB conducted a baseline survey to grasp basic information related to these model sites for the purpose of elaborating IP&TP. To complement the basic information collected during the baseline survey, a supplementary survey with the following interview items was carried out in Ngiryi and Nyabuyogera model sites in January 2020. Data were collected on the status of IWUO registration ; Existence of cropping calendar, water distribution plan, irrigation & drainage plan ; Situation of performance contract between cooperative and IWUO ; Soil erosion ; Water shortage / imbalance of water distribution in the scheme ; Options to conduct training on rehabilitation of minor damages

Besides, field visit to Nyiramageni was done to observe this scheme.

Gisagara : DISC meeting : On 3rd March 2020, Gisagara District Irrigation Steering Committee (DISC) meeting was held and it was chaired by the Vice Mayor in Charge of Finance and Economic Development (VM FED). Introduction of WAMCAB, Ministerial Order establishing IWUOs and DISC, election of DISC board members, draft proposal for the procedure in the IWUO management, etc. were on agenda of this meeting. The board members have been elected.

Photo 104: Elected DISC Committee in Gisagara District / VM FED & Chair of DISC addressing the members

Gisagara: Merging the existing two IWUOs: Besides the inclusion of Nyiramageni to the project model sites, the merging two IWUOs of Ngiryi and Nyiramageni into one strong IWUO is strongly suggested in terms of the smooth scheme management of both upstream (Ngiryi) and downstream (Nyiramageni). Through discussion and explanation among IWUOs, District and WAMCB, the beneficiaries understood the importance of having a single strong IWUO, welcome this idea and showed the keenness to be merged as it will help them to solve a number of issues they used to experience. The farmers from Ngiryi were happy to hear the idea because Nyiramageni scheme has great potential because of its size. Also, the farmers from Nyiramageni welcomed this idea especially for the better water distribution. It was agreed to undertake the further steps for merging IWUOs.

Gisagara: Meeting with District Officials (Vice Mayors and DISC and TF members): A meeting with Gisagara District officials (VM FED, TF members and Director of Agriculture and Natural Resources) was held to discuss the reorganization of IWUO in Ngiryi and Nyiramageni. This meeting was organized following some complaints and misunderstandings of WAMCAB approach by some people. This comes to clearly explaining the reorganization of IWUO and the merging of two existing IWUOs.

Gisagara: Reorganized IWUO (Creation of WUTs, Zones and SMC) in Ngiryi/ Nyiramageni: As a result of explaining to Gisagara District officials, WAMCAB conducted workshops in Ngiryi and Nyiramageni separately to firstly creating IWUO structures such as **Water Users Teams (WUTs)**, **Zonal Committees (ZC)** and **Scheme Management Committee (SMC)** and then elected their respective leaders. As described below, after the reorganization of lower structures, the board members of the overall & joint IWUO was elected to unite both Ngiryi and Nyiramageni.



Photo 105: Election of leaders at different levels of IWUO Structures in Ngiryi/Nyiramageni

Gisagara workshop at Nyabuyogera: In Nyabuyogera, workshops were organized to explain to beneficiaries the necessity of creating WUTs, ZC, SMC and reorganization of the existing Farmer Producing Groups (FPGs) under cooperative. At SMC level, 3 people have been elected from the upstream, downstream and women with regard to gender mainstreaming principles. At ZC level, initially in Nyabuyogera, there were existing zones with a committee of 3 people namely President, Deputy President and Secretary. Their responsibilities have been changed to match the new structure as follows: In charge of IWUO and zone leader; In charge of production and he will coordinate FPGs within zone (7 to 14 groups); WUT leader: left side; and WUT leader: right side. A total number of 10 zones were created considering the existing zones with 20 WUTs based on one WUT on the right side and one WUT on the left side in each zone. Sector agronomist / Save Sector has participated in this activity.



Photo 106: Creation of WUTs, ZC, SMC and FPGs under cooperative in Nyabuyogera

Gisagara: Election of Overall & Joint IWUO Governing Body for Ngiryi/Nyiramageni: On 25th November, 2020, a workshop was organized at Ngiryi/Nyiramageni, and the board members of the overall & joint IWUO were elected from different levels of IWUO structure. To perform this activity, all key players namely local leaders from Cell, Sector and District have been highly sensitized and involved and their contribution for this activity to become a reality was undeniable/unquestionable. Due to good cooperation, mobilization and communication, the participation rate of local leaders and beneficiaries (water users) was very good.

Gisagara: Workshop for the IWUO governing body: The purpose of this workshop was to discuss ongoing activities (planned activities/action plan, naming of the IWUO, place of IWUO office, use of collected water fee and other resources, fixing the day of handover, etc.) with the established overall & joint IWUO governing body of Ngiryi/Nyiramageni. This workshop concluded to identify the name of newly formed IWUO, and location place for its office; need to prepare a handover between the outgoing IWUO committee and ongoing one; and a Joint action plan for both IWUO areas.

Gisagara: Financial management training to IWUO members: Five-day training was organized in Ngiryi/Nyiramageni to a total number of 28 IWUO members especially those involved in collection, management and expenditure of O&M fee such as 12 members from the governing board, 6 members from SMC and 8 members from ZC, and 2 accountants. Similarly, the same training on financial management has been conducted in Nyabuyogera and a total number of 21 members of ABAKORANAMURAVA cooperative have been trained especially those involved in collection, management and expenditure of O&M fee such as cooperative executive committee, audit committee, SMC, advisors and zonal leaders who are in charge of O&M activities. During the training, to use limited resources and collected O&M fee effectively, the issues covered focused on role, function and importance of financial management, assessment of required amount for O&M activities, determination of O&M fee; mobilization of O&M fund; preparation of accounting books (revenue and expenditure); budget planning; establishment of the O&M fee management mechanism through preparation of O&M fee collection agreement sheet; preparation of O&M fee bill and receipt sheets; preparation of expense order sheet; establishment of O&M fee flow mechanisms; and auditing. During this training, WAMCAB team explained to participants about the responsibilities of the President, Deputy President and Secretary; composition of the procurement committee inside overall IWUO structure; President of audit committee who will be the secretary of procurement committee. Regarding the financial records especially bill and receipt, as most of the farmers are members of the marshland cooperatives (COOPRORIZ Ngiryi and COOPRORIZ Nyiramageni), there is no need for the IWUO to issue the bill and receipt to each individual farmer, only a bill or a receipt to the cooperative is needed. They added that only water users who are not member of rice producing cooperative and who pay directly water fee to IWUO will be given bill and receipt.

Photo 107: Financial management training to IWUO members at Ngiryi (left), Nyiramageni (center) and Nyabuyogera (right)

Gisagara: Cooperative strengthening training at Nyabuyogera: Cooperative strengthening training was conducted at Nyabuyogera for the leaders at different levels of the cooperative such as executive committee, audit committee, procurement committee, advisors, SMC and zonal leaders. As it was expected, at the end of this training participants showed up to be able to understand the procedures of constitutional making, organizational structure, complete Water Users List, content of O&M manual and making seasonal action plan.

Photo 108: Training on strengthening cooperative and SMC at Nyabuyogera

Gisagara: Exchange with IWUO leaders in Ngiryi/Nyiramageni*:* During this visit, WAMCAB was interested to hear the impression from the IWUO leaders in both sides of Ngiryi and Nyiramageni schemes towards the merging existing IWUOs. Both leaders understand well the importance of merging two IWUOs into one strong IWUO and they all have a common request to be helped / supported in construction of new irrigation infrastructures. It was also an occasion to visit the new office that will be hired by overall & joint IWUO committee located at Rwatano. Also, WAMCAB team visited an office of the existing IWUO in Nyiramageni.

Photo 109: New office that will be hired by IWUO and Office of the existing IWUO in Nyiramageni

Gisagara: Meeting with overall & joint IWUO governing board of Ngiryi/Nyiramageni: Meeting with overall & joint IWUO governing board of Ngiryi/Nyiramageni was held to discuss some issues such as procedures to be followed for merging the two existing IWUOs, and procedures to get approval from the District. The meeting concluded to hold the GA meetings of former IWUOs separately in Ngiryi and Nyiramageni. Once they get the two third (2/3) of participants' votes for merging, the meeting minutes will be taken and used for further steps

of registration as a new merged IWUO. It was agreed upon that the GA meetings will take place on 17th and 18th February, 2021 for Ngiryi and Nyiramageni, respectively.

Gisagara: The GA meetings of Ngiryi/Nyiramageni: As described above, on 17th and 18th February, 2021, an extraordinary GA meeting was organized by the current IWUO in each Ngiryi and Nyiramageni, solely for members themselves to vote for the dissolution of the existing IWUOs to become one. District Agronomist, District Agriculture Sector Inspector and Sector Agronomist also attended the meeting in Nyiramageni. In GA meeting of Ngiryi scheme (upstream), all members (100%) agreed on the idea of dissolution of the existing IWUO to be part of the new joint IWUO. On the other hand, in GA meeting of Nyiramageni scheme (downstream), less than the two thirds (2/3) of the members that is 44 among 73 participants voted in favour. This is below the required number of RGB. Initially, all the farmers from both schemes welcomed the idea of merging to become a single strong IWUO. However, at the side of Nyiramageni, there were some self-serving objections due to misunderstandings. Further discussion and consensus-building within the IWUO is needed.

Photo 110: The GA meeting for IWUO in Ngiryi (left) and Nyiramageri (right)

Gisagara : Data collection of land owners in Ngiryi/Nyiramageni and Nyabuyogera and map preparation : The row data related to land owners in Ngiryi was collected with aim to prepare irrigation scheme map. The data have been collected in 14 farmer groups namely Cyabigega, Akazababa, Migogo, Ntankono I and II, Bishungo, Ruhabyo II and III, Kigarama, Kijinja, Nyabitare, Musha, Nyirarweza I and II also some parts of Ruganzo. Also, the data collection of land owners in Nyiramageni has been conducted in 24 farmer groups and irrigation scheme map prepared. The GPS data of plots was collected with purposely to prepare the irrigation scheme map and water users list in Nyabuyogera marshland. The data was collected in 10 zones.

Gisagara: Measurement of water discharge of springs in Nyabuyogera: In order to know the quantity of water discharge from springs in Nyabuyogera for estimating the available water resources in the scheme, six springs in Nyabuyogera namely Rurongi, Nyakariba, Gashubi, Rugori, Gahoko and Nyabuhoro were identified to be measured regularly and taking readings on daily basis. The 3 employees living in the vicinity of identified springs were hired and trained to perform this observation. Also, the simple type rain gauge has been set up around Ngiryi (office of save sector for its safety) to measure the amount of rainfall within a period of one year at least to know amount of available water resources and the relationship between rainfall and discharge from spring. This data will help to look for appropriate alternatives to respond to the issue of water shortages in Nyabuyogera.


Photo 111.Taking data related to spring discharge and rainfall for Nyabuyogera

Gisagara: Inspection of irrigation facilities in Ngiryi /Nyiramageni: Inspection of irrigation facilities has been conducted in Ngiryi and Nyiramageni. The results showed that the irrigation facilities of both schemes are very old and some were submerged by sediments. The status of Irrigation facilities in Ngiryi/Nyiramageni was examined.

Photo 112: Nyabuyogera irrigation infrastructure status

Gisagara: Conducted civil work training in Ngiryi and Nyabuyogera From 14th to 19th September 2020, a training on civil work has been conducted in Ngiryi/Nyiramageni where 14 people (7 from Ngiryi and 7 from Nyiramageni) have been trained on stone masonry work both theoretically and practically. From 20th to 24th October 2020, a training on civil work has been conducted in Nyabuyogera where 13 people were trained on basic civil work both theoretically and practically. An advanced civil work training was conducted in Ngiryi from 22nd to 27th February 2021. The ttrainees were O&M team and farmer repair teams from both Ngiryi and Nyiramageni. The theory and practice on reinforcement concrete were well acquired so that they will be able to do it by themselves.


Photo 113: Teaching trainees how to use of spirit level and Product from advanced civil work training

Gisagara: Conducted training on road repair in Ngiryi: From 27th to 30th October 2020, a training on road repair has been conducted in Ngiryi and 14 people have been trained on farm road repair using *Do-nou*, sands bag, technology in locally available materials both theoretically and practically.



Photo 114.Compacting Do-nou Bags and illustration after the road is repaired in Ngiryi

Gisagara: Guiding farmers in maintaining & installing secondary canal in Ngiryi: The farmers (water users) in Ngiryi have been provided with guidance on how to maintain canals and existing facilities like turnouts. The Right Turn out number 03 (RT_03) has been cleaned and the secondary canal at the same point was partially cleaned by the farmers themselves under the guidance of WAMCAB staff. In addition, the existing tertiary canal was cleaned and farmers were encouraged to keep all facilities clean for a better and fair water distribution.



