



RWANDA AGRICULTURE BOARD

**Annual Report
2016-2017**



August 2017

FOREWORD

Since its establishment in 2011, the Rwanda Agriculture Board (RAB) has a mandate to enhance agricultural productivity and ensuring food security in the country through developing innovations in crop and animal resources research and extension, natural resource management, promotion of irrigation, mechanization and modern inputs use.

Agriculture is the backbone to the Rwanda economic growth as it provides 33% of the country's GDP and employs 80% of the population. However, this sector is facing the challenges of increasingly changing climate; focus on short term solutions seeking to address the urgent and immediate emerging problems; important soil fertility loss and nutrient leaching exacerbated with rapid urban growth and nutrient removal off farms; poor knowledge transfer system; poorly developed capacity for developing high tech research solutions; little involvement of private sector in research and extension; limited variety range and imperfect seed system and limited financial investments in the most sustainable or long-term solutions.

This summary of annual achievements provides an opportunity to reflect on RAB's contribution in ensuring food security through transformation of agriculture from subsistence to modern agriculture. The achievements presented in this report reflect many efforts invested by different people who deserve recognition.

George Nyombaire, PhD
Chairperson of the RAB Board of Directors

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EXECUTIVE SUMMARY

In the fiscal year 2016-2017, RAB accomplished various achievements in crop research, natural resources management research, animal resources research, animal resources and crop production as well as land husbandry, irrigation and mechanization. The major achievements in these areas are as follows:

CEREALS:

Maize research developed 19 inbred lines from local Open Pollinated Varieties and hybrid lines from these varieties. These lines are being used to generate new hybrid maize varieties; further inbred line crossing of 23 highland lines; Study of combining abilities of 18 inbred lines for mid altitudes; Evaluation of Three Cross Hybrid (TWCH) varieties for mid altitudes in multi-location trials; Evaluation of Rwandan germplasm for MLN resistance/tolerance under artificial and natural inoculations and selection of two MLN mild resistant and three MLN tolerant hybrid varieties; Official release of eight hybrid varieties; and Production of breeder and pre-basic seeds for RAB hybrid varieties; and Backstopping of seven local seed companies for hybrid seed production.

Rice research focused on development of female parents for breeding of local rice varieties; adaptability trials of high yielding introduced rice varieties, rice blast disease pathogen identification, basic seed production, and Farmer Field Schools research in rice marshlands for technology adoption and scaling out. Five lines, RCE004, RCE005, RCE 006, RCE 007, and RCE 008 were selected from F3 population crosses with long grain and good cooking preferences. Study of rice blast disease caused by *Magnaporthe oryzae* showed increased pressure of the pathogen in Rugeramigozi and Cyabayaga marshlands and large diversity of the pathogen. Basic seeds were produced in Rwamagana (2903kg), Rubona (2505kg) and Bugarama (1374kg) marshlands. Farmer Field Schools were organized in Bugarama I-IV, Rwinkwavu, Gacaca; MP8 rice schemes to accelerate the adoption of modern rice variety and management packages.

Wheat research continued development of wheat varieties adapted to Rwandan agro-ecological zones through on-station and on-farm trials as well as seed production. On-station evaluation of wheat lines, Wheat variety development, Quality seed production, On-farm evaluation of promising varieties and lines for adaptability testing, Field day and Surveys were also carried out. Wheat trials included Screening nurseries, which evaluated 272 lines from 50th IBWSN (International Bread Wheat Screening Nursery) and 165 lines from 11th STEMRRSN (Stem Rust Resistance Screening Nursery) for the first time in 2017B in Rwerere and Kinigi; Preliminary and advanced yield trials evaluated 590 lines from local and international trials, and 209 lines were selected. On-farm participatory variety evaluation selected Gihundo, Majyambere and Keza varieties yielding up to 4.99 t/ha in farmers'fields. A total of 12,811 kg of basic seed were produced for 10 released varieties (Nyaruka, Cyumba, Keza, Mizero, Rengerabana, Nyangufi,

Kibatsi, Gihundo, Reberaho, and Majyambere) in Rwerere (10,743 kg), Kinigi (450 kg) and Masogwe (1,618 kg). Pre-basic seed totaling to 319 kg was produced from Kibatsi and Nyangufi in Kinigi. A total of 730 kg of breeder seed were produced in Kinigi (50 kg) and Rwerere (680 kg) for these varieties.

PULSES:

Bean research evaluated more than 500 lines for stability to high yield, altitude adaptability, cold resistance, high seed Fe/Zn content, good color and multiple disease resistance. A total of 1,582 MT of seed was produced and disseminated.

Soybean research focused on participatory evaluation of early maturing (87-95 days) and high yielding (up to 3t/ha) locally bred varieties S0102 and S0103. Soybean breeding produced 354 crosses. A total of 1107 lines were evaluated for adaptability and a total of 100 lines were selected. Seeds were produced for pre-basic: 500kg of Peca 6 and SB24, and basic seed: 6000kg of Peca 6 and 1000kg of SB24.

ROOTS AND TUBERS:

Cassava research selected 11 improved clones for CMD and CBD tolerance from a Preliminary yield trial. New promising clones earlier introduced from IITA are now under field evaluation: MM06/0090-OP/12, MM06/0128-OP/1, MM06/0128-OP/4, MM06/0128-OP/3, MM06/0128-OP/10, Bulk/35, Bulk/16, NASE14 (Check), MH05/0091-OP/11, Bulk/13, MH05/0091-OP/12 and NAROCASS1. Pre-basic seed of 01/1206/75, 05/0127/35, TME 419/60 and 01/1412/63 improved clones were multiplied at Rubona and Rubungo centers. Basic seed of NASE 14 and NAROCASS1 improved clones were produced on 22 ha in Rubona and Karama.

Irish Potato research focused on germplasm maintenance, clean seed production through tissue culture, minituber production through conventional and aeroponic methods and variety development. Seventy potato varieties and clones were maintained *in vitro* in the tissue culture laboratory and in open field. New method for minituber production by direct transfer of *in vitro* potato plantlets to open field was developed. Seeds were produced *in vitro* (1,283,770 plantlets), in conventional screenhouses (1,054,000 minitubers), through direct transfer from laboratory to field (8,002,166 minitubers), and aeroponics (653,891 minitubers). Potato variety development selected CIP393077.159, CIP393251.64, CIP396081.241, CIP392617.54, CIP395112.6, CIP399075.22 and CIP393371.58 clones in Musanze, Burera, Nyabihu and Rubavu. A total of 14 potato clones were bred locally and are being evaluated: RWPOT012.8, RWPOT012.10, RWPOT012.3, RWPOT012.22, RWPOT012.7, RWPOT012.46, RWPOT012.14, RWPOT012.24, RWPOT012.43, RWPOT012.34, RWPOT012.28, RWPOT012.2, RWPOT012.26 and RWPOT012.16.

A total of 98 Fe- and Zinc-biofortified potato clones were introduced from CIP and are being evaluated in Kinigi, Rwerere and Sigira. Variety development through crossing has been initiated to improve local varieties.

Sweet Potato research paid more attention to development of new sweet potato varieties. Using a crossing block in diallel mating design of sixteen parents, 1,758 controlled true seed and 2691 of non-controlled seeds were generated. Clonal evaluation, preliminary trial and advanced yield trials were conducted. Sixty-eight demonstration plots of 5 promising sweet potato varieties (Terimbere, Kakamega7, Kabode, Vita, Gihingumukungu) and Local check were established in collaboration with Imbaraga, Dern and Unicopagi organization. Kabode variety was the high yielding variety across districts, followed by Kakamega-7. The preferred high yielding orange fleshed sweet potato (OFSP) varieties, which are Naspot 9, Naspot 10, Cacearpedo, Gihingamukungu, Terimbere (RW11-2560) and Ndamirabana (RW11-2910) including some white fleshed varieties were maintained, produced and availed to Decentralized Vines Multipliers (DVMs) for further multiplication and distribution.

BANANA research focused on germplasm conservation, new cooking varieties evaluation, and study of intercropping practices (bean and banana). A total of 117 banana varieties were conserved in field genebanks in Rubona and Ngoma. Scaling out of banana management activities concentrated on rehabilitation of the existing banana fields and management of banana wilt disease. Banana wilt control campaigns were organized in Eastern Province and involved 13,625 people. A total of 20,786 ha were rehabilitated.

HORTICULTURE research targeted citrus disease management, water melon variety development, hot pepper pest management, Stevia research on adaptability, and participatory research on vegetable production through FFS. Use of Benlate alternating with copper dioxide was evaluated and recommended as cost-effective and efficient to reduce incidence and severity of *Pseudocercospora* leaf and fruit spot disease on Citrus spp. Water melon varieties Julie F1 hybrid, Sukari F1 and Sugar baby were evaluated and seasonal rate of 90:60:60 of N: P: K kg/ha; spacing of 2 x 1.5m; and pruning to 4 main vines with two fruits per vine were recommended for best performance. For aphid pest management on hot pepper, use of sunflower border intercrop over sorghum and maize were evaluated and recommended to keep the pest population at minimum level. Study of Stevia diseases identified water mould disease (Downy mildew), fungal disease, and soil insects like termites and cutworms. Mancozeb combined with cypermetrin proved to be efficient for management of this pests and disease complex. For agronomic practices, use of 20 x 20cm spacing and organic manure were evaluated and recommended to achieve 2.7 ; 2.4 and 2 t/ha in Musanze, Rubona and Karama, respectively.

INDUSTRIAL CROPS: For **Tea**, 17 clones were evaluated for yield and quality traits. The use of organic fertilizer and its effect on productivity and value were also assessed. In **Coffee** research, new variety, Batian, resistant to coffee leaf rust and CBD and combining high yield, good adaptation and excellent cup quality was developed. An IPM package was developed for Antestia bug management, and recommendations for banana-coffee intercropping were developed. A total of 2.5 tonnes of clean seeds (covering 3000ha plantation) from 3 commercial varieties (BM 139, Jackson and RABC 15) were distributed to coffee farmers through NAEB. The amount of seed distributed can cover 3,000 ha of land. A total of 450 field technicians and farmers were trained on best coffee cultural practices.

CROSSCUTTING RESEARCH:

Genebank focused on conservation of plant, animal and forestry genetic resources. A total of 105 plant accessions were collected and conserved, 209 were morphologically characterized; 46 local animal genetic resources including indigenous cows - Inyambo and Inkungu - were morphologically characterized. For forestry genetic resources, a total of 22 tree species were collected and conserved.

Biotechnology research at RAB targets activities geared towards utilizing modern technologies to improve agricultural productivity hence increasing food security. Emphasis is put on tissue culture and development of modern disease diagnostic tools. For tissue culture, 20,399 banana plantlets and 29,073 sweet potato plantlets were produced as nucleus seed stock for use by the respective commodity programs for mass production. Furthermore, in vitro regeneration protocols for cassava and coffee hybrids were optimized, with a weaning success of up to 85%. Plant diseases diagnostics indicated that there are more potyviruses involved in MLN disease development than originally known, and the disease can be transmitted through seed.

NATURAL RESOURCES MANAGEMENT

Soil fertility research targeted improving soil fertility and climate change indicators of nutrient loss through erosion, soil acidity and low organic matter. Crop yield improvement studies were performed by promoting integrated soil fertility management interventions. Fertilizer evaluation led to best bet combinations and rates of N, P & K for rice, wheat, beans and maize in different agroecologies. Agricultural Production Systems simulator (APSIM) was used to assess the effect of climate change on maize yield across a range of soil types and seasons.

Forestry and agroforestry: In forestry and agroforestry, different activities were implemented and included the evaluation of existing experiments pertaining to diversification and selection of indigenous tree species having an agroforestry potential, bamboo species site matching,

development of forest management tools including volume and yields tables, demonstration of the use of lime and fertiliser trees for increased yields of crops on bench terraces and conservation agriculture practices. Specifically, nine crop (maize, bean)-indigenous tree species systems in Ruhande and Rubona were evaluated for the yields of crops and trees. Tree management by pruning and thinning was carried out in order to reduce tree competition on crops. Further, the demonstration of the effect of use of lime on different crop yields (wheat, Irish potato, bush bean) on bench terraces at various sites in Nyaruguru, Nyamagabe, Huye and Nyanza was made along with the establishment of agroforestry fertiliser trees of risers of bench terraces. These trees will provide green manure that will be used as organic input in combination with lime in order to increase crop productivity on unproductive bench terraces. Trials on sustainable maize-legume (bean) based conservation Agriculture (CA) practices were also initiated, monitored and evaluated in Kamonyi and Musanze. The adaptability of five Bamboo species was compared on the sites of Nyaruguru and Kicukiro on the basis of their growth and number of shoots per bamboo stool. Early assessment of the adaptability of a range of tree species was made by determining their survival rate and growth performance.

ANIMAL RESEARCH: was done on Large and Small Stocks; Aquaculture and Fisheries, and Commercial insects (bees and sericulture).

Cattle improvement focused on evaluation of artificial insemination with 68% the success rate in RAB stations; the calving interval is high (13 -18 months) in indigenous cattle, 14 months for crosses. The calving rate is 70% for indigenous, 65% crosses. Study of factors affecting milk yield showed the effect of season and time of milking. It declined in dry season and was related to fresh feed availability. The decline period is between May and August, while increase was observed after September, after rains have established and grasses grew. Embryo transfer research targeted staff training on transfer and flushing, as well as selection of appropriate cow donors.

Goats research includes maintenance of Boer and Galla races and their crossbreeds with local goats. A total of 453 goats were maintained and evaluated at Karama Center. Adaptability studies on Boer, Galla goats and their crosses led to a recommendation on use of crossbreeds for improved production of meat and lower level of disease susceptibility.

Animal nutrition research identified 7 improved forage grasses as alternative feed resources. Animal feed formula developed and disseminated: 288 tons of rice straw were collected, treated and fed to 400 cows in communal sheds of Mpanga, Nasho, Kitazigurwa, Mukarange and Rweru sectors. As a test for Livestock feeding strategies a formula from maize-stovers- and rice-straw-based rations was developed. Study of Brachiaria identified clones with best nutritive traits. Improved Brachiaria grasses have been established by 354 farmers in Rwamagana, Bugesera and

Nyamagabe districts. Selected *Brachiaria* genotypes were Piatá, MG-4, Xaraes and Marandú. Two hundred and eleven (211) new farmers from Nyamagabe, Bugesera and Rwamagana districts were provided with seeds from these genotypes, and they established them in their farms. Four livestock farmer field schools (LFFS) were established across the country.

Poultry research focused on Kuroiler chickens being evaluated for adaptability to Rwandan intensive management conditions. They showed good potential for intensive production and improved growth rates as compared to local chicken, and better meat characteristics as compared to broiler chicken. Egg weight of Kuroiler was measured, and is greater than for local chicken: 65.7g for pure Kuroiler, 55g for crossbreed (75% Kuroiler) and 45.5g for local chicken. Current Kuroiler flock consists of 107 birds, and this number will be increased for further breed production and dissemination.

Aquaculture and fisheries research focused on improving fish hatchery productivity, breeding of *Tilapia nilotica*, assessment of limnological quality of Rwandan lakes, development and dissemination of fish production guidelines for pens and cage farming, trigger production of carp and catfish, development of local fish feed formulations. A total of 483,712 *Tilapia* fingerlings have been produced in hatchery: 161,040 distributed to fish farmers and 322,72 kept in Kigembe Center. Best *Tilapia nilotica* genitors were selected for reproduction, with 6,000 brood stock selected and conditioned for reproduction. From these brood stock, 200,060 eggs were collected, out of which 150,200 eggs hatched and 100,170 fries were obtained. Best *Tilapia* brood stock were selected and mated to obtain F2 generation. Gaharwa and Kirimbi lakes were assessed for water quality and bio-characteristics (Temperature, pH, DO, Transparency, nitrite, nitrate, ammonia, hardness, alkalinity, CO₂, Chloride, phytoplankton). To improve fish feed availability, prospecting on locally available feed were made and new sources for fish feed formulations were identified: maize, rice, wheat, soybean bran and blood meal. They can be used in future fish feed formulations with high crude protein levels and relatively low cost.

COMMERCIAL INSECTS:

Apiary activities focused on selective breeding of honey bee after identifying highly productive bee and clean *Varroa*-free family hive, and 23 queens were obtained and distributed to bee keepers. Honey quality from Southern Rwanda samples was assessed, and the best honey characteristics were identified in honey from Ibisi bya Huye sample. Training on colony splitting for bee keeping cooperatives was conducted, where 100 bee keepers were trained.

Sericulture research included mulberry variety characterization, silkworm breed characterization, germplasm maintenance for mulberry and silkworms, production of silkworm eggs, and development of mulberry varieties and silkworm lines. Ten mulberry varieties from the National Genetic Resources of mulberry were characterized: Rubona-03.11 (H), Polyplod-01/03

(lob), SF" Gift"-11 (K), SF" ISAR"-09 (H), MSF-02 R, ISAR HW-3 (lob), M-600/13, CV-1, CV-2, TPGF-4. Among 21 silkworm breeds characterized, the breed V5(W) had the highest cocoon weight and therefore the best market value. To screen the less consuming and best growers among silkworm breeds, 5 breeds (IS-2, R-50H, NGL-13, H-50, and GH-2) were evaluated for feeding efficiency. Results showed R-50H and NGL-13 breeds were the least feed consuming. A total of 800 boxes of silkworm hybrid eggs were produced and 178 boxes were delivered to National Sericulture Center (NSC). Eighty-five (85) silkworm hybrid egg boxes were distributed to farmers.

CROP PRODUCTION AND EXTENSION: Crop Intensification Program has facilitated farmers to access 2,399 MT of hybrid maize; 237 MT of soybean and 549 MT of wheat seeds; more than 34,000 MT of mineral fertilizers and 24,363 MT of lime. More than 14,200 farmer promoters were trained under Twigiremuhinzi program and season learning trials in 290 sectors of the country.

LAND HUSBANDRY, IRRIGATION AND MECHANIZATION: Establishing terraces for soil protection reached 6,123 and 10,392 Ha for radical and progressive terraces, respectively. Irrigated land reached 2m130 ha and 4,400 Ha of land was cultivated using mechanization. A total of 2,814 people were trained for Water User Organization on appropriate use and management of irrigation water.

Part 1. RESEARCH AND TECHNOLOGY TRANSFER

1.1 Enhance breeding research infrastructure

The tenders to acquire advanced laboratory equipment and laboratory consumables were processed and seven laboratory technicians were recruited to empower RAB laboratories. Through a framework contract the Musanze in vitro laboratory received various equipment including autoclave, laminar flow, Water distiller GLF, pH meter, STERI 350, and water distiller GLF. About 18 air conditioners for Rubona laboratories were acquired. For full functioning of RAB laboratories, seven laboratory technicians were recruited. Currently five and two laboratory technicians were appointed in Rubona and Musanze laboratories, respectively, these technicians are responsible of daily laboratory activities. The first phase for establishment of irrigation facility was implemented at Rubona RAB station. Two water harvesting dams with the capacity of 900 m³ were established, rehabilitation of underground older water tank and strengthening of old pumping system were carried out through this fiscal year, this irrigation system is currently functional but it requires additional work for its extension. Four greenhouses (2 at Rubona, one at Musanze, and one at Gakuta) and aeroponic facility of Musanze were rehabilitated, these facilities will strengthen and increase the capacity of seed production.

1.2 Enhance breeding skills for RAB breeders

RAB breeders have established the crossing blocks for bean, maize, wheat, potato, sweetpotato, cowpea and cassava at Karama, Musanze, Rubona and Nyagatare RAB research centers, to develop new crop varieties. The combined seed harvested will be evaluated in next growing seasons, breeder and pre-basic seeds for bean, maize, wheat, potato, cassava were produced under respective programs and these seeds will serve as starting materials for seed companies and private seed multipliers for mass production. Other research works consisted of establishing field trials to develop new pest and disease management technologies and good agronomy practices were carried out by different RAB scientists in RAB centers, for instance the bioassay to identify recommendable pesticide and dose to control fall armyworm were carried, results from this study are available to control the armyworm in case of a new outbreak of this pest. In addition, a field day to select good agroforestry and cover crops to rehabilitate new radical terraces were carried out in Nyanza District. The importance of this approach to value the abandoned terraces were noticed by farmers and agreed to adopt this approach. New crop varieties are being developed: 5 wheat, 6 hybrid maize, 4 cassava clones, 2 soybeans, and 5 potato and sorghum.

1.3 Crop and Horticulture Research

1.3.1 Cereals

1.3.1.1 Maize

Inbred lines development

In the year 2016-2017, the studies of the combining abilities of 19 inbred lines developed from three released Open Pollinated Varieties for mid altitudes of Rwanda: ZM607 (Kigega), Pool 32 (Ndaruhutse) and ISARM101 using diallel and North Carolina II mating designs were completed (Table 1). Therefore, these inbred lines are ready to be used to generate new hybrid varieties. Furthermore, 22 inbred lines developed for high altitudes ecologies were also completed (Table 2) by studying their combining abilities through testcrossing system. They were developed from five populations: Pool 9A, Mamesa-WN, ISARH071, ZM607×Pool15-QPM-SR and Pool 9A×POOL15-QPM-SR.

Table 1: Nineteen finished inbred lines for mid altitudes

No	Name	Pedigree	Source of germplam	Grain color	50% anthesis (days)	50% Silking (days)
1	RML0001	ZM607-76-3-1-B*4-#	ZM607 (Kigega)	White	66	67
2	RML0002	ZM607-79-1-1-B*4-#	ZM607 (Kigega)	White	66	67
3	RML0003	ZM607-38-1-1-B*4-#	ZM607 (Kigega)	White	65	67
4	RML0004	ZM607-34-2-1-B*4-#	ZM607 (Kigega)	White	64	66
5	RML0005	ZM607-80-4-1-B*4-#	ZM607 (Kigega)	White	67	69
6	RML0006	POOL32-70-2-1-B*4-#	Pool32 (Ndaruhutse)	White	65	66
7	RML0007	POOL32-76-1-1-B*4-#	Pool32 (Ndaruhutse)	White	64	65
8	RML0008	POOL32-76-3-1-B*4-#	Pool32 (Ndaruhutse)	White	64	65
9	RML0009	POOL32-17-1-1-B*4-#	Pool32 (Ndaruhutse)	White	64	65
11	RML0011	POOL32-6-3-1-B*4-#	Pool32 (Ndaruhutse)	White	66	66
12	RML0012	POOL32-11-4-1-B*4-#	Pool32 (Ndaruhutse)	White	66	68
13	RML0013	POOL32-6-1-1-B*B-#	Pool32 (Ndaruhutse)	White	63	65
14	RML0014	ISARM 101-27-1-5-6-2-3-B	ISARM101	White	65	66
15	RML0015	ISARM 101-41-2-2-7-7-1-B	ISARM101	White	66	67
16	RML0016	ISARM 101-27-1-5-6-2-5-B	ISARM101	White	66	67
17	RML0017	ISARM 101-41-2-2-7-7-5-B	ISARM101	White	66	67
18	RML0018	ISARM 101-64-1-4-27-5-3-B	ISARM101	White	65	68
19	RML0019	ZM607-38-4-1-B*4-#	ZM607 (Kigega)	White	66	67

Evaluation of 14 new hybrid varieties developed for mid altitudes of Rwanda

Thirty entries were involved in evaluation trials. They comprised 14 new Three Way Cross Hybrid (TWCH) varieties formed in the season 2015 A, two Single Cross Hybrid (SCH) varieties formed by

RAB and one SCH introduced from CIMMYT, six TWCHs introduced from CIMMYT, four TWCHs introduced from NASECO, one TWCH from Seed Co used as a check, two Open Pollinated Varieties (OPVs) used as a checks as well (Table 3). They were evaluated at Bugarama, Rubona, Cyabayaga, and Karama in 2016 A season (October 2015-February 2016) and in 2016 B (March-July 2016).

Table 2: Twenty two finished inbred lines for high altitudes

No	Name	Pedigree	Source of germplasm	Grain color	50 % anthesis (day)	50 % silking (day)
1	RML0020	Pool9A-5-2-1-B-B-B	Pool 9A	White	87	87
2	RML0021	Pool9A-5-1-1-B-B-B	Pool 9A	White	87	87
3	RML0022	Pool9A-4-1-2-B-B-B	Pool 9A	White	93	98
4	RML0023	MAMESAWN-29-2-1-B-B-B	Mamesa-WN	White	80	78
5	RML0024	MAMESAWN-18-2-6-B-B-B	Mamesa-WN	White	79	80
6	RML0025	MAMESAWN-13-2-4-B-B-B	Mamesa-WN	White	85	89
7	RML0026	MAMESAWN-13-2-3-B-B-B	Mamesa-WN	White	87	89
8	RML0027	MAMESAWN-13-1-3-B-B-B	Mamesa-WN	White	80	83
9	RML0028	MAMESAWN-25-2-2-B-B-B	Mamesa-WN	White	72	75
10	RML0029	MAMESAWN-18-2-4-B-B-B	Mamesa-WN	White	76	79
11	RML0030	ISARH071-4-2-5-B-B-B	ISAH071	White	82	85
12	RML0031	ISARH071-10-2-1-B-B-B	ISAH071	White	98	95
13	RML0032	ISARH071-10-1-2-B-B-B	ISAH071	White	81	83
14	RML0033	ISARH071-10-1-1-B-B-B	ISAH071	White	81	83
15	RML0034	[(ZM607/PL15-QPM-SR)-S1-F2]-7-1-1-B-B-B	ZM605×Pool 15-QPM-SR	White	81	81
16	RML0035	[(ZM607/PL15-QPM-SR)-S1-F2]-30-1-1-B-B-B	ZM605×Pool 15-QPM-SR	White	85	85
17	RML0036	[(ZM607/PL15-QPM-SR)-S1-F2]-28-2-2-B-B-B	ZM605×Pool 15-QPM-SR	White	92	89
18	RML0037	[(ZM607/PL15-QPM-SR)-S1-F2]-28-2-1-B-B-B	ZM605×Pool 15-QPM-SR	White	89	89
19	RML0038	[(ZM607/PL15-QPM-SR)-S1-F2]-19-1-5-B-B-B	ZM605×Pool 15-QPM-SR	White	87	87
20	RML0039	[(ZM607/PL15-QPM-SR)-S1-F2]-17-2-6-B-B-B	ZM605×Pool 15-QPM-SR	White	80	80
21	RML0040	[(Pool9A/PL15-QPM-SR)-S1-F2]-19-1-1-B-B-B	Pool9A×Pool 15-QPM-SR	White	91	90
22	RML0041	[(Pool9A/PL15-QPM-SR)-S1-F2]-28-2-5-B-B-B	Pool9A×Pool 15-QPM-SR	White	81	85

Grain yield (t/ha at 15 % grain moisture) was the major agronomic trait recorded. Grain yields were obtained by weighing the total number of ears harvested in a plot and obtaining the fresh weight in kg (FW). At the same time, a sample of kernels was taken in the middle of ten selected ears and was used to determine the grain moisture in % (GM) using a portable moisture-meter. Ears were thereafter dried at constant grain moisture, weighted to have the dry weight (DW) in kg, and then shelled to obtain the grain weight (GW) in kg. Taking A, as the distance (in m) between rows, and B the distance (in m) between hills at planting, C the length (in m) of harvested rows, and D the number of rows harvested, grain yield (GD) in t/ha at 15% of grain moisture was obtained by the following formula:

$$GY = 10 \times \frac{FW}{A \times (B + C) \times D} \times \frac{100}{100} \times \frac{GM}{15} \times \frac{GW}{DW}$$

Table 3: Entries in multi-location trials for mid altitudes in 2016 A and B seasons

No	Code	Names	Type of hybrid	Origin
1	V01	RHM1402	Three Way Cross	Rwanda Agriculture Board
2	V02	RHM1407	Three Way Cross	Rwanda Agriculture Board
3	V03	RHM1409	Three Way Cross	Rwanda Agriculture Board
4	V04	RHMM111	Three Way Cross	Rwanda Agriculture Board
5	V05	RHMM113	Three Way Cross	Rwanda Agriculture Board
6	V06	RHMM122	Three Way Cross	Rwanda Agriculture Board
7	V07	RHMM127	Three Way Cross	Rwanda Agriculture Board
8	V08	RHMM130	Three Way Cross	Rwanda Agriculture Board
9	V09	RHMM139	Three Way Cross	Rwanda Agriculture Board
10	V10	RHMM142	Three Way Cross	Rwanda Agriculture Board
11	V11	RHMM150	Three Way Cross	Rwanda Agriculture Board
12	V12	RHMH1502	Three Way Cross	Rwanda Agriculture Board
13	V13	RHMH1505	Three Way Cross	Rwanda Agriculture Board
14	V14	RHMH1519	Three Way Cross	Rwanda Agriculture Board
15	V15	RHM1407P	Single Cross	Rwanda Agriculture Board
16	V16	RHM104P	Single Cross	Rwanda Agriculture Board
17	V17	CML444/CML449	Single Cross	CIMMYT
18	V18	CHMLND0093	Three Way Cross	CIMMYT
19	V19	CKIR11027	Three Way Cross	CIMMYT
20	V20	CKIR12032	Three Way Cross	CIMMYT
21	V21	CKIR1204	Three Way Cross	CIMMYT
22	V22	CKIR11010	Three Way Cross	CIMMYT
23	V23	CKIR11025	Three Way Cross	CIMMYT
24	V24	Longe10H	Three Way Cross	NASECO
25	V25	UH5354	Three Way Cross	NASECO
26	V26	Ex0629-034	Three Way Cross	NASECO

27	V27	Ex3152-442	Three Way Cross	NASECO
28	V28	SC513	Three Way Cross	Seed Co
29	V29	Kigega	Open Pollinated Variety	Rwanda Agriculture Board
30	V30	ISARM101	Open Pollinated Variety	Rwanda Agriculture Board

The AMMI analysis of variance (Table 4) showed that variations due to varieties, environments and VEI were highly significant ($p < 0.01$). The genotype effects accounted for 18.6 % of the treatment Sums Squares (SS), environments 54.8 % while VEI explained 18.2 %. In AMMI analysis of variance, the treatment variation is subdivided into three types of variations: variation due to genotypes main effects, variation due to environments main effects and variation due to GEI effects. The genotype variation pertains to broad adaptations, the GEI variation is related to narrow adaptations while genotypes and GEI variations jointly determine mega-environments. The variation due to environments was larger than that of varieties together with that of VEI implying that environments were very diverse and effects due to individual environments were far important than that of mega-environment. Furthermore, broad adaptation was more important than narrow adaptation implying that varieties had tendency to be widely adapted than to be adapted to specific environments.