Photo 115: Maintaining secondary & Tertiary canals with water users in Ngiryi under guidance of WAMCAB Staff

Gisagara: Guided water users in maintaining irrigation facilities in Nyabuyogera and Ngiryi: In Nyabuyogera, the farmers from the zone 2, 3, 4 and 10 were guided in maintaining the left main canal. The maintained main canal section is 115 meters. This activity was carried out through community works organized at zone level. In Ngiryi, through the community work organized in zone 2, the left main canal laying from the LW03 was

maintained. Also, the locally made weir was repaired to ensure that water will reach to the farm plots properly. In addition, **t**he technical assistance was provided during maintenance of main drain such as keeping the shape of the drain so that the embankment cannot slide or eroded easily as the trapezoidal shape of the drain was kept.


Photo 116: Community work in maintaning left main canal in Ngiryi and After maintaining left main canal in Ngiryi


Photo 117: During maintaining main drain in Ngiryi and After maintaining main drain in Ngiryi

Gisagara: Repair works of embankment in Nyabuyogera: Community work organized in zone 2 and 4 of Nyabuyogera, the activity of repairing the embankment in zone 2 was done. The section of embankment with dimension of 3m length, 1.10m width and 1.30 m height was repaired using soil bags filled. 200 *Do-nou* bags and wooden poles were used.

Gisagara: Practice of Alternative Wetting and Drying (AWD) tubes in Ngiryi: The water saving irrigation method (AWD: Alternative Wetting and Drying) were introduced in Ngiryi demo plots, to reduce the irrigation water usage in order to improve the water management in the irrigation schemes and during installation the farmers were explained the importance of IWUO and water saving and agreed to continue monitoring the water level in AWD tube.

Gisagara: Introduction of the night storages idea to the farmers of Nyabuyogera: WAMCAB experts paid a field visit in Nyabuyogera where they met farmers participating in community work to clean canals. The purpose of this visit was to explain to farmers one of the solution to cope with the colossal challenge they use to face of water scarcity/shortage and poor irrigation facilities in Nyabuyogera. WAMCAB experts explained to them technically the night storage to be created so that the wasted water during the night from the springs will be collected and used for agricultural purposes by farmers. Farmers were excited and committed to actively participate in the implementation of this activity through community works. Also farmers were keen to avail lands where the night storages will be excavated. In Nyabuyogera, also WAMCAB experts met the farmers who were being trained on chili seed bed preparation by WAMCAB and the idea of night storage was explained to them. They were happy to hear that and they pledged their full participation.

Photo 118 : In Nyabuyogera, WAMCAB experts explaining to farmers one of the solution (night storages) to cope with water shortage

Ngoma district activities

Ngoma : ***Discussion with Task Force members in Ngoma District :*** In order to elaborate the IP&TP, different ideas and training materials have been collected in various target districts through the interaction with TF members. Training for farmers on the use of fertilizers both organic and minerals was based on the soil analysis results. Nutrition improvement especially for the most vulnerable farmers. The data could be collected from Cell record under UBUDEHE program. Mechanization for land preparation will be promoted on terraces where the traditional system of hand hoes is currently used.

Ngoma: Meeting with Vice Mayor, TF members, Core counterparts: A meeting has been held with the Vice Mayor in charge of Finance and Economic Development (VM FED), TF members and Core C/Ps in Ngoma District. Reactivation of District Irrigation Steering Committee (DISC), reorganization of IWUO and the coexistence of cooperative and IWUO in developed schemes were on agenda.

Ngoma: Meeting with District Irrigation Steering Committee (DISC): In a bid to reactivate DISC in Ngoma District, a meeting has been organized by the District. The meeting discussed the implementation plan for WAMCAB Project; Ministerial Order establishing IWUOs and DISC; Election of DISC board members, and draft proposal for the procedure in the IWUO management.


Photo 119. The elected DISC board members and WAMCAB experts in Ngoma District

Ngoma: Mobilized farmers on reorganization of IWUO and election process: For the successful reorganization of IWUO, WAMCAB strongly mobilized farmers through various meetings with local communities commonly known as "INTEKO Z'ABATURAGE" in Ndekwe Cell of Remera Sector and in Rujambara Cell of Rurenge Sector. During these meetings, WAMCAB have showed the importance of irrigation infrastructures constructed by the government to improve their livelihoods, and their active key role to managing, O&M. During the meeting, farmers were requested to bring back the facility equipment such as valve, taps, etc. that were distributed after the completion of the Ngoma 22 grant aid project. Some of these valves and taps have been stolen or damaged and others kept in their homes. To respond to this poor use of irrigation facilities and lack of ownership, WAMCAB reminded them that their active participation and support is highly needed to control the misbehaviour.

Ngoma: Reorganization of IWUO in Ngoma 22 and Mwanbu irrigation schemes: Ngoma model site has both marshland and hillside schemes that is sharing the same water source, so the involvement of both schemes is requred for the scheme management. Accordingly, a new IWUO organizational structure of Ngoma model site was proposed. It included **Irrigation Unit (IU) and Seasonal Water Distributor (SWD), Water Users Team (WUT), Zonal Committee (ZC) ; Scheme Management Committee (SMC).** In hillside scheme, **WUTs** shall be considered as the lowest-level organ under IWUO structure, and **ZC** and **SMC** follows on that upper level same as the marshland system. Covering both marshland and hillside schemes, the overall IWUO shall be created by nominating equal members from each scheme where the president, vice president and other committee members are organized. The overall IWUO shall be the governing body, and they will hire supporting staffs who will help in the management of the organization and operation of the scheme. These supporting staffs include manager, accountant, irrigator, operator etc. as the need arises.



Photo 120. Elected IWUO leaders in both hillside and marshland in Ngoma

Ngoma : ***Elaboration of rules and internal regulations of Ngoma IWUO:*** The rules and internal regulations for the Ngoma IWUO "**TUYAKORESHE NEZA NGOMA 22**" have been elaborated. The document has been prepared as a governing instruction for IWUO to be applied in the O&M and management of the irrigation facilities installed in the hillside and marshland that are organized under two (2) cooperatives namely hillside crop producing cooperative (KOTUNGO) and marshland rice producing cooperative (COPRIMWA). A workshop has been organized to consult and collect ideas and opinions from the members of both IWUO and cooperative, also the local leaders have been involved to have comprehensive rules and internal regulations to be applied in Ngoma IUWO. A handover between the old IWUO and the reorganized IWUO has been done. In this handover exercise, different records/books including bank account opened in Banque Populaire du Rwanda (BPR) with a sum of 171,050 Rwf.

A **workshop on initial training** with the elected IWUO leaders from WUT, ZC, SMC and overall IWUO governing board has been conducted. WAMCAB explained the scheme layout to promote their understandings of the irrigation network, the IWUO structure according to irrigation facilities, and the roles and responsibilities of elected IWUO leaders. Also, the explanation paper of the scheme translated in Kinyarwanda was distributed to them. The C/Ps from RAB (Mr. Emmanuel and Mr. Jules) have attended this workshop and their participation has been of paramount importance.

Photo 121. Workshop on initial training with WUO leaders in Ngoma

Ngoma: Meeting between the IWUO and Cooperative: Following the resolution of the meeting held on June 24th 2020 chaired by the newly elected IWUO president where it has been concluded to call an extra meeting with COPRIMWA and KOTUNGO leaders to discuss the right way of managing irrigation infrastructures sustainably, and the transfer modalities of the water fees previously collected by COPRIMWA to the IWUO account, and activities of O&M to be performed by IWUO. WAMCAB staff have attended this meeting of three parties: newly reorganized IWUO, COPRIMWA and KOTUNGO leaders where the followings have been agreed upon:

The O&M activities of irrigation infrastructures must be performed by IWUO rather than cooperative as it was.

The leaders of COPRIMWA have accepted to transfer the collected water fees to the account of IWUO.

Increase the water fees from 50Rwf per 0.01ha to 200Rwf per 0.01ha each season both hillside and marshland.

KOTUNGO will actively engage in agricultural activities and be able to pay water fees as well as COPRIMWA.

All elected IWUO leaders at different levels (IU, WUT, ZC and SMC) in both marshland and hillside will start their responsibilities since the handover has taken place.

WAMCAB staff will attend community work scheduled on 17th July 2020 to support COOPRIIMWA leaders in explaining the changes related to O&M of irrigation infrastructures to members who will be participating in community work.

Signing performance contract agreement between IWUO and both cooperatives related to the water fees collection.

Ngoma: Workshop on leadership training: A pre-training on leadership focusing the IWUO governing board and SMC has been conducted. They have been deeply explained the qualities of a good leader, the synergy and complementarity among leaders for the proper management of IWUO to achieve its objectives and goals. Their responsibilities have been clearly explained too. In a bid to have a common understanding of the IWUO organizational structure and to avoid confusion in terminologies in local language where both IU and WUT had similar names in Kinyarwanda "Itsinda", these were differentiated as follows: Participants agreed to call IU in Kinyarwanda as "Irembo ryuhira" instead of "Itsinda ryuhira" whereas WUT as "Itsinda ry'Abakoresha amazi". The performance contract agreement between the IWUO and COPRIMWA has been signed. In this contract agreement, each party has committed to play its role for the sustainable management of irrigation facilities and the rice production as well. The agreement has been reached in the presence of DISC and TF member.

Photo 122. Signing of performance agreement between COPRIMWA and IWUO

Ngoma: Training on financial management to IWUO members: To empower IWUO and improve their skills in management of water fee (O&M fee) and other limited resources, a five-day workshop has been organized to train a total number of 33 IWUO members especially those involved in collection, management and expenditure of water fee such as 11 members from the governing board, 6 members from SMC and 16 members from ZC of both marshland and hillside. During this workshop, a number of topics were covered to be able to use the collected water fee and limited resources effectively. The covered topics were: Role and function of financial management; Importance of financial management; Assessment of required amount for O&M activities; Determination of water fee (O&M fee); Mobilization of O&M fund; Preparation of accounting books (revenue and expenditure); Budget planning; Establishment of the water fee management mechanism; Preparation of

water fee collection agreement sheet, water fee bill and receipt sheets and expense order sheet; stablishment of water fee flow mechanisms; and audit. At the end of this training, for proper management of IWUO budget, the following financial records have been prepared: bank book, cash book, water fee bill and receipt sheet, expenses order sheet and water fee payment agreement.

Ngoma: workshop on reorganizing WUTs in pipeline part: To reorganize the IWUO in Ngoma 22 particularly in pipeline side, two workshops have been held targeting the farmers from hillside/pipeline sides. In right pipeline side, farmers have been reorganized into seven (7) WUTs, and the farmers from left side have been reorganized into six (6) WUTs. Each WUT elected a leader who will be responsible for coordination of irrigation activities under WUT. Also, a ZC has been created from the regulating tank to where the pipeline ends for both sides. Two people have been elected for ZC.

Ngoma : Conducted workshop with the newly established IWUO structures: The main objective was to introduce the recently elected leaders of WUT and ZC from the pipeline area in Ngoma 22 to the IWUO governing board. Before the establishment of the IWUO structures (WUT and ZC) in pipeline area, people were not aware of what is going on with WAMCAB, and irrigation facilities such as valves were stolen and damaged because no one was responsible for it. Now, the pipeline area is also covered by the IWUO, and the leaders are committed and responsible. In addition, they pledged to safeguard the irrigation facilities and preventing from the theft. In an occasion of this workshop, farmers requested more proximity coaching and training so that they can be at the same level as their neighbours.

Photo 123. Elected leaders from pipeline are have been introduced to the IWUO leaders

Conducted online study tour in Ngoma 22 irrigation scheme

Following the restrictions of COVID -19, an online study tour was conducted to C/Ps and TF member to Ngoma 22 irrigation scheme. The study tour is consisting of 1. Introduction, 2. Watching video materials (dam body, marshland and hillside) and 3. Q&A session. WAMCAB encouraged the participants to understand the irrigation system, layout and organizational structure of the scheme comprehensively.

Field visit with C/Ps in Ngoma model site

RAB as an implementing agency of WAMCAB has the responsibility to follow up and monitor implementation and progress of WAMCAB activities on the ground. A field visit with Core C/Ps has been paid to Ngoma 22 model site to know better the WAMCAB model site and see with their own eyes what is going on. In this field visit C/Ps and Ngoma District Agronomist (Mme. Laetitia) together with WAMCAB experts toured the entire scheme to observe

the status of the irrigation infrastructures and the WAMCAB experts showed them how the lowest irrigation unit and WUT have been organized based on turnouts and diversion weirs accordingly to form IWUO that will be responsible for water management, O&M of the scheme.

Photo 124. Field visit paid by C/Ps/RAB, District Agronomist and WAMCAB Experts in Ngoma 22 scheme

Facility coding in Ngoma hillside and marshland

The facility coding activity in Ngoma model site both in hillside (division boxes, secondary canals) and in marshland (weirs, turnouts) have been done. This is very key for the IWUO leaders and members to know irrigation facilities and the formed WUT, zones, etc. based on the facilities in place.

Photo 125. Facility coding in Ngoma hillside and marshland

Establish an O&M team and farmers' repair team

O&M team and farmers' repair team have been established. O&M team has the responsibility of planning, monitoring and evaluation of O&M activities whereas farmer repairs' team is responsible for routine repair works like minor rehabilitation works, cleaning, etc. of irrigation facilities. The O&M team was composed of 7 people namely in charge of infrastructure at the IWUO governing board and 6 people from elected SMC of both marshland and hillside. The farmers' repair team was composed of 16 people (two people from each zone both hillside and marshland).