Table 4: AMMI analysis of variance of 30 maize varieties evaluated in eight environments of mid-altitudes of Rwanda

Sources of variation	DF	SS	MS	F	P
Total	719	3822.7	5.32	-	
Treatments	239	2746.8	11.49	9.32	<0.001
Varieties	29	741.5	25.57	20.74	<0.001
Environments	7	1505.3	215.04	6.83	<0.001
Environments/Replications	16	503.7	31.48	25.54	<0.001
Variety × Environment Interaction	203	500.0	2.46	2.00	<0.001
IPCA1	35	303.8	8.68	7.04	<0.001
IPCA2	33	77.7	2.35	1.91	0.002
IPCA3	31	54.4	1.75	1.42	0.068
Residuals	104	64.2	0.62	0.50	0.999
Error	464	572.1	1.23	-	-

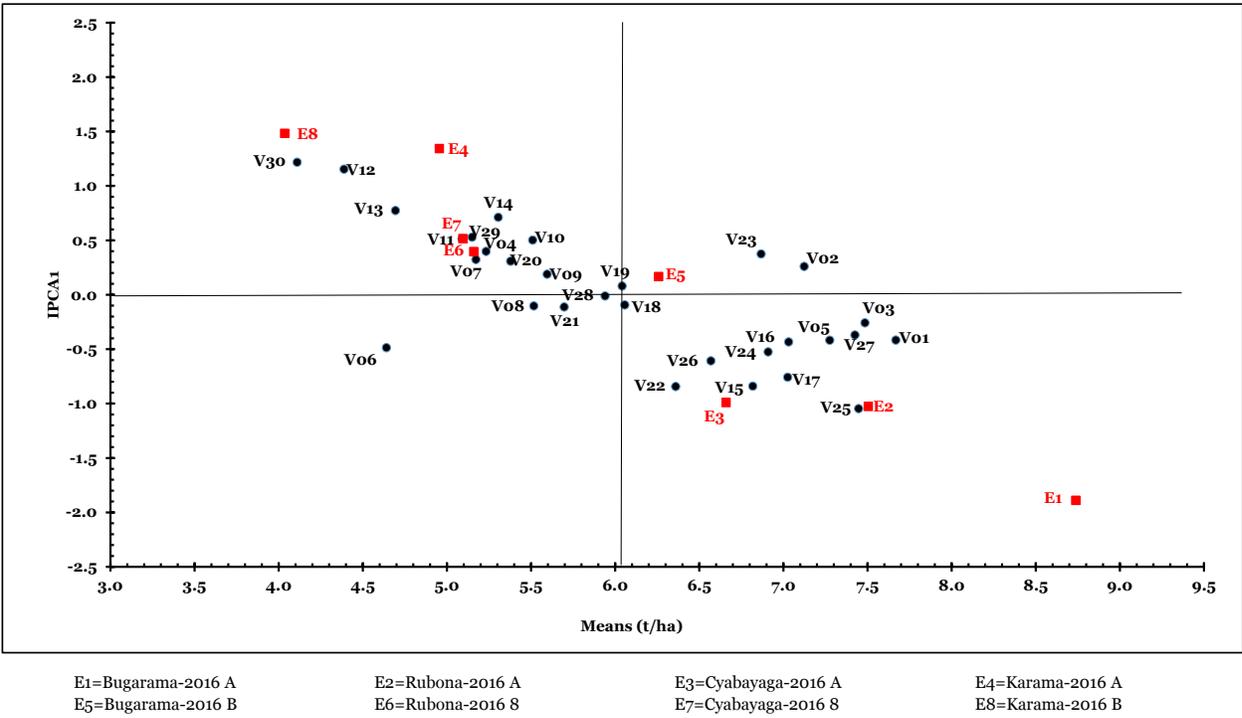


Figure 1: Biplot of grain yield obtained by plotting the means (t/ha) against IPCA1 $[(t/ha)^{0.5}]$ for 30 varieties evaluated in eight environments in mid-altitudes of Rwanda

The AMMI analysis of variance (Table 4) showed that variations due to varieties, environments and VEI were highly significant ($p < 0.01$). The genotype effects accounted for 18.6% of the treatment Sums Squares (SS), environments 54.8% while VEI explained 18.2%. In AMMI analysis of variance, the treatment variation is subdivided into three types of variations: variation due to genotypes main effects, variation due to environments main effects and variation due to GEI effects. The genotype variation pertains to broad adaptations, the GEI variation is related to narrow adaptations while genotypes and GEI variations jointly determine mega-environments. The variation due to environments was larger than that of varieties together with that of VEI implying that environments were very diverse and effects due to individual environments were far important than that of mega-environment. Furthermore, broad adaptation was important than narrow adaptation implying that varieties had tendency to be widely adapted than to be adapted to specific environments.

The AMMi 1 biplot indicated that nine hybrid varieties: RHM1402 (V01), RHM1407 (V02), RHM1409 (V03), RHMM113 (V05), RHM104P (V16), CHMLND0093 (V18), CKIR11025 (V23) and Ex3152-442 (V27) had means superior to overall mean (6.05 t/ha) and IPCA1 scores between -0.5 and +0.5. Furthermore, UH5354 (V25) had high means of 7.45 t/ha and was almost with the

E2 (Rubona-2016 A), while RHM1407P (V15) was also high yielding and was very close to E3 (Cyabayaga-2016A) (Figure 1).

In AMMI 1 biplot, the usual interpretation is that displacements along the abscissa indicate differences in main effects, whereas displacements along the ordinate indicate differences in interaction effects. If a genotype has high mean (mean > overall mean) and an IPCA1 score closer to zero (near the abscissa), it is considered as stable across environments. The varieties: RHM1402 (V01), RHM1407 (V02), RHM1409 (V03), RHMM113 (V05), RHM104P (V16), CHMLND0093 (V18), CKIR11025 (V23) and Ex3152-442 (V27) had high means and were close to the abscissa and hence they were stable across environments. Furthermore, the varieties: UH5354 (V25) and RHM1407P (V15) were high yielding and had specific adaptations. Therefore, the varieties: RHM1402, RHM1407, RHM1409, RHMM113, CHMLND0093, CKIR11025, Ex3152-442, and UH5354 must be quickly be released and made available to farmers. Specifically, the inbred lines parents of the hybrids: RHM1402, RHM1407, RHM1409, and RHMM113 are currently available. Hence, this availability will allow a rapid seed production of these varieties.

Seed production

Breeder's seed : The breeder's seed production was conducted at Nyagatare-Cyabayaga in the season 2016 A and concerned all the parent lines of hybrid varieties to be released and utilized by farmers. However, the breeder's seed of the line CML464 was produced at Musanze because the line is for highlands. Each inbred line was planted ear-to-rows. Prior selfing plants, all rows that seemed to be off types were eliminated in the fields and in the store of remnant seed. In each row, all plants were selfed (Photo 1). At harvest, all selfed ears were shelled in the bulk to constitute the breeder's seed. The quantity of breeder's seed produced was 41.7 kg (Table 5).

Pre-basic seed production: The pre-basic seed production was conducted at Rubona in 2016 A for the parent inbred lines: CML442, CML444, CML539, CML445, CML488, CML203, CML204, and CML464. Each line was planted in isolated plot and was left to pollinate freely. However, a thoroughly roguing was performed two times prior flowering period where any suspected plant to be off-type was eliminated. Only uniform plants were left in the field for pre-basic seed production. The total quantity of 861 kg of pre-basic seed was produced (Table 6).

Table 5: Quantity of breeder's seed produced in 2016 A season

NO	Inbred lines	Hybrids for which the line is the parent	Pedigrees of the hybrids	Quantity of seed produced (kg)
1	CML442	RHM104 RHM1402	CML442/CML444/CML445 CML442/CML444/CML488	6.3

		RHMH1520	CML442/CML444/CML464	
		RHM104	CML442/CML444/CML445	
		RHM1402	CML442/CML444/CML488	
2	CML444	RHMH1521	CML442/CML444/CML464	8.7
		RHM1407	CML539/CML444/CML445	
		RHM1409	CML539/CML444/CML448	
3	CML445	RHM104	CML442/CML444/CML445	4.4
		RHM1407	CML539/CML444/CML445	
4	CML539	RHM1407	CML539/CML444/CML445	5.1
		RHM1409	CML539/CML444/CML448	
		RHM1402	CML442/CML444/CML488	
5	CML488	RHM1409	CML539/CML444/CML448	4.2
		RHMM113	RML0004/RML0010//CML488	
6	CML203	RHT132	CML203/CML204//CML216	3.3
		RHMH1520	CML203/CML204//CML464	
7	CML204	RHT132	CML203/CML204//CML216	2.2
		RHMH1520	CML203/CML204//CML464	
8	RML0004	RHMM113	RML0004/RML0010//CML488	2
9	RML0010	RHMM113	RML0004/RML0010//CML488	1.5
10	CML464	RHMH1521	CML442/CML444/CML464	3
		RHMH1520	CML203/CML204//CML464	
11	CML216	RHT132	CML203/CML204//CML216	1
Total				41.7

Dissemination activities

Demonstration trials: The demonstration trials on the new hybrid varieties: RHT132T, RHM104, RHM1407, RHM1409, RHM1402, and RHMM113 (Table 7) were conducted in the Districts of Nyagatare, Gatsibo, Kayonza, Ngoma, and Kirehe of Eastern Province in 2016 A season (October 2015-February 2016). The demonstration trials were conducted in seven sites. These sites were chosen by considering their easy access by farmers and visitors, the fact that there were hybrid varieties being commonly grown in the area and the presence of cooperatives whose activities include growing maize. Field days were organized, especially at harvest period where farmers were requested to rank the varieties. The results in the Table 8 indicate that most of farmers ranked RHM1402 and RHM1409 as their first choice whereas RHT132 was almost the last choice. RHM104, RHMM113, and RHM1407 were mainly their second choice. The main criteria used in the ranking were plant aspect, kernel aspect, number of ears per plant and maturity.

Table 6: Quantity of pre-basic seed produced

No	Inbred lines	Hybrids	Pedigrees	Quantity of seed (kg)
----	--------------	---------	-----------	-----------------------

		RHM104	CML442/CML444/CML445	
1	CML442	RHM1402	CML442/CML444/CML488	207
		RHMH1520	CML442/CML444/CML464	
		RHM104	CML442/CML444/CML445	
		RHM1402	CML442/CML444/CML488	
2	CML444	RHMH1521	CML442/CML444/CML464	165
		RHM1407	CML539/CML444/CML445	
		RHM1409	CML539/CML444/CML448	
3	CML445	RHM104	CML442/CML444/CML445	52
		RHM1407	CML539/CML444/CML445	
4	CML539	RHM1407	CML539/CML444/CML445	223
		RHM1409	CML539/CML444/CML448	
		RHM1402	CML442/CML444/CML488	
5	CML488	RHM1409	CML539/CML444/CML448	81
		RHMM113	RML0004/RML0010//CML488	
6	CML203	RHT132	CML203/CML204//CML216	62
		RHMH1520	CML203/CML204//CML464	
7	CML204	RHT132	CML203/CML204//CML216	43
		RHMH1520	CML203/CML204//CML464	
8	CML464	RHMH1521	CML442/CML444/CML464	35
		RHMH1520	CML203/CML204//CML464	
Total				868



Photo 1: Breeder's seed production for the inbred line CML203

Table 7: Varieties involved in demonstration trials conducted in 2016 A

No	District	Sector	Entries in demonstration trials
1	Nyagatare	Nyagatare	RHM104, RHT132, RHM1407, Kigega (check)
2	Nyagatare	Nyagatare	RHM1402, RHM1409, RHMM113, Kigega (check)
3	Nyagatare	Matimba	RHM104, RHM1402 RHM1409, Kigega (check)

4	Gatsibo	Remera	RHM1407, RHT132, RHM113, ISARM101 (check)
5	Ngoma	Rukumberi	RHM1407, RHT132, RHM104, ISARM103 (check)
6	Kirehe	Nyamugali	RHM113, RHM1409, RHT132, RHM1402, Kigega (check)
7	Kayonza	Kabare	RHM1407, RHM1402, RHM104, RHM113, ISARM103 (check)

Table 8: Ranking of varieties involved in demonstration trials in 2016 A

No	Names	Average grain yield (t/ha)	Ranks by men	Rank by women	Average rank	Remarks
1	RHM1409	6.22	1.98	1.99	1.985	Bear all most two ears per plant, excellent kernels
2	RHM104	6.15	2.15	2.25	2.20	Nice plant aspect but kernels are too dent
3	RHM1407	5.95	2.46	2.56	2.51	Nice plant aspect but it has almost one ear per plant
4	RHMM113	5.65	2.86	2.76	2.81	Early maturity, nice kernel aspect, but it has small ears
5	RHT132	5.75	3.36	3.34	3.35	Nice plant and kernel aspects but it is very tall, it has small ears
6	Kigega	4.67	4.25	4.25	4.25	It has less yield
7	ISARM101	4.65	4.00	4.00	4.00	It has less yield
8	ISARM103	4.23	4.50	4.50	4.50	It has less yield

Demonstrations and field days for variety release to farmers and seed producers: A demonstration trial comprising three new hybrid variety: RHM104, RHM1407, and RHT132 were planted in Mimuri Sector, Nyagatare District in March 2016 with the objective of using it for release to farmers' new hybrid maize varieties. Each variety was planted on large plot of approximately 200 m². Moreover, another demonstration trial was planted at Cyabayaga research station and comprised five hybrid varieties: RHM104, RHM1402, RHM1407, RHM1409 and RHM113 and their parents including the parent Single Crosses and the parent inbred lines. The second demonstration trial was targeting mainly seed companies. The field days were organized in the two sites on 14 July 2016. Forty-two men and 72 women attended the field day on the new hybrid varieties. The participants appreciated two hybrid: RHM104 and RHM107 while they rejected RHT132 (Table 9, Photo 2). They requested the local seed companies present in the field day to undertake the seed production of the two varieties so that they are available very quickly. Furthermore, seed companies visited the plot planted with five hybrid varieties and their parents and made selection on the variety they preferred the most (Plank 3). The seed companies were excited to see that the parents were available to start immediately to multiply these hybrid varieties. With these demonstration trials, eight hybrid varieties were released:

RHM104, RHM1402, RHM1407, RHM1409, RHMM113, RHT132, RHM1520, and RHM1521. RHM1520 and RHM1521 are for highlands.

Table 9: Remarks of farmers on three hybrid varieties in 2016 B demonstration trials

Variety	Men				Women			
	Positive criticism	Negative criticism	Rank	Season	Positive criticism	Negative criticism	Rank	Preferable Season
RHM104	-High yield - Big ears	- Dent kernels, - Late	2	Season A	- Drought tolerant - Two ears per plant - Big ears - Ears well covered	- Late maturing - Dent kernels	2	Season B
RHM1407	- Big ears - Early maturing - Strong stem - High yielding	- One ear per plant	1	Season A. season B	- Drought tolerant - Big cobs - Early maturing - Big cobs	- Not prolific - Liked by bird	1	Season A, season B
RHT132		Extremely late	3	It may be good in highlands		- Not drought tolerant - Extremely late	3	Rejected



RHM1407

RHM104

Photo 2: RHM1407 and RHM104 in demonstration trials

1.3.1.2 Rice

Rice consumption in Rwanda is on rise due increased urbanization particularly the capital Kigali. Growing demand for rice will be met from increased production in irrigated marshlands, which covers 1.2% of the total arable land. Self-sufficiency in Rice production will be achieved by rising the productivity of existing lands and by further expanding the area under rice cultivation. Since the release of 20 new varieties in

2010, the yield has increased at a slow slope of 0.08 ($R^2=0.810$) and the land under rice crop gained 16% of the total lands use. The Rice cultivation faced three major constraints: variety suitability, Quality of certified seeds, diseases pressure and poor extension services. Therefore, rice research focused on the following objectives:

- a) To develop 3 populations using local varieties as female parents;
- b) To identify the blast pathogen in targeted schemes;
- c) To test the adaptability of high yielding varieties in NAVR;
- d) To produce high quality basic seeds for all certified seeds producers;
- e) To manage farmer fields schools (FFS) in selected marshlands.

Development of new varieties

Efforts to improve varietal adaptability to Rwandan environments have been underway since 2000. Temperate climate provides a limited number of varieties for different rice production zones with low temperatures that are common at planting and grain formation stages. Most of cultivated varieties with resistance to low temperature-induced sterility do not have adequate levels of grain quality. Screening for seedling vigour, resistance to low temperature sterility, grain quality and maturity are integral parts of the breeding program. Rice varieties have been developed with emphasis on physical grain quality with different agronomic characters (maturity, cold tolerance, etc.). High yielding long-grain varieties have been successfully adapted for mid-altitudes zones. Disease resistance is a major research emphasis with special attention given to blast and Rice yellow mottle virus (RYMV) diseases. Cooperative research with AfricaRice Center and International Rice Research Institute (IRRI) that involves characterizing existing disease of RYMV has improved progress in managing the virus. Some crosses were undertaken using Yun Yin, WAT 1395-B-24-2, and Yun Keng varieties as female parents and Moreberakan, a tolerant variety to both Blast and RYMV diseases as donor. The F1 progenies were obtained from crossing of the following pairs of parents: WAT 1395-B-24-2/Moroberekan; Yun Yin/Moroberekan and Yun Keng/Moroberekan.

Development of new varieties with marketable traits has been undertaken from 2015 and emphasis was given on milling quality, grain size and shape, and cooking and processing characteristics. A total of 30 F3 populations were selected for physical traits at Rubona and advanced for further evaluation.

Blast disease population structuring in Rwanda

Rice intensification in Rwanda going along with continuous cultivation of rice in monoculture results in increased pressure of blast disease caused by *Magnaporthe oryzae*, and substantial yield loss. Facagro, Yun Yin and Intsingirabigega, farmer preferred varieties became very susceptible to blast after few years of cultivation in Rwanda. Understanding the population structure of the blast disease is key to determining effective resistance genes towards their deployment in breeding and selection of rice varieties with relatively durable resistance. Six trapping nurseries have been installed during the 2017B season in rice schemes with high pressure of rice blast disease (Cyabayaga, Kanyonyomba, Cyunuzi, Mukunguri, and Rugeramigozi). Monogenic lines carrying each a known specific resistant gene conditioning resistance to *Magnaporthe oryzae* strains were used and arranged in randomized complete block design with

susceptible and resistant varieties used as checks. Blast disease was scored subsequently at weekly intervals for severity determination using the scale rating system (IRRI, 2013). Data were analysed with the analysis of variance and LSD test using GENSTAT (15th Edition). From the genes reaction above, we can clearly see that there is a great diversity of *M. oryzae population* on the sites studied, and this diversity varied from one site to another (Table 2). Many strains were found to be able to overcome the vertical resistance of the monogenic lines that were used during this study. Pathogen pressure was found to be greater in Rugeramigozi and Cyabayaga sites where 19 and 11 R-genes developed a compatible reaction, respectively. A total of 25 R-genes showed an incompatible reaction on the sites of experiment (Table 10). Five R-genes in Cyunuzi, eight in Cyabayaga, 2 in Kanyonyomba, 6 in Mukunguri and 4 in Rugeramigozi.

Table 10: R-genes that showed incompatible reaction in different sites

Cyunuzi	Cyabayaga	Kanyonyomba	Mukunguri	Rugeramigozi
Pik-s	Pit	Pita-2	Pita-2	Piz
Pita-2	Pi19	Pit	Pi-z, Pi-i, Pi-a	Pita-2
Pi-z, Pi-i, Pi-a	Pikh		Pi5(t), Pi7	Pi5(t), Pi7
Pi5(t), Pi7	Pi5		Pi-km	Pit
Pit	Pita-2		Pit	
	Pit		Pi-a	
	Pik-p			

Some resistance genes have shown incompatible reaction for the disease across almost all the sites, namely: *Pita-2*, *Pit* and *Pi5(t)*, *Pi7* (except in Cyabayaga and Kanyonyomba).

Table 11: Variety reaction to rice blast pathogen in 5 sites in Rwanda

Variety	Resistance gene	Site				
		Kirehe	Cyabayaga	Kanyonyomba	Mukunguri	Rugeramigozi
K59	Pit	MR	R	MR	MR	S
IRBLKS-F5	Pi-k ^s	MR	S	MR	S	S
C102TTP	Pita	MR	S	MR	MR	MR
DULAR ACC	Pi-k ^a	MR	MR	MR	MR	S
IRBL19-A	Pi19	MR	R	MR	MR	MR
K3	Pikh	MR	R	MR	MR	MR
IRBLS-M	Pi5	S	R	S	S	S
IRBLKS-S	Pi-k ^s	-	-	MR	MR	S
IR56	?	MR	-	MR	MR	MR
IRBLB-B	Pib	MR	-	MR	MR	S
FUKUHIKARI	Pii+Pi-k ^s	MR	-	MR	MR	MR
IBL7-M	Pi7	MR	S	MR	MR	S
IRAT104			R	MR	MR	MR

IRBLA-A	Pia	MR	MR	MR	MR	MR
C101A51	Pi2	MR	MR	MR	MR	S
IRBL3-CP4	Pi3	MR	S	MR	S	MR
AICHI ASAHI	Pia+Pi19	MR	MR	MR	MR	MR
IRBLKH-K3	Pik-h	MR	MR	MR	MR	MR
REIHO	Pita-2	MR	MR	MR	MR	MR
FUJISAKA5	Pi-i, Pi-k ^s	MR	S	MR	MR	MR
IRBLZ-FU	Piz	MR	MR	MR	MR	R
IBLTA2-Pi	Pita-2	R	R	R	R	R
C105TTP-1	Pita	MR	MR	MR	MR	MR
IRBLA-C	Pia	MR	S	MR	MR	S
IRBL12-M	Pi12	MR	S	MR	S	MR
MOROBBERKAN	Pi5(t), Pi7	R	MR	MR	R	R
MODAN	Pb-1	MR	MR	MR	MR	MR
IRBL11-ZH	Pi11	MR	-	MR	S	S
IRBL20-IR24	Pi20	MR	MR	MR	MR	S
C103TTP	Pi1	MR	MR	MR	-	MR
KASABUE	Pik	MR	MR	MR	MR	S
IRBLK-KA	Pik	MR	S	MR	MR	MR
CT13432-3R	Pi1+Pi2+Pi33	MR	MR	MR	MR	MR
TSUYAKE	Pi-km	MR	MR	MR	R	S
IRBLT-K59	Pit	R	R	R	R	R
IRBLKP-K60	Pik-p	MR	R	MR	MR	S
IRBLI-F5	Pii	MR	MR	MR	MR	S
USEN	Pi-a	MR	MR	MR	R	S
IRBLZT-T	Piz-t	MR	MR	MR	S	MR
OWARI	HATA Pi-21	MR	S	MR	MR	MR
MOCHI						
MARATELLI	-	S	S	S	S	S

R- resistant; MR- Moderately resistant, S- Susceptible

Adaptability trials

The field experiment was conducted in 2017A with 5 varieties (RAB-101, RAB-103, RAB-104, RAB-106, RAB-111, RAB-118 and local check). Standard management practices were applied. The following growth parameters were recorded at 30, 60, 90 DAT and at harvest: Plant height, Number of tillers hill-1, Number of tillers, Date of Maturity, Effective tillers m⁻²Number of panicles hill-1, Panicle length, Panicle weight (g), Number of filled and unfilled grains per panicle, thousand grain weight (g) and Yield. Rice variety RAB-106 had the highest panicle weight (3.2g). The average number of filled grains panicle-1 significantly differed in rice cultivars. The highest filled grains were recorded in RAB-118 (152.0) followed by RAB-106 (135). Respectively, the number of unfilled grain per panicle was higher in RAB-111 (24) followed by RAB-104 (22) ([Tables 12 and 13](#)).

Table 12: Plant characteristics of the tested varieties

Variety	Plant Height (cm)				Number of tiller per hill		
	30	60	90	At Harvest	30	60	90
RAB 101	32.5	71.2	85.7	95.2	10	17	26
RAB 103	29.7	69.6	92.4	98..9	7	15	18
RAB 104	27.6	75.3	88.1	96.4	6	11	13
RAB 106	32.3	73.8	87.4	93.7	9	17	22
RAB 111	31.3	72.1	79.5	95.5	6	10	15
RAB 118	31.5	66.9	92.2	95.2	10	16	25
CV	13	10	7	6	10	13	12
SE m \pm	3.17	4.56	4.06	3.62	0.62	0.63	0.72
CD(P=0.05)	NS	13.63	12.31	10.97	1.92	1.88	2.1

DAT = Days after transplanting, cm = Centimetre, CV = Coefficient of variance, SE m = Standard error of mean

Table 13: Yield characteristics of tested varieties

Variety	Effective tillers/m ²	Panicle length/cm	Panicle weight/g	Test weight/g	Filled grains per panicle /number	Unfilled grains per panicle /number	Grain Yield/kg per ha
RAB 101	255	26	3.3	24.5	152	15	5937
RAB 103	262	25	3.1	23.4	122	19	5623
RAB 104	210	15	1.9	18.1	117	22	3950
RAB 106	270	23	2.6	21.3	130	13	5731
RAB 111	239	18	1.7	20.9	111	24	4250
RAB 118	260	26	2.3	25.2	142	18	5594
CV	11.72	9	11.99	9.8	7.5	13	12.8
SE m \pm	19.3	1.8	0.22	3.62	0.62	0.63	358.17
CD(P=0.05)	57.85	3.84	0.66	3.76	15.27	21.3	886

DAT = Days after transplanting, cm = Centimetre, CV = Coefficient of variance, SE m = Standard error of mean

Basic seed production

Rice (*Oryza sativa*) is a self-pollinating crop with both the male and female reproductive organs residing in the same flower but located differently. As a self-pollinating crop, the pollen produced by the plant fertilizes itself. In seed production, an understanding of the mode of pollination and fertilization in plants is of utmost importance. The seed can be nursed before transplanting, sown directly by broadcasting or drilling. For each method, achievement of quality control standards, follow the same control measures, procedures and methods. However, with the practice of nursing before the seedling is transplanted, a lot more attention and care are given to the agronomy of seed nursing and nursery management in order to meet acceptable quality control standards. Field trials have also shown that, seeding rates are lower and crop yields are higher when the rice is nursed before transplanting. Therefore, seed nursing and nursery management are important components of seed production practices. Below is the total basic seed produced during seasons 2017A and 2017 B (Table 14).

Table 14: Quantity of basin riceseed produced by RAB in 2017A

Variety	Seed produced, kg (Rwamagana)	Variety	Seed produced, kg (Rubona)	Bugarama	Seed produced, kg (Bugarama)
Yun Yin 4	353	Yun Yin 4	280	Basmati 370	162
WAT 1395-B-24-2	251	WAT 1395-B-24-2	320	Fashingabo	179
FAC 56	264	FAC 56	280	Jyambere	135
Buryohe	612	Buryohe	140	Imbatutabukungu	378
Gakire	530	Gakire	210	Icyerekezo	254
Rurambi	314	Rumbuka	145	WAT54TGR	136
Cyizere	250	V7	238	Nerica 9	130
Duterimbere	84	Johnson	210		
Gatera	41	Ramba	140		
Mpembuke	28	Mbakungahaze	280		
Dutsinde	176	Yunkeng	140		
		Zhongeng	140		
Total seed (kg)	2903		2523		1374

Farmer field schools(FFS) in Rwinkwavu, Gacaca, MP 8, Bugarama I-IV.