Inspections of irrigation facility in Ngoma 22

An inspection of facilities in Ngoma 22 irrigation scheme has been conducted to analyse erosion causes which destroy farm plots and roads. The established causes of erosion were overflow at the end of upper main canal on both side, and overflow at the regulating tank on both side. The proposed solution to face these issues was the combination of soft and hard component by training farmers and operator of the pump to use water efficiently by closing all valves when they are not using water and opening the water at the intake depending on the quantity of water needed.

Conducted facility survey in pipeline part (right hand side) in Ngoma 22 scheme

The facility survey in Ngoma 22 hillside in pipeline right hand side has been conducted with purpose of preparing water users list and assessing the current situation of irrigation facilities located in the part of pipeline in Remera sector.

Photo 126. Facility survey in pipeline Remera side

Conducted an inspection of pipeline in Ngoma 22 and possible solutions

The inspection of pipeline in Ngoma 22 on the right side has been conducted with purpose of assessing the issues of lack of water on that side. After checking WAMCAB found that the pipeline was full of sediments from open canal and the reservoir tank. The inspection was done at the intake, in the middle of pipe and at the end of pipe. To all those points, the issue of sedimentation has been noted. The cause of those sediments are soil erosion from the road and alongside the canal, the crop residuals deposited on canal and reservoir tank by farmers and children. As solution we suggest to install the filter on intake of pipe, installation of flushing point of network, installation of weir for controlling the sediments.

Photo 127. Sediments in valves at the middle of pipeline and The pipe was full of sediment at the starting point

Prepared the Water Users List of Ngoma 22 Hillside

The data to be used on preparation of water uses list of Ngoma 22 were collected. Also the list of farmers who grew chia seed, chili and maize in Ngoma 22 has been prepared. The total area is summarized as follows: Chilli = 8.72ha, Maize = 55.17ha; Chia Seed = 58.10ha. From the map below, you can see the difference between Remera and Rurenge side farmer related to chia-seed coverage.

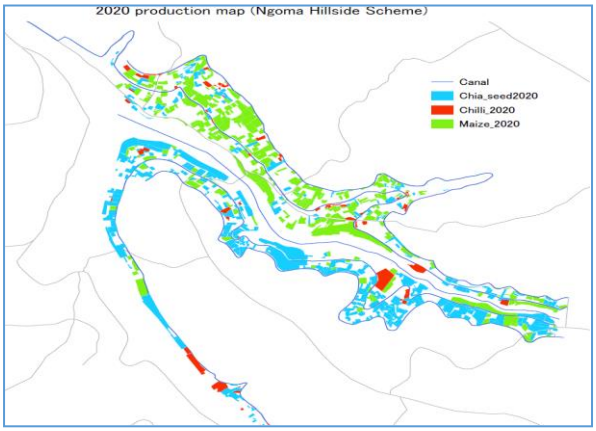

Photo 128: The land use map of 2021A of Ngoma hillside scheme

Conducted training on civil works in Ngoma

In Ngoma 22 irrigation scheme, a training on civil works has been conducted to the formed O&M team (In charge of infrastructure, scheme management committee both hillside and marshland) and farmer repair team (zone leaders).

A total number of 23 people were trained theoretically and practically on concept of concrete, type of concrete, materials and tools used for making concrete, the quality of materials, steps of concrete construction, mixing ration of concrete, calculation of volume of concrete, concept of stone masonry, materials used for stone masonry, classification of stone masonry, steps in construction of masonry and mixing ration the mortar for masonry. As a result of the training on basic civil works, the trainees repaired the main canal of 12 m long and turnout at the selected demonstration site located in Mwambu marshland on the first turnout right side, this showed that the trained farmers will be able to repair themselves the similar damaged irrigation facilities on their own.

Photo 129. Theoretical and practical training

Photo 130. Practice of basic civil works in Ngoma 22

Conducted training on water management and hydrant repair in Ngoma 22

A three days training on water management and hydrant repair was conducted in Ngoma 22 model site and 23 people including O&M team and farmer repair team were trained. A demonstration site was selected in Ngoma 22 hillside to practice skills acquired in participatory irrigation management; basic irrigation knowledge; water management and water distribution; hillside irrigation using hydrants. The trainees have also acquired expertise to use Mc Erloy butt joint machine (for 63mm pipe) and observed installation of gate valve by butt joint; identification of all spares/ fittings related to plumbing.



Photo 131. Repairing work by trainees, Visit inside the pumping station, Repair work using different fittings respectively

Conducted a training on farm road repair in Ngoma 22 Model site

A five days training on farm road repair in Ngoma model site has been conducted where O&M team and farmer repair team from marshland and hillside have been trained. The participants have been theoretically and practically trained on Do-nou, sand bags, technology. This training has been conducted in collaboration with Core Rwanda. Participants were very motivated to acquire skills on Do-nou technology and a road of 44m length has been repaired by trainees during the practical work.



Photo 132. Repair of farm road by trainees in Ngoma 22 model site

Inventory of irrigation materials left by KONOIKE at Muhurire cell office

Together with RAB Ngoma station, Ngoma District and WAMCAB National staff have conducted an inventory of irrigation materials, office furniture and spare parts left by KONOIKE (Japanese company that constructed Ngoma 22 scheme). These materials were in the store/ former office of KONOIKE at Muhurire cell office in Ngoma District. These left materials are part of Ngoma 22 project and are currently under management of RAB. The inventory

aimed at identifying the materials and spare parts that can be used by IWUO during the routine repair of damaged irrigation facilities in Ngoma 22 scheme.

Photo 133. Inventory of the irrigation materials left by KONOIKE at Muhurire cell office/Ngoma District

Ngoma: Meeting between RAB and IWUO in NGOMA 22 on replacement of stolen air valves: The meeting between IWUO and RAB was held with purpose of replacement of air valves stolen on the right side of the pipeline. In this meeting an agreement was reached and the IWUO accepted to replace 5 air valves stolen through the payment of 50,000 Rwf to buy the spare parts not available in the store of RAB. Also IWUO was committed to raise the ownership of the water users' members by safeguarding the installed irrigation facilities in the scheme. In this meeting, it was agreed to replace the air valves stolen and see an alternative of preventing them from easy removal by thieves or install /fixing them permanently. Regarding the tasks of casual labors under RAB working the activities of O&M in Ngoma 22, the meeting wished to make clear their responsibilities as RAB and the same on the side of IWUO with regard to O&M of Ngoma 22 irrigation scheme.

Ngoma: Maintenance of irrigation facilities in Ngoma 22 model site and supported in repairing of irrigation facility: Maintenance of irrigation facilities in Ngoma 22 model site was done, where the famers participated in cleaning of weirs to remove sediments and other materials that impeded the normal flow of water in the canal.

Photo 134. Cleaning of weir in Ngoma 22 model site (left) and

The repairing works of low left side main canal in Ngoma 22 were done, the embankment and main canal were repaired by compacting the embankment where was damaged and IWUO provided the cement for repairing the main canal.

Rwamagana district activities

Rwamagana: Discussion with Task Force members in Rwamagana District: In order to elaborate the IP&TP, different ideas and training materials have been collected in various target districts through the interaction with TF members. In Rwamagana District, the following ideas were raised:

- They suggested that WAMCAB project could consider other farmers who are growing crops other than rice crop surrounding all schemes, meaning other areas in command area of the schemes (Bugugu, Gashara, Cyimpima and Cyaruhogo) which are not used for rice cultivation to be organized in to groups so that they can be advised on good agriculture practices and the best way of water management.
- They suggested the consideration of the land located at the end of the main right canal from Gashara even if there is no irrigation facilities, in this area they grow rice but only one season. Help them to be able to have more than one season by applying irrigation system.
- Prior to prepare the secondary canals, they suggested to firstly establish the Irrigation Units (IU) that shall be responsible for the creation of secondary irrigation canals.
-

Rwamagana: Meeting with Vice Mayor, TF members, District Cooperative Officer and Core counterparts: A meeting with the Vice Mayor in Charge of Finance and Economic Development (VM FED), TF members, District Cooperative Officer and Core C/Ps from RAB has been organized in Rwamagana District. Reactivation of District Irrigation Steering Committee (DISC), establishment of IWUO, merging 4 existing cooperatives into one, and explanations on the existence of IWUO in developed schemes were on agenda of the meeting. The concept of DISC was explained as a committee consisting of different stakeholders at the District level whose overall responsibility is management and supervision of irrigation schemes. Also, the VM FED is the chairperson of DISC. To respond to this meeting, the VM assured that the DISC that was dormant would be activated as project activities resumed. After all this effort to explain the key role of DISC in implementation of WAMCAB activities not only in model sites but also in other irrigation schemes of Rwamagana District, the VM pledged the District support to establish the DISC by organizing a DISC meeting on 7th February 2020. During this meeting, the measures will be taken to keep DISC active for the proper management of irrigation infrastructures and its sustainability as well. Regarding the establishment of IWUO, a WAMCAB expert explained the plan to revive the IWUOs through creation from the lowest level unit, IU, depending on water source, size of unit area and existing crop rice group, which is a bottom-up approach. He added that there are a number of steps to be followed which will result to one strong IWUO in the four irrigation schemes namely Bugugu, Gashara, Cyimpima and Cyaruhogo. Concerning the idea of merging 4 existing cooperatives, and the existence of IWUO in developed schemes in Rwamagana, the VM said that a series of meetings will be held to discuss the possibilities of how this merging activity can be done either merging them into one cooperative or creation of a union. Moreover, the VM requested the District Cooperative Officer to cope with this issue, and he revealed the eagerness of farmers to merge the cooperatives. The VM also recommended an audit to be conducted prior to the merging in each cooperative to avoid conflicts that may occur later. From experience, cooperative leaders are less concerned about or not very comfortable with the existence of IWUO. WAMCAB requested to the VM and District

Cooperative Officer to support in convincing them to understand the importance of IWUO especially in terms of O&M of irrigation infrastructures and its sustainability. To this point, developed schemes in Rwamagana are expected to be a model site where both cooperative and IWUO will coexist in harmony and in complementary manner.

Photo 135. A meeting with Vice Mayor, TF members, District Cooperative Officer and Core counterparts/RAB

Rwamagana : DISC meeting: On 7th February 2020, a DISC meeting in Rwamagana District has been organized to introduce WAMCAB Project; discuss on Ministerial Order establishing IWUOs and DISC; elect DISC board members; to draft proposal for the procedure in the IWUO management. WAMCAB explained the draft proposal for the procedure in the IWUO management to participant, and requested them to provide their idea and comments on the proposed steps that can be combined to come up with the summarized procedures. The presentation focused on a step to organize and select IU and Water Users Team (WUT). Also, the irrigation map and water user lists were being prepared after which the lowest level structure will be organized. In short, IWUO will be organized by bottom-up approach. After receiving the comments from participants, the final document in Kinyarwanda would be produced.

Rwamagana: DISC Meeting organized by Rwamagana District: On 26th November 2020, a DISC meeting was organized by Rwamagana District. Amid of the DISC meeting, WAMCAB presented the management model of the interconnected irrigation schemes of Bugugu, Gashara, Cyimpima and Cyaruhogo, also the activities of O&M being done there were presented and the challenges being faced like soil erosion, farmers who disobey rules and regulations. RAB has presented other projects such as SAIP, which is supporting farmers to acquire SSIT equipment, etc.

Rwamagana: Database preparation for Rwamagana Scheme: In order to manage the exact database of the water users in irrigations schemes of Rwamagana, their plot size per farmer, the rearrangement of water users list has been done without repeated farmers' names. Also, the summation of the plots owned by one farmers has been done purposely to know the size of lands owned by each farmer. This has been done according to IUs.

Rwamagana: Explanation of scheme layout, how IWUO structure is prepared and election process: A series of workshops was conducted to explain the layout of the interconnected four schemes, how the IWUO structure is prepared, and the election process of WUT, Zonal Committee (ZC), and Scheme Management Committee (SMC).

Rwamagana: Formation of IWUO in Rwamagana: On 7th July 2020, a workshop has been organized to elect the members of the governing body of Rwamagana IWUO. As described above, Rwamagana model site is composed of four interconnected schemes namely Bugugu, Gashara, Cyimpima and Cyaruhogo. The governing body of IWUO shall consist of three (3) elected representatives from each scheme, which means that twelve (12) people shall be elected from four schemes for **the Executive Committee (6)**, **Conflict Resolution Committee (3)**, and **Audit Committee (3)**. Scheme Management Committee (**SMC**) is formed in each four scheme and composed of three people from both right and left sides of the scheme and women considering gender mainstreaming principles. Zonal Committee (**ZC**) leaders has been elected from each left and right main canal. The committee shall be responsible for water distribution of main canal, and they will be trained on maintenance of infrastructures such as concrete and masonry work. Water Users Team (**WUT**) leaders have been elected according to the existing group and the manageable number of IUs at the left and right sides of the scheme separately so that management of irrigation water can be conducted smoothly. Also, the Seasonal Water Distributors (SWD) have been decided at each Irrigation Unit (**IU**) organized according to the number of turnouts set in each scheme. SWD is responsible for the operation of stop-logs in the IUs. After electing people in all levels of the IWUO structure (SMC, ZC, WUT) in each scheme, all the elected leaders have been gathered together at Cyaruhogo drying ground, and the members of the governing body of Rwamagana IWUO have been elected.