The rice program avails to the farmers the seed of productive varieties along with good agronomic practices. Most of marshlands in Eastern province are new for rice production, and the farmers are not familiar with cultivation techniques. Therefore, trainings through Farmer Field School (FFS) and new variety testing (up to 20 at each site) were organized in following rice schemes (Bugarama I-IV, Rwinkwavu, Gacaca, MP8) (Photo 3). After transplantation, the following topics were discussed and practiced with the technical team: weeding, tillering, pest and disease management, water management and fertilizer application.



Photo 3: Field of Farmer Field School

Table 15: FFS evaluation of tillering ability and diseases incidence at Rwinkwavu and Gacaca

Variety	Number of tillers		RYMV disease incidence	
	Rwinkwavu	Gacaca	Rwinkwavu	Gacaca
1. RAB101	21	22	1	5

2. RAB102	28	17	1	5
3. RAB103	13	17	1	3
4. RAB104	16	17	1	3
5. RAB105	20	22	1	1
6. RAB106	19	17	1	3
7. RAB107	17	20	1	3
8. RAB108	26	17	1	3
9. RAB109	19	17	1	5
10. RAB110	17	16	1	3
11. RAB111	14	16	1	1
12. RAB112	16	16	1	1
13. RAB113	24	16	1	1
14. RAB114	16	16	1	3
15. RAB115	11	9	1	1
16. RAB116	16	17	1	1
17. RAB117	19	18	1	5
18. RAB118	19	18	1	3
19. RAB119	18	19	1	5
20. Local check	WAT :19	Gakire:18	1	1

Disease evaluation for Rice Yellow Mottle Virus was scored as 1 – no symptoms; 3 - Leaves green but with sparse or streaks and less than 5% of height reduction; 5 - Leaves green or pale green with mottling and 6 to 25% of height reduction, flowering slightly delayed; and 7 - Leaves pale yellow or yellow and 26-75% of height reduction flowering delayed; 9 - Leaves turn yellow orange more than 75% of height reduction, no flowering or some plants dead.

The exercise of counting the rice tillers, pest and diseases observation, were done for comparison of different rice varieties, which was to help the farmers to select the best varieties (Table 15 and 16). The rice variety with high tillers and resistance to the diseases can be considered as the best promising. The following results are the data collected during the FFS training at Rwinkwavu, Gacaca and P8 at panicle initiation stage.

Table 16: Data collection for evaluation of tillering ability and disease incidence at MP8

Variety	Number of tillers	RYMV disease incidence
1.RAB101	28	5
2.RAB103	18	5
3.RAB104	17	7
4.RAB106	17	7
5.RAB111	16	7
6.RAB118	13	7
7.WAT	16	9
8.TETA57	18	1

9.TETA76	15	7
10.TETA70	15	5
11.Yun Yin	12	1
12.Buryohe	17	9
13.TETA6	12	1
14.TETA56	12	3
15.TETA11	14	5
16.TETA54	11	5
17.TETA40	7	3
18.TETA52	10	9
19.TETA45	13	5
20.RUMBUKA	8	5

Disease evaluation for Rice Yellow Mottle Virus was scored as 1 – no symptoms; 3 - Leaves green but with sparse or streaks and less than 5% of height reduction; 5 - Leaves green or pale green with mottling and 6 to 25 of height reduction, flowering slightly delayed; and 7 - Leaves pale yellow or yellow and 26-75% of height reduction flowering delayed; 9 - Leaves turn yellow orange more than 75% of height reduction, no flowering or some plants dead.

Water management

The farmers were trained on water management before heading. The field should be irrigated from 5 to 10 cm of water depth. The bund should be closed after irrigation and water kept in the field. The field should remain flooded until the end of milking stage

Fertilizer application

The leaf color turns light green during the maximum tillering, because of shortage of nutrients especially the nitrogen in the soil. The application of urea is very important at this stage. However, lodging is possible by the application of excessive amount and attacks by diseases like blast.



Photo 4: Fertilier application on rice

Following FFS evaluation, the number of varieties were selected in each marshland: IR13A335, IR90245-B-166-4-1, IR09L-272, IR10L139, IR84350-B-27-2-3, ZX117, LHI, IR90247-B-165- 3-2, SUPA, IR84350-B-27-2-2 (Bugarama I-IV); Buryohe, IR09L337, IR84350-B-27-2-2, IR77713-30-1-1-3 (Rwinkwavu); IR13A335, IR09L337, IR90245-B-166-4-1, IR90245-14-B-165-4-3, Teta 56, Teta 6 (MP 8). The FFS in Gacaca rice scheme got destroyed by heavy rain and storms.

1.3.1.3 Wheat

Wheat is an important staple crop in Rwanda. The demand for wheat and wheat-based products in Rwanda has been rapidly growing as a consequence of urbanization, rising incomes and dietary diversification in the region. Wheat is grown in highlands of Rwanda with cooler climate. Wheat yield is low due to limited number of appropriate varieties, low soil fertility, pests and diseases and limited knowledge on both seed/grain production and postharvest management practices. Therefore, wheat research is focused on variety development, seed production, adaptability trials, field days and surveys.

On-station evaluation of new accessions

Over both 2017 A and B seasons the trials have been established in Kinigi, Rwerere and Musanze sites. The evaluation seeks to (1) determine the agronomic potentials of new wheat lines and varieties introduced from CIMMYT or NARES and evaluate their adaptability to wheat growing areas of Rwanda, and (2) select the superior lines for on-farm evaluation, baking quality tests and subsequent release to farmers.

Screening nurseries (SN): Three nurseries were established at Kinigi and Rwerere. Two sets of varieties (272 and 165) composed of 50th IBWSN¹ and 11th STEMRRSN² lines, respectively, were evaluated against local check (Nyaruka) in 2017B. The lines were obtained from the International Maize and Wheat Improvement Center (CIMMYT)-Mexico, in 2017. Screening nurseries were distributed in non-replicated sets, and are composed of advanced lines selected from the CIMMYT crop programs. Individual envelopes containing the seed (10 g) for each line to be screened are included in the seed boxes. Every 20th envelope is empty and provided for the packaging of a local check cultivar. The amount of seed needed for the local check has to be the same as that provided for the other entries in the trial to allow for a uniform and minimum seeding rate. Furthermore, all the envelopes are arranged in each box in the order in which they should be planted, as indicated by the plan of the trial. Selection focused on major diseases, namely stem and yellow rusts, *Helminthosporium*, Barley Yellow Dwarf Virus (BYDV), *Fusarium* and Powdery mildew, plant vigour, spike appearance and general adaptation to the growing conditions. The purpose is to screen wheat germplasm obtained as nurseries from outside the country for adaptability to the growing conditions of Rwanda with the aim of identifying those with desirable traits. Moreover, the nurseries help not only to obtain information on the performance of experimental germplasm under local climatic and disease conditions, but also serve as a source of new genetic variability. After being screened for the major diseases, plant vigour, spike appearance and other agronomic characteristics, about 100 promising lines were selected from both nurseries and advanced for further testing in the season 2018A.

Preliminary yield trials (PYT): Ten sets of nurseries of 49 lines from 25th HRWYT³, 49 from 37th ESWYT⁴, 49 from 24th SAWYT⁵ and 49 from 23rd SAWYT obtained in 2017 from CIMMYT-Mexico and evaluated in both Rwerere and Kinigi in 2017B; 39 lines from 8th STEMRRSN, 49 from 9th STEMRRSN, 49 from 36th ESWYT, 12 from 1st RAVEN⁶ selected from the previous seasons, but now evaluated in Kinigi only because of limited amounts of seed; 29 from both 9th STEMRRST and 47th IBWSN resulting from the previous evaluations, but currently evaluated on in Rwerere as they have few seeds; and 21 varieties from PERBWYT⁷ obtained from Nigeria in 2016. The 21 varieties were evaluated in Kinigi and Musanze sites in 2017A and Kinigi, Musanze and Rwerere in 2017B.

A part from Nigerian set that has to follow a particular field layout, each of the other sets of lines has been planted in a randomized complete block design with 2 replications. The plot size was 3m x 1.20 m. Seeds were hand-drilled in a plot of 6 rows spaced at 0.20 m. Nyaruka variety was used as a local check. Data have been collected on plant stand, plant height, days to flowering and to physiological maturity, grain yield, reaction type to major pests such as aphids, and diseases, such as rusts, *Fusarium*,

¹ IBWSN : International Bread Wheat Screening Nursery

² STEMRRSN : Stem Rust Resistance Screening Nursery

³ HRWYT : High Rainfall Wheat Yield Trial

⁴ ESWYT : Elite Selection Wheat Yield Trial

⁵ SAWYT : Semi-Arid Wheat Yield Trial

⁶ RAVEN : Regional Africa Variety Evaluation Nursery

⁷ PERBWYT : Preliminary Elite Rainfed Bread Wheat Yield Trial

Helminthosporium, *Septoria*, powdery mildew and BYDV. As for the varieties from Nigeria, 21 PERBWYT accessions introduced in 2016 from Lake Chad Research Institute, Maiduguri, Borno State, Nigeria, have been planted for being evaluated for adaptability to Rwandan environments to select superior varieties that would be released as varieties. Three local checks (Njoro BW2, Gihundo and Nyaruka) have been involved in the evaluation.

Preliminary results from the evaluation indicated that about 60 lines were selected from 25th HRWYT, 37th ESWYT, 24th SAWYT and 23rd SAWYT. Selection for diseases was done in the field and as such, the reaction of these materials is affected by several uncontrolled factors. To confirm susceptibility or tolerance, these materials will have to be assessed over one more season. From 39 lines (8th STEMRRSN), 49 (9th STEMRRSN), 49 (36th ESWYT), 12 (1st RAVEN) and 29 lines (9th STEMRRST & 47th IBWSN) were selected 18, 21, 23, 3 and 14 lines, respectively. They will be advanced to the next evaluation stage for further testing. Furthermore, five superior varieties were selected from the 21 PERBWYT. They will be advanced for a participatory variety selection in farmer's fields in the next cropping season 2018A.

Advanced yield trials (AYT) : Groups of 35 lines from both 32nd SAWYT and 35th ESWYT planted in Rwerere only, 25 from both 20th HRWYT and 6th STEMRRSN planted in Kinigi only; and 25 from both 7th STEMRRSN and 22nd HRWYT planted in both Kinigi and Rwerere were tested for advanced yield evaluation, with Nyaruka as a check. The study aimed to (1) determine the agronomic potentials of wheat lines from CIMMYT-Mexico and regional NARES and evaluate their adaptability to the highlands of Rwanda, and (2) select the best lines for on-farm evaluation, baking quality tests and subsequent release to farmers. A total of 31 lines were selected from all sets. They will be evaluated in 2018A.

Comparative yield trials (CYT) : Two sets of 8 lines (20th HRWYT & 23rd HRWSN), and 11 lines (21st HRWYT & 34th ESWYT) were evaluated in CYT established in Kinigi and Rwerere in the seasons 2017A and B. Kibatsi and Nyaruka were used as checks. A total of 15 lines were selected from a total of 19 lines evaluated. They will be evaluated in the next cropping season in farmers' fields.

Variety development: Local variety development began with 12 parents comprising 4 local parents (Musama, Bisagi, Kibatsi and Nyangufi) and 8 parental materials obtained from Kenya. They produced F1's populations. Currently, 29F6 progenies obtained from F5 populations have been evaluated for preliminary yield in Kinigi and Rwerere. Eighteen best progenies were selected for further evaluation. In Musanze, a total of 68 F1's seed were produced and replanted in 2017B to produce F2's seeds. Another set of crossing blocks was established in 2017B to successfully produce 53F1's seed including 18F1's seeds that were totally missing in the crossing exercise. Produced seed will be replanted in the next season to obtain next generations and select good families and individual/single plants from those generations ([Photo 5](#)).



Photo 5: F1's seed formed from Musama x Chozi crosses, Musanze, 2017B

Seed production: Breeder seed were produced in Kinigi (50 kg) and Rwerere (680 kg) for 10 commercial varieties, namely, Nyaruka, Cyumba, Keza, Mizero, Rengerabana, Gihundo, Reberaho, Majyambere, Kibatsi and Nyangufi. In 2017A, a total of 12,811 kg kg of basic seed were produced for the varieties Nyaruka, Cyumba, Keza, Mizero, Rengerabana, Nyangufi, Kibatsi, Gihundo, Reberaho, and Majyambere in Rwerere (10,743 kg), Kinigi (450 kg), Masogwe (1,618 kg). For pre-basic seed, 319 kg were produced from Kibatsi and Nyangufi in Kinigi. In 2017B, more than 6 tons of Nyaruka were produced in Rwerere as basic seed.

On-farm technology verification trials for participatory variety selection: Several promising bread wheat lines were identified from multi-location on station evaluation for further participatory assessment on farm. In participatory variety selection (PVS), farmers are involved in selecting promising genotypes among finished or nearly finished varieties. Therefore, 23 on-farm trials including three in Gataraga, one in Shingiro, one in Butaro, two in Rwerere, one in Gashenyi/Gakenke, 2 in Nyamagabe and 16 in Cyumba (Gicumbi District) were established in farmers' fields in both 2017A and B seasons for a participatory variety selection, demo plots and awareness creation to popularize 10 new commercial wheat varieties, that is Gihundo, Majyambere, Keza, Nyaruka, Reberaho, Cyumba, Rengerabana, Mizero, Kibatsi and Nyangufi. The varieties were evaluated in comparison with 3 local checks (Njoro, Chozi, Musama) usually grown by farmers. Each line was planted on 0.005 ha plot. Towards maturity, farmers from the surrounding areas and other stakeholders were invited to view these lines and select those they like best and name them (Photo 6). Based on their agronomic potentials, the varieties tested were ranked from the higher to the lower performant as follows: Gihundo, Nyaruka, Majyambere, Keza, Reberaho, Njoro, Cyumba, Rengerabana, Mizero, Kibatsi, Chozi, Musama and Nyangufi. On average, grain yield varied in farmers' fields from 4.99/ha for Gihundo to 3.54 t/ha for Nyangufi.



Photo 6: Participatory variety selection, Cyumba/Gicumbi, 2017A

A field day organized on 25th January 2017 for variety appreciation and dissemination. Additionally, there is no doubt that their baking quality is desirable by millers, bakers and consumers as they were earlier tested in Kenyan labs before they got disseminated in Rwanda. They can also be used as parents in a crossing program.

Field day and national agricultural show: The objective of both events, field day and agricultural show, was to showcase new varieties among the farmers, to create demand for improved seed of the varieties and other technologies, and to create visibility for RAB. RAB organized a field day that took place on January 25th, 2017 in Rwerere to popularize new 10 high yielding varieties with acceptable milling and baking qualities and consumers' preferences. The variety names popularized are Gihundo, Majyambere, Keza, Nyaruka, Reberaho, Cyumba, Rengerabana, Mizero, Kibatsi and Nyangufi. It involved more than 100 wheat stakeholders from different corners of Rwanda. Participants included farmers, seed producers, agro-dealers, processors, local leaders, security staff, media agents, decision makers, consumers, traders, extension agents and researchers. Honorable Minister of State in charge of Agriculture in Ministry of Agriculture and Animal Resources (MINAGRI) was the Guest of Honor in the event (Photo 7). The field day was an opportunity for wheat stakeholders to share knowledge and various views on wheat value chain and agree on strategies aiming at increasing productivity and improving wheat market.



Photo 7: Participants (L) and Hon. Minister of State /MINAGRI & Journalists (R), Rwerere, Jan. 2017

Moreover, exhibition of good wheat heads and/or grains is another way that can be used to attract farmers to ask for wheat production technologies from RAB. National agricultural show organized by MINAGRI in June 2017 was an opportunity to the wheat subprogram of RAB to popularize the newly-promoted varieties so that farmers, agricultural partners, policy-makers, and other stakeholders are made aware of technologies developed by RAB through wheat research. Therefore, the varieties comprising Nyaruka, Gihundo, Majyambere, Keza, Nyangufi, Reberaho, Cyumba, Kibatsi, Rengerabana and Mizero were exhibited in the 12th National Agricultural Show organized by MINAGRI from 22nd to 27th June 2017 at Mulindi Show Ground (**Photo 8**). About a half kilo of wheat grains picked from each of the 10 varieties were separately packed in different plastic pots that were placed on a stand for exhibition.



Photo 8: 12th National Agricultural Show, at Mulindi Show Ground, 22-27 June 2017

In addition, 300 factsheets of yellow and stem rusts and powdery mildew; and 2,400 leaflets on appropriate agronomic practices (1,200) and post-harvest management practices (1,200) were developed and disseminated to the visitors.

Assessment and identification of capacity gaps in technology utilization and management practices in wheat production systems and value chains

A baseline study on wheat crop production and marketing was conducted in Musanze, on 13-16 December 2017. The activity was financially supported by IFAD-CIMMYT-funded Project known as “Enhancing Smallholder Wheat Productivity through Sustainable Intensification in Wheat-based Farming Systems of Rwanda and Zambia (SWPSI)”. The research sites were located in 4 Cells (Mudakama, Rungu, Rubindi and Murago) of Gataraga Sector, Musanze District. Structured questionnaire was jointly prepared by RAB and CIMMYT scientists. Questionnaires were used by enumerators to interview wheat farmers randomly selected from those who had grown wheat in 2017A in the target sites. Selection of research sites and households involved local leaders (District, sector, Cell and Village leaders), farmer groups and individual farmers. A total of 160 households from the target area were subjected to the study and formed a representative sample.

The survey aimed to collect information on knowledge of wheat variety and use, cropping system (land utilization), production and average prices at harvest, plot level information on wheat production (main plot), labor use in wheat production (main plot), comparison of production costs between wheat (main plot) and the major cash crop (potato), more information from the main wheat plot in season 2017A, and wheat produce utilization and marketing.

The study revealed that the commonly grown wheat varieties include Maroko, Gisukari, Sayire and Ingwizabukundu with 23.2%, 19.9%, 19% and 15.9%, respectively; with Chozi and Gihundo being the less known varieties (0.2% each). High yield and taste are the major qualities for variety preference, while lodging, susceptibility to diseases, low yields and lower prices were identified as the main challenges to wheat production in the area. The information obtained from the survey will be used in determining the intervention points, and assist in setting monitoring benchmarks for impact assessment.

Rust diagnostic: Three types of rusts (stem or black, stripe or yellow and leaf or brown) are among the most devastating fungal diseases of wheat worldwide and can cause 60% yield loss or more under favourable conditions. Unfortunately, little is known about the diversity of the pathogens in Rwanda while wheat is one of the priority crops in the country. The objective was to collect wheat rust samples from on-station trials and farmers' fields and to identify rust races that are prevailing in wheat growing areas of Rwanda to subsequently design appropriate breeding strategies.

In February 2017, 81 samples of stem rust samples caused by *Puccinia graminis* f. sp. *tritici* (*Pgt*), were collected in February 2017 from Research Centers of Kinigi, Musanze and Rwerere and wheat farmers' fields of Burera and Musanze Districts. The survey complies with the global rust surveillance as a strategy to combat wheat rusts worldwide. Collected rust samples were killed with 80% ethanol and sent to the Cereal Disease Laboratory (CDL) at USDA-ARS, at University of Minnesota in USA, for race analysis. Preliminary results revealed that 3 *Pgt* races, namely, TTKSK, TTKST and TKTTF have been prevalent in Rwanda. Three samples of yellow rust, caused by *Puccinia striiformis* f. sp. *tritici* (*Pst*), were collected from diseased plants in CAVM field, in Busogo. These samples were shipped alive to the Global Rust Reference Center (GRRRC), Denmark for DNA analyses and races characterization, the results are still awaited.

1.3.1.4 Sorghum

Sorghum is one of important cereal crops in Rwanda. It is a drought resistant, low input cereal grain grown throughout the world. It is adapted to a wide range of tropical as well as temperate climates, although it is best known for its adaptation to drought-prone semi-arid tropical regions. Despite its importance, sorghum productivity in Rwanda had not yet reached its yield potential

due to insufficiency of improved varieties, poor agronomic practices and pests. Therefore, sorghum research is focused on variety improvement to reduce the gap between the potential and real yield. During 2016-2017, sorghum sub-program has carried out a number of research activities. These dealt mainly with variety development so as sorghum farmers can access good seed that that can help them obtain good yield. Preliminary yield trials as well as advancing lines to next generations were done.

Preliminary yield trials

Twenty seven (27) high yielding, multipurpose uses and early maturing lines were evaluated in preliminary yield trials. Out of 27 lines, 21 lines were selected and will be evaluated in advanced yield trials.

Generation of F6 high yielding, early maturing sorghum varieties (Kigufi ×Ikinyaruka)

At Rubona experimental fields, 28 F5 lines were advanced to generate F6 high yielding, early maturing sorghum varieties. As results, 22 high yielding, early maturing sorghum varieties were selected. Selected lines will then be advanced to F7 generation.

Generation of F6 high yielding, early maturing and vigorous sorghum varieties (Amabanda × Mabereyingoma)

Fourteen (14) F5 high yielding, early maturing and vigorous sorghum varieties (Amabanda *Mabereyingoma) were advanced to give F6 generation and 8 lines were selected and will subsequently be advanced to F7 generation.

Generation of F6 high yielding, white grain and early maturing varieties (IS9202 × IS21219)

Twenty three (23) F5 high yielding, early maturing and high land sorghum varieties were advanced to F6 generation. At harvest, 18 lines were selected to be advanced to F7 generation.

Generation of F 7 high yielding, multipurpose uses and early maturing sorghum varieties

Out of 29 lines evaluated, 15 F6 high yielding, multipurpose uses and early maturing sorghum lines were selected. These lines will be assessed in preliminary yield trials in next season.

Generation of F5 high yielding, low tannin and early maturing sorghum varieties (SDL-160 × IS21219)

In this trial, twenty-two lines (SDL-160*IS21219) were chosen among forty-eight lines and were therefore advanced to F5 generation. Selected lines should be used to develop F6 generation.

Generation of F4 high yielding, vigorous and early maturing sorghum varieties (Kigufi × Mabereyingoma)

Thirty-one lines (F3 generation) were used to develop high yielding, vigorous and early maturing varieties. At harvest time, lines were evaluated following desired traits. It was realized that only 15 lines were good and they will be used to produce F4 generation.

1.3.2 Pulses

1.3.2.1 Beans

Bean is the most important staple in Rwanda and the main source of protein in local diets. Bean yields are threatened by frequent droughts, violent rains, and a complex of pests and diseases. Current bean research targets to develop bio-fortified varieties with high yield and good pests and disease resistance. To improve population iron intake and decrease the prevalence of iron deficiency among women of child bearing age, school children, and children under 5 years of age through improved access to iron bio-fortified bean varieties in Rwanda, bean research concentrates on the development and testing of bean high in iron, and as a secondary objective, high in zinc content.

Variety evaluation: A total of 1157 segregating bean lines including 610 climbing lines and 547 bush lines were evaluated and advanced to subsequent generations from 2017A to 2017B. A total of 155 lines including 100 climbing and 50 bush bean lines will be advanced to preliminary yield trail in 2018A and B seasons. A total of 653 varieties were tested in preliminary yield trials, intermediate yield trial, advanced yield trial, multi-location yield trial, adaptability trial and national performance trial of bush and climbing types.

National performance trial (NPT), 1st set of climbing beans: In 2017A and B 7 genotypes including 665SI-4/1 and MBC 71 introduced from CIAT, RWV 2350-2B, RWV 2365-2 bred from Rwanda, Rwibarura collected from farmers and RWV1129, a released high Fe bean variety used as check, were tested in 20 environments in national performance trial (1) involving climbing beans. Significant differences were observed among tested genotypes ($P < 0.001$), among environments and the genotype X environment effects were highly significant at $P < 0.001$ on both yield, Fe and Zn content, respectively. Due to drought that affected yield, all tested genotypes were superior on minimum basis while 665SI-4/1, MBC 71 and RWV 2350-2B were superior to the rest. Nyiramagorori, Rwibarura and RWV 2365-2 have specific adaptation to the highlands of Northern Rwanda ([Table 17](#)).

Table 17: Mean yield of 7 bean varieties evaluated in 20 environments in national performance trial 1 (NPT1) of climber beans during 2017 A and B seasons

Location + season/variety	665SI-4/1	MBC 71	Nyiramagori	Rwibarura	RWV 1129	RWV 23501-2B	RWV 2365-2
Kanyirakagori 2017A	3000	3000	1800	1300	2400	1600	2500
Kanyirakagori 2017B	3000	3000	1800	1300	2400	1600	2500
Karama 2017B	1600	1600	800	2000	1200	2000	1400
Kinigi 2017A	4200	4400	3300	3100	4500	4800	3800
Kinigi 2017B	3500	4333	3417	2583	3000	2500	4167
Kitabi 2017A	1571	1571	1714	1041	1357	1214	714
Kitabi 2017B	1571	1571	1714	1041	1357	1214	714
Muhanga 2017A	2800	1720	1784	880	2320	2400	1080
Muhanga 2017B	2750	2060	1792	1690	1760	2200	1640
Muhoza 2017A	4400	4600	3200	3200	4400	5000	4000
Muhoza 2017B	4867	4383	3267	3933	4700	4833	4583
Ngoma 2017A	753	850	379	1391	873	671	425
Ngoma 2017B	740	626	832	947	622	635	683
Nyagatare 2017B	2155	2500	864	708	375	2793	1897
Nyamagabe 2017B	184	408	469	1204	127	167	363
Rubona 2017A	1156	1069	1239	849	1055	1385	842
Rubona 2017A Site2	2737	2325	1905	2252	2075	2492	3123
Rubona 2017B	1156	1069	1239	849	1055	1385	842
Rwerere 2017A	4031	4362	4375	4656	4906	3500	3281
Rwerere 2017B	4031	4474	4375	4656	4906	3500	4165
LSD= 220 kg		Grand mean = 2225 kg		CV=16%	G***	E***	GXE***

Rwibarura and RWV 2350-2B had higher Fe than other genotypes. All tested genotypes had higher than average Zn performed better but only 3 genotypes that showed superior performance in previous seasons were selected for release. These include Rwibarura, RWV 2350-2B and MBC 71. Though Nyiramagorori showed 6% higher Fe than the check, its capacity to accumulate Fe might be unstable. It should be used in bean improvement and more tests are recommended to confirm its stability and Fe content absorption.

National performance trial (NPT), set 2 of climbing beans: During 2017 A and B seasons, 8 bean varieties including MBC 23, MBC 64 introduced from CIAT, RWV 2352-1A, RWV 2357-B-3, RWV 2699-1, RWV 2828-1 and RWV 3346 bred from Rwanda were evaluated along with RWV 1129, a high Fe bean variety released in Rwanda, which was used as improved check. Varieties performed differently with significant differences among tested genotypes ($P<0.001$), test environments ($P<0.001$) with strong genotype X environment effects ($P<0.001$) on yield performance.

Table 18: Mean yield of 8 bean varieties evaluated in 17 different environments in national performance trial (NPT), 2nd set of climbers during 2017 A and B seasons

Environment + season/ variety	MBC 23	MBC 64	RWV 1129	RWV 2352-1A	RWV 2357-B-3	RWV 2699-1	RWV 2828-1	RWV 3346	
Kanyirandoli 2017A	2875	2500	1625	2627	3500	1125	2375	2875	
Karama 2017A	1800	1600	1200	1600	1800	1600	1800	1200	
Kinigi 2017A	1937	1250	2687	4687	1937	3125	3000	2812	
Kitabi 2017A	2800	800	880	2073	2800	1760	2320	1640	
Muhanga 2017A	1680	2480	1600	2560	1760	2560	1920	2400	
Muhanga 2017A	1538	1923	1231	1538	923	1692	385	1308	
Muhoza 2017A	2375	1625	2500	2125	2750	2000	2750	1250	
Musanze 2017B	3917	2833	4167	4000	3500	2500	3333	3500	
Ngoma 2017 A	1399	1218	1113	1498	1870	2100	1868	1641	
Ngoma 2017 B	1288	1012	1279	1483	1318	1600	1393	1141	
Nyagatare 2017A	1240	1160	1120	1100	1420	1520	1640	1320	
Nyagatare 2017B	2856	2462	2885	2500	2904	2596	2596	2500	
Nyakiriba 2017A	2500	2625	1875	2500	2250	1250	2125	1125	
Rubona 2017A	1068	1209	1161	1618	1919	1381	421	1127	
Rubona 2017B	1921	2758	2362	3247	3189	2715	3208	1935	
Rwerere 2017B	1140	891	1333	833	937	990	1344	1281	
Rwerere 2017A	4232	3982	5667	2969	3896	4042	3750	4958	
LSD = 98kg	Grand mean= 2103 kg				CV = 12%	GxE***			

The mean yield ranged from 5,667 to 385 kg/ha with the grand means ranging from 1902 and 2292kg/ha. The genotype MBC 23, which was selected for its Fe potential performed better along with RWV 2352-1A, RWV 2357-B-3 and RWV 2828-1, which were selected to this trial for their high yielding capacity (**Table 18**).

The evaluation of iron content of tested varieties showed that RWV 2699-1 and MBC 64 performed better than the rest of the genotypes, which were selected to this trial for their yield performance. The variety MBC 23, which was recommended for many previous seasons did not show -4% of ppm compared to high iron check used. The results on mean zinc content of tested genotypes indicate that MBC 23 and RWV 3346 performed better than the high iron content check, with 1 and 5 % more, respectively. Based on the potential of accumulating Zn content, there is no difference between MBC 23 and the actual high Fe check.

National performance trial (NPT), 1st set of bush beans

No significant differences were observed in yield of the tested varieties. This implies that all tested varieties are superior and are recommended for release as high yielding bush bean varieties. Environments were significant at $P < 0.001$ while no genotype X environment effects

observed. The mean yield ranged between 1394 and 1581kg/ha with the potential yield ranging from 2481 to 3040kg/ha (Table 19).

Table 19: Mean yield of 4 varieties evaluated in 11 different environments in national performance trial (NPT), 1st set of bush beans during 2017 A and B seasons

Location/ variety	BOA 5-1/16	RWR 2245	RWR 3194	RWR 3228
Kanyirandoli	1,200	1,160	1,040	560
Kitabi	83		1,015	967
Muhanga A	3,040	1,600	1,440	1,920
Muhanga B	2,640	1,800	1,600	1,840
Ngoma A	841	917	1,388	1,239
Ngoma B	701	608	588	617
Nyagatarre A	1,900	1,733	1,867	2,333
Nyagatara B	1,821	2,481	2,474	2,564
Nyamagabe B	1,061	449	980	1,633
Rubona A	913	946	1,013	1,026
Rubona B	2,823	2,247	2,828	2,696
LSD= 781kg	Grand mean= 1601 kg	%CV= 32	G ns	E*** GXE ns

This report shows that the varieties RWR 3194 and BOA 5-1/16 performed better on Fe accumulation with 2 to 6% above the high Fe check, respectively. These results confirm the previous evaluations and these varieties as recommended for projected release for high Fe content varieties. The mean Fe content of tested genotypes ranged from 71 to 77 ppm with the mean Fe content potential of 88 to 93 ppm (Table 20).

The zinc content evaluation shows that BOA 5-1/16 and RWR 3228 had high potential of accumulating high zinc content during the 2017A and B seasons. The mean zinc content varied from 32 to 36 ppm with the potential mean of 40 to 48ppm.

Table 20: Mean Fe content of 4 varieties evaluated in 11 different environments in national performance trial (NPT) 1st set of bush beans during 2017 A and B seasons

Environments	BOA 5-1/16	RWR 2245	RWR 3194	RWR 3228
Kanyirandoli	84	68	82	84
Kitabi	78	73	73	71
Muhanga A	78	92	84	88
Muhanga B	65	71	70	69
Ngoma A	73	66	63	55
Ngoma B	84	68	67	61

Nyagatare A	81	65	76	68
Nyagatare B	74	77	78	65
Nyamagabe B	65	71	70	69
Rubona A	93	82	86	82
Rubona B	74	69	68	67
LSD= 10ppm	Grand mean= 73.62ppm	%CV= 8	G ns	E** GXE ns

National performance trial (NPT), 2nd set of bush beans

Five genotypes including CIMR00321-L, SCB 790, SCR16 and USCR9xRWR 2074xG2333xRWR 719F2-1-4 were tested along with the improved check (RWR 2245) in 12 environments during 2017 A and B seasons. The results of yield evaluation of 5 bush bean genotypes tested under 12 different environments show no significant differences among tested varieties with significant differences among test environments. No genotype X environment effects were observed on yield performance of tested varieties. Though the general yield performance of tested varieties was not superior to improved check, the tested genotypes were previously selected for their yield potential.

Fe content evaluation shows that CIMR00321-L and USCR9xRWR 2074xG2333xRWR719F2-1-4 had high potential of Fe content accumulation and are recommended to be planted in the nutritional nursery. The Fe accumulation potential varied from 70 to 89 ppm with the grand mean ranging from 57 to 70ppm (Table 21). Zn content results show that none of tested genotype had the potential of high Zn content when compared to improved check. The mean zinc content ranged from 32 to 37ppm for the tested varieties while the improved check had the grand mean of 37ppm. Since these varieties have been tested for many years, they might have got other beneficial and preferred traits and might be improved for yield and Fe content.

Table 21: Mean Fe of 5 varieties evaluated in 12 different environments in national performance trial (NPT) 2nd set of bush beans during 2017 A and B seasons

Environments and season	Mean Fe content (ppm) of 5 bean genotypes tested in NPT 2nd set of bush beans in 2017				
	CIMR00321-L	RWR 2245	SCB 790	SCR16	USCR9 X RWR 2074 X G2333 XRWR 719F2-1-4
Kanyirandoli	69	71.3	69.8		65
Karama B	57.9	79.8	67.8	60.9	71.9
Kitabi B	66.4	69.07	49.4	64.1	82
Muhanga A	89.3	78.73	56.2	69.5	82.1
Muhanga B	63.3	68.7	54	75	63.7

Ngoma A	69.2	65.6	59	67.3	63.5
Ngoma B	75.3	67.5	50.9	56.2	83.7
Nyagatare A	65.8	64.5	62.5	52.2	69.4
Nyagatare B	74.72	67.9	56.2	72.8	84.2
Nyamagabe B	62.1	61.2	53.4	70.4	73.9
Rubona A	85.35	81.95	63.15	76.15	72.25
Rubona B	65.67	68.57	46.73	62.3	72.33
LSD= 8.6ppm	Grand mean= 67.5ppm	%CV= 8.4	G ***	E**	GXE ns

Advanced yield trials (AYT): The results of the experiment of advanced yield trial of 22 bush bean entries showed the potential of accumulating the Fe content of all tested genotypes with the potential range of 77 to 99 ppm of Fe content while the yield performance varied from 568 to 2920. This experiment is recommended to be repeated in different environments to validate Fe content and yield stability.

Multilocation yield trials (MYT): Of 18 climbing genotypes tested in multi-location yield trial phase 1 of climbing beans, all genotypes had high yield and Fe content. The mean Fe content ranged from 65 to 86 ppm of Fe with the potential ranging from 79 to 94 ppm of Fe. Yield results were ranging from 763 to 2235 kg/ha. The trial will be repeated in 2018A and B for the validation of the results. Of 18 bush entries evaluated in multi-location yield trial of bush phase one, based on minimum capacity of accumulating Fe content, all genotypes performed better than the check with the potential Fe content varying from 69 to 91 ppm. Based on yield performance the average yield varied between 1125 and 2229kg/ha. Participatory variety selection was performed on these trials and will be validated in 2018A and B.

1.3.2.2 Soybean

Soybean is an important pulse crop in Rwanda, but its productivity is low being affected by droughts and diseases. Thus, soybean research is focused on (i) developing high yielding, early yielding and adapted varieties through breeding; (ii) seed production and (iii) rhizobium production for inoculation.

Variety breeding

Selection of parents for future crosses: A total of 354 single plants of the available local varieties ([Photo 9](#)) were selected for good health (no symptoms of any disease), good vigor (more branches, height, biomass), number of pods on single plant, number of grains in a pod (at least 2 to 3 grains), early maturing, not lodging, not dehiscent and good physical appearance. The individual plants selected were separately harvested in its own container and will be planted in next season for evaluation of their stability and performance.



Photo 9: Individual plant selection for stability and performance

Soybean lines evaluation

A total of 1107 tested lines from Missouri University, USA, showed high genetic potential for seed yield, resistance to pod dehiscence and lodging, satisfactory field resistance to major diseases and adaptation to the growing conditions in Rubona and Karama. A total of 100 lines were selected for adaptability and disease tolerance.

Participatory variety selection on farm

Four new varieties, in which two varieties (S822/6/13 and S823/6/16) received from Seed Co and other two (RWSOY-15-1 and RWSOY-15-2) were tested on farm in Ruhuha, Rwinkwavu, Ngororero and Kamonyi with altitude range from 900 m to 1600m. Variety selection focused on high and early yield and tolerance to diseases. The farmers appreciated all varieties due to their early maturity with high yield arranged between 1.5 to 1.9 t/ha ([Photo 10](#)).



Photo 10: Participatory selection of soybean varieties

Production of soybean breeder, pre-basic and basic seeds

Breeder (330.5kg) , pre-basic (548kg) and basic seeds (20188kg) were produced during 2016-2017 at Rubona, Nyagatare, Ngoma and Karama Centers (Table 22). Seeds were produced in accordance with procedures to ensure genetic purity and diversity including site selection, soil preparation, isolation, fertilization, phytosanitary treatments, negative and positive selection, harvesting and post-harvesting procedures.

Table 22: Seed production during the season 2017A&B

	Site/ Variety	Rubona	Nyagatare	Ngoma	Karama	Musenyi	Gashora	Total
Breeder seed (kg)	Peka6	0	83	28.5	0	0	0	111.5
	SB 24	0	0	26	0	0	0	26
	S0102	0	55	27	0	0	0	82
	S0103	0	87	24	0	0	0	111
	Subtotal							330.5
Pre-basic seed (kg)	Peka6	0	425	0	0	0	0	425
	SB 24	97	26	0	0	0	0	123
	S0102	0	0	0	0	0	0	0
	S0103	0	0	0	0	0	0	0
	Subtotal							548
Basic seed (kg)	Peka6	2000	829	7457	2800	3000	3050	19136
	SB 24	0	1052	0	0	0	0	1052
	S0102	0	0	0	0	0	0	0
	S0103	0	0	0	0	0	0	0
	Subtotal							20188
Total								

Rhizobium inoculum production

From July, 2016 to June, 2017 the Laboratory of microbiology has produced inoculants for soybean and bean as it is mentioned in table below.

Table 23: Rhizobium inoculum doses produced at RAB Rubona

Description	Quantity (Packet)
Total rhizobium produced	7494 pcs of 80g and 500 pcs of 10g
Sold & Authorized for research use	2124 pcs for 80g and 500 pcs for 10g
Available in stock by June 30/2017	5370 pcs for 80g

Quality control was regularly checked by performing the Most Probable Number (MPN) test every 6 months to confirm the number of viable cells in the produced inoculants. If the number of cells found was below 10 cells, the concerned inoculants was discarded.

1.3.3 Roots, Tubers and Banana

1.3.3.1 Irish Potato

Potato (*Solanum tuberosum L.*) is an important food and cash crop in Rwanda. It is mainly grown in the highlands of the country especially in the North-West. Potato crop is cultivated on 100,000ha. The current yield is around 10t/ha. This is low yield is caused by a mixture of different challenges faced by farmers such as pests and diseases pressure, shortage of clean potato seeds, inadequate agricultural practices, declining soil fertility, postharvest losses and weak technical information flow.

In vitro and in vivo maintenance of potato germplasm

A total of 70 potato clones including released varieties, clones under evaluation and those maintained for breeding purpose were maintained in vitro and in open field.

In vitro rapid multiplication for mass propagation of potato plantlets in the tissue culture laboratory

Potato micropropagation is a routine activity providing plantlets for minituber production in the screenhouses. A total of 1,283,770 *in vitro* plantlets were produced.

Potato minituber production

Minitubers are produced from *in vitro* propagated plantlets planted at high density in a soil medium in conventional screenhouses. A total of 1,054,000 minitubers were produced. In addition, direct transfer of *in vitro* potato plantlets to the open field. The direct transfer covered 2.4 hectares at RAB Kinigi Center and 1 hectare at BRAMIN Farm in Kayonza and a total of 8,002,166 minitubers were produced. A total of 653,891 potato minitubers were produced by aeroponics at RAB Musanze.

Potato variety development

Participatory evaluation experiments with 6 clones: CIP393077.159, CIP393251.64, CIP396081.241, CIP392617.54, CIP395112.6, CIP399075.22 and CIP393371.58 have been established in Musanze, Burera, Nyabihu and Rubavu districts. The most outperforming clones were CIP393077.159, CIP 392617.54 and CIP 393371.58 (Table 24). Breeder seeds were produced for the following clones: CIP393077.159, CIP393251.64, CIP396081.241, and CIP393371.58 using direct planting of plantlets in the field.

Table 24: Total tuber yield (T/Ha) in two sites

Cultivar name	Muhoza	Nyabihu
Kinigi	38.88	38.22
CIP 393077.159	38.88	45.91
Kirundo	33.93	31.41
CIP 392617.54	33.47	33.21
CIP 395112.6	29.28	38.44
Victoria	29.12	Not evaluated
CIP 393371.58	26.8	47.85
CIP 393371.164	26.33	29.58
CIP 399075.22	25.39	34.66
CIP 398190.615	16.97	28.25
CIP 396018.241	16.06	19.85
CIP 393280.64	14.03	29.72
Kuruseke	Not evaluated	36.74
LSD(5% level)	5.7	13.8

The first on- station potato experiments were established in Kinigi and Tamira station, consisting of the following clones: CIP394611.112, CIP398190.89, CIP392797.22 and CIP392657.8 to evaluate their agronomic performance (yield and resistance to diseases). The local checks were Kirundo and Kinigi. The experiments have been harvested and data analyzed on yield. The yield obtained were as follows Kirundo (28.97 t/ha) CIP392797.22 (22.03 t/ha) and Kinigi 21.95 t/ha, CIP394611.112 (12.63 t/ha), CIP398190.89 (16.45 t/ha) and CIP392657.8 (18.78 t/ha).

The second on- station experiment was established in Kinigi, consisting of the following local bred potato clones: RWPOT012.8, RWPOT012.10, RWPOT012.3, RWPOT012.22, RWPOT012.7, RWPOT012.46, RWPOT012.14, RWPOT012.24, RWPOT012.43, RWPOT012.34, RWPOT012.28, RWPOT012.2, RWPOT012.26 and RWPOT012.16. The experiments have been harvested and data analyzed on yield. There was significant difference in terms of total tuber yield between the clones (Table 3). However, the clones are promising for yield because most of the evaluated clones have yield above 20.0t/ha

Table 25: Total tuber yield (T/Ha)

Clone name	Yield (T/ha)
RWPOT012.28	29.7
RWPOT012.10	27.5
RWPOT012.24	26.74
RWPOT012.16	26.04
RWPOT012.8	23.76
RWPOT012.34	21.64
RWPOT012.46	21.41
RWPOT012.26	20.63
RWPOT012.2	20.43
RWPOT012.14	20.15
RWPOT012.7	17.85
RWPOT012.43	17.18

Experiments of biofortified potato clones were also established in collaboration with “Centre International pour la Pomme de terre (CIP)” to develop potato cultivars with increased Iron and Zinc content. For this purpose, two populations of biofortified potato clones were evaluated: the first on- station trials evaluation of 98 biofortified (cycle III breeding) were established in Kinigi, Rwerere and Sigira. The second evaluation of 16 biofortified (cycle II breeding) was established in Kinigi and Rwerere. The established experiments have been harvested and data collected on phenotypic characteristics as well as on yield. Samples of 98 biofortified clones harvested in Kinigi, Rwerere and Sigira and samples of 16 biofortified clones harvested in Kinigi and Rwerere were also collected for Nutritional quality (Fe and Zinc) analysis.

Establishment of potato crossing block to generate new potato genotypes: The purpose of the activity is to build the national potato breeding program. For this activity crossing block to generate new potato genotypes have been established and crosses between selected potential potato parents are being conducted to improve the local adapted potato varieties preferred by farmers but lacking some quality preferences by consumers.

New variety evaluation

Ten new potato varieties were imported from Netherlands by BRAMIN Ltd (as minitubers) in March 2015. These varieties are namely Fabula, Panamera, Voyager, Sagitta, Challenger, Sifra, HZD 02-1499, Memphis, Taurus and Derby. These varieties belong to HZPC Holland B.V, a Dutch breeder company in Netherlands. In 2016B season, they were planted at Kinigi and Musanze for seed increasing for National Performance Trial (NPT).

In Cyuve site, new varieties had similar yield with local checks. In Mudende site, only three new varieties (Voyager, Panamera and HZD02) performed as well as local check (Kinigi). In

Cyanika site local checks (Kinigi and Kirundo) yielded better than any of new varieties. Thus, across the sites, none of new varieties outperformed local checks (Kinigi and Kirundo) (Table 26). The evaluation will be continued in the next season.

Tolerance to late blight: Even if all trials were treated with fungicides, symptoms of late blight were observed. Few leaf lesions (score 2) were observed in Mudende trials, low to medium damage (score 2-5) on stems and leaves in Cyuve trial and Medium to severe damage (score 5-9) on stems and leaves at Cyanika trial. Late blight pressure varies from one site to another, high in Cyanika, medium in Cyuve and low in Mudende.

Table 26: Total tuber yield (T/Ha) in three sites during season 2017A

Variety	Cyuve	Cyanika	Mudende	Mean
Kirundo (Check)	39.8 ^a	37.1 ^a	51.4 ^a	42.8
Mean of 2 checks	33.7	40.0	45.6	39.7
Kinigi (Check)	27.5 ^{abc}	43.0 ^a	39.7 ^b	36.7
Voyager	24.4 ^{bcd}	24.0 ^b	31.9 ^{bcd}	26.8
Panamera	22.7 ^{bcd}	22.2 ^{bc}	30.7 ^{bcd}	25.2
Sagitta	30.9 ^{ab}	19.6 ^{bc}	19.7 ^{de}	23.4
HZD02	22.5 ^{bcd}	14.2 ^{bc}	33.2 ^{bc}	23.3
Derby	18.3 ^{bcd}	16.6 ^{bc}	27.0 ^{cde}	20.6
Challenger	21.7 ^{bcd}	12.2 ^c	26.3 ^{cde}	20.1
Memphis	15.2 ^{cd}	16.7 ^{bc}	25.5 ^{cde}	19.1
Taurus	21.3 ^{bcd}	12.8 ^c	19.2 ^f	17.8
Fabula	12.1 ^d	16.4 ^{bc}	21.6 ^{cde}	16.7
Sifra	12.3 ^d	11.6 ^d	23.3 ^{cde}	15.7
Mean	22.4	20.5	29.1	24.0
LSD(5% level)	12.5	9.4	10.9	10.9

Note: a, b, c, d, e and f are group stratum

1.3.3.2 Sweet Potato

Sweet potato is one of the main starchy staples in Rwanda. During this year, the program has focused on in situ conservation of 152 accessions, in vitro and on field multiplication of orange fleshed sweet potato varieties, their dissemination and promotion of high yielding sweet potato varieties through different channels including exhibition and agri-show. The Sweet potato sub-program has been supported by Sweet potato Action for Security and Health in Africa (SASHA II), SUSTAIN, The Feed The Future Rwanda Orange Fleshed Sweet potato (OFSP) for Income and Nutrition Project in Rwanda (FtF project) and AGRA projects in collaboration with the International Potato Center (CIP) and Alliance for Green Revolution in Africa (AGRA) project.

Development of new sweet potato varieties

A total of 152 accessions were maintained *in situ* in Rubona center. In order to develop new sweet potato varieties, 16 sweet potato varieties with 16 replications were planted in crossing block in Rubona center. The diallel was used as a mating design in sweet potato crossing block. After hand pollination activities, a total number of 1,758 controlled sweet potato seed and 2691 non controlled sweet potato seeds were harvested and stored. A scarification of sweet potato seed in Rubona laboratory is planned, to allow the seed germination and set up a clonal evaluation trial.

On station trials

One clonal evaluation trial, one preliminary yield trial and one advanced yield trial were established in Southern zone (Rubona center) and Eastern zone (Karama center) during the season 2017B. **Clonal evaluation:** A total of 314 clones were planted and evaluated for disease tolerance in Rubona and Karama. After harvesting, selected clones will be assessed for disease tolerance, especially, for virus and *Alternaria*, and the root flesh colour. **Preliminary yield trial:** A preliminary yield trial of 18 varieties was established in Rubona and Karama center during the season 2017B. Data will be recorded on virus and *Alternaria* tolerance, biomass and yield. **Advanced yield trial:** A total of 88 clones (76 clones and 12 parents) were established in Rubona and Karama in 2017B. Data will be recorded on virus and *Alternaria* tolerance, biomass and yield.

Basic seed multiplication

High yielding and early maturing yellow fresh sweet potato (YFSP), white flesh sweet potato (WFSP) and Orange flesh sweet potato varieties (OFSP) rich in vitamin A were maintained and multiplied in Rubona *in vitro*. A total of 74,260 sweet potato plantlets of Vita, Kabode, Terimbere and Gihingumukungu, Maryoha, SP1123, SP 3736, UW-11906, SP 5091, SP 2569, Maphuta, Tacna were produced.

Multiplication and dissemination of sweet potato vines

In vitro plantlets were transferred in nursery beds to produce enough sweet potato cuttings. In total, 5.65 ha vine plots were planted in Rubona, Kigembe and Karama. They produced 2,641,650 sweet potato vines, which were distributed to sweet potato vine multipliers and individual farmers in Southern, Northern and Eastern zones ([Photo 11](#)).



Photo 11: Sweet potato multiplication plot in Karama center (Left), distribution of sweet potato vines (right)

Establishment of sweet potato demonstration plots

A total of 68 demonstration plots were established in 17 districts (Bugesera, Rwamagana, Kayonza, Gatsibo, Rulindo, Gakenke, Musanze, Burera, Rubavu, Gicumbi, Karongi, Rutsiro, Ngororero, Muhanga, Ruhango, Nyamagabe and Nyaruguru). Four demonstration plots in each district with 5 sweet potato varieties (Terimbere, Kakamega 7, Kabode, Vita, Gihingumukungu) and local check were established supported by SUSTAIN and FtF project in collaboration with the key partners, Imbaraga, YWCA, DERN, OSPECA and UNICOPAGI in season 2017B. On each site, each variety had been planted on four ridges with 17 plants per ridge without replication. Data were recorded on yield and disease tolerance. Yield and virus tolerance were highly affected by variety and environment (district) ($p < 0.001$, [Table 27](#)).

Effect of variety : Kabode and Gihingumukungu were the best yielders with 13.7 and 12.9 tonnes/ha, respectively. However, the new varieties (Terimbere, Vita, Gihingumukungu and Kabode) did yield as good as the local variety ([Table 27](#)).

Table 27: Mean yield and virus tolerance of the tested varieties

Variety	Mean yield, t/ha	Variety	Mean virus tolerance
Kakamega 7	7.33a	Kabode	1.7a
Local variety	11.37b	Vita	1.7a
Terimbere	12.42b	Gihingumukungu	1.9ab
Vita	12.85b	Terimbere	2.1bc
Gihingumukungu	12.87b	Local variety	2.4c
Kabode	13.74b	Kakamega 7	2.8d

Effect of environment: Gatsibo and Rubavu were the districts presenting the best yield of 19.64, 19.42 tonnes/ha respectively while Gicumbi, Burera and Ruhango presented the lowest yield of 6.71, 6.98, 7.03 tonnes/ha, respectively ([Table 28](#)). All varieties showed low score of virus tolerance (less than 3) ([Table 27](#)). For *Alternaria* tolerance, all varieties were highly resistant to *Alternaria* with a score ranging between 1.0 and 1.5 (none or low

incidence). Yield was the highest in Gatsibo, Rubavu and Muhanga (17.8-19.6 t/ha, [Table 27](#)). Virus pressure was the lowest in Gicumbi with a score of 1.4, while Rwamagana, Gakenke and Ruhango presented the highest score of 2.8, 2.9, 2.9, respectively ([Table 28](#)). *Alternaria* incidence was very low, with highest value of 1.5 in Gatsibo, and Rubavu, Muhanga and Ngororero showing higher incidence than in the rest of districts ([Table 28](#)).

Table 28: Mean yield, virus tolerance and *Alternaria* incidence per district

District	Mean yield, t/ha	District	Mean virus tolerance	District	Mean incidence of <i>Alternaria</i>
Gicumbi	6.71a	Gicumbi	1.4a	Burera	1.0a
Burera	6.98a	Nyamagabe	1.6ab	Gakenke	1.0a
Ruhango	7.03a	Rubavu	1.6ab	Gicumbi	1.0a
Karongi	7.92ab	Rulindo	1.7ab	Karongi	1.0a
Bugesera	7.92ab	Nyaruguru	1.7ab	Muhanga	1.0a
Nyamagabe	8.11abc	Rutsiro	1.8ab	Musanze	1.0a
Nyaruguru	8.62abc	Karongi	1.9ab	Ngororero	1.0a
Musanze	8.78abcd	Kayonza	1.9ab	Nyamagabe	1.0a
Rulindo	10.02abcd	Ngororero	1.9ab	Nyaruguru	1.0a
Rutsiro	12.43bcde	Bugesera	1.9abc	Rubavu	1.0a
Kayonza	12.77cde	Muhanga	2.2bcd	Rulindo	1.0a
Rwamagana	13.35def	Burera	2.5cde	Rutsiro	1.0a
Gakenke	16.18efg	Musanze	2.5cde	Bugesera	1.1ab
Ngororero	16.22efg	Gatsibo	2.6de	Ruhango	1.3bc
Muhanga	17.82fg	Rwamagana	2.8e	Kayonza	1.4cd
Rubavu	19.42g	Gakenke	2.9e	Rwamagana	1.4cd
Gatsibo	19.64g	Ruhango	2.9e	Gatsibo	1.5d

During harvesting time, a consumer test was conducted on one site in each district where the farmers cooked the harvested roots from 6 varieties, tasted and ranked them according their preference, colour and other traits ([Photo 12](#)).



Photo 12: Farmers ranking sweet potato varieties during the consumer test conducted in Southern zone

Promotion of sweet potato varieties through agriculture show

Sweet potato sub-programme participated in agriculture show organized from 22nd to 27th June 2016 at Mulindi, when in collaboration with CIP (International Potato Center) and 2 Key partners (Imbaraga and YWCA) we exhibited sweet potato highly yielding varieties with vitamin A content, different products made from sweet potato puree and sweet potato flour and the sweet potato value chain from in vitro up to the end users. In addition to the distribution of 13.6 million cuttings, which were affected by 2017A season drought, the programme has participated in large campaign to avail vines during the Army week as indicated in the [Table 29](#).

Table 29: Sweet potato area covered, vines distributed and related cost in Agriculture Army week

District of Destination	Area to be covered (ha)	Number of Sweet potato vines	Lot of Sweet potato vines	Weight of Sweet potato vines (kg)	Vines Cost (Frw)
Nyaruguru	27.5	1,155,000	578	17,325	11,550,000
Nyagatare	106.83	4,486,800	2,243	67,302	44,868,000
Kirehe	17	714,000	357	10,710	7,140,000
Ngoma	66.87	2,808,600	1,404	42,129	28,086,000
Gisagara	26.2	1,100,400	550	16,506	11,004,000
Nyanza	20.5	861,000	431	12,915	8,610,000
Kamonyi	9.5	399,000	200	5,985	3,990,000
Ruhango	2.5	105,000	53	1,575	1,050,000
Muhanga	12.5	525,000	263	7,875	5,250,000
Huye	19.1	802,200	401	12,033	8,022,000
Bugesera	14.07	591,000	296	8,865	5,910,000
Kayonza	26	1,092,000	546	16,380	10,920,000
Rulindo	16.69	700,980	350	10,515	7,009,800
Gakenke	10	420,000	210	6,300	4,200,000
Gicumbi	16	672,000	336	10,080	6,720,000
Burera	11	462,000	231	6,930	4,620,000
Musanze	1.3	54,600	27	819	546,000
Karongi	50.04	2,101,628	1,051	31,524	21,016,280
Ngororero	20.5	861,000	431	12,915	8,610,000
Nyamasheke	6.3	264,600	132	3,969	2,646,000
Rwamagana	47.3	1,986,192	993	29,793	19,861,920
Nyamagabe	23.6	991,200	496	14,868	9,912,000
Gasabo	24.9	1,045,800	523	15,687	10,458,000
Total	576.2	24,200,000	12,100	363,000	242,000,000

Training of farmers to promote dual-purpose sweet potato varieties

A training on sweet potato agronomic practices, construction and management of net tunnels as a low cost method of preservation of commercial vines at farmer's level, were organized by SUSTAIN and FtF project in Muhanga and Kigali. A total of 123 participants (Agri promoters, Decentralized Vine Multipliers, agronomist from CARITAS, One Acre Fund, FXB, CRS, AEE) were trained (Photo 13). The use of net tunnels helped sweet potato multipliers to multiply themselves clean sweet potato vines and expand their sweet potato multiplication plot.