Photo 136. Organization of IWUO in Rwamagana

Rwamagana: Training on scheme layout and IWUO structure: A training has been conducted in all schemes to explain the scheme layout, organizational structure of IWUO (WUT, ZC and SMC).
Rwmagana: Discussing the rules and internal regulations: A meeting with all elected leaders was organized to discuss the rules and internal regulations to be applied in this irrigation schemes. The handouts in Kinyarwanda were distributed to the participants. Also, their responsibilities as leaders were explained and discussed. During this exercise, the local leaders at Sector and Cell level, cooperative leaders and the District Officials were invited as well.

Rwamagana: General assembly meeting to ratify rules and internal regulations of Rwamagana IWUO: A general assembly (GA) meeting has been organized to ratify the rules and internal regulations. The 67 delegated people including farmers' representatives from all four schemes, District Irrigation Officer (Mr. Alfred), IWUO specialist from RAB (Mr. Jules), cooperative leaders from all four schemes, two Sector Agronomists (Rubona and Munyaga

Sectors), two leaders from Union of Rice Growers, etc. have attended. The GA meeting has been led by the elected president of the IWUO executive committee, Mr. Ernest DUKUZEYESU. WAMCAB staff also intervened to explain the rules and internal regulations. In their speeches both Mr. Alfred and Mr. Jules, they appreciated the progress towards the registration, and added that the ratification of rules and internal regulations by the GA is the prerequisite for getting collaboration letter from District and further legal recognition. The GA meeting ratified the rules and internal regulations with just minor amendments.

Photo 137. President of IWUO chairing the GA meeting to ratify rules and internal regulations

The handover ceremony from the former IWUO committee to the newly established IWUO took place in Rwamagana. There was a mission by RAB to create IWUO in around 2016, and cooperatives contributed for the registration. However, the IWUO had not have the real activities, and no status was given by the District. During this ceremony, the President of the former IWUO, Mr. Telesphore SINIGENGA, handed over some records and documents to the newly elected President of IWUO, Mr. Ernest DUKUZEYESU. Regarding the financial records, a book of bank account with the amount which is equivalent to 160,420 Rwf has been handed over to the newly established IWUO. In this ceremony, the outgoing IWUO and the newly established IWUO have agreed to meet on 20th July 2020 with all required documents like ID, Photos, etc. at COPEDU (Financial Institution) where the old IWUO opened the bank account to change signatories for the smooth transactions. The three confirmed signatories were: President, Treasurer and person in charge of infrastructures.

Photo 138. Handover between outgoing and ongoing IWUO executive committees at Cyaruhogo drying ground

Rwamagana: Financial management training to IWUO members: To empower IWUO members and improve their skills in management of O&M fee (water fee) and other limited resources, a five-day training was organized

for a total number of 40 IWUO members especially those involved in collection, management and expenditure of water fee (12 members from the executive committee, 12 members from SMC and 16 members from ZC). Regarding the establishment of procurement committee at the IWUO level, when the O&M team realized the need to repair or rehabilitate any irrigation facilities, i.e. to procure materials, in this case, they need an ad-hoc committee responsible to deal with the procurement issue. Regarding the financial records, for example, bill and receipt, in Rwamagana as most of the farmers are members of the marshland cooperatives, there is no need for the IWUO to issue the bill and receipt to each individual farmer, only a bill or a receipt to the cooperative can be enough.


Photo 139. Trainees during the training on financial management in Rwamagana

Rwamagana: Field visit with core counterpart (C/Ps)/RAB in Rwamagana Model sites: A field visit was paid in four model sites of Rwamagana namely Cyimpima, Cyaruhogo, Gashara and Bugugu for the Core C/Ps to see the status of irrigation facilities built and being constructed. WAMCAB Expert (Dr. SHEMSU) showed and provided explanations to C/Ps on Cyimpima dam where construction works was completed and full of water, also a tour continued to Gashara and Bugugu schemes where dams were under construction and upon completion the entire scheme will be irrigated throughout the year.



Photo 140. Field visit with Core C/Ps/RAB in Cyimpima, Gashara and Bugugu schemes under construction

Rwamagana: Formation of O&M team, farmer repair team and explanation on responsibilities of each team:

The O&M team and Farmers' repair team have been formed in Rwamagana irrigation schemes. The O&M team will be responsible for operation and maintenance planning, monitoring and supervision at scheme level while the farmer repair team will be responsible for routine maintenance of irrigation facilities. A team of 30 people has been formed whose 2 people in Charge of irrigation infrastructures at IWUO level, 12 people elected at SMC (3people from each of the four schemes) to form the O&M team and 16 people elected at ZC (2people from each zone of the 8zones in all schemes) to form Farmers' Repair Team. The participants have also been explained their responsibilities.


Photo 141. Formation meeting of O&M team and Farmers' Repair Team at Cyimpima

Rwamagana: First trial in making secondary canal in Cyimpima scheme: A training on creation of the secondary canal has been conducted in Cyimpima scheme at the first IU on the first right turnout. The farmers who get water from the first right turnout created the secondary canal parallel to the main canal. It was also an occasion to mobilize all water users to create the secondary canals in their IUs. The measures of the created secondary canal are 20cm of depth, 20cm in the bottom and 60 cm on the top of the canal.



Photo 142. Creation of the Secondary canal in Cyimpima scheme

Training on basic civil work in Rwamagana model sites: The O&M team and farmers' repair team from Cyimpima, Cyaruhogo, Gashara and Bugugu schemes have been theoretically and practically trained on basic civil works. Participants have acquired following skills on basic civil works. On the other hand, the TF member from Rwamagana District called Alfred NDAYISHIMIYE and in charge of O&M in WAMCAB attended the first day of the training and in his opening remarks encouraged participants to acquire carefully the skills and reminded them to abide by COVID-19 Preventive measures during this training.

Photo 143. Preparation of foundation, Theoretical lecture and Preparation of reinforcement bar

Facility coding in Rwamagana model sites: In Rwamagana model sites, the irrigation facilities (turnouts) have been coded in both side of the schemes (left &right), the turnouts have been coded with codes readable by farmers as these turnouts are the basis for the creation of IUs as the lowest level of the IWUO structure.

Photo 144. Examples of coding facilities in Cyimpima scheme

Rwamagana: Survey in Cyaruhogo scheme: A facility survey of two existing weirs, the Culvert, and proposed two new weir's site in Cyaruhogo schemes has been conducted with purpose of assessing the current situation of those facility and propose the required intervention. The size of drain and road crossing the culvert was measured.

Photo 145. Culvert in Cyaruhogo, Culvert crossing road and Junction of Gashara and Cyaruhogo drains

Extension of main canal of Nawe farmers group in Rwamagana: Through community work, an extension of main canal from Gashara scheme has been made in Nawe farmer group. This canal has been excavated to address the issue of water shortage and consequently increase the cultivated area.

Photo 146. Extension of main canal in Nawe farmers groups

Rwamagana: Inspection of soil erosion points with District staff: All sources of soil erosion in Rwamagana model sites have been visited together with TF member from Rwamagana District, the countermeasures have also been proposed. Countermeasure is conducted by collaboration of community work and Vision 2020 Umurenge Program (VUP).

Photo 147. Sources of soil erosion

Rwamagana: Handover of stop logs between District and IWUO: Handover of stop logs from District to IWUO has been done for Cyimpima, Gashara and Bugugu schemes.

Farming in Gisagara District

To improve farming in Ngiryi and Nyabyogera irrigation schemes, crops were inventored and soil sample and yield data were collected. On 11th February, 2020, WAMCAB experts attended a seasonal preparation meeting

in Gisagara District to report on season 2019C and 2020A, preparation of season 2020B, competition among farmers 2019/2020, improvement of livestock and small stock (pigs, layers, sassa, etc.) and role of stakeholders. In Ngiryi, a training on composting using rice straws, soil, urea and water has been conducted and 7 farmer producing groups totalizing 103 farmers have been trained.

Photo 148. Composting making in Ngiryi

An assessment on crop profitability has been conducted on different crops in both, Ngiryi and Nyabuyogera. This was done by interviewing different farmers who grow different crops. **Besides**, training on cooperative management and gender mainstreaming has been conducted in both schemes, and the farmers acquired skills and knowledge on cooperative management, leadership and records management. In Nyabuyogera, a training on marketing has been conducted and the participants have conducted the market survey in three markets of Huye Districts including the wholesaler market who purchase the vegetables brought by farmers in the morning hours and retailed during the day by the retailers.

Photo 149. Plot levelling before and after sowing

Nursery preparation and sowing: In Ngiryi, the nurseries have been established where three rice varieties (*Yun Yin*, *Buryohe* and *Fashingabo*) have been sowed on seven separate plots (two for *Yun Yin* , two for *Buryohe* and three for *Fashingabo*), prior to sowing the seeds have been pre-treated (soaked) with water and fungicide and the germination rate was 90%.

Rice transplantation in demo farms in Ngiryi: In Ngiryi, the demo farms have been established and covered (levelling using hand hoes, wooden rakes, manure application where SMAP techniques and SMAP+AWD have been done, and inorganic fertilizer has been applied in all demo farms) the transplantation has been conducted smoothly.

Procured seeds for Nyabuyogera demo farms: In Nyabuyogera model site, the three varieties of eggplants, three varieties of french beans and peas have been procured and nursery for eggplants have been prepared and sowed.
Applied fertilizers and chemicals spraying in demo farms in Ngiryi: In Ngiryi, both insecticide and fungicide have been sprayed in all installed demo farms to control diseases and pests. Also, the second top dressing has been done in all demo plots.
Conducted training on nursery establishment and seeding in Nyabuyogera: In Nyabuyogera, a two sessions (theoretical and practical) training on nursery establishment has been conducted smoothly, all expected trainees has been attended 100%, they all appreciated the training and committed to apply same learned techniques in their respective zones, trainees learned how to establish nursery of chili in an organically way and egg plant nursery conventionally. The 21 participants of the training were SMC, cooperative executive and audit committees and all zonal leaders.


Photo 150. Training on nursery establishment and mulching the nursery after training in Nyabuyogera

Attended extra ordinary cooperative GA meeting in Nyabuyogera: The extra ordinary meeting was organized by the cooperative executive committee of ABAKORANAMURAVA, two articles was on agenda 1. Maize harvesting preparation grown in season 2021A and 2. Season 2021B progress evaluation and AoB, during the meeting the starting date for harvesting was predicted which is 15th March, 2021 and speed it up so that it will be covered in few days just to start land preparation for season 2021B, during this meeting especially on maize harvesting techniques, a techniques of using trees in hangar (shed) just to increase the places where to put extra maize was explained to participants, also explained how other zones with no hangars namely zone 1, zone 6 and 10 to make temporary hangars using locally available materials. Also, an announcement of the minimum maize price of season 2021B was made, which is 226 Rwf/kg for shelled maize and 204 Rwf/kg for maize on cobs (not shelled maize).

Signed agreement for installing demo farms and nursery follow up in Nyabuyogera: In Nyabuyogera, an agreement has been signed by and between all farmers' owners of plots where demo farms will be installed and the cooperative for the management of the conflicts that may arise from the use of the plots for the establishment of demo farms.

Checked the status of rice all over in Ngiryi: Ngiryi has been crosschecked in all 5 zones, different challenges have been identified: (1) Farmers who do not follow up their plots leading to poor irrigation as fields dry up to the level soil start cracking, which is a sign of over drying, and it affect negatively rice yield. This issue has been addressed to executive committee members of cooperative and they promised that it will be resolved after hiring

the employee (agronomist) in charge of every day farming activities and water will be availed smoothly by respecting season water distribution calendar with IWUO cooperation. (2) Unneven crop growth in the side where other crops has been grown, due to uneven soil distribution in plot, caused by bringing out subsoil while taking of soil mounted on lastly made beds, and unbroken hard pan, so this makes some rows different from other due to different soil fertility and not well broken hard pan. This issue will be handled by training on land preparation and manure fertilizer application. (3) Late and uneven fertilizer within one field or field of farmer producing groups, it makes also conflict in irrigation while some farmers in the same FPGs need water at different period while other do not need to apply water due to fertilizer application. (4) Sand, which is deposited on some fields, especially upper part of the scheme, which also reduces rice yield of paddy rice.

Photo 151. Uneven crop growth in the same field and Sand deposited on rice field in Ngiryi upper stream

Recorded growth parameters of rice in demo farms in Ngiryi: The growth parameters records have been done smoothly and it is continuous activity up to the comparison of productivity of all models (conventional model, SMAP model and SMAP + AWD model).