Photo 13: Decentralized Vine Multipliers (DVM) training in Musanze district

1.3.3.3 Cassava

Cassava (*Manihot esculenta* Crantz), an important staple food crop, was introduced into Rwanda in the 1930s and spread in different agro-ecologies. The current average yield of 1.5 t ha^{-1} (NISR, 2016) in Rwanda is nine and fifty-six times lower than the average yield in SSA and yield potential of at 90 t ha^{-1} , respectively. This could be attributed to the lack of good varieties (high yielding, disease resistant, high dry matter content), long growing cycle, low soils fertility, poor agronomic practices, disease free planting materials and postharvest losses (Nduwumuremyi et al., 2016). The crop is currently being promoted as a cash crop through the establishment of cassava processing plants. But the established cassava processing plants face challenges of lacking raw materials (good quality and enough quantity of cassava storage roots without pulp defects).

In 2012, the Kinazi Cassava Plant (KCP) commissioned to add value to the large and growing cassava production in the country targeting the production of high quality flour for local, regional and international markets. But since 2015, cassava production declined considerable mainly due to the pandemic of cassava brown streak disease (CBSD) and cassava mosaic disease (CMD). In addition, a collapsed seed system and supply mechanisms, low productivity, poor market linkage between producers and processors, poor agricultural practices and undeveloped value chain, and as consequence the KCP does not functioning at its full potential while some small cassava processing plant were posed to close their doors. In order to unravel the challenges and promote cassava as cash crop in the country, RAB cassava sub-program embarked on development of a sustainable production system through development of superior varieties. Therefore, the 2016-2017 research and extension agenda focused on cassava variety development and disease assessment countrywide.

Variety development

Germplasm collection

Thirteen parental genotypes (Table 30) were collected and planted in crossing block to generated half and full sibs. They showed various level of tolerance to diseases indicating the possibility of generating good recombinants through hybridization. This germplasm will be very useful in future breeding.

Table 30: List of collected genotypes with useful traits

Parental materials collected	Attributes
MM96/0669	Dual tolerance (CMD and CBSD) and improved yield (Southern-Muhanga)
MM96/2134	Dual tolerance (CMD and CBSD) and improved yield (Southern-Muhanga)
Gahene/2	Dual tolerance (CMD and CBSD) and improved yield
MM96/8299/1	Dual tolerance (CMD and CBSD) and improved yield
05/0127/35	Dual tolerance (CMD and CBSD) and improved yield
MH95/0414/1	Dual tolerance (CMD and CBSD) and improved yield
TME419/60	Dual tolerance (CMD and CBSD) and improved yield
NAROCASS1	Dual tolerance (CMD and CBSD) and improved yield
Ndamirabana/7	Dual tolerance (CMD and CBSD) and improved yield
Mushedile	Landrace with tolerance to CBSD in Western province

Clonal and yield trials

Eleven clones were advanced at Preliminary yield trial (PYT) for further testing at Nyagatare, Karama and Rubona in 2017A. The progress results at six months after planting showed that CMD and CBSD, incidence and severity were observed at different levels. The incidence and severity varied between centers, they were high at Karama and relatively low at Rubona.

GxE interaction and clonal selection

The locations or environments affected differently ($p < 0.05$) the expression of yield, CMDs, CBSDi and CBSDs for the evaluated clones. The variation due to locations for CBSD was 42.3% and 51.7% for CBSDi and CBSDs respectively (Table 31). The GxE effects were significant ($p < 0.05$) for all traits, implying the importance of conducting multi-locations trials and selection and varietal release based on agro-ecological zones.

Table 31: Combined analysis of variance and variation

Source of variation	Mean squares					
	DF	FSRY	CMDi	CMDs	CBSDi	CBSDs
Locations	2	1066.67*	20.89	0.84*	1754.93***	35***
Rep (Locations)	6	107.67**	4.29	0.13	8.91	0.73
Clones	11	39.6	7.42***	0.49***	86.56**	0.91
Clones : Locations	22	60.23**	7.52***	0.39***	90.04***	0.93*
Residuals	66	28.28	1.94	0.1	28.11	0.52
Source of variation	Sum squares					
	DF	FSRY	CMDi	CMDs	CBSD	CBSDs

Locations (L)	2	2133.34	41.79	1.68	3509.9	70
Rep (Locations)	6	646	25.75	0.79	53.5	4.38
Clones (C)	11	431.87	81.63	5.43	952.2	10.07
Clones :Locations	22	1325.15	165.58	8.64	1980.9	20.53
Residuals	66	1866.79	128.4	7.09	1855.4	34.83
% variation due to L		37.06	10.01	7.36	42.30	51.69
% variation due to C		11.22	19.56	23.77	11.47	7.44
% Variation due to C:L		23.02	39.67	37.83	23.87	15.16
% residual		32.43	30.76	31.04	22.36	25.72

DF: degree of freedom, FSRY: Fresh storage root yield, CMDi: cassava mosaic disease incidence, CMDs: cassava mosaic disease severity, CBSDi: cassava brown streak disease incidence, CBSDs: cassava brown streak disease severity

The biplot of yield indicates the superiority (high yield, stable and tolerant to cassava viral diseases) of the clones: 01/1412/63 and 01/1371-5. The selection index also demonstrates the same (Figure 3 and Table 32).

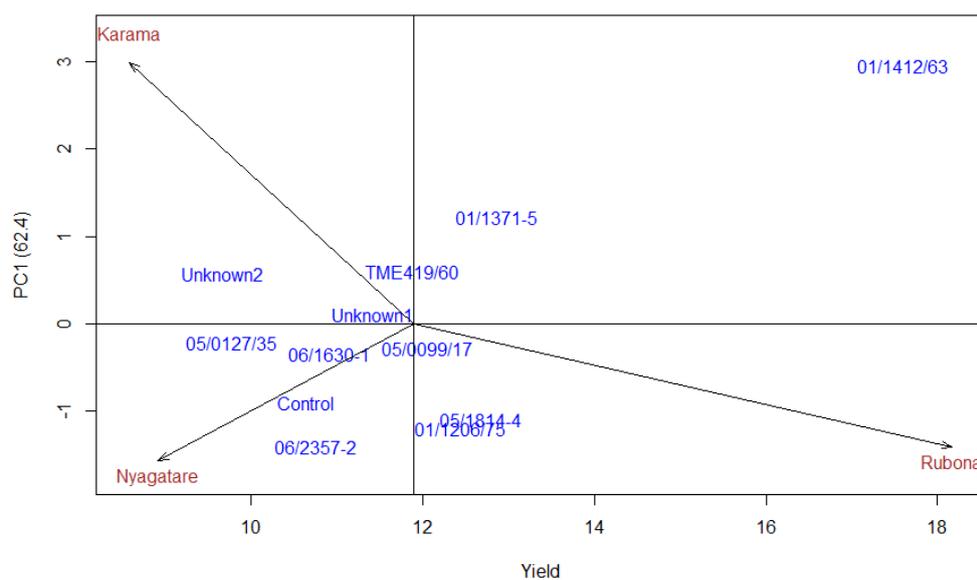


Figure 2: Biplot for yield of evaluated clones

Table 32: Selection of elite clones

Clones	Yield t ha ⁻¹	CMDi	CMDs	CBSDi	CBSDs	SI	Ranks
01/1412/63	17.6	0.6	1.1	5.0	1.6	70.5	1
01/1371-5	12.9	0.0	1.0	0.6	1.4	63.2	2
05/1814-4	12.7	3.0	1.6	7.9	2.3	39.2	5
01/1206/75	12.4	0.0	1.0	4.2	1.7	45.5	4
05/0099/17	12.1	1.0	1.2	11.0	2.1	17.8	10
TME419/60	11.9	0.0	1.0	2.7	1.8	48.5	3

Unknown1	11.4	0.2	1.3	8.1	2.1	22.6	9
06/1630-1	10.9	0.0	1.0	6.9	2.4	24.1	8
06/2357-2	10.8	0.0	1.0	5.1	2.0	32.2	6
Control	10.6	1.6	1.7	9.3	2.3	17.0	11
05/0127/35	9.8	0.9	1.2	9.7	1.9	12.2	12
Unknown2	9.7	0.0	1.0	4.4	1.9	29.9	7

SI: selection index, CMDi: cassava mosaic disease incidence, CMDs: cassava mosaic disease severity, CBSDi: cassava brown streak disease incidence, CBSDs: cassava brown streak disease severity

New clones for release

Four clones with dual tolerance to both CMD and CBSD and yield ranging from 20 to 30 t ha⁻¹ were selected for superior quality. The table 4 summarizes the major characteristic of the selected clones ready for release pending availability of enough planting materials for large distribution the multipliers and farmers.

Table 33: New clones for release

Characteristics	Clone 1	Clone 2	Clone 3	Clone 4
Clone name	01/1206/75	01/1412/63	05/0127/35	TME 419/60
Fresh root yield (t/ha)	25 - 30	25 - 30	20-25	20-25
Duration to harvest	12 months	12 months	12 months	12 months
Color of root pulp	Cream	Cream	White	White
Taste	Intermediate	Intermediate	Intermediate	Intermediate
Disease tolerance	Dual (CMD &CBSD)	Dual (CMD &CBSD)	Dual (CMD &CBSD)	Dual (CMD &CBSD)

Pre-basic seed multiplication

Under emergency response to cassava seed crisis, millions of cuttings of NASE14 and NAROCASS 1 were imported from Uganda for basic seed and large-scale multiplication in mother gardens with support from FAO and MINAGRI. The selected clones were multiplied. Currently basic seed multiplication of NASE14 and NAROCASS 1 is on 22 ha at RAB research centers. The large scale of multiplication of mother garden estimated at more 835 ha countrywide.

Cassava disease assessment

A country-wide survey was conducted in 10 cassava growing districts of Rwanda. Ninety-three cassava farmers' fields of 3 to 6 months and 100 fields of above 6 months were visited. About 279 and 300 cassava leaf samples were collected for laboratory analysis for CMBs and CBSVs, respectively. Molecular characterization for CMBs and CBSVs was done for 279 and 300 samples, respectively. A total of 40 out of 93 (43%) fields of 3 to 6 months and 36 out of 100 (36%) fields of above 6 months showed CMD and CBSD symptoms, respectively. Mean CMD severity was the highest in Nyagatare and Nyanza (4) and the lowest in Bugesera (2.6) districts. The majority of fields (56.9 %) were free of CMD, while the number of infected fields ranges between 1.1% and 22.6% for severity scores 2 to 5 (Table 33). For CBSD, the majority of fields (64 %) were free of CBSD, while the number of infected fields

ranges between 13.6% and 55.6 % for severity scores 2 to 4 (Table 34). The incidence of CMD was the highest in Nyamasheke (70%) and the lowest in Nyanza and Rusizi (10%) districts (Table 1). The incidence of CBSD was the highest in Kamonyi (90%) and the lowest in Kirehe and Nyamasheke (0%) districts (Table 4).

Table 34: Incidence and severity of cassava mosaic disease in different districts

District	No fields	Frequency of CMD Severity score					Severity	%Incidence
		1	2	3	4	5		
Nyagatare	10	5	0	1	3	1	4.0	50
Kayonza	10	5	0	4	1	0	3.2	50
Kirehe	10	5	1	3	1	0	3.8	50
Bugesera	10	5	2	3	0	0	2.6	50
Kamonyi	10	6	1	2	1	0	3	30
Ruhango	10	7	0	3	0	0	3	30
Nyanza	10	9	0	0	1	0	4	10
Gisagara	10	6	2	2	0	0	2.5	40
Nyamasheke	10	3	0	3	4	0	3.6	70
Rusizi	3	2	0	0	1	0	4	10
Total	93	53	6	21	12	1	3.4	47
%	100	56.9	6.5	22.6	12.9	1.1		

Table 35: Severity of Cassava Brown Streak Disease` in different districts

Districts	No of field	CBSD Severity score					Mean severity	% Incidence
		1	2	3	4	5		
Nyagatare	10	9	1	0	0	0	2.0	10
Kayonza	10	8	2	0	0	0	2.0	20
Kirehe	10	10	0	0	0	0	0.0	0
Bugesera	10	5	2	2	1	0	2.8	50
Kamonyi	10	1	7	2	0	0	2.2	90
Ruhango	10	4	4	1	1	0	2.5	60
Nyanza	10	3	2	5	0	0	2.7	70
Gisagara	10	6	1	1	2	0	3.3	40
Nyamasheke	10	10	0	0	0	0	0.0	0
Rusizi	10	8	1	0	1	0	3.0	20
Total	100	64	20	11	5	0	2.1	100
Percent		64	55.6	30.6	13.9	0.0		

Cassava mosaic disease was more widespread and severe in Eastern and Western provinces (Figure 4), while CBSD was mostly severe and distributed in Southern province (Figure 5).

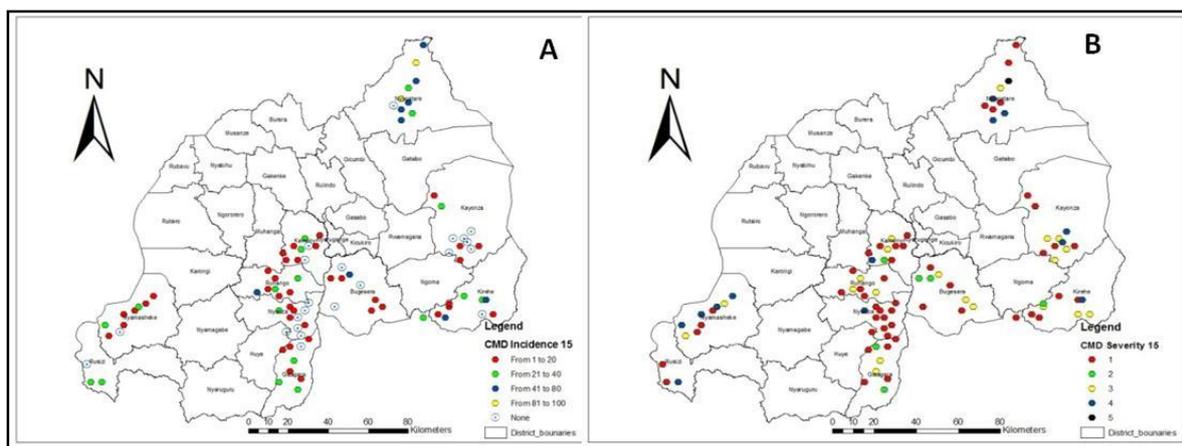


Figure 3: Incidence (A) and severity (B) distribution maps of cassava mosaic disease in Rwanda

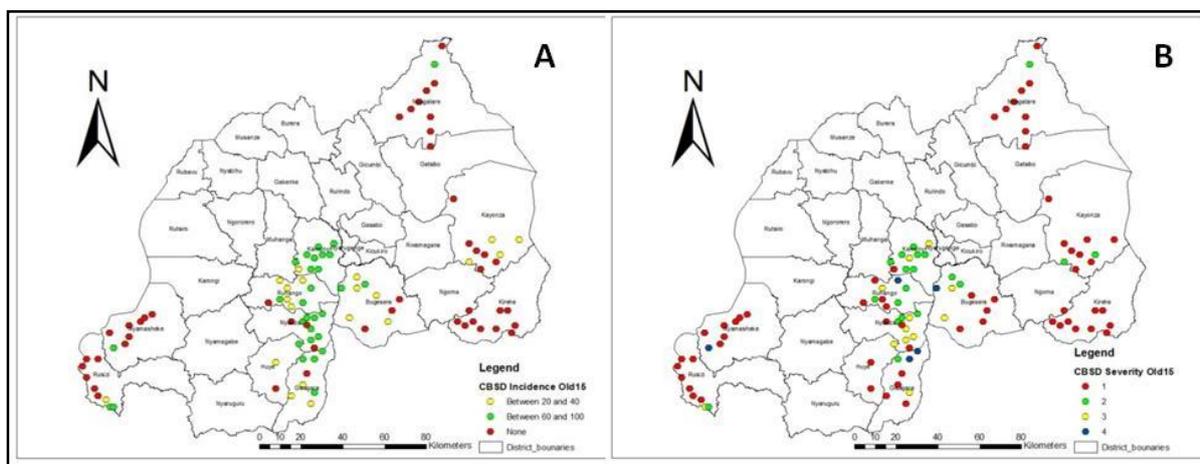


Figure 4: Incidence (A) and severity (B) distribution maps of cassava brown streak disease in Rwanda

Characterization of emerging viruses

A total 28 out of 279 samples (10%) were positive for CMBs, with EACMV (7.9%), ACMV (1.1%) and co-infection (1.1%). EACMV was the highest in Kirehe, while ACMV and co-infection were the highest in Nyanza and Kirehe, respectively (Table 6). The RT-PCR analysis for CBSVs showed a high percent of CBSV infection (10%) followed by UCBSV (9.67%) and 1.67% co-infected plants. Co-infection was found in Southern Province (Nyanza and Gisagara) and Eastern Province (Bugesera) (Table 36).

Table 36: Cassava mosaic begomo-viruses detection

Districts	Number of samples	CMBs			Mean	Percent
		ACMV	EACMV	ACMV+EACMV		
Kayanza	30	0	3	0	3	1.1
Kirehe	30	0	9	3	12	4.3
Nyagatare	30	0	2	0	2	0.7
Bugesera	30	0	2	0	2	0.7
Kamonyi	30	0	4	0	4	1.4
Ruhango	30	0	1	0	1	0.4
Nyanza	30	2	1	0	3	1.1
Gisagara	30	0	0	0	0	0
Nyamasheke	30	1	0	0	1	0.4

Rusizi	9	0	0	0	0	0
<i>Total</i>	<i>279</i>	<i>3</i>	<i>22</i>	<i>3</i>	<i>28</i>	<i>10</i>
<i>%</i>	<i>100</i>	<i>1.1</i>	<i>7.9</i>	<i>1.1</i>	<i>10</i>	

ACMV: African cassava mosaic virus, EACMV: East african cassava mosaic virus, ACMV+EACMV: combined cassava mosaic virus

Table 37: Occurrence of cassava brown streak viruses in leaf samples

District	No samples	CBSVs			Total	Percent
		CBSV	UCBSV	CBSV+UCBSV		
Kayonza	30	3	0	0	3	1.1
Kirehe	30	0	0	0	0	0.0
Nyagatare	30	0	0	0	0	0.0
Bugesera	30	2	4	1	7	2.5
Kamonyi	30	9	1	0	10	3.6
Ruhango	30	6	2	0	8	2.9
Nyanza	30	7	9	3	19	6.8
Gisagara	30	3	8	1	12	4.3
Nyamasheke	30	0	0	0	0	0.0
Rusizi	30	0	5	0	5	1.8
<i>Total</i>	<i>300</i>	<i>30</i>	<i>29</i>	<i>5</i>	<i>64</i>	<i>22.9</i>
<i>Percent</i>		<i>10.0</i>	<i>9.7</i>	<i>1.7</i>	<i>22.9</i>	

UCBSV: Ugandan cassava brown streak viruses, CBSV+UCBSV: combined cassava brown streak viruses and Ugandan cassava brown streak viruses

1.3.3.4 Banana

Banana is one of the major staples and important cash crops in Rwanda, occupying 23% cultivated land. Banana yields and production are declining due to banana wilt and its current control, insufficient quantity of and access to quality plant material, low management standards and increased nutrient removal from farms to cities. Dessert banana yields and cultivated are extent are limited by fusarium wilt affecting market preferred varieties (Gros Michel and Kamaramasenge). Thus, banana research and development activities focused on germplasm conservation, introduction of new varieties, seed production, banana rehabilitation and disease control.

Germplasm conservation

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

Introduction of new varieties

A total of 29 new cooking banana varieties, which were bred by NARO and IITA through conventional breeding using East African banana parents, were introduced. They include 3 PITA-s and 26 NARITA-s series of varieties. These varieties have good cooking quality attributes. Field experiment aiming to evaluate their yield potential was established in Rubona and the plants are close to first flowering stage.

Seed production

RAB was involved in limited seed production of suckers. A total of 2,800 suckers was produced in Rubona and disseminated to farmers in the Southern Province. About 80 seed multipliers were involved in certified seed production, mostly in Eastern province. They have capacity to provide about 120,000 suckers from their banana fields. Disseminated varieties included Injagi (cooking), Mpologoma (cooking), FHIA 17 (cooking and dessert) and FHIA 25 (juice).

Banana rehabilitation

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

Banana disease control

Banana wilt, the most serious and epidemic banana disease, was controlled through organization of banana wilt control campaigns with support from districts and sectors. Banana research team has provided technical support to local authorities during campaigns, and during the Army week in May-June 2017. A total of 20, 500 farmers were involved in banana wilt control campaigns.

1.3.4 Horticulture and cash crops

1.3.4.1 Horticulture

The Horticulture Program at RAB focuses its research for development on a few priority fruits and vegetables. The fruits include avocado, citrus, tree tomato (tamarillo), passion fruit (maracuja), mango, pineapple, water melon and apple. Vegetables include exotic ones (tomato and sweet and hot pepper) and indigenous ones like amaranths (imbwija/dodo), spiderplant (isogi), nightshade (isogo) and African eggplant (intoryi). The selection of priority fruits and vegetables is based on the commercial interest and the potential to generate income for farmers.

Evaluation of performance of four watermelon varieties under different rates of NPK fertilizer

This trial was carried out in 2017A (September to December) and 2017B (February to May) seasons at two RAB stations, which are Karama (Bugesera) and Rubona (Huye). Generally, the

yield of water melon was higher in Karama than that in Rubona (Figure 1). This is probably because watermelon performs well in middle altitude compared to higher altitude. The optimum performance was recorded with 100% of recommended fertilizer (90:60:60 of N:P:K kg/ha) for both hybrids and open pollinated varieties.

Evaluation of spacing and pruning techniques for cultivation of open pollinated varieties and hybrids of watermelon (Citrullus lanatus)

This trial was carried out in 2017A (September to December) and 2017B (February to May) seasons at two RAB stations, which are Karama (Bugesera) and Rubona (Huye). For the cultivation of watermelon Hybrids, the 2 m x 1 m spacing was the best compared to others and recorded the highest fruit size, fruit yield per plant (kg) and fruit weight per ha (t) at both Karama and Huye sites in the two seasons (Figure 6). The same spacing was also the best for cultivation of watermelon open pollinated varieties. Pruning to four main vines with two fruits per vine is the best method for management of watermelon vines. This practice resulted in the highest number of fruit per plant, fruit yield per plant (kg) and fruit weight per ha (Figure 3).

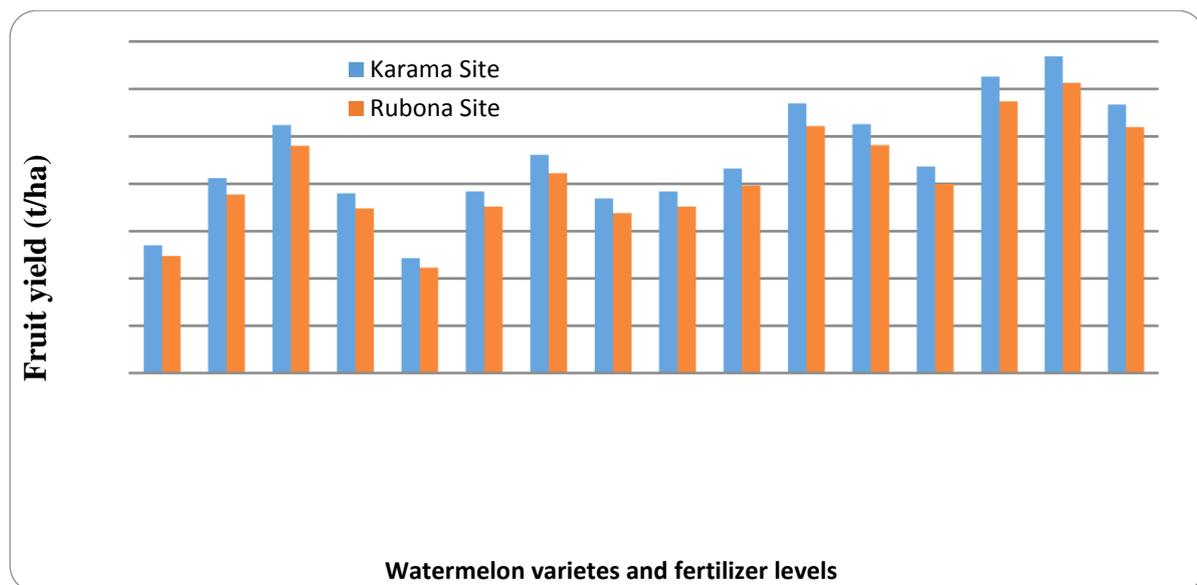


Figure 5: Yield of four watermelon varieties under different rates of NPK fertilizer

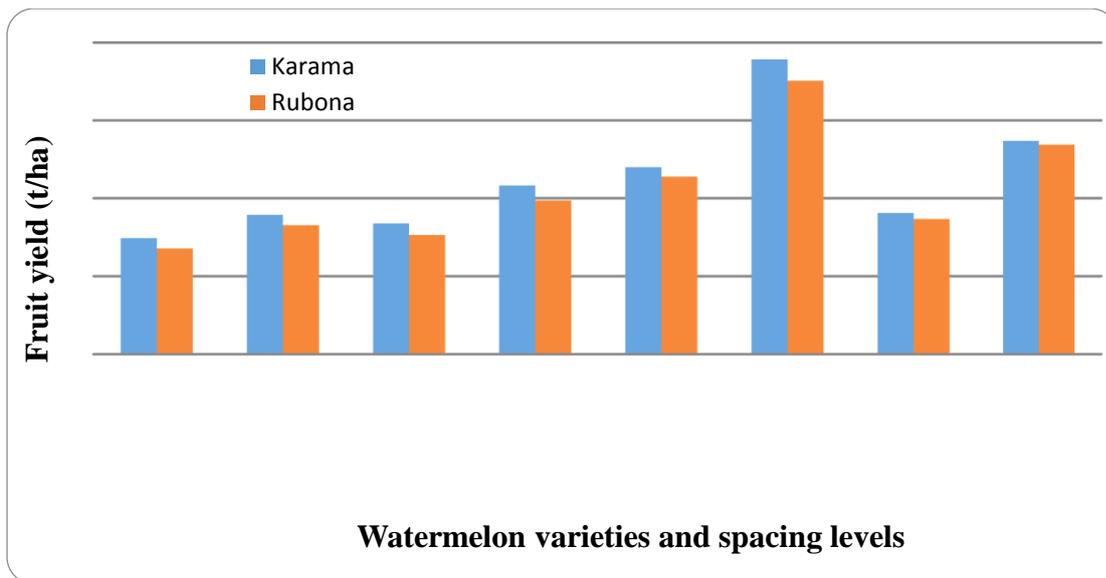


Figure 6: Fruit yield (t/ha) of watermelon under different spacing levels

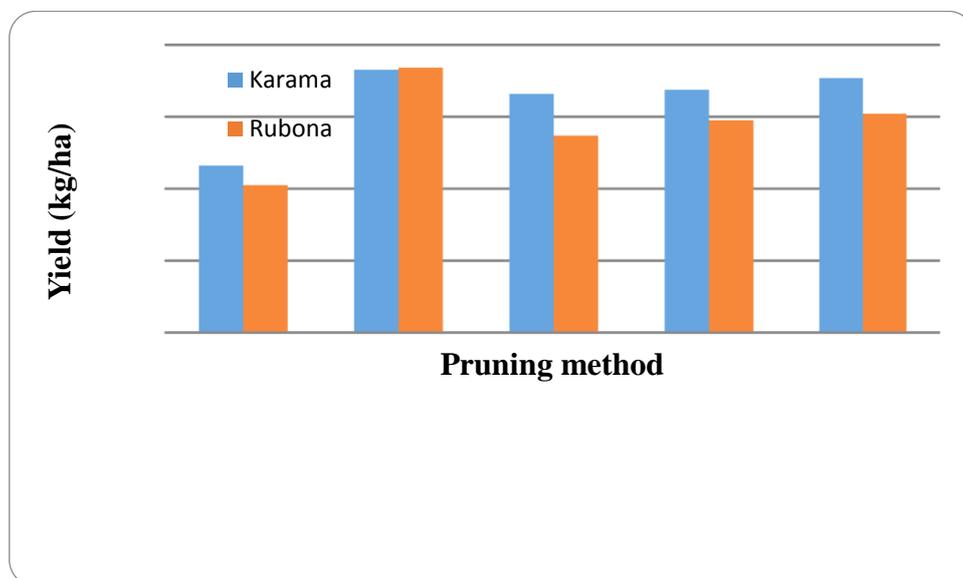


Figure 7: Pruning effect on growth and yield of watermelon

Integrated management of *Pseudocercospora* leaf and fruit spot disease in on-station and on-farm citrus orchards

The experiment was carried out in one RAB site (Bugarama) and a farmer's field in Rwinkwavu sector, Kayonza district, starting in season A 2017 (November 2016). The components tested for the integrated management of *Pseudocercospora* leaf and fruit spot disease are fungicides, weeding, collection of fallen and diseased fruits and burying them, pruning of old branches, planting of cover crop (*Mimosa spp.*) and application of inorganic fertilizer NPK (17-17-17). At Rwinkwavu, the best disease control on leaves was observed with Daconil alone, which reduced the disease incidence to 27.35% as compared to the control with 55.97% (Figure 9) while Bugarama had the lowest disease severity after applying Benlate in alternation with Copper hydroxide (1.17 %) (Figure 10). Since Benlate is a systemic and

expensive fungicide, it could be used by alternating it with copper fungicides, thereby avoiding pathogen resistance and reducing fungicide application costs. For efficient and effective disease control, we recommend that pesticides use be combined with cultural practices like pruning, collection and burying of diseased plant parts, cover crop, fertilizer application and weeding.