Photo 152. Recording growth parameters in rice demo farms in Ngiryi

Proximity coaching of farmers and cooperative assistance in daily activities: In addition to the conducted trainings and workshops, WAMCAB performed proximity coaching in all cooperative activities especially farming related activities (good agricultural practices) in all sites located in Ngiryi and Nyabuyogera. In Nyabuyogera, WAMCAB started on cooperative reorganization, and the reorganization started producing positive results by activating zones and farmers producing groups, they are now active and leaders are performing their respective responsibilities as a results of reorganization.

Farming in Ngoma 22

Collection of soil samples in Ngoma 22 and Mwambu: The entire scheme of Ngoma 22 has been toured to grouping zones with similar physical properties, 7 groups corresponding to 7 composite samples have been collected and taken to laboratory for analysing the chemical properties of the soil.

Conducted trainings on composting in Ngoma model site: Based on the laboratory results that showed a lack of organic matters in soil of Ngoma 22 irrigation schemes, WAMCAB started to conduct a series of trainings on compost making in Ngoma 22 and Mwambu schemes using locally available materials (farm wastes) like rice straw and improvement of soil fertility.

Photo 153. Training on compost making

Reorganization of KOTUNGO cooperative: In Ngoma 22 hillside, there was no organized cooperative; WAMCAB Project has started by re-organizing KOTUNGO (hillside cooperative) from bottom up by forming Farmer Producing Groups (FPGs), Zones and Executive committee (replacement of non-active members by cooperative itself). Zones have been formed following the limits of villages so that every village has been considered as a zone and the number of villages covering the irrigation scheme will be equal to the number of zones in cooperative. FPGs have been formed following canals (upper and lower canals on both sides), this means that under one zone, there might be two, three or four FPGs depending on the number of farmers and the size of their farms. The elected IWUO leaders have not been allowed to be the leaders in re-organized cooperative to avoid concentration of responsibilities to the same farmers. In KOTUNGO, 9 zones and 27 FPGs have been formed. In

marshland (COPRIMWA) the existing FPGs have been kept but the FPGs leaders who have been elected in IWUO have been substituted by their deputies.

Conducted a workshop with farmer group leaders of KOTUNGO

A workshop has been organized to collect information about irrigation equipment (hose pipes, taps, watering cans, etc.) and lists of farmers of every group and mobilize farmer group leaders to speed up the collection of membership fee.

Conducted workshop with KOTUNGO Executive Committee in Ngoma 22: A workshop has been organized to discuss the draft of contract between KOTUNGO and AKENS & KERNELS LTD as recommended by Minister of MINAGRI during her previous visit in Ngoma 22, and collection of cooperative membership fees from farmers as part of re-organization and farming activity plan and any other businesses. Also, the discussions and interpretations on farming contract between KOTUNGO and Spice Rwanda Ltd have been made. The contract has been translated to Kinyarwanda and explained to executive committee. Finally, an agreement has been reached between both parties.

Photo 154. Discussions between Spice Rwanda Ltd and KOTUNGO on farming contract in Ngoma 22 scheme

Conducted trainings on rice straw plowing in in Mwambu marshland: A series of trainings on rice straw plowing for soil improvement have been conducted in all zones of Ngoma 22 schemes. A total number of 78 farmers have been trained.

Photo 155. Training on rice straw plowing in Mwambu marshland

Measuring the selected area for chili and chia seed in season 2021A: The total measured area for chili (African bird eye chili variety) was 21 ha, and sites for nursery beds has been identified. The total area measured inside irrigation scheme for chia-seed is 45 ha, outside the irrigation scheme is 17 ha which can be increased, and non-valorised fields inside the irrigation scheme have been identified.

Study tour to Nasho irrigation scheme: A total number of 21 farmers' growers of chili have been taken to a study tour at Nasho irrigation scheme in Mpanga Sector, Kirehe District. They have visited COVAMIS cooperative.

Photo 156. During the study tour at Nasho in the field of chili

Agricultural practice for chili: In total, 12 nurseries have been established and the good agriculture practices such as sowing, mulching, earthing, thinning etc. have been conducted.

Photo 157. Good agriculture practices: nurseries, sowing, mulching, earthing and thinning in Ngoma 22

Demonstration of chili transplantation and chia seed sowing: A demonstration on chili transplanting and chia seed sowing has been conducted in Ngoma 22 irrigation scheme, famers who have been trained and taken to study tour had time to put in to practice what they have learnt during this demonstration time.

Photo 158. Demonstrating farmer how digging holes for chia seed sowing and the quantity of seed to be sown in a hole

Demo site identification in farms in collaboration with KOTUNGO: In order to increase the yield and agricultural incomes, WAMCAB will show the performance of farming methods and appropriate varieties in the target districts through the management of demonstration plots in irrigation scheme. Also, WAMCAB considers to conduct a series of Farmer Field School (FFS) utilizing the training material by RAB and JICA projects. This activity for site identification, where demo farms has been installed in Ngoma 22 and GPS data was taken. The meeting for season preparation in KOTUNGO was held in the presence of executive committee, audit committee, and sector agronomist of Remera sector and WAMCAB Agronomists. Mainly the following topics have been discussed: Harvesting and collection of production (chia seed); selection of crops to be cultivated

Conducted training on nursery preparation in Ngoma 22 hillside and sowing: The training on nursery preparation for KOTUNGO was conducted on 10th February, 2021. The participants were executive committee of

KOTUNGO, audit committee and zone leaders. Chia seed, onion and green pepper have been used for sowing in demonstration farms and 17 participants have been trained.

Follow up on the progress of nurseries in Ngoma 22 hillside

For chia seed: The progress of nurseries in Ngoma22 is well, meaning that germination is good for both seeds of green pepper and onion, the land owners were urged to manage nurseries by irrigating in morning and evening and weeding if necessary. For identifying the areas to be grown with chia seed for the next season, this activity was done in collaboration with zone members after the meeting aimed at crops selection by each zone. The zones located in Remera sector are now interested in farming chia seeds after experiencing the production of other zones in Rurenge sector, but the total areas to be cultivated is not yet confirmed because the contract will be signed soon.

- **For chili**

  The progress of chili is not good generally, due to different conditions faced like water shortage at the beginning of transplanting and heavy rain after two months, but some farmers hope to get some production then in two weeks later they will start harvesting. Due to some factors mentioned above, the productivity will be decreased and the harvesting will be in March 2021.

- **For maize**

  This activity of monitoring the progress of maize and to give the instructions how to maintain the production to the farmers has been done. The farmers were reminded the proper time to harvest and how to judge it.

- **Harvest of chia seed, chili and maize**

  We have been working with farmers in Ngoma 22 to show them how to harvest the chia seed, chili and maize and monitoring post-harvest, such as to judge the right time to harvest, drying at proper moisture content, winnowing and packaging or storing.

  This activity of seed distribution was done around 80kg, and distributed to the farmers for season B and 45 tons have been collected and sold to the company.

- **Land preparation for season B**

  Farmers have already started the season B, for chia seed, beans. We have collaborated with them for land preparation and sowing.

Farming at Rwamagana

In order to improve soil properties and structure to increase its productivity, WAMCAB has collected soil samples across four schemes in Rwamagana model sites with the purpose of knowing what is missing in soil in terms of soil nutrients. The laboratory results showed that there was a problem of lack of sufficient organic matters. Based on the laboratory results that showed a lack of organic matters, WAMCAB started to conduct a series of trainings on compost making in Bugugu, Gashara, Cyimpima and Cyaruhogo schemes using locally available materials (farm wastes) like rice straw to increase organic matters and improvement of soil fertility. After the construction of the main canals, the cultivated land has increased and farmers have extended the area grown with paddy rice which were not exploited previously.

Photo 159. Extended land after the construction of concrete main canal in irrigation schemes

Installation of demo farms: WAMCAB has installed a total of 2,700m^2 (300m^2 x 9 plots) of demo farms in Cyaruhogo scheme, where the farmers from Cyaruhogo, Cyimpima, Gashara and Bugugu gather to learn the knowledge through Farmer Field School (FFS). This help farmers to improve their rice cultivation techniques for good productivity which lead to the increase of income. WAMCAB will test three different farming methods; 1) conventional farming, 2) SMAP farming, 3) SMAP + AWD (Alternate Wetting and Dry) farming. Also, WAMCAB will test three different rice varieties recommended by RAB; 1) *Yun Yin* (short grain), 2) *Fashingabo* (long grain), 3) *Buryohe* (long grain) or *Umujagi* (long grain), therefore a total of nine (9) different plots will be tested to compare the performance of each.

Rwamagana cooperatives re-organization: During the reorganization of cooperatives, the existing farmer producing groups (FPGs) and zones have been maintained as they are all active and functional. Cyimpima cooperative (CORICYI) remained three (3) zones and seven (7) FPGs, each FPGs has a committee of 5 people. Cyaruhogo cooperative (COCURICYA) has two (2) zones and seven (7) FPGs, also every farmer producing group has a committee of 5 people. Gashara cooperative (COCORIGA) has four (4) FPGs, there is no zone. Bugugu cooperative (COCORIBU) has three (3) FPGs, there is no zone.

Trained cooperative on gender mainstreaming: In order to empower cooperatives, WAMCAB has conducted a training on gender mainstreaming in daily farming activities. Cooperative management, through good leadership, book keeping and gender balance have been the key subjects of the training.

Conducted Survey on COVID-19 impact: Following the global pandemic COVID-19, WAMCAB has conducted a survey to assess COVID-19 impact in farmer beneficiaries of irrigation schemes. Based on the findings of this survey, strategies will be taken to help farmers recovering from the impact of COVID-19.

Established demo plots and follow up in Cyimpima: The demo farms in Cyimpima were established and the follow up was made to ensure that these demo farms are well managed in terms of water management, weeding and cleaning. The rice planted in these demo farms have a good growth performance. The landowners, board members of Cyimpima, cooperative agronomist were requested to collaborate for better management of demo farms. The progress status of demo farms in Cyimpima model site was relatively good, there was no serious problem of agricultural practice management, the land owners are following the guidelines of WAMCAB agronomist and cooperative agronomist collaborative to manage demo farms.

Organized seed distribution activity (provided by JICA): For the contribution of economic recovery plan of GoR, JICA planned the distribution of vegetable seeds as a response to COVID-19 impact to farmers in season A&B 2021 in model site. An identification of the areas and farmers who were ready for growing vegetables was conducted, therefore the list of the farmers was made and submitted to District for further approval and procurement procedures.

Transplanted rice in Bugugu: The growth was not good due to poor water management. Thus, the cooperative was advised to have an irrigator person to solve the problem of disorganization of water distribution. The frequent field visits were required since the cooperative does not have an agronomist. The farmers were reminded the best agricultural practices like spraying agrochemicals on time for diseases and pest control, 1st top dressing urea and weeding. Also, there was water management issues, but some farmers could not access irrigation water due to some canals which are damaged.

Conducted the training for 1st top dressing, diseases and pest control in demo farms: The training for 1st top dressing in demo plots was done at Cyimpima and Cyaruhogo model sites and sector agronomist of Munyaga attended in the first group and the participants from Bugugu and Gashara model sites and sector agronomist of Rubona attended in the second group. Both groups were formed to abide the measures for COVID-19. The training topics were the following: Application of Urea for the 1st top dressing; Weeding operation by rotary weeder or weeding by hand; Diseases and pest control; Improvement waterlogged problem plot. During this training, farmers /participants were explained about the process of demo farms activities from sowing, land preparation, transplanting and water management.

Photo 160. Training at demo farms in Cyimpima / weeding demo farms in Cyimpima / recording the plant growth

Monitoring and growth record every week at demo farms: This work should be done from two weeks after transplanting up to flowering stage in order to make clarifications on the performance of each variety. Three varieties have been used namely *Yun-yin*, *Mfashingabo* and *WAT* at demo farms and three methods such as SMAP, SMAP+AWD and conventional have been used. The growth performance is almost good, except for *Yun-yin* which is affected by blast disease.

3.4 Integrated soil fertility management

3.4.1 CARAVAN Project mapping soil fertility in Nyabihu district

The project aimes to equip the RAB and the mobile laboratory with the necessary equipment to produce the soil fertility map of a pilot zone of 50,000 ha, provide fertilizer quality control equipment for better use of fertilizers ; strengthen the scientific and technical capacities of RAB staff ; and organize the agricultural caravan in Rwanda for soil fertility analysis.

Photo 161. Soil sampling map for Nyabihu (left) and meeting with local leaders to itroduce the project (right)

The key project activities included resource mobilization, baseline data collection for the project area, maintain regular information and communication between the Parties involved in te project, conduct soil analysis for the collected soil, and interprete results.

Soil Sampling methodology : Properly collecting soil samples is the most important step in any nutrient/soil amendment management program. Soil sampling should reflect tillage, past fertilizer/soil amendment placement, cropping patterns, soil type (including drainage and slope characteristics). The most commonly used method for soil sampling is be based on soil types. Hillsides are kept separate from bottoms since the soil types

will vary. Three 3 classes base on topography and slop will be developed from 0 to 5% ,5 to 25 % and 25 to 45 % and grid sampling maps will be developed in for those classes. Development of site-specific topography global positioning systems (GPS) will be organized into a systematic grid pattern of 50 ha. Grid soil samples should be taken within the grid cell or at intersection points between grid cells, consisting of 8-10 cores per sample taken within a 370 m (**Photo 174**) at 20 cm depth. To more correctly represent soil test variability within a field (especially for implementation of soil test mapping), the grid sample points should be organized into a systematic grid-rectangle sampling pattern as shown.