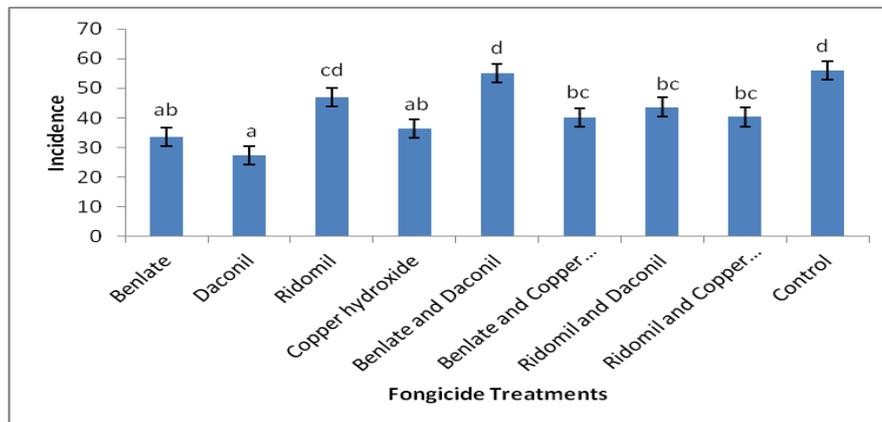


Figure 8: Effect of fungicides sprays on incidence of *Pseudocercospora* leaf spot disease of citrus at Rwinkwavu, Kayonza District

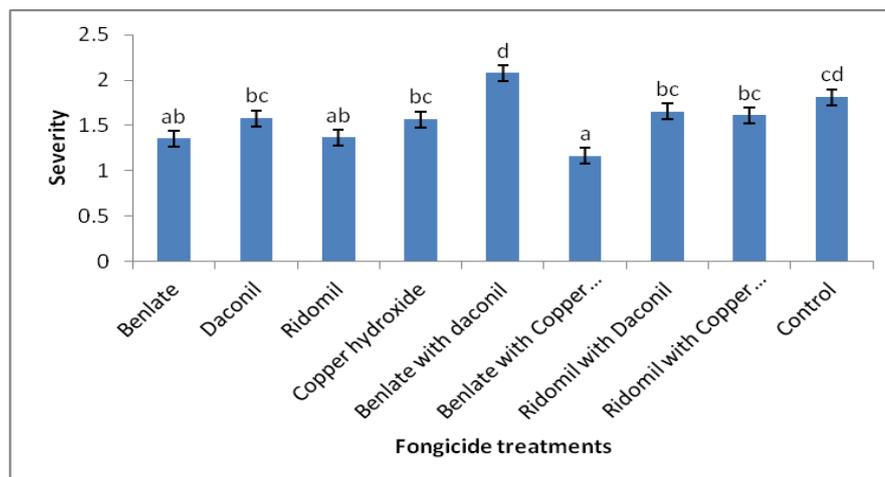


Figure 9: The effect of fungicides sprays on severity of *Pseudocercospora* leaf spot disease of citrus at Bugarama RAB site, Rusizi District

Evaluation of border/intercrops for management of aphids as virus vectors in hot pepper

The study was conducted at Rubona and Karama RAB stations located in Southern and Eastern provinces, respectively, from November 2016 to August 2017 (Photo 14). At both sites, sunflower used as a border plant or intercrop recorded the lowest number of aphids (Table 38). More importantly, the crops used either as border crops or intercrops did not affect the yield of hot pepper indicating that they can be utilized in the management of aphids during hot pepper production.



Photo 14: Field layout showing evaluation of the efficacy of border crops for management of aphids as vectors at Rubona (left) and Karama (right) RAB stations.

Table 38: Effects of different border/intercrops on aphid population on hot pepper (Var. Scotch bonnet) yield at Rubona and Karama sites

Treatment	Season (Nov16-May 17)		Season (April-Aug 17)	
	Rubona	Karama	Rubona	Karama
Sole pepper	1.5 ^a	1.0	1.8 ^{bc}	1.6 ^{bc}
Maize intercrop	–	0.9	2.1 ^{ba}	1.9 ^a
Sorghum intercrop	0.9 ^d	0.9	1.6 ^{dc}	1.6 ^{bc}
Sun flower intercrop	1.1 ^{bd}	0.8	1.6 ^{dc}	1.5 ^{dc}
Maize border	–	1.0	2.2 ^a	1.8 ^{ba}
Sorghum border	1.4 ^{ba}	1.0	2.0 ^{ba}	1.3 ^d
Sunflower border	1.0 ^{dc}	0.9	1.3 ^d	1.5 ^{dc}
Insecticide (Rocket 44EC)	1.2 ^{bac}	1.0	1.6 ^{dc}	1.4 ^{dc}
P Value (0.05)	0.0014	0.2682	<.0001	<.0001

Mean values with different alphabet along the column are significantly different from each other at $P \leq 0.05$

Screening of local and international isolates of beneficial nematodes for management of target pests under laboratory conditions

These studies aimed at evaluation of native and exotic isolates of Entomopathogenic Nematodes (EPNs) as biocontrol agents of cutworms and bean fly both under laboratory conditions. The native ones were recently isolated in Rwanda. All the work was carried out at the biocontrol laboratory at Rubona RAB station. At a concentration of 50 IJ/Larva, exotic strains *Steinernema longicaudum* (X-7) and *S. carpocapsae* (ALL) caused greater cutworm larval mortality of 70% and 33%, respectively, after 96 hrs (Figure 11). This was followed by the Rwandan strain *S. carpocapsae* (GR3a-2) with 13% mortality. At a concentration of 100 IJ/larvae, exotic strain *Steinernema longicaudum* (X-7) and *S. carpocapsae* (ALL) caused even greater cutworm larval mortality of 100% and 62.2%, respectively. This was followed by the

Rwandan strain *Steinernema* sp. (MC2b-1) with 26.7% mortality. These observations indicate the possibility of using local isolates for the management of cutworms. However, more experiments are needed to confirm the results.

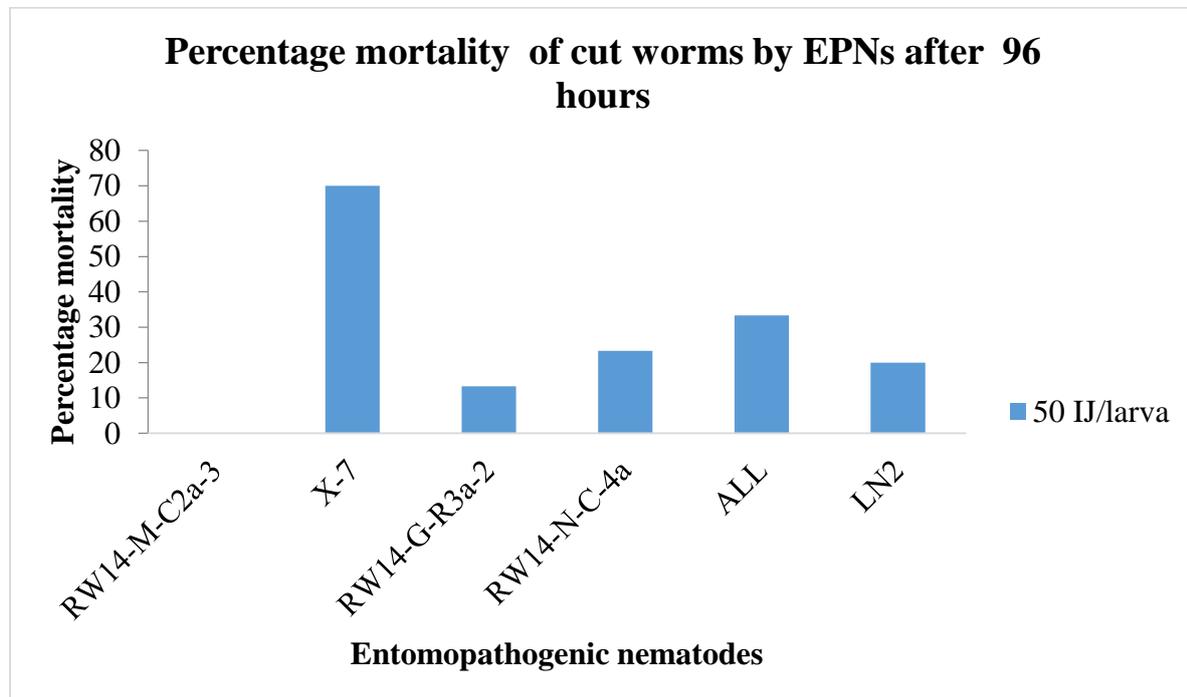


Figure 10: Percentage mean mortality of cutworms larva caused by entomopathogenic nematodes compared to control after 96 hours of infection

The first set of the bioassay involving bean fly, the percentage mortality of bean fly maggot caused by Rwandan strain *Steinernema carpocapsae* (G-R3a-2) ranged between 25-32% while, *Steinernema* sp. (MC2b-1) registered a mortality of 15-25% compared to control (Fig. 8). In the second set of the bioassay, Rwandan strain *Steinernema carpocapsae* (GR3a-2) caused a greater mortality (31%) to bean fly maggot at a concentration of 100 IJ/maggot, when compared to other nematodes, followed by *Steinernema* sp. (MC2a-3) (25.8%) and exotic the isolate *Heterorhabditis indica* (LN2) (25%). This shows the possibility of using this local isolate for the management of bean fly maggot.

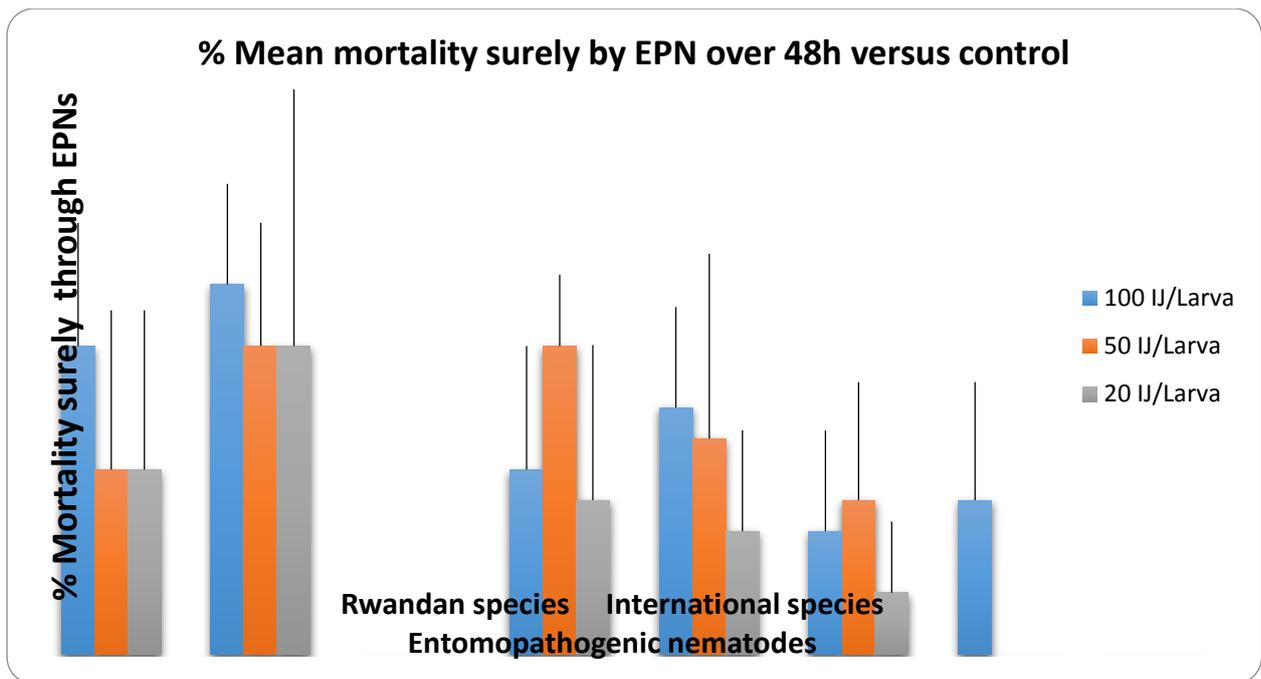


Figure 11: Percentage mean mortality of bean fly maggot caused by entomopathogenic nematodes compared to control after 48 hours of infection

Investigation of yield performance of Stevia rebaudiana and development of agronomic practices for increasing its productivity

The study was conducted at Rubona, Musanze and Karama RAB stations located in the Southern, Northern and Eastern province, respectively, from November 2016 to August 2017. Two parameters were tested: 1) fertilization doses and regimes and 2) planting density. A combination of Organic manure + NPK 17-17-17 (105kg) and Urea granular (178kg)+KCl(262kg) recorded the highest yield compared to other treatments. The highest leaf yield of 3000 kg/ha was recorded at Musanze station.

The planting distance of 20 cm between rows and 20 cm within rows resulted in the best performance of Stevia, and is therefore recommended to be used by farmers. Our studies indicate that *Stevia rebaudiana* is quite adaptable and capable of being cultivated in Rwanda. However, propagation through seed is poor, and vegetative means are recommended. Stevia plants do best in a rich, loamy soil and since the feeder roots tend to be quite near the surface, it is also good to add compost for extra nutrients if the soil is sandy.

Performance of two apple (Malus domestica) cultivars (Anna and Golden dorsett) under different management techniques

After different adaptability trials in Rwanda, it was observed that cultivation of apple has an economic benefit. The first varieties being tried in Rwanda are Anna and Golden Dorsett, the types that have been proven to be grown in other tropical countries including neighboring Uganda and Kenya. Investigations were carried out to evaluate the response of apple to different management techniques in Musanze, Northern Province. As indicated in

Figure 13, the best performance (133 fruits/tree) was recorded on Golden dorsett cultivar under optimum management (organic manure, mulching, pruning, pesticide application).

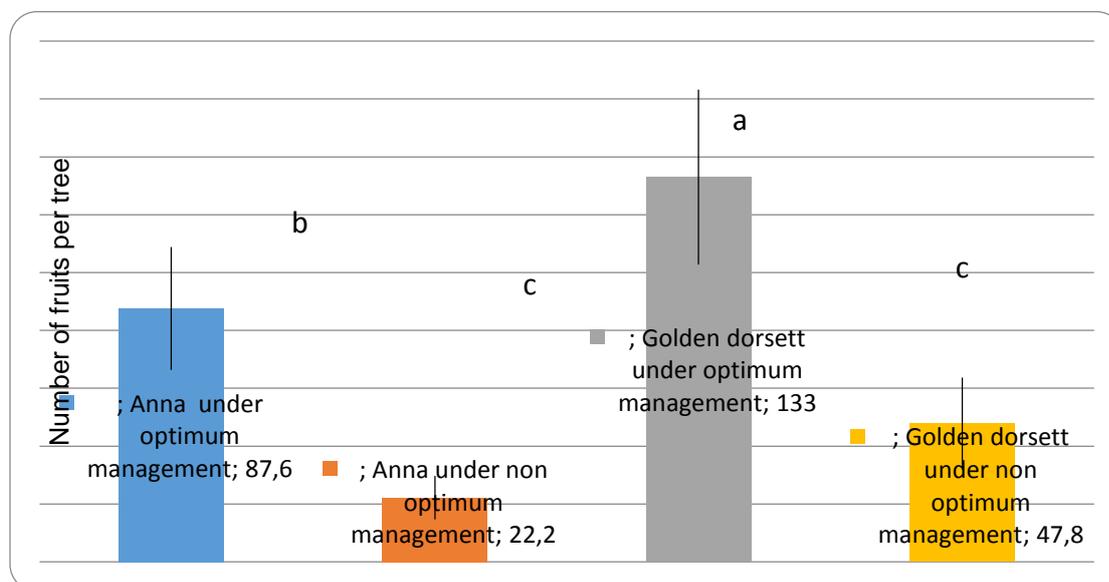


Figure 12: Number of fruit per plant for two apple cultivars under optimum vs. non optimum management techniques

Optimization of techniques for clean seed production of passion fruit

This study was designed to optimize techniques for clean seed production of passion fruit. Specifically, the influence of passion fruit pruning on fruit yield and quality as well as effectiveness of different fungicides on fungal diseases was evaluated. The trials were established in November 2016 at Ntendezi RAB station (Nyamasheke District) and Gashonga in Rusizi District, respectively. The results show that at Ntendezi RAB station, the only significant difference observed was among different fungicides evaluated (Table 39). Among the fungicides used, a sulfur based product (Thiovit) was more effective in controlling septoria spots (SS), brown spots (BS) and anthracnose (A). The same trend was observed at Gashonga site.

Table 39: Effect of different fungicides on major diseases of passion fruit (Ntendezi site)

Parameters	Septoria spot (score)	Septoria spot (8)	Brown spot (4)	Brown spot (8)	Anthracnose(4)	Anthracnose(8)
F1: Metalaxyl	4.17c	3.92b	4.25b	4.08c	4.50c	4.33c
F2: Sulfur	1.17a	1.17a	1.83a	1.00a	2.00a	1.33a
F3: Copper	2.50b	1.75a	2.83a	2.58b	3.17b	2.50b
Significance	***	***	***	***	***	****

*** Significant at 1/1000.

1.3.4.2 Tea

Evaluation of tea cultivars for yield and quality traits under different Rwanda tea growing conditions

This trial was first carried out on young tea clones, which were established in 2014 and 2015 at Ntendezi (Nyamasheke), Mata (Nyaruguru), Cyohoha Rukeri (Rulindo) and Pfunda (Nyabirasi). Different parameters were tested. These include crop cover, stem girth, plant height and pest infestation. Results indicate that out of the 17 clones tested, four clones were outstanding. These are clone TRFK 301/5, TRFK 301/4, TRFK 31/8 and SFS 475. This means that the four clones possess the potential for wide adaptability.

Evaluation of pest incidence on the tea clones revealed that mites were most prevalent pests at all sites assessed with highest severity at Mata site (Figure 14). At this site clone SFS 204 was found to be highly susceptible (32%) while clones SFS 475, TRFK 54/40, SFS 150 and TRFK 301/4 were free from attack. Cricket was found as the major pest at the sites of SORWATHE and ASSOPTHE with some cases of aphids. Cricket was particularly the most severe at SORWATHE probably due to lower soil moisture content. SORWATHE site is located on a hill while ASSOPTHE site is in a valley. Clone SFS 475 was highly affected (63%) and TRFK 12/56 was less affected (12%) at SORWATHE. The clone SFS 204 was most affected at ASSOPTHE (12%) while SFS 110 was not affected at all.

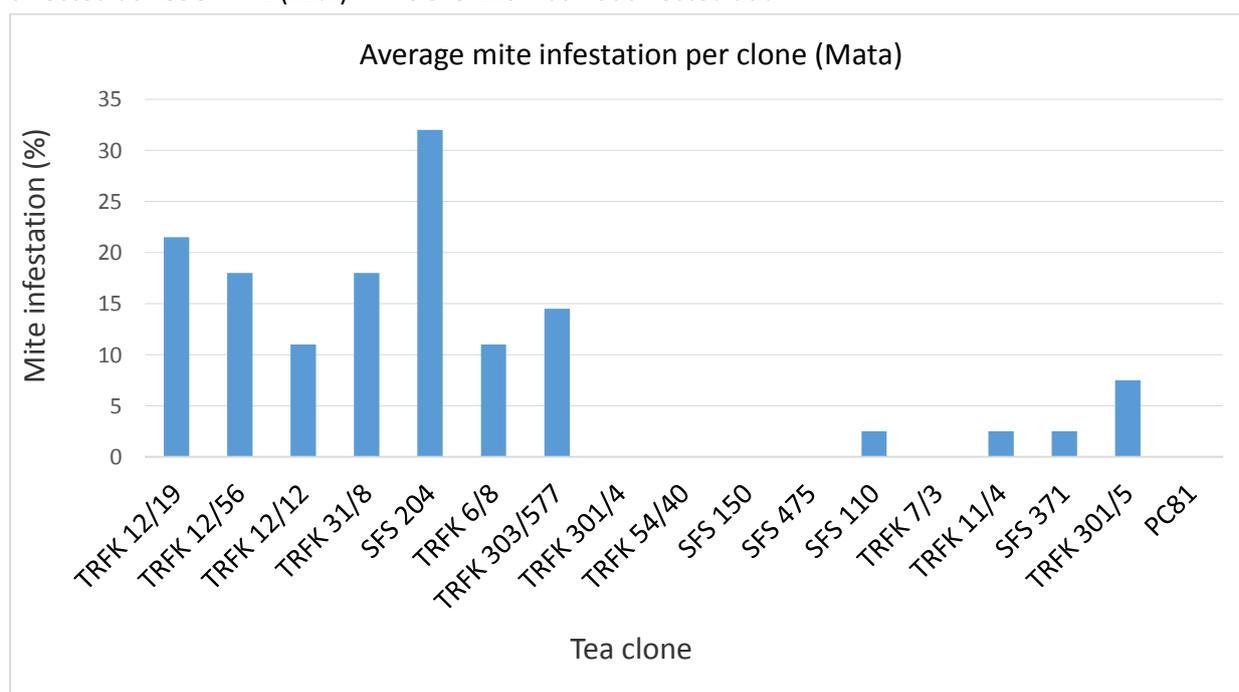


Figure 13: Average mite infestation per tea clone in the young clonal trial at Mata

Evaluation of genotype by environment interactions and genotype stability among twelve tea clones in Rwanda

This trial was carried out in Shagasha (Rusizi) on mature tea clones. The results indicate that clones TRFK 301/5, TRFK 301/4 and 303/357 (introduced to Rwanda in 2007) together with clones TRFK 6/8 & BBK 35 outweighed other clones in terms of yield (Figure 15). This is a long time experiment (yield over six year period). Previous studies had classified these clones as high yield, with average

adapatability and medium quality. Thus, we recommend the clones to tea growers for new tea planting sites or gaps in-filling in existing plantations, can be used as alternatives to clones TRFK 6/8 and BBK 35 widely found in tea plantations of Rwanda.

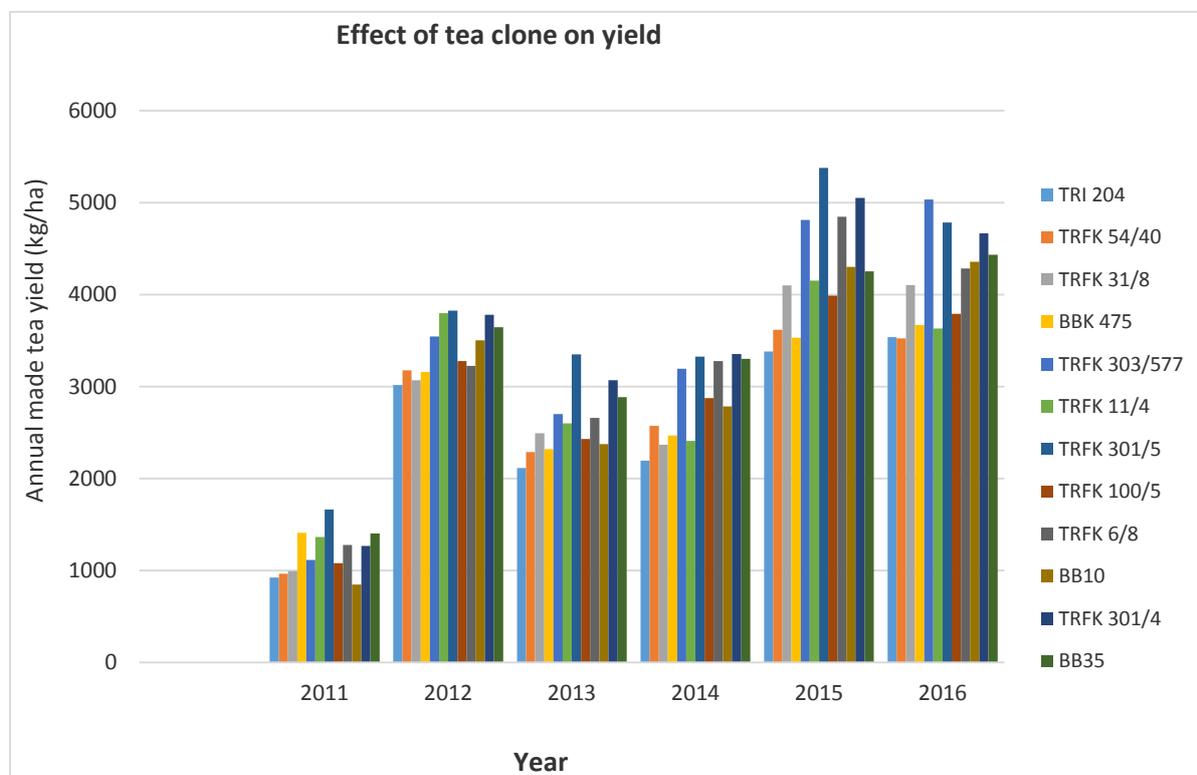


Figure 14: Annual yield of mature tea clones (kg made tea/ha) established at Shagasha

Introduction of new tea clones and evaluating them for adaptability, yield and quality

In collaboration with a private tea company, UNILIVER TEA RWANDA LTD, 679,045 cuttings of three new clones (UTK 9710342, UTK 9400247 and UTK401658) were introduced from Kenya in December 2016. These tea clones are under evaluation in the nursery at Kibeho (Nyaruguru), which is run by UNILIVER TEA RWANDA LTD, together with clone TRFK 11/4 common in Rwanda tea plantations. Among the four clones from Kenya UTK 9710342 has shown the best germination rate.

Evaluation of types and rates of fertilizers in tea plantations for increased tea productivity

Clone 6/8 was evaluated for response to different nitrogen fertilizer rates. This is a long term experiment, which was established in 2009 in existing fields of tea plantations of Kitabi (Nyamagabe) and Mulindi (Gicumbi). Results from the trial showed different yield responses due to fertiliser rates. The highest response was from the rate of 150 kg N ha⁻¹ y⁻¹ to 225 kg N ha⁻¹ y⁻¹ at Kitabi (Table 40). At Mulindi tea estate, growers should not apply more than 150 kg N ha⁻¹ y⁻¹ as the site experiences recurrent floods. There is an assumption that high amounts of fertilizers get lost through leaching. The study also confirmed that shorter tea harvesting intervals are better than longer ones. They are mostly recommended during peak yield seasons.

Table 40: Effect of nitrogenous fertilizer rates and harvesting intervals on tea yield (Kitabi: Average of six years (2009-2015))

Fertilizer N/ha/year)	Rates (kg)	Harvesting Intervals			Mean Rates	Fertilizer
		7days	14days	21days		
0		2511	1877	1612	2000	
75		2547	2394	1579	2173	
150		2788	2359	2529	2559	
225		3264	2791	2550	2869	
300		3249	2733	2247	2743	
Mean	Harvesting Intervals	2872	2431	2103		
LSD (0.05)		N Rates: 100	HI: 107.8	N Rates x HI: 186.5		

Evaluation of organic fertilizers on tea: productivity and value

The main aim of the trial was to compare nitrogenous fertilizer (NPKS 25:5:5:5) to organic fertilizers (Organomex and cattle manure) and determine options that enhance tea productivity. The experiment were established in 2011 at two sites of Cyohoha-Rukeri (Gatorwa and Rugando) planted with clone TRFK 6/8 at 121.9 x 76.2 cm. The yield data from 2011 to 2016 is presented in Figure 16. The six-year results at both sites show that yields were not decreased by the organic fertilizers compared to inorganic fertilizers (NPKS) commonly used in tea production. Although there was no data on cup quality parameters from the study, the quality of fresh leaves delivered to factory, which is an indicator of the final cup quality, was not altered by the organic fertilizers. Tea growers should therefore adopt the use of organic fertilizers as since organic tea fetches premium prices compared to tea produced with use of inorganic fertilizers.