Photo 162. Scientist and farmers talking about soil sampling (left) and soil sampling with auger (right)

Laboratory analysis: Proposed parameters to be analyses in the laboratory for soil samples - pH (H_2O), Tex*ture, Cation Exchange Capacity,* Exchangeable cations (Ca^{2+}, K^{+}, Na^{+} and Mg^{2+}), Exchangeable acidity, Available Phosphorus, Soil Organic Carbon, Mineral N ($NO^{-}3$) and Available sulfur.

Soil analysis partial results : Among the 12 sectors of Nyabihu District 8 sectors namely Mulinga, Jomba, Rambura, Karago, Rugera, Kintobo, Mukamira, Rurembo, sector have been covered with an area of **23,300 Ha**. Composite soil samples were analyzed to assess the fertility status of the area. Soil samples were tested for pH, Exch. acidity, Mineral Nitrogen NO_3N, C, Ca^{2+}, Mg^{2+}, Na^{+}, CEC, S, Soil Texture. Data from laboratory showed the following results (Table… below).

Table 94: Variation in soil parameters in the sampled sites of Nyabihu sampled by CARAVAN project

Parameter	Results Interpretation	Observation
pH, Exch. acidity	70 % of the area is moderately to low acidic	The land to be limed to correct soil acidity
$Ca^{2+,}$ Mg^{2+}	86 % of the area is moderate to low	Corrected need to be done through lime

CEC	64 % of the area is low	Lime + Organic Manure need to be applied
Texture	99% of the area is sandy clay loam and Sandy Loam do not keep water	Organic Manure to increase water holding capacity
Nitrate NO_3N	100 % of the area is low < 20 mg	Nitrogen level to be increased
Org.C	81% of the is low to moderate < 2.9%	Organic Manure is required
Avail.P	84 % of the area is low < 20 mg/kg	Phosphorus level need to be increased
K+	54 % of the total area is low to medium	A certain portion of Potassium is needed
Na+	100 % very low < 200 mg/kg	No salinity
S	98 % of the total area is high >20 mg/kg	No addition sulfur required

Capacity building

A training was conducted on crop fertilization recommendation, and 19 soil scientist and technicians attended.

3.4.2 Establishment of radical and progressive terraces

The radical and progressive terraces were planned to be implemented at 2,736 ha and 10,376 ha, respectively, for FY 2020-2021 at national level. The construction of radical terraces was done in 22 districts on a total of area of 3,717 hectares, which represents 135.8 % of the achievement against the total annual target. The progressive terraces, which include ditches, agroforestry plantation, shrubs and grasses plantation, were established in 21 districts on 13,278 ha (**127.9%** from annual target). The execution of these activities was done using different approaches such as community approach, service provider and VUP. Below are photos illustrating the above mentioned infrastructures (**Photo 175**).

Photo 163. Photo illustrating Constructed radical terraces (left) and progressive terraces (right)

3.4.3 Soil survey for soil information establishment

This activity is one of the activities planned in the Rwanda Soil Information Service project (RwaSIS). It is linked with one of the use cases of the project related to developing a functional and interactive National Soil Information System (RwandaSIS). The interactive soil information system will help to monitor changes in soil properties and crop yields to inform the GoR about the changes occurring in food production and the delivery of other ecosystem services, and to influence future investment plans. *Level 1 and 2 Geosurvey conducted and map completed (250 m resolution):* With AFSIS support, the geosurvey observations was conducted to rapidly assess where human impacts, agriculture on ecosystem and soil processes are expected. This served highly spatial predictions providing data collection for analyzing geospatial land cover observations from images captured by High-resolution satellite images, mobile phone photography, and drone imagery. Results identified regions of interest for ground investigations, mapping, and monitoring as agriculture land. In order to fine tune this geosurvey process, RAB has provided to AFSIS team the legacy datasets that seemed valuable to improve the accuracy of landscape characteristics in Rwanda in the process. This include the National Land Use and Development Master Plan (NLUDMP) 2020-2050 which could help to delineated lands that are currently having and planned for agriculture land in order to develop a sampling methodology aligned with the master plan. ***Predictive soil mapping (based on legacy data):*** We updated the topsoil property maps of Rwanda with additional georeferenced soil data obtained by RAB, and the gridded covariates, taking into account the distribution of croplands obtained via GeoSurvey and using our ensemble machine learning algorithms (**Figure 2**).

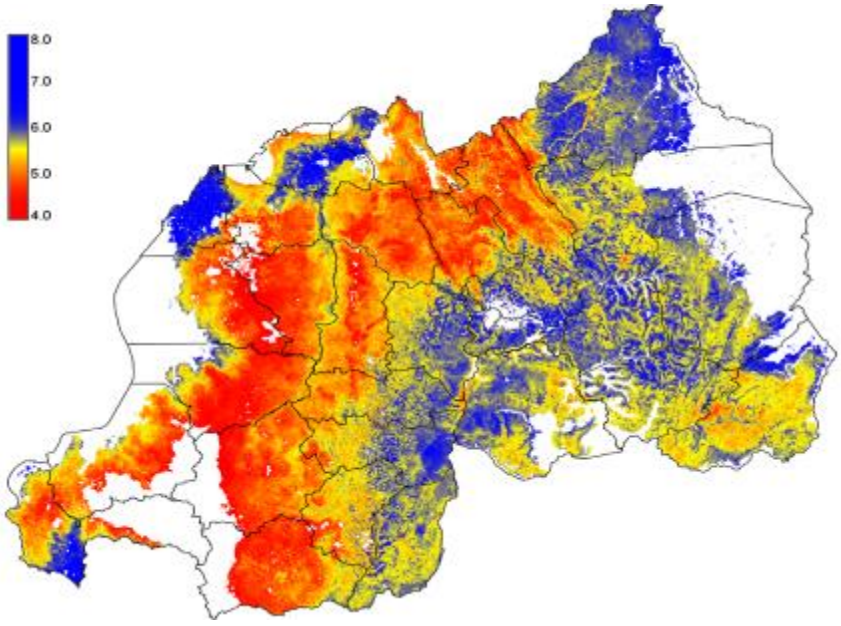

Figure 2: Updated cropland topsoil pH map of Rwanda (2020). The RMSE of this map is +/-0.5 pH units

A national scale soil sampling campaign has been conducted using GIS tools and soil laboratory materials such as GPS, Kobo toolbox, ODK, tablets, soil augers, etc. Soil samples were taken at two layers for each sampling location (0-20 and 20-50 cm). Currently, 2333 sample points against the total project points of 2925 points have been covered in more than 25 districts, equivalent to more than 4500 samples (fig.170). The majority of remaining sample points are located in the Western Provinces including Rutsiro, Nyamasheke, Karongi and Ngororero.

Others are from Nyagatare and Gatsibo district. Collected samples are stored and handled at RAB Rubona Laboratory of soil and plant nutrition.

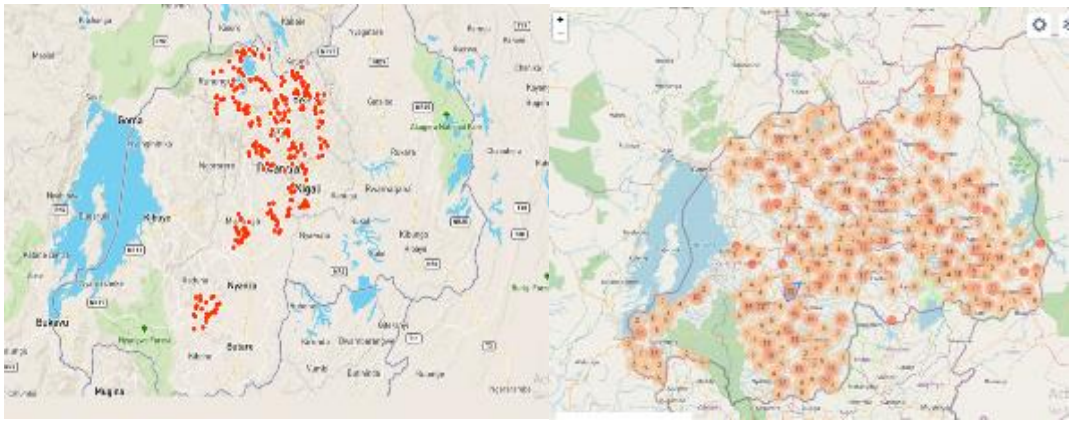

Figure 3: Samples collected illustrative map in February 2021 (left) and June 2021 (right)

Soil samples are being prepared for analysis including drying samples and arrange them accordingly. Around ***1,300*** **soil samples** have been dried and grinded so far. Here below are some pictures to illustrate the steps to follow until the soils breakdown.

Photo 164. Some of the collected soil samples

3.4.4 Soil erosion risk maps

We have started looking at soil erosion/deposition phenomena in Rwanda, and are assembling the relevant data and maps to take a closer look. We have run a number of standard initial assessments of soil erosion risk factors and will keep updating these in the near future. Some of the relevant spatial data layers are included in the raster stack.

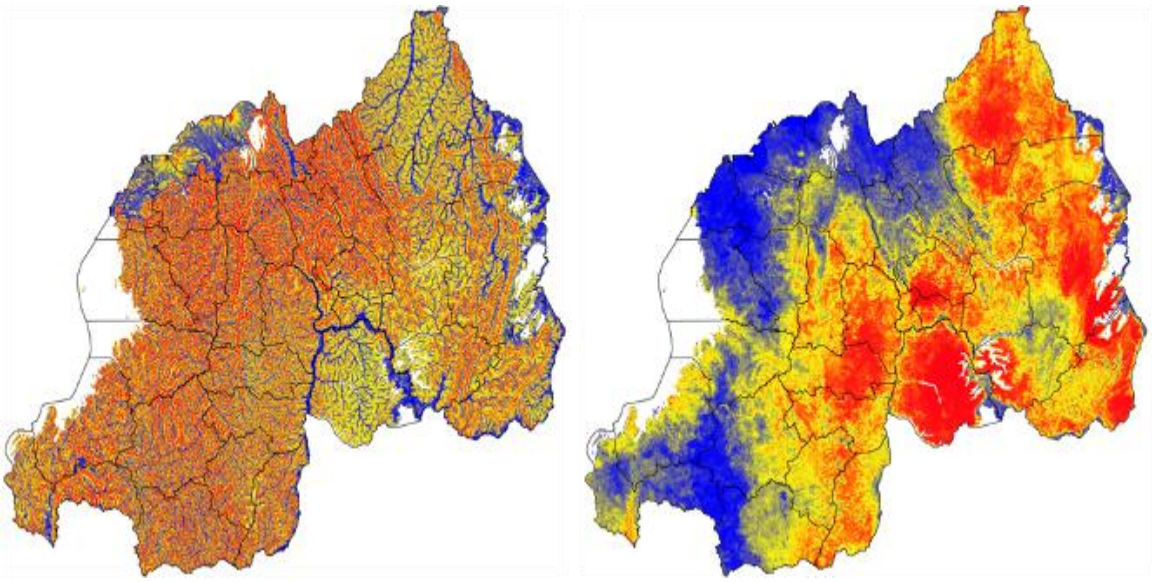

Figure 4: Compound Topographic Index (left) based on MERITDEM and Erodibility-factor (K, right) based on soil property maps

3.4.5 Soil characterization of developed land husbandry schemes

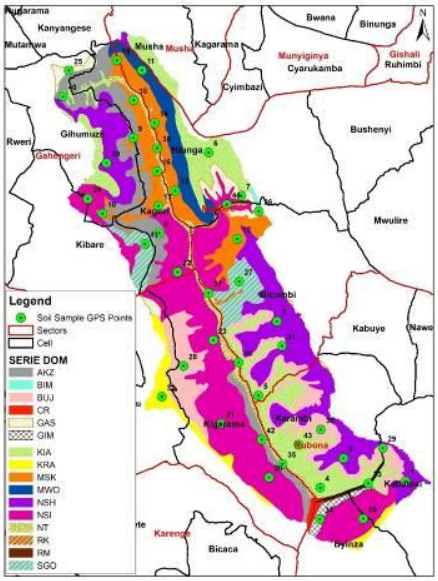

Figure 5: Soil series and sampling points in Rwamagana 34 Command area and catchments

This activity was initiated though collaboration between RAB and the SAIP with the aim of assessing the actual soil fertility status for sustainable land management and boosting agriculture production in schemes/catchments developed by LWH in previous years. Soil survey and characterization was carried out three sites namely Karongi 12 &13, Muyanza and Rwamagana 34. Soil sampling was conducted taking into consideration the three main parts of the developed catchment**,** namely Water catchment (WC), Command area (CA), and Command Area Catchment (CAC). The total number of soil samples taken in the three sites are included in the Table 1 below.

Table 95. Number of samples collected in Karongi 12 & 13, Muyanza and Rwamagana sites

Site	Taken Samples	Bulk Densities
Karongi 12 and 13	55	55
Muyanza	59	59
Rwamagana-34	58	58
Total	**172**	**172**

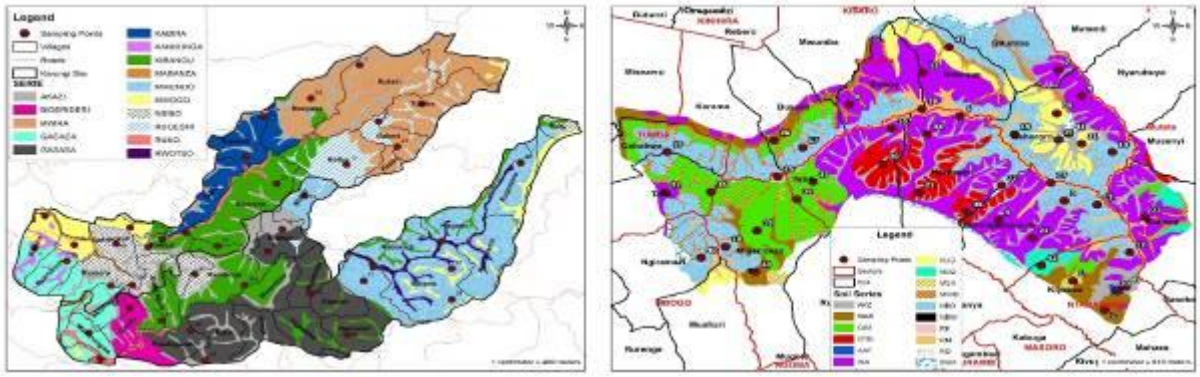

Figure 6: Soil series and sampling points in Karongi 12 &13 (left) and Muyanza catchments (right)

Soil samples were collected in the dominant soil series using GIS tools and soil sampling materials including among others, GPS and soil augers. Below are maps showing the sampling areas (soil units and sampling points distribution within the soil units for the three sites. Collected samples have been taken to the soil laboratory of NAEB for analysis. Results from the laboratory analysis will serve to elaborate a descriptive report of this soil survey assessment.

3.4.6 Establishment of Public Private Partnership program for results (PforR)

This activity has been conducted in the framework of implementation of public private partnership (PPP) program on Irrigation schemes and Radical terraces through Disbursements Linked Indicators (DLI). The program for results has set a number of indicators that are based on to assess effective implementation the PPP for irrigation and radical terraces establishment. These include, existence of legalized owner of the interventions (e.g cooperative with certificate), agreement/MoU between the owner (cooperative) and district/sector, contracts with buyers, and action plan. The two respective indicators are formulated as follow :

- Number of hectares identified, developed and put under recognized PPP are 1,680 ha for DLI5
- Number of hectares identified, developed and put under recognized PPP are 2,453 for DLI6

Mpanga irrigation project

The Project envisaged construction of water intake system on the left bank of Akagera River in Mpanga Sector in Rwanda for irrigating 1194 Ha as Geographical Project Area, 824 Ha as Gross Area and 659 Ha as Cultivable Command Area (CCA) and two pockets of marshland having a total GCA of 269 Ha and 218 Ha as CCA. The project is multipurpose in nature, namely Irrigation, Integrated Watershed Management, Capacity Building and Value Addition, hence only a part of the cost of the project can be attributed to the agriculture sector for water charges. In agricultural sector, even though total benefits may be uneconomical in terms of domestic currency, overall project may result in earning of foreign currency through export of the produce.

Kavunja Irrigation scheme

The goal of the study for the hydro-agricultural development Kavunja for 76 ha, which is located in Southern province, between districts Kamonyi and Bugesera along Jenda-Mugina-Mbati cells in Mugina sector in Kamonyi district, is to assess the works and cost required for the construction of the key hydraulic infrastructures and various supporting arrangements needed to boost property agriculture production on site. All the documents on the PPP checklist were submitted with a period of five years to break the even as indicated in the appraisal financial excel documents shared in the files.

Kibuza Irrigation scheme

The main objective of this study was to assess the realistic alternative to cater water for irrigation of Kibuza marshland mainly in dry season/Season A where there is a shortage of water for growing vegetable on this site. It is in that context Rwanda Reserve Forces carried out a hydro-agricultural study under RWARRI in partnership with KAMONYI District and the support of National Climate Change and Environment Fund (FONERWA) to develop a dam solution to retain water in rainy season and use it further in dry season for growing vegetable on this site (Kibuza marshland). Kibuza irrigation scheme covered 75 ha with full PPP, where all documents were provided with an appraisal financial study well detailed in the provided feasibility study (session: 5.3.2. Socio-economic data and analysis-5.3.3.5. Cost of the development works, equipment and expropriations).

Cyimimpa irrigation scheme

JICA conducted the “Preparatory Survey on the Project for Rehabilitation of Irrigation Facilities in Rwamagana District” aiming at (1) rehabilitating and upgrading the existing irrigation facilities (4 dams/reservoirs, irrigation and drainage channels and appurtenant structures) so that farmer’s organizations can manage, operate and maintain; (2) formulating basic plan of the Project and propose the contents of cooperation on the premise of Japan’s Grant Aid, and (3) confirming the appropriateness, validity and effectiveness of the Project. The project has 400 ha of irrigation scheme with full PPP and the entire document were provided but without handover report, and the appraisal document was detailed in the excel appraisal financial modelling document with five years of return.

Urwonja irrigation scheme

The URWONJYA marshland is located between Cyahinda and Nyagisozi sectors, Nyaruguru District of the Southern Province of Rwanda and extends within the borders of Rutobwe and Cyahinda cells on the left. The marshland is positioned North-South direction and extends downstream to discharge into Akanyaru River in the same Nyaruguru District. The SOCOSE Ltd has signed a contract with MINAGRI/RAB to carry out a Feasibility study for hydro-agricultural development for Nzavu and Urwonjya marshlands located respectively in Nyamagabe and Nyaruguru Districts of the Southern Province of Rwanda. The project comes in the Quick Win Program II of

MINAGRI. In the side of Urwanja, the marshland covers 120 hectares under UBUZUZANYA URWANJA Cooperative with full PPP, and all the documents were provided. The present study used some of the most common and classical cost-benefit methods for assessment of the profitability using the Net Present Value (NPV) and the Internal Rate of Return (IRR), and results gave 26,3 % of IRR higher than the Opportunity Cost of Capital assumed at 12% and the positive NPV of 221,530,915 Rwf.

NB: During year 2, DLI 5 was approved with an excess of 480 hectares of irrigation scheme, and the balance was added in year 3 to complete the target of 1680 hectares.

The expected supporting documents for DLI5 &6:

Capacity building of farmer's organization: Farmers need to be organized into cooperatives for newly irrigated and terraced areas and provide certificate.

Prepare and avail the agreements between farmers' organization (cooperatives) and public institution (s).

Develop and avail a MOU between potential buyers (markets) and farmers' organization.

Cooperative action plan

Water Users Association (WUAs) contract agreement between cooperative and public institution (only for the irrigation schemes)

Provide an acceptable feasibility study with the Appraisal Document (Financial and technical) for identified irrigation and terraced sites.

Radical Terraces

A target of 2,453ha of radical terraces was expected to be established and fulfilling the above requirements. This report presents results from eleven (11) districts (Gicumbi, Rulindo, Gakenke, Rubavu, Muhanga, Ngororero, Karongi, Rutsiro, Nyabihu, Nyamasheke, Nyamagabe) whose total achievement was 2,815.49ha. The detailed achievement per district are summarized in the table 2.

Table 96. Established radical terraces in different districts and sector under PPP framework

Name of District	Name of Sector	Name of the site	Donor project	Reported area (ha)	Potential crops	Name of Cooperative
Burera	Bungwe	Mbuga	LODA-MINALOC	50	Wheat, Irish poato, Beans	TWITEZIMBERE MBUGA
	Kivuye	Burango	LODA-MINALOC	50	Wheat, Irish poato	KUNDUMURIMO KIVUYE
GICUMBI	Rushaki	Muyumbu	GCF-FONERWA	50	Beans,Potato	Abatubuzi b'Imbuyo ba Muyumbu
	Kaniga	Kanyaru and Katoma	GCF-FONERWA	50	Beans,Potato	TUZAMURE UMUSARURO
	Rubaya	Rugereka	GCF-FONERWA	50	Beans,Potato	HINGA WEZE NEZA
	Cyumba	Cyumba	GCF-FONERWA	90	Beans,Potato	ICYEREKEZO CYÍTERAMBERE
	Mukarange	Mukarange A	GCF-FONERWA	120	Irish potato, beans	KOJYAMU
	Manyagiro	Kigarama	GCF-FONERWA	40	beans, potato, wheat and maize	ABISHYIZEHAMWE
Rulindo	BASE	GITWA	LODA/District	50	Maize, beans and wheat	ABARWA

	BUSHOKI	KARAMBO	LODA/District	51,13	maize and potato	KOAHIRU
	Tumba	Nyirabirori	LODA/District	105,6	maize and beans	ZAMUKA NYIRABIRORI/CYOHOHA RUKERI
Gakenke	Rushashi	Rushashi	LODA-MINAGRI	95	maize and beans	INDINGANIRE
	Muyongwe	Muyongwe	LODA-MINAGRI	167.1	maize and beans	COPPROTEM
	Gakenke	Kagoma	LODA-MINAGRI	12	maize and beans	TUZAMURANE
Rubavu	Nyundo	Mukondo	RWB	41,31	Maize, beans	KOTUIIBI
	Kanama	Kamuhoza	RWB	293,00	Potato	KOZAMUIKA
Muhanga	Rongi	Ruterana	FONERWA	60	Maize, beans	KOTUBU
		Ruhango	FONERWA	29	Maize, beans	COIABIND
	Kibangu	Kinagi, Musekera Nyarangari, Mushubaguri ka, Mwumba, Nyarubuye Muhororo	FONERWA	34,00	Beans and Maize	KOTWUMUSAKI
	Nyabinoni	Murama	FONERWA	15,00	Beans and Maize	IMPARURWAKURUSHA
	Nyarusange	Nyanza	FONERWA	50,00	Beans	Twongere Umusaruro Ndaru
Ngororero	Kavumu	Mwiyanike	HINGAWEZE	50,00	Irish potato, wheat and bean	GIRUBUKIREMUHINZI WA KAVUMU
		Tetero	VUP	40,00	Irish potato, wheat and bean	KOSUMUKA
		Rugeshi	VUP	62,00	Irish potato, wheat and bean	KOKUMUKA
	Muhanda	Gatomvu and Rurambo	VUP	79,00	Irish potato and bean	CEPF/SEBEYA
		Kagano, Maryoha and Burorero	HINGA WEZE	40,00	Irish potato and bean	TERIMBERE MUHINZI MUHANDA
Karongi	Murundi	Gitwa, Gisenge and Gasharu	RAB	82,00	Maize	ABATANYURANYA
	Rugabano	Rufungo	HINGAWEZE	40,00	Maize	Duterimbere Rufungo
	Mutuntu	Kanyage	HINGAWEZE	23,00	Potato	Urunana Mutuntu
Rutsiro	Murunda	Kirwa	RWB	139,96	Potato	KOAIMURU
	Ruhango	Gihira	RWB	114,57	Potato	KOAIMURU

	Nyabirasi	Busuku, Mubuga, Ngoma	RWB	78,81	potato, maize and beans	KOABUNYA
	Manihira	Rufungo	HINGAWEZE	30,00	Potato	Turwanyisuri B
Nyabihu	Rurembo	Gahoko	HINGAWEZE	30,00	Maize	Abishyizehamwe
	Kintobo	Kintobo	HINGAWEZE	50,00	maize	KOABIB
Nyamasheke	Gihombo	Kadobogo	HINGAWEZE	8,00	Maize	Abahujumurimo-Kadobogo
	Karengera	Bori	HINGAWEZE	50,00	Maize	COPERATIVE ABAHIGWA KARENGERA
	Rangiro	Kibavu and Munini	VUP	170,00	Maize and beans	KOPERATIVE TERIMBERE MUHINZI RANGIRO
	Karengera	Gihaya, Gitunda, Mugerero, Nyiracyagara, Kabuye and Mbanda	VUP	155,00	Maize and beans	KOPERATIVE URUGERO RW'UMUHINZI
Nyamagabe	Tare	Buhoro	HINGAWEZE	20,00	Potato	Abasonzeye Iterambere
	Buruhukiro	Rambya, Mpanga, Rusere and Nkamba	HINGAWEZE	50,00	Potato	Imbereheza Cooperative
Total				**2815,49**		

3.4.7 Effect of balanced fertilizers for crop yield

This activity was conducted in collaboration with the International Fertilizer Development Center (IFDC). The present report summarizes results from demonstrations, basal trials and top-dress trials, established on rice, maize, wheat, potato, common bean and soybean in Rwanda.