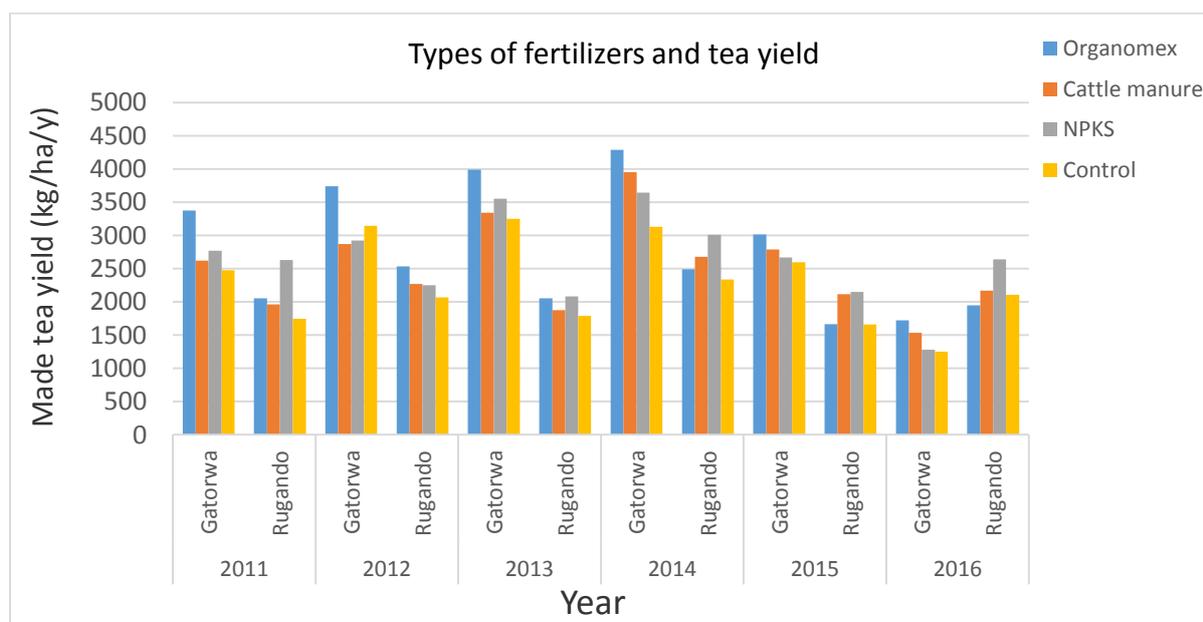


Figure 15: Effect of types of fertilizers and manure on tea yield at Gatorwa and Rugando

Effect of plucking frequency and shear plucking on tea yield and quality

Like most of the tea trials, this is an on-going one at Mata (Nyaruguru) and Gisakura (Nyamasheke), which was established in mature tea fields in 2009. Results suggest that the shorter harvesting cycle (seven days) is better than longer harvesting intervals and mechanical harvesting in terms of cumulative annual yield and green tea leaf quality. Therefore, short harvesting intervals can be recommended to tea growers. Shears resulted in both lower tea yield and quality; they are not recommended to tea growers.

A survey conducted in Rwanda tea plantations to identify major tea pests and diseases

Data collection specifically focused on three major tea pests and diseases namely Armillaria root rot disease, mites (pests) and Hypoxylon wood rot disease. These are considered as the most threatening pests and diseases in Rwanda tea plantations. What is presented here is a summary of the survey results. The survey showed that the characteristics of tea growers and fields vary across different tea plantations. Distribution of major pests and diseases of tea was found to vary depending on site specific agroecological conditions (Figure 4). For instance, the proportion of trees attacked by mites was higher in Muganza Kivu (78%), Sorwathe (62%), Gatare (60%) and Nshili Kivu (60%). Hypoxylon wood rot disease incidences higher than 50% were observed in Mata, Mulindi, and Shagasha while Armillaria root rot was more prevalent in Gatare, Gisakura, Gisovu, pfunda and shagasha.

In general, tea growers showed varying levels of knowledge of pests and diseases and their management, agricultural practices and how agricultural practices can be optimized for control of pests and diseases. Most importantly, some farmers from various plantations indicated that they had no information on tea pests and diseases or about how agricultural practices control them. Therefore, there is need to establish and implement a program on continuous training to equip tea growers and plantation personnel with knowledge on tea pests and diseases as well as their management. Given the endemic status of pests and diseases in Rwanda tea plantations, tea growers in collaboration with research institutions are encouraged to set up, and implement, a participatory research for development program to investigate the dynamics of the pests and diseases and establish effective management measures.

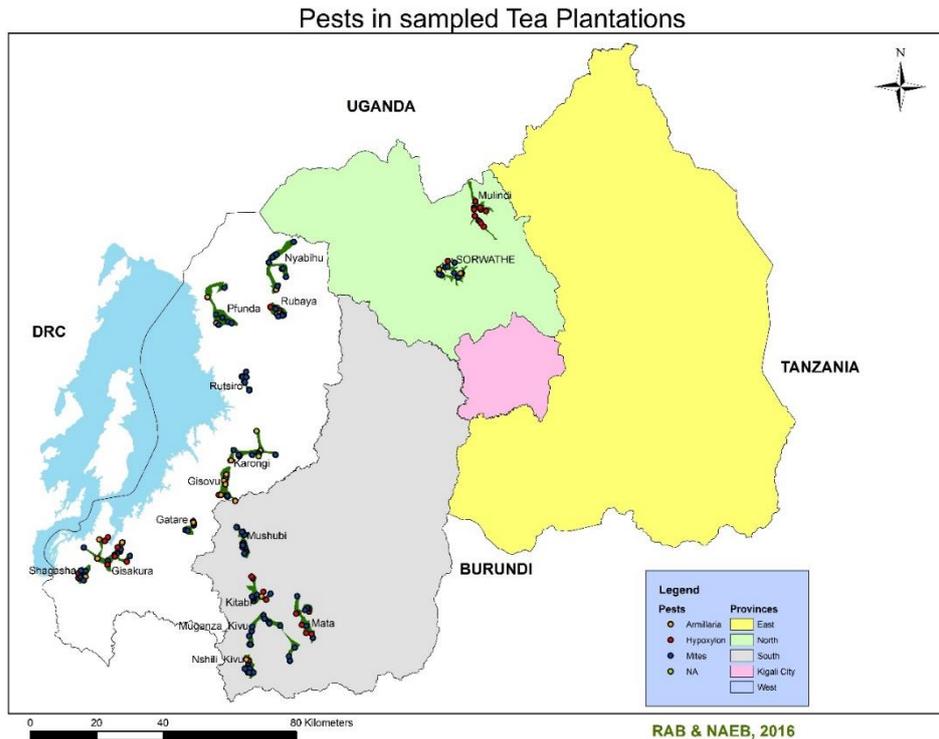


Figure 16: Prevalence of major pests and diseases in tea plantations across Rwanda

1.3.4.3 Coffee

Development of new disease resistant, high yielding coffee varieties with good adaptation and improved quality

The short term plan of the current coffee breeding program is to develop high yielding first generation of varieties that are mainly resistant to Coffee Leaf Rust (CLR) and with good cup quality within a short span of time. During this reporting period, we multiplied the newly released coffee variety RAB C15 for dissemination to coffee farmers. This was done by establishing two more seed gardens (one at Rubona and the other at Ngoma RAB stations). Both fields were established on 1 ha and at least 2.500 kg of clean seeds are expected to be produced by the end of the next fiscal year. This will yield enough seed to cover at least 1, 200 ha of land each year.

During this reporting period, we also evaluated a newly introduced Batian variety. Specifically, data on yield and diseases was collected. Results from the two trials located in Rubona and Ngoma showed morphological variability among Batian populations with variability for yield and disease resistance potential. Individual plant selection was made and mean yielded per tree ranged between 3.5 and 4.2 kg after 3 years of crop production. The yield is expected to increase and the maximum yield is expected in the 5th year of production. By simple extrapolation the potential yield is between 8.75 and 10.50 tonnes per ha of cherries. This is not different from existing commercial varieties such as BM 139, BM 71 and Jackson. On the

other hand, individual plant selection resulted in good resistance to CLR and Coffee Berry Disease (CBD) in both environments. Quality evaluation through cupping conducted in Starbucks laboratories did not show any significant differences with existing commercial varieties. A promising Batian variety will be pre-released at the end of 2017/2018 fiscal year.

The medium term plan of our coffee breeding program is to develop superior hybrid varieties obtained through crossing progenitors that possess different disease resistance genes, and represent considerable genetic diversity, to the local commercial varieties. Morphological characterization of yield and yield related traits on three years old F1 hybrids from different hybridization programs was carried out. Promising F1 hybrids were clonally multiplied through tissue culture for subsequent multilocational trials in at least 5 locations. These trials are set to start in the first quarter of 2017/2018 fiscal year.

Improvement of coffee system agronomy through intercropping with banana

Trials on coffee-banana intercropping were established in Ngoma, Rubona and Mwito stations and sites as well as a scale out demonstration plot was established in Ruhango in farmers conditions. For the Ngoma trial, coffee monocrop resulted in slightly higher yields but not significantly different from the rest of treatments except treatment six (1.250 coffee trees/ha+500 banana plants/ha) which gave least yields records (Table 41). These results show that intercropping coffee with 500 banana trees per ha did not lead to any significant yield decrease compared to coffee monocrop. This can be attributed to shade effect (less empty grains, less incidence of coffee leaf rust and coffee berry disease, modulated effect of dry season on soil humidity, soil nutrient use efficiency, among other things) and less competition between main crop (coffee) and intercrop (banana) for light and soil nutrient. These observations were not different from those for Rubona and Mwito.

The fact that coffee in a monocrop produced the same yield as that in intercrop with banana indicate that keeping the same coffee population density with less than 1000 banana trees per ha will not have any significant negative impact on coffee yield. An added advantage will come with banana production which will have positive implications on farmers' socioeconomic status. This practice, if adopted by farmers, would motivate them to keep doing coffee cultivation since they will benefit from double income resulting from intercropping.

Table 41: Mean yields comparison for different treatments for Ngoma coffee-banana intercrop trial

Treatments	Population density: Number of trees per ha	Coffee yield (t/ha/yr)	Banana yield (t/ha/yr)
T1	2,500 coffee monocrop	11068.28a	
T2	2,500 coffee + 1,000 banana	9558.7ab	24094.93ab
T3	2,500 coffee + 500 banana	109856.1ab	8727.012bc

T4	1000 banana monocrop		27485.86 a
T5	1,250 coffee+ 1,000 Banana	7222.37bc	15249.57 bc
T6	1,250 coffee + 500 banana	4137.22c	8230.917 c

Means followed by same letters are not significantly different

Spatial variability of soil chemical properties in different coffee zones of Rwanda

For this study, samples were collected from 150 sites at both 30 cm and 60 cm soil depth. The samples were analyzed at the Rubona soil laboratory. Spatial variability among Rwandan coffee soils was assessed using principal component analysis followed by evaluation of the degree of spatial dependence. Results of this study indicated a considerable spatial variability of almost all soil nutrients although nutrient such as Magnesium, Nitrogen Potassium and sodium showed a weak spatial dependence (Figure 18). Based on these results, fertilizer programs in Rwanda should consider site specific soil chemical and physical properties in order to come up with fertilizer use efficiency. Recommendations need to consider site specific chemical properties like soil pH, Calcium, CEC, Nitrogen, Organic carbon, Phosphorus, and Sulfur. Variability of Aluminium, Magnesium, potassium, Sodium and Nitrogen was not high enough to suggest site specific fertilizer recommendation for these nutrients.

This study identified the most limiting factors as liming, organic fertilization (beneficial effect of mulching) and correction of potassium deficiencies. Site specific fertilizer recommendation using adequate models will boost coffee yield in different zones in regards to the 4Rs: right rate, right source, right placement, and right timing. Based on these soil analysis results, a fertilizer recommendation for each study site will be developed and climate analogue tool and GIS-based variograms will enable the extrapolation of recommendations to other coffee growing zones. New site specific fertilizer recommendations will be developed and tested during the 2017/2018 fiscal year.

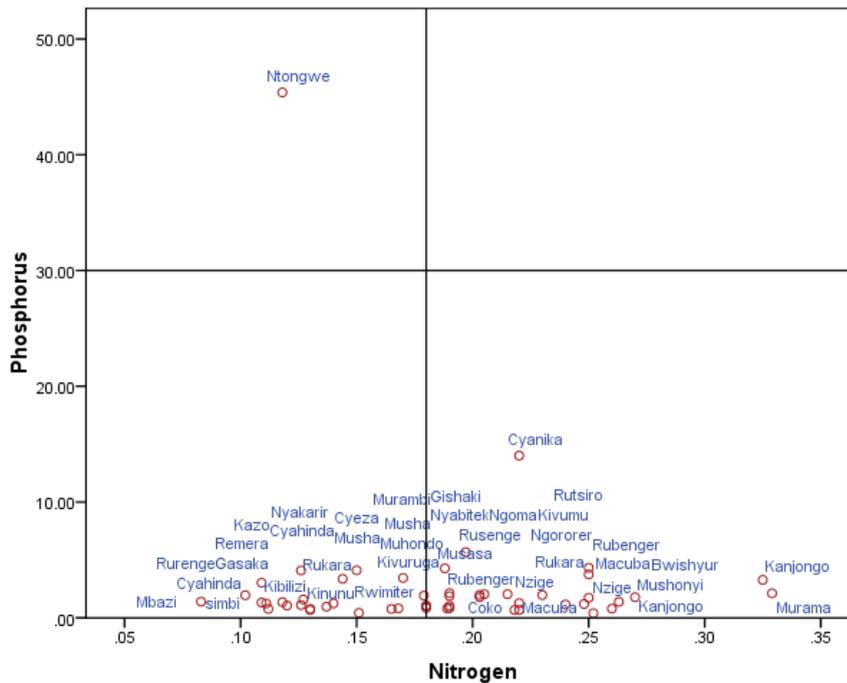


Figure 17: Example of spatial variability analysis resulting from this study: Case of nitrogen and potassium

IPM for the control of Antestia bug: Testing the efficacy of Closer against Antestia bug

The aim of this trial was to search for an alternative insecticide to imidacproprids. Closer 240 SC, a new insecticide based on Sulfoxaflor with no proven insect resistance, was tested against antestia bug as a possible candidate for replacing imidacproprids in bioassays (both laboratory and field experiments). Three doses (200ml/ha, 300 ml/ha and 400 ml/ha) were compared to current farmers standard (confidor; imidacproprid). Field experiments were conducted in three trial locations with three replications in each.

Results showed significant differences between treatments for both lab test and field trials for the knock out effect and insect mortality rate. Means comparison tests revealed that all the treatments (Closer 240 SC and Confidor) resulted in 95-100% mortality rate. Despite these differences between treatments, the mean performance of each treatment did not show any significant differences for knock out effect and mean mortality rate in either lab test or site specific treatment performance across the trial locations. All the three doses of Closer 240 SC had the same effect with that of Confidor suggesting that both chemicals can be used in an alternating manner to avoid insect resistance to either of them for sustainable management of antestia bug on coffee. However, because the study was conduct in just one season, further tests are needed to determine if there are seasonal variations in the efficacy of the insecticides and how often (cycle) spray should be carried out to effectively reduce antestia population below the economic injury level throughout the year.

1.3 Natural Resource Management

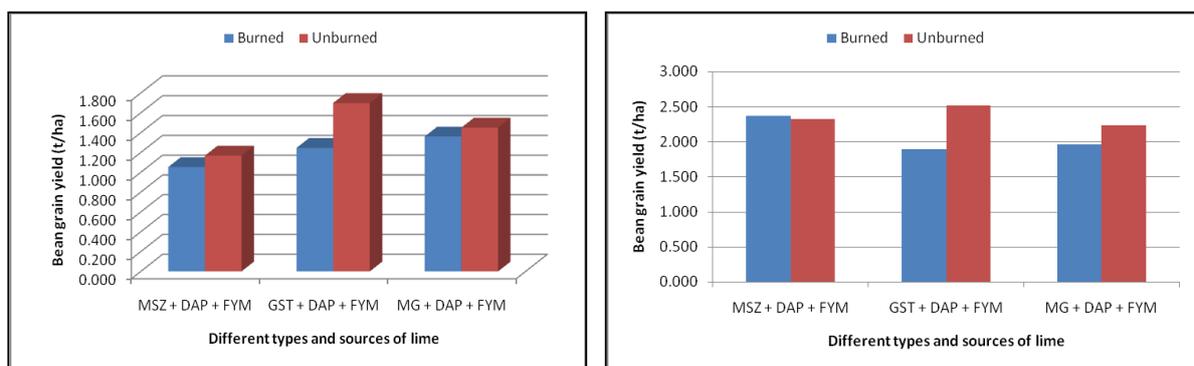
1.3.1 Soil and Water Management

Different activities were carried out by the Soil and water management research during the year 2016-2017 focused on: Promotion of the use of lime and other inputs to increase agriculture productivity in acidic soils of Rwanda; Improving crop productivity and agricultural land management in the rural area farming system; Enhancing fertilizer use efficiency for improved rice yield and profitability in Rwandan wetlands; Intensification of maize-legume based cropping systems for food security; Support to research for fertilizer recommendation.

Promotion of the use of lime and other inputs to increase agriculture productivity in acidic soils of Rwanda

During 2015/2016 fiscal year farmers in Nyaruguru, Nyamagabe, Nyamasheke and Karongi have accessed Earmarked funds from Lime project to facilitate them to use travertine (Lime). In the fiscal year 2016/2017, the Lime project extended to Huye, Nyanza, Muhanga, Ruhango and Gakenke. This report presents the results of the demonstration plots for seasons 2017 A and B and other project activities such as capacity building.

The study, which was testing different rates of lime to evaluate its optimum application, revealed that: Doubling the recommended rate of Travertine does not have any significant difference on bean yield, size and weight (Figure 19); The recommended rate (2.5T/ha) is still able to reduce the soil acidity up to the tolerable pH by crops; Comparing to the control treatment, the remaining treatments showed that using other agricultural inputs is recommended to the farmer for high crop productivity.



Nyabivumu site / Gasaka

Remera site / Gasaka

Figure 18: Effect of different types and sources of lime in combination with other input on Beans yield Where MSZ= Mashyuzi source, GST= Gishyita source, MG= Mpenge source. FYM= Farm Yard Manure

Improving crop productivity and agricultural land management in the rural area farming system

A baseline survey has been conducted in Nyanza, Karongi and Rutsiro aiming at determining the potential production factors, bio-physical and socio-economical resources. It also aimed at providing information on the farmers' awareness on the use of ISFM technologies. This will help in formulating recommendations and guidelines for sustainable valorization and management of the study areas for increased crop productivity.

Results revealed that crop rotation is the most dominant cropping system in the study area as reported to be practiced by 74.5, 80.8, and 83.5% of farmers in Nyanza, Karongi and Rutsiro, respectively. This system is recognized by farmers to have advantages of disease control, fertility restoration and increased production. Intercropping is mostly practiced in Nyanza district as confirmed by 61% of the respondents compared to Karongi and Rutsiro where 35.6% and 19.8% are reported. The following system is uncommon across the three districts as confirmed by 86.8% of respondents. This could be attributed to land scarcity in these areas. The general status of soils from farmers' views range from low to moderately fertile as confirmed by 40 and 45% of farmers in average. Among the criteria for soil fertility determination, crop yield was the most considered with an average of 94% of respondents followed by vegetation reported by 32.7%.

Farmers reported (80.8%) that Farmyard manure is mostly known as the best fertilizer followed by Chemical fertilizers (67.4%) (Figure 22). Although very low percentage of farmers (1.3%) reported having knowledge on the importance of lime/travertine, the soils in these regions are known to be acidic.

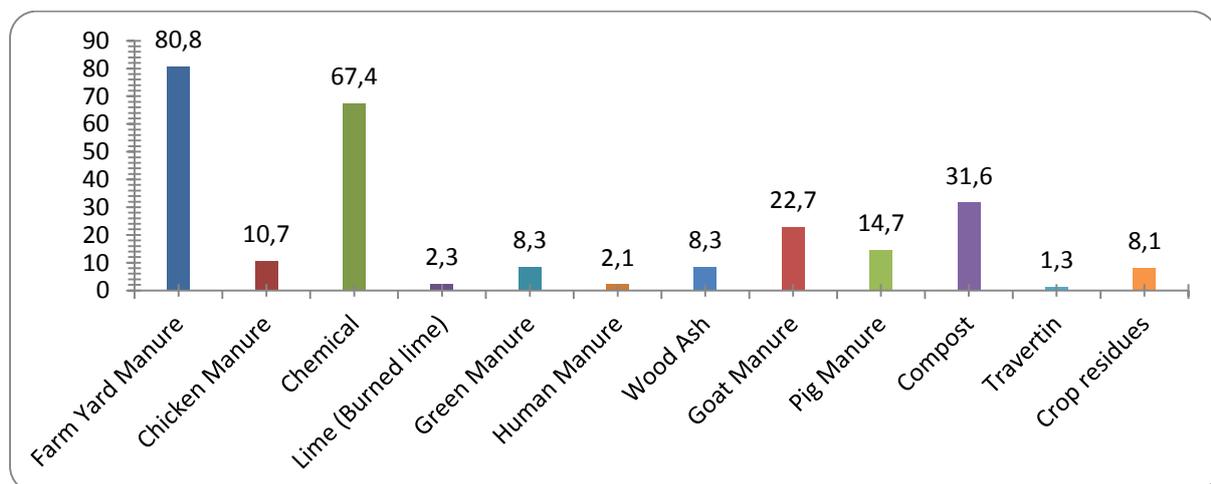


Figure 19: Number of farmers who have knowledge on fertilizer use

Based on the biophysical and socio-economic characteristics of the study areas, different management options for integrated soil fertility management were suggested for trials in rural areas and adapted to grown priority CIP crops (beans and maize in Nyanza site; maize and Irish potato in Karongi). In Karongi and Rutsiro, combination of lime/travertine, FYM and

inorganic fertilizer was the most performing, while control and lime/travertine applied alone were least performant. In Karongi, the performing treatment had generated 9.6 t/ha maize yields and 24.2 t/ha potato yield. In Rutsiro this treatment had 26.0 t/ha of potato yield and 6.2 t/ha of maize yield (Figure 20).

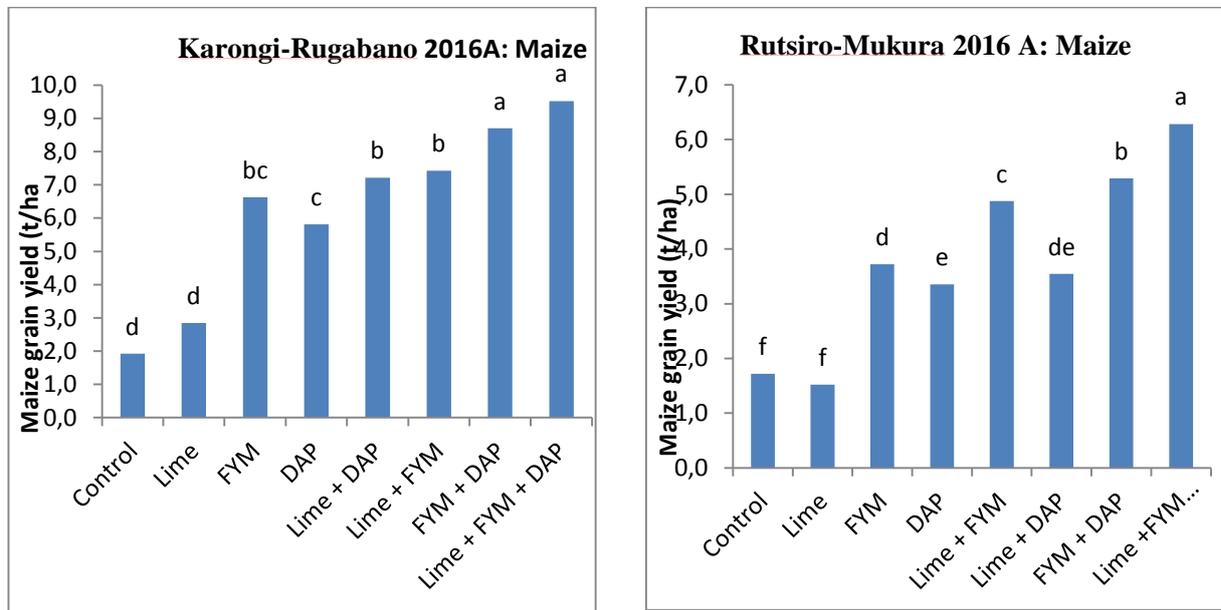


Figure 20: Maize yield in Karongi and Rutsiro site

In order to assess the effect of the treatments on the soil properties, soil samples were taken at the beginning of the demonstration trials installation and at harvesting of every cropping season. The different parameters which were analyzed are: pH water, NT, Organic Carbon, available phosphorus, basic cations (Ca^{2+} , Mg^{2+} , K^+ , Na^+), CEC, acidity (H^+ and Al^{3+}).

Results of the effect of treatments on dynamic change of soil properties in different sites indicate improvement of soil properties with application of lime/travertine in combination with organic and inorganic fertilizers. The pH has increased from 5.7-6.7 and 6.0-7.7 respectively at Nyarusange and Mushirarungu in Nyanza, which resulted in fully neutralization of exchangeable aluminium. Results from Rugabano and Mukura in Karongi and Rutsiro indicate an increase of pH from 4.6-5.3 and 4.5-6.2 respectively with application of lime/travertine associated with organic and inorganic fertilizers. Considering the dynamic change of pH and organic carbon across seasons in these sites, there is need to further apply lime/travertine after the second cropping season and continuously add organic and inorganic fertilizers at each cropping season.

Enhancing fertilizer use efficiency for improved rice yield and profitability in Rwandan wetlands

This study aimed to enhance soil quality management options and fertilizer use efficiency for increased rice yield and profitability. Results highlight that the most performing treatments under best bet trial were T6 (120N- 48P- 96K+Liquid fertilizer), T7 (120N- 48P- 96K+ Zn+B+Cu) and T3 (80N- 34P- 34K+Liquid fertilizer) (Figure 21).

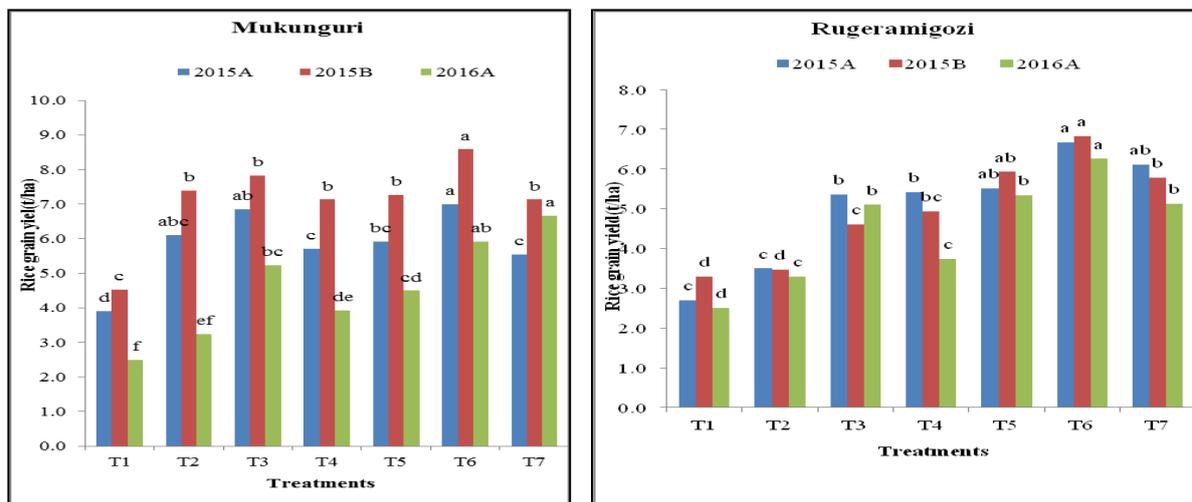


Figure 21: Effect of best bet treatments on rice yield in Mukunguli and Rugeramigozi wetlands

Results of rice grain yield under omission trials from different marshlands are illustrated by Figure 22. In Rugeramigozi the best performing treatment was NP (5.5-6.9 t/ha) followed by NPK with 5.9-6.1 t/ha. In Rwasave wetland all combinations i.e NP, NK, PK and NPK induced higher rice grain yield with yield ranging from 4.4-6.2 t/ha.

In Cyiri, Bugarama and in Mukunguli wetlands NPK and NP were the best performing treatments while control recorded the lowest rice grain yield suggesting P as the most limiting nutrient.