The objectives of these demonstrations and trials were to:

- Identify formulations that offer substantial yield improvements over DAP and 17-17-17, the most used fertilizers in Rwanda, when applied at the same recommended rates;
- Use a minimal number of ingredient sources to facilitate blending procurement;
- Reduce the costs of fertilizer production by testing some formulations with reduced micronutrients;
- Provide data for product registration;
- Target some formulations regionally where data indicates;
- Understand at what rates nitrogen (N) becomes limiting.

The distribution of these trials across different locations is shown by the map below.

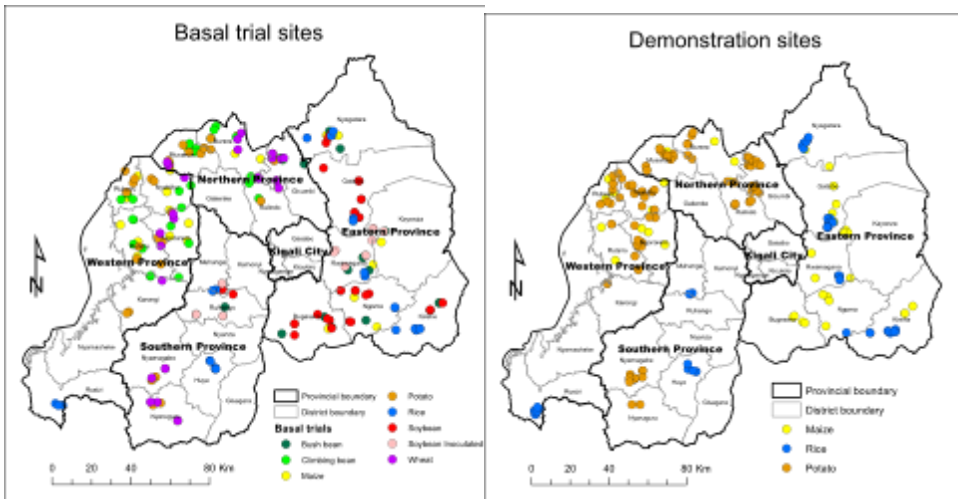

Figure 7: Distribution of these trials across different locations

In both demonstrations and trials, 3 formulations were tested ;

(1) 18-18-18 +3.4S +0.33Zn +0.1B +0.1Cu
(2) 11-23-21 +4.5S +1Zn +0.3B +0.1Cu (demos)
(3) 11-23-21 +4.5S +0.33Zn +0.1B +0.1Cu (trials)

Formulae 1 and 2 above were used in the demonstrations, while formulas 1 and 3 were used in the trials. The lower Zn and B levels used in the trials did not affect yields relative to formulation 2, which demonstrates that the formulation is as effective with the lower Zn and B concentrations, hence this result in cost savings vs. the formulation (2).

Demonstrations and trials were executed in Northern, Western and Southern provinces. An examination of individual site data showed in the Northern region, the formula 2 and 3 performed slightly better, while on average the formula 1 performed better in the Western and Southern regions. Therefore, both 18-18-18 +3.4S +0.33 Zn +0.1B +0.1Cu and 11-23-21 +4.5S +0.33Zn +0.1B +0.1Cu can be advised.

In the Eastern province, demonstration trials showed that 15-25-15 +4.7S +1Zn +0.3B +0.1Cu (demonstrations) outperformed all other formulations in demonstrations, increasing rice yields by an average of 1.8 mt/ha. The similar reduced micronutrient formulation 15-25-15 +4.7S +0.5Zn +0.2B +0.15Cu outperformed 17-17-17 by 2.4 t/ha. Reducing the Zn and B therefore had no negative effect on yields.

In the Southern province, a formulation in the trials but not in the demonstrations, 11-22-21 +4.5S +0.5Zn +0.2B +0.15Cu was the best formulation, outperforming 17-17-17 by 1.2 t/ha.

In Western province demonstrations showed no significant differences between treatments, though the two blends, on average outperformed 17-17-17 by some 0.5 t/ha of rice yields.

For maize, the formulation 18-36-0 +7S +1Zn +0.3B +0.25Cu out-yielded DAP by 2.0 t/ha in demonstrations, while the reduced micronutrient formulation 18-36-0 +7S +0.5Zn +0.25B +0.25Cu out-yielded DAP by 2.4 t/ha in trials in Eastern Province. In the Western province, this formula was superior to all formulations in demonstrations while the Northern Province, all 4 blends were statistically equivalent but 3 were superior to DAP. A 2 t/ha yield advantage or greater was maintained over DAP in Eastern and Western provinces. For wheat, the formula 18-36-0 +7S +0.5Zn +0.25B +0.25Cu in the Northern Western while 14-25-15 +5S +0.5Zn +0.25B +0.25Cu and 11-22-21 +4S +0.5Zn +0.25B +0.25Cu were best performing and statistically equivalent. For legumes, there were no clear differences between inoculated and uninoculated soybean yields. The formulation with high K did significantly better, increased soybean yields over DAP by 1.3 t/ha. There were no clear differences in bush bean grown in the Eastern and Southern provinces. The no-K formulation did significantly better in the high-K Northern region, and out-yielded DAP by 1.6 t/ha for climbing bean.

3.4.8 Fertilizer products efficacy trials

Different efficacy trials of new fertilizers fertilizer supplements products were conducted through agreements signed between RAB and private companies with the aim of evaluating the performance of these products for registration and recommendation for public use. One of them is the trials of D.I Grow liquid fertilizer products which was tested as supplement to common fertilizer on rice in Mukunguli, Rugende and Cyunuzi marshlands. Trials were harvested, data are being gathered for recording, analysis and reporting.

3.4.9 Capacity building

A series of training were conducted in the program through its projects. In RwaSIS project, a training of surveyors composed of 10 teams of two persons (20 persons) and their supervisors have been selected and trained for conducting soil sampling campaign at national scale. The training was focused on the following aspects: (1) Brief introduction about geo-surveying that generated the coverage of cropland and distribution of sampling locations spread at country wide; General knowledge on spatial distribution of soils in Rwanda and their classification, (2) Understanding the use of spatial tools (projection) for developing digital soil mapping and field navigation with GPS and Tablets, (3) Hands-on on using GPS units and Tablets for field navigation in the process of locating sampling points and data collection using online based ODK form, and (4) Techniques of soil sampling procedures. The ICRAF team provided remote technical support to the program on equipment needs and detailed equipment specifications for building the RwaSIS soil-plant spectroscopy laboratory. ISRIC provided also a training to program staff and other RAB and partner institutions staff on soil data compilation and standardization. This training event was held online using Zoom and MS Teams from 10 to 15 September (four full days) and was attended by more than 25 participants from RAB and affiliated institutions. CABI and the program through RwaSIS project teams conducted a national data landscape assessment around soil data to determine and understand cultural, institutional, and technical barriers as well as opportunities to data access, management, and sharing. Currently, final version of the data landscape management assessed in Rwanda is available to support further steps of developing data access policy.

3.5 Mechanization

The mechanization activities started during the FY2020/2021 executed by irrigation and mechanization task force with the responsibilities; to promote use of farm machinery in different farming operations for rural farmers,

develop local skills and strengthen capacity in agricultural mechanization. The agricultural mechanization strategic document, 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**.** In 2013, private sector involvement in mechanization service provision started, where by now; **27** service providers (17farm machinery hire, therefore there are 3 news which are Pride farm, VIRUNGA, and YALLA YALLA started mechanization services provision during this fiscal year 2020/2021 and 10 sales/Local manufactures and dealers). Therefore, over 45,000 ha of farmland have been tilled, 13000 ha for seeding, 9,500ha of crop treatment and 6,500 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 has up to 25 **%** of mechanized farm operations and will be at **50% by 2024 (PSTA4)**.

Detailed Agricultural Mechanization Achievement for FY 2020-2021

The main achievement of agricultural mechanization were expansion land tilled with farm machinery, planting, crop treatment, demonstration and training, engagement of youth in agricultural mechanization service through training of youth on agricultural mechanization technologies.

Table 97. Table of agricultural mechanization achievement for FY 2020-2021

Output	**Target (ha)**	**Achievement (ha)**	**Comment**
Access to mechanization services and area mechanized Increased	6500ha	• **7,894ha** for land preparation • **Over 5,00 tons** baling of hay • **Over 2,000 ha** have been planted • **Over 7,000 tones** have been drying • **Over 500ha** have been covered for pest control by spraying pesticide with farm machinery	The new over-achievement of target due to awareness for which farmers start to acquire on farm machinery
Farmers awareness to farm mechanization through intensive mobilization in collaboration with service providers Increased	10	11	Through post-harvest Handling program, different farm machinery demonstrations have been conducted
New private sector invest in mechanization Increased	N.A	3	There is awareness on mechanization therefore some farmers started to invest in mechanization service provision (Pride farm, VIRUNGA and YALLA YALLA)

3.6 Export Targeted Irrigation Project

The Export Targeted Modern Irrigated Agricultural (ETI) Project is financed by EXIM Bank of India through a Line of Credit of **USD 120.05 Million**, aiming to develop 7,000Ha in Mpanga and Mahama sectors of Kirehe district by supplying and installation of modern irrigation facilities for year-round farming. Besides, the Project aims to establish a research-based center for farm mechanization, build capacity for irrigation and watershed management. For irrigation development, the project has established irrigation facility on a total of 5,000 ha and will establish the remaining rea of 2,000ha. Mechanization Center of Excellence is under contruction planned to be completed by March 2022. Trainings in India are planned after completion of the construction work.

Challenges faced during implementation of the contract for irrigation & watershed development in Mpanga :

The Contract is being implemented by OM Metals SPML Joint Venture with a budget of 16,584,644.77 USD to develop irrigation on 659 Ha net and watershed on upper hillsides. At the beginning of the Contract, the Project faced the constraint of design that required important changes as a part of the command area which was not feasible was replaced by the other feasible part.

Photo 165. Erection of the center pivot and pipes offloading at Mpanga

In addition to the design, the Project has also faced with the issue of procurement of irrigation materials/equipment that has to come from India since 75% of the goods and services have to come from India. Other factor that amplified the delay in shipment are related to COVID 19 where lockdown were imposed in India which hindered the process of inspection and shipping of equipment/materials. Currently, all issues related to design are cleared and the Contractor has procured almost all of the equipment/material necessary for the completion of remaining works. Meanwhile, sites establishment and watershed development works are complete. The headwork's (pump houses, intakes, sedimentation tank, and reservoir) are also near completion.

Contract for Center of Excellence in farm mechanization: After suspension of works by the EPC Contractor for a period of 1 year and half, the contract amendment was signed on 12 December 2020 and works were resumed on 10th March 2021.

Photo 166. View of the Center of Excellencefor Mechanization under construction

The progress achieved is 36% for engineering and construction, and 27% for procurement of Electro-mechanical equipment (Submission, review, approval inspection, shipment, reception and installation & Commissioning). *The cumulative progress (civil works and procurement of electromechanical equipment) is at 63.61%.*

Works for Irrigation (1220/1752Ha) & Watershed Development in Mahama Lot 1 and irrigation development (1956/2669 ha) in Mahama lot 2 : The retendering process is at the level of Contract signature. The achived activities associated with procurement are as follows: Preselection of company in India ; Restricted publishing of the preselected compies in Rwanda procurement portal ; Evaluation of bids ; Awards of tenders for both Mahama 1 and Mahama 2. The process of tendering is now at the level of Contract signing.

Photo 167. Pipes laying at Mahama 2

Solar Power system : To develop solar power system, consultation meeting between RAB and REG on 02nd September 2020 regarding the revised DPR which was submitted on 25th April, 2020, seeking for advice at policy level to allow the grid connected solar power plant. Virtual consultation meeting between RAB and REG on 05th February 202, discussing on the two options: grid evacuation and stan-alone, which recommended to assess the behaviour of existing grid network to accommodate the 12 MW to be generated by Solar Power Plant. Virtual consultation meeting between Consultant, RAB and REG on 12th March 2021, where REG declared not ready to accommodate the electricity to be generated by the Solar Power Plant and proposed to use batteries for stand-

alone plant. Though the letter No:01.11/471/PK/HQ dated March 30, 2021, the consultant/ WAPCOS Ltd was requested to submit a concept of stand-alone Plant based on which the DPR will be developed. On 5th May 2021, the Consultant/WAPCOS Ltd submitted the concept with three (3) options including the Plant without storage, Plant with storage of Batteries system and Plant with substation, for review and approval. The findings from analysis of the concept were shared on June 10, 2021 to REG for the feedback which recommended to resign from establishing the solar power plant and use the available electricity at the sites from grid and reduction of current tariff can be discussed but not at industrial rate.

Capacity building : Through RAB Capacity building committee, five (5) RAB staff were selected to attend master's program for Irrigation and Mechanization to Indian Universities. After missing the intake 2020-2021 because of Covid 19 pandemic, Indian Institute of Technology (IIT) Roorkee is processing the admission of 2 students for irrigation and Haryana Agriculture University (HAU) is processing the admission of 3 students for Mechanization, for intake 2021-2022. Besides, short-time trainings were held up and will be resumed by selection of candidates after COVID 19 normalization to allow the attendance of trainings in India.

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