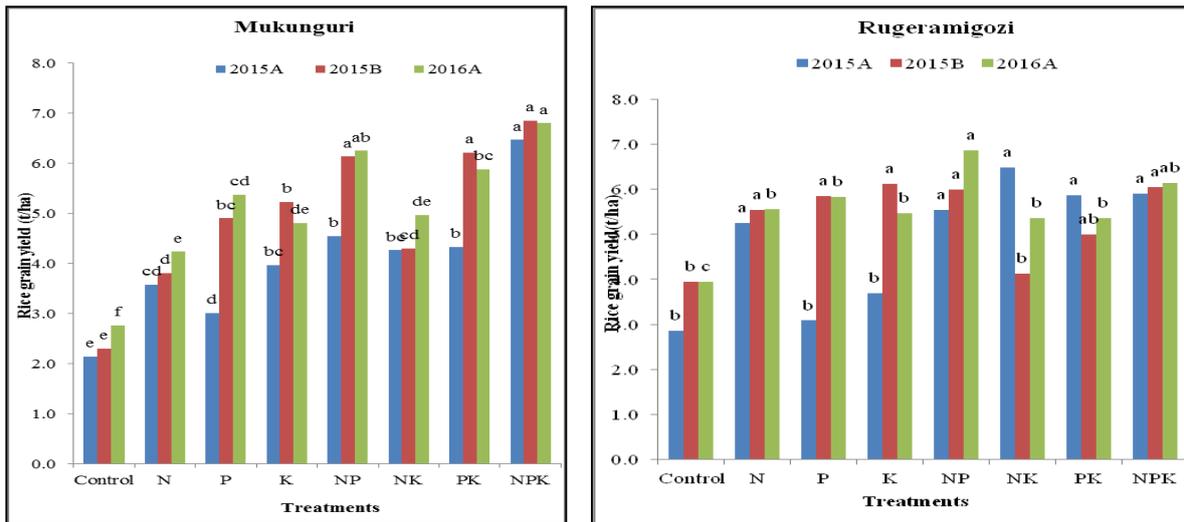


Figure 22: Effect of omission treatments on rice yield in Mukunguli and Rugeramigozi wetlands

1.3.2 Forestry and Agriforestry

During the fiscal year 2016-2017, different activities were implemented and included the evaluation of existing experiments pertaining to diversification and selection of indigenous tree species having an agroforestry potential, bamboo species site matching and development of forest management tools including volume and yield tables. Specifically, nine crop (maize, bean)-indigenous tree species systems in Ruhande and Rubona were evaluated for the yields of crops and trees. In these tree-crop systems, tree management by pruning and thinning was carried to in order to reduce tree competition on crops for further evaluation of their effects on crop yields. The adaptability of five Bamboo species was compared on the site of Kanombe (Kicukiro district) on the basis of their growth performance and number of shoots per bamboo stool. Further, early assessment of the adaptability of a range of tree species was made by determining their survival rate and growth particularly in Ruhande and Rubona sites.

Selection of indigenous tree species suitable for agroforestry in Rwanda

A long term experiment was set up in Ruhande and Rubona sites to assess potential indigenous agroforestry species and their effects on crop yields. Specifically, the experiment aims at (i) evaluating the performance of nine indigenous tree species on farms, (ii) broadening the diversity of species to be incorporated on farmland and farm boundaries, (iii) selecting indigenous multipurpose tree species (MPTs) whose planting materials could be in ease reach of farmers, (iv) quantifying tree biomass production of these MPTs when planted on crop land, (v) assessing the compatibility of these MPTs with crops, (vi) obtaining farmers evaluation of the species and (vii) determining the appropriate management of indigenous species associated with crops.

The experiment was established at Rubona and Ruhande in 2009. The indigenous tree species that are compared for their growth performance, biomass yields and impacts on crop yields consist of *Entandrophragma excelsum*, *Syzigium parvifolium*, *Markhamia platycalyx*, *Pterygota mildbraedii*, *Erythrina abyssinica*, *Polyscias fulva*, *Maesopsis eminii*, *Croton megalocarpus* and *Ficus thonningii*. The design comprises also a control treatment, for which no tree species is present. These treatments (nine indigenous tree species + control plot) are laid out in randomized complete block designs, replicated three times, both at Ruhande and Rubona. Each plot within a block contains nearly 30 trees. Each cropping season, crops are introduced, managed and evaluated for their yields under each treatment. At the same time, data on growth of trees are collected. Each tree species occupies a plot of 12.5 m by 10 m or 125 m². During the year 2016-2017, maize crop was associated with the nine indigenous tree species. Further, in heavily stocked plot and where competition for light was evident, trees were thinned or pruned. Thinning was done on 30% of the total number of trees present in a plot while pruning was done on a two-third of the total tree height. The managed tree species were compared on the basis of biomass yields.

Growth and pruned production of indigenous tree species

Figures 23 and 24 indicate the characteristics of pruned trees in terms of the average diameter at breast height (DBH) and total height of the indigenous trees that were pruned in both experiments at Rubona and Ruhande. For the same tree species that were pruned on both sites, *M. eminii*, *P. fulva* and *P. mildbraedii* had statistically similar diameter growth. In contrast, *C. megalocarpus* and *S. parvifolium* had significantly higher DBH at Rubona than at Ruhande. *M. lutea*, *F. thonningii* and *P. falcatus* growing in Ruhande did not require any pruning operation since their canopy was still open or the trees did not grow to large sizes to exert shading effect on the ground layer or crop underneath.

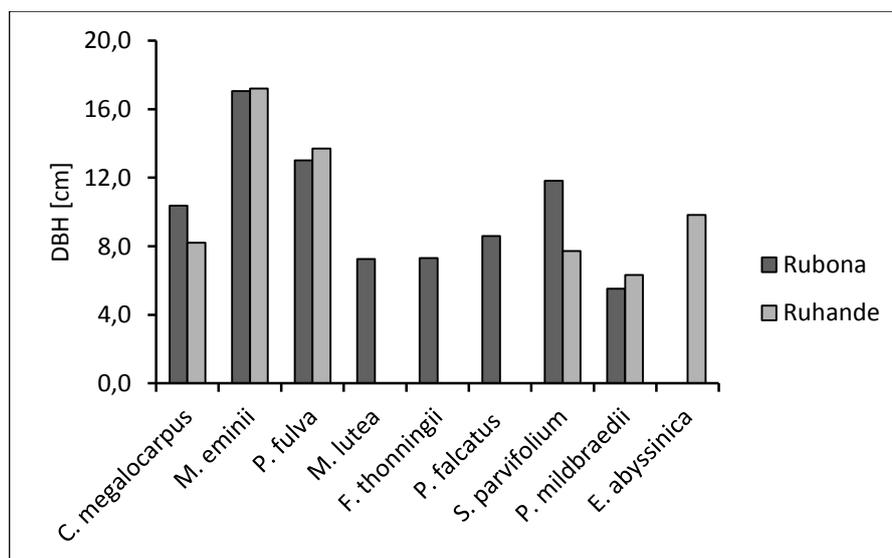


Figure 23: Average DBH of pruned trees in Rubona and Ruhande

At all the assessment occasion of the indigenous tree species, the statistical analysis did not reveal any significant differences in height growth of *P. fulva* and *P. mildbraedii* between the two sites. In general, pruned trees were taller for *M. eminii*, *P. fulva* and *C. megalocarpus* but both *M. eminii* and *C. megalocarpus* performed better at Rubona than at Ruhande (Figure 24). Average height of *S. parvifolium* was higher at Rubona than at Ruhande, suggesting that more favourable environmental growth conditions of the species prevail at Rubona.

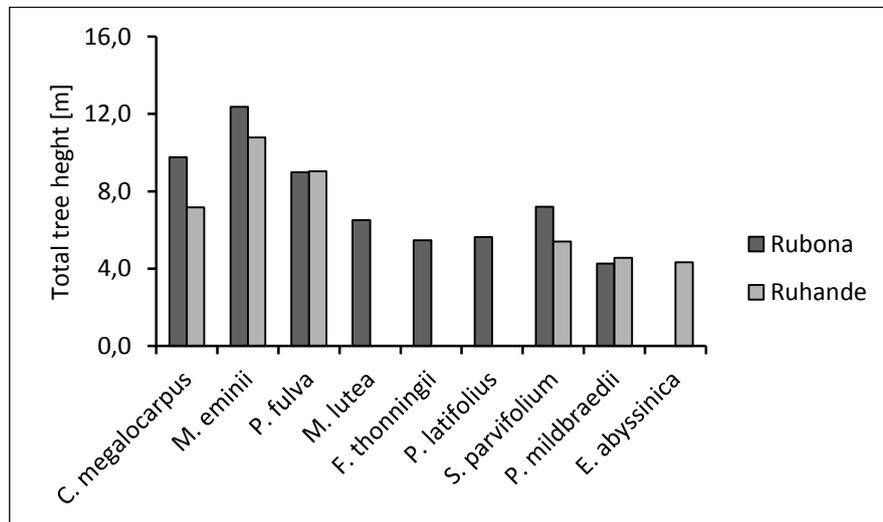


Figure 24: Average total height of pruned trees in Rubona and Ruhande

The two comparative experiments of indigenous tree species showed that the harvested biomass during pruning was different among species and between Rubona and Ruhande sites (Table 42). Total branch weight of *C. megalocarpus* and *M. eminii* was higher at Ruhande than at Rubona and as a result of this, branch wood weight and weight of leaves of these tree species were high at Ruhande. In contrast, total branch weight of *S. parvifolium* (56.9 T ha^{-1}) and *P. mildbraedii* (17.7 T ha^{-1}) were larger at Rubona than at Ruhande. Differences in branch biomass production of a tree species reflect different levels of competition for light between the two sites. The total pruned biomass of the remaining tree species at Rubona was in the order: *P. latifolius* (29.6 T ha^{-1}), *M. lutea* (25.3 T ha^{-1}) and *F. thonningii* (8.7 T ha^{-1}) and the differences were important. *Polyscias fulva* was self-pruning on both sites.

Table 42. Pruned biomass fresh weights of different indigenous tree species planted at Rubona and Ruhande

Species	Rubona			Ruhande		
	Total branch weight (T/ha)	Branch wood weight (T/ha)	Weight of leaves (T/ha)	Total branch weight (T/ha)	Branch wood weight (T/ha)	Weight of leaves (T/ha)
<i>C. megalocarpus</i>	43.5	31.9	11.6	111.5	61.4	50.0
<i>M. eminii</i>	0.6	0.4	0.2	45.7	32.6	13.1
<i>P. fulva</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>M. lutea</i>	25.3	15.1	10.3			
<i>F. thonningii</i>	8.7	6.4	2.4			

<i>P. latifolius</i>	29.6	6.4	23.2			
<i>S. parvifolium</i>	56.9	31.9	25.0	35.3	23.2	12.0
<i>P. mildbraedii</i>	17.7	9.4	8.2	12.1	8.6	3.5
<i>E. abyssinica</i>				22.3	18.2	4.1

Growth and thinned production of indigenous tree species

With the exception of *P. mildbraedii*, the average total height of all indigenous tree species was comparatively higher at Rubona than at Ruhande (Figure 25), as it was almost the case for pruned trees. Measurements of growth parameters showed that *P. fulva* and *M. eminii* attained the highest height on both sites followed by *C. megalocarpus*, *S. parvifolium* and *P. mildbraedii* while *E. abyssinica* performed poorly.

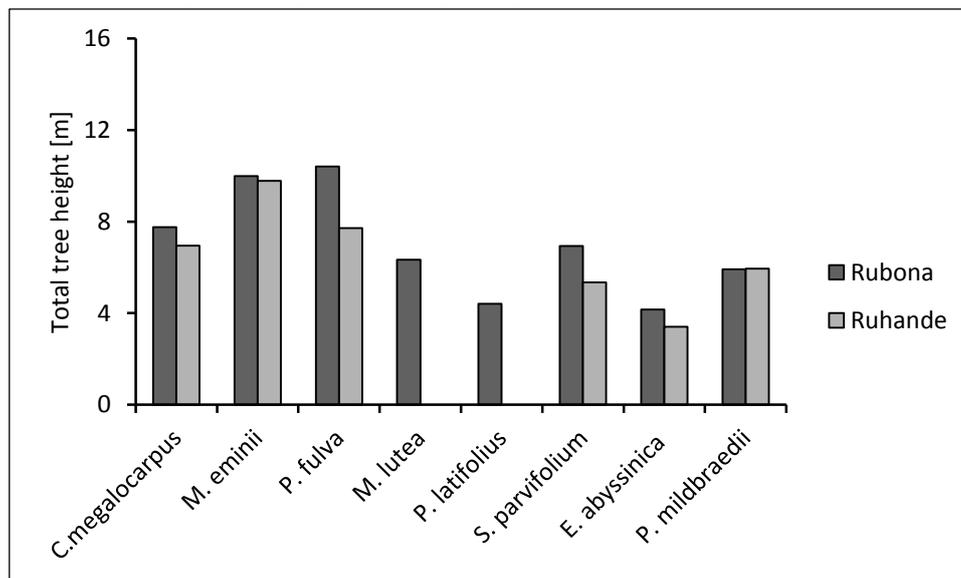


Figure 25: Average total height of thinned trees in Rubona and Ruhande

Similarly, larger trees that were thinned on both sites included *M. eminii* and *P. fulva* but larger diameter trees of *M. eminii* were recorded at Ruhande while those of *P. fulva* were found in Rubona (Figure 26). Also, thinned trees of *S. parvifolium*, *E. abyssinica* and *C. megalocarpus* at Rubona had larger DBH than those thinned in Ruhande site. Therefore, competition among trees and between trees and crop appear to be important in Rubona site.

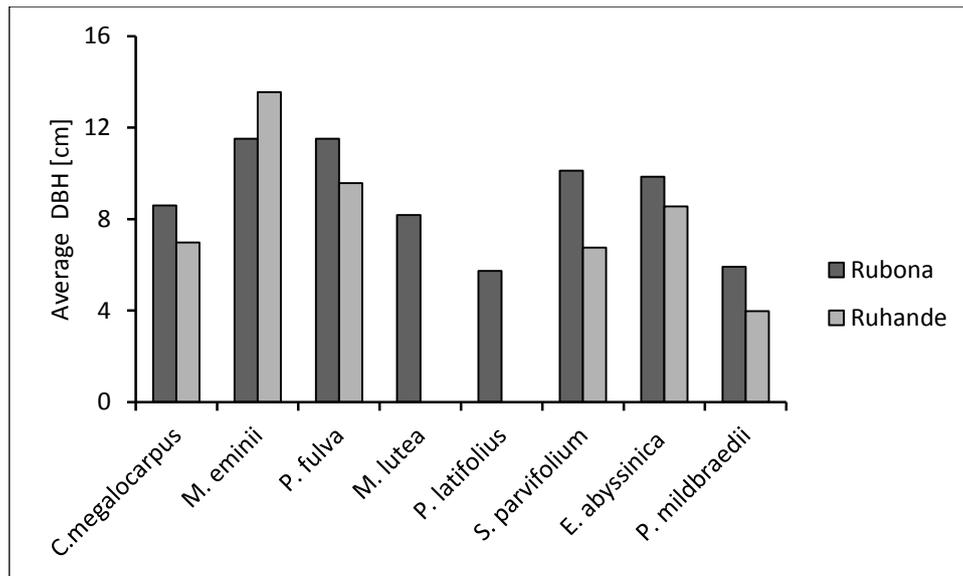


Figure 26: Average DBH of thinned trees in Rubona and Ruhande

The total thinned biomass fresh weight was different among the species and between sites (Table 43). For all the species, total biomass was higher in Rubona than in Ruhande, which could explain partly that these species adapt to Rubona climatic and soil conditions. In Rubona, the three top species with high thinned biomass were in the order of: *P. fulva* (53.5 T ha⁻¹), *C. megalocarpus* (46.3 T ha⁻¹) and *M. eminii* (36 T ha⁻¹). In Ruhande, best thinned biomass producer tree species were *C. megalocarpus* (36 T ha⁻¹), *S. parvifolium* (33.2 T ha⁻¹), and both *M. eminii* (17.1 T ha⁻¹) and *P. fulva* (17.3 T ha⁻¹).

Table 43: Pruned biomass fresh weights of different indigenous tree species planted at Rubona and Ruhande

Indigenous tree species	Rubona				Ruhande			
	Weight of branches (T/ha)	Stem weight (T/ha)	Leaf weight (T/ha)	Total biomass (T/ha)	Weight of branches (T/ha)	Stem weight (T/ha)	Leaf weight (T/ha)	Total biomass fresh (T/ha)
<i>C. megalocarpus</i>	19.1	18.1	9.0	46.3	15.2	14.3	6.5	36.0
<i>M. eminii</i>	7.4	23.3	5.4	36.0	3.9	10.7	2.4	17.1
<i>P. fulva</i>	4.0	38.2	11.3	53.5	1.3	12.6	3.4	17.3
<i>M. lutea</i>	5.5	10.6	5.7	21.7				0.0
<i>P. latifolius</i>	1.4	6.6	5.9	13.9				0.0
<i>S. parvifolium</i>	12.3	12.6	10.1	35.0	8.2	19.7	5.3	33.2
<i>E. abyssinica</i>	9.3	23.1	2.1	34.5	5.4	5.5	1.5	12.4
<i>P. mildbraedii</i>	2.1	4.5	2.2	8.9	1.9	3.4	1.6	6.9

Relative to total thinned production between sites, the proportions of biomass of branches, stems and leaves were not different namely for *C. megalocarpus*, *M. eminii* and *P. fulva*. For *C. megalocarpus*, the proportions of biomass of branches, stems and leaves were in the range of 41-42% for branch fresh weight, 39 - 40% for stem fresh weight and 18 - 19% for fresh leaf

weight. On both sites, *Maesopsis eminii* recorded branch biomass of 20 - 23%, stem biomass of 63-65% and leaf biomass of 14-15% of the total thinned production. *Polyscias fulva* had higher proportion of stem biomass in the range of 71 - 73%, low proportion of branch biomass (7 - 8%) and fresh biomass yield of 20 - 25%.

However, indigenous trees including *Syzygium*, *Erythrina* and *Pterygota* showed variations in the proportions of the different components of total thinned production in both sites. For instance, branch biomass of *Syzygium* was 35% of total thinned production in Rubona against 25% in Ruhande. The stem biomass represented 36% in Rubona and 59% in Ruhande while the leafy biomass was 29% in Rubona and 16% in Ruhande.

Branch biomass of *Erythrina* was 27% of total thinned production in Rubona against 44 % in Ruhande. The stem biomass represented 67% in Rubona and 44 % in Ruhande while the leafy biomass was 6 % in Rubona and 12% in Ruhande. For *Pterygota*, branch biomass was 24% of total thinned production in Rubona against 28 % in Ruhande. The stem biomass represented 51% in Rubona and 49% in Ruhande while the leafy biomass was 25% in Rubona and 23 % in Ruhande.

Crop performance and yield in crop-tree systems

After pruning and thinning operations, maize was associated with the various indigenous trees at Rubona and Ruhande and yields evaluated at harvest. Unfortunately, drought followed the planting of maize and crop failed at Ruhande site. For this site, therefore, maize plant height and total biomass were used as measures of crop performance while at Rubona, maize grain yield was assessed as the response to effect of trees on crop.

Figure 27 shows that average maize plant height varied within and among the crop-tree systems. While average maize plant height in the control treatment was nearly the same as that found under the majority of indigenous tree species, plants in plots of *E. excelsum*, *E. abyssinica* and *F. thonningii* had comparatively lower heights than those in the sole main crop.

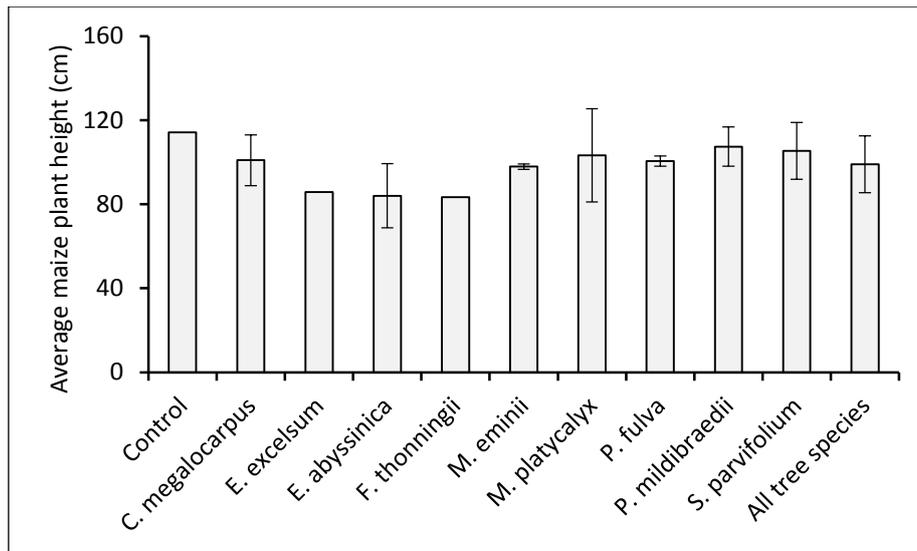


Figure 27: Average height of maize plants in the control plot and in maize-tree plots at Ruhande

Maize biomass fresh weight varied also within and among the maize – tree crop systems (Figure 28), with important variations between the control plot and *F. thonningii*, and within the plots of *M. platycalyx*, *C. megalocarpus*, *E. abyssinica* and *S. parvifolium*. In general, maize biomass fresh weight was higher in the control plot than in plots associating indigenous trees with maize. Although the drought event had affected maize performance at Ruhande, it was likely that pruning and thinning operations did not lead to large differences in biomass yields between the control and tree treatment components.

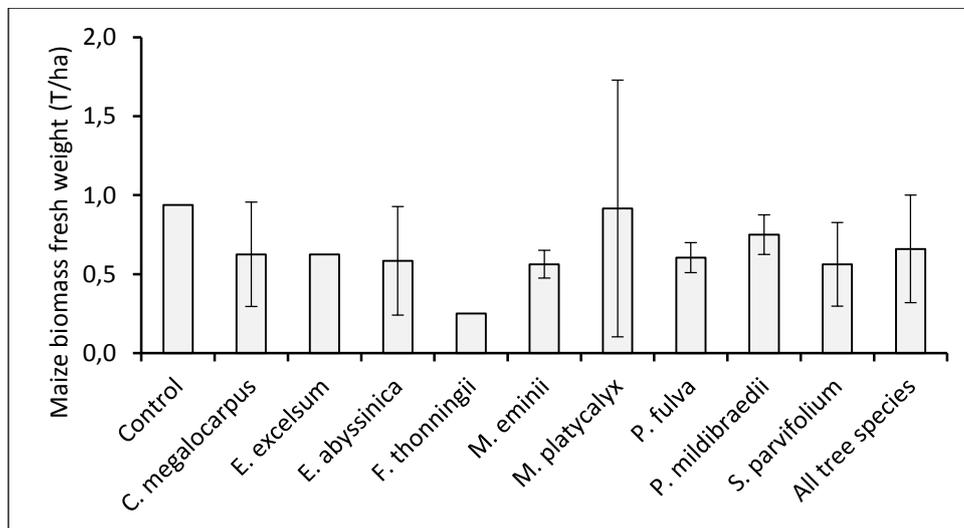


Figure 28: Maize biomass fresh weight recorded in the control plot and in maize-tree plots at Ruhande

Figure 29 indicates maize grain yields obtained in the control plots and in plots of indigenous tree species at Rubona. Average grain yield in the control plot was high and approximately the same as in *Ficus* and *Podocarpus* plots. Yields were the lowest in Maize-Maesopsis system (0.9 T ha^{-1}) and in Maize-Croton system (1.0 T ha^{-1}).

Compared to the control, smaller yields reduction of 2% and 9% were observed under *F. thonningii* and *P. falcatus*, respectively. *M. eminii* and *C. megalocarpus* reduced the maize grain yields significantly by nearly 67% and 63% respectively. Yield reduction in the remaining plots was also high, ranging from 25 % (*P. fulva*) to 44% (*P. mildbraedii*).

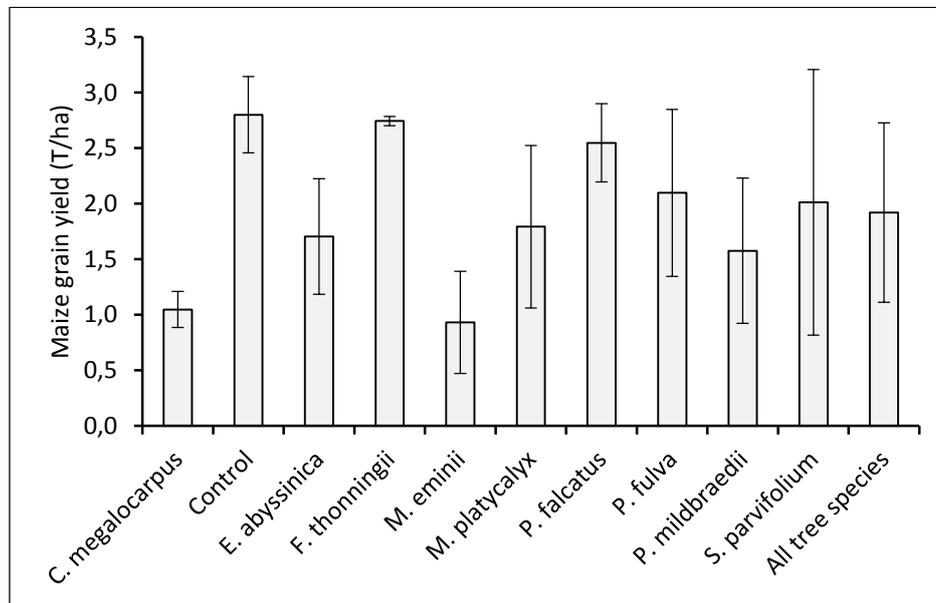


Figure 29: Maize biomass fresh weight recorded in the control plot and in maize-tree plots at Ruhande

Assessment of growth performance of different afforestation tree species in Ruhande arboretum

In Rwanda several tree species do not have volume and yield tables. Yet, the growth rates of many indigenous and exotic tree species are still unknown. Only a few tree species such as *Cupressus lusitanica*, *Cedrela serrata* and limited number of *Eucalyptus spp.* have been assessed for their growth, biomass production and annual increments. There is a need not only to enhance tree species diversity but also to provide data and information that guide decision making in forestry. This study has been conducted in order to: (i) evaluate growth performance and yields of both indigenous and exotic tree species and (ii) recommend promising high value and environmentally friendly species for use in afforestation activities in the country.

The study was conducted in various Permanent Sampling Plots implanted in young woodlots that have been planted since 2006 in Ruhande Arboretum, Huye District, Southern Province, with age ranging from 3 to 10 years old. Nine tree species comprising native, naturalized and exotic, were included in the experiments. The tree species were established from potted seedlings, in different plots of 0.25 ha each. Detailed information on the planted tree species and planting design are presented in Table 3. In the fiscal year 2016-2017, the performance of nine tree species introduced in Ruhande Arboretum were evaluated in terms of early growth and annual increments in diameter and height.

Table 44: Information on planted tree species and planting design

Plot no	Tree species	Provenance of seeds	Age(years)	Initial Spacing (m)	initial Number of stems/ ha
543	<i>Eucalyptus dunnii</i>	Arboretum of Ruhande	3.5	2 x 2	2,500
541	<i>Pinus carbaea</i>	Ngoma District	3.5	2 x 2	2,500
513	<i>Eucalyptus terticornis</i>	Tanzania	5.5	2 x 2	2,500
536	<i>Cupressus funebris</i>	Arboretum of Ruhande	5.0	2 x 2	2,500
536	<i>Juniperus procera</i>	Arboretum of Ruhande	5.0	2 x 2	2500
548	<i>Eucalyptus dunnii</i>	Arboretum of Ruhande	3.1	2 x 2	2500
349	<i>Syzygium porvifolium</i>	Nyungwe National Park	10.4	2 x 2	2,500
397	<i>Measopsis eminii</i>	Arboretum of Ruhande	9.4	2.5 x 2.5	1,600
381	<i>Measopsis eminii</i>	Huye District	9.4	2.5 x 2.5	1,600
386	<i>Eucalyptus dunnii</i>	Arboretum of Ruhande	3.1	2.5 x 2.5	1,600
404	<i>Faurea saligna</i>	Nyungwe National Park	5.0	2 x 2	2,500
231	<i>Zanthoxylum gulletii</i>	Nyungwe National Park	7.0	2.5 x 2.5	1600
530	<i>Cupressus funebris</i>	Arboretum of Ruhande	5.0	2 x 2	2,500
434	<i>Pinus carbaea</i>	Ngoma District	7.0	2 x 2	2,500

Data were collected in PSPs of 0.04 ha or 11.28 m radius, that were delineated in square stands of 0.25 ha established in Ruhande arboretum. The PSPs were set up from the center of stands in order to avoid border effect on measured tree parameters. The plot centre was marked by painted standing tree in the center of plot. Using a measuring tape, trees that were within the predetermined radius were considered to fall within the plot and boundary trees were marked by paint. The exception in the delineation of PSPs was for two exotic coniferous species including *Juniperus procera* and *Cupressus funebris*, which were contingent sub plots within plot n° 536, and separated by a path of 4 m wide. For those two species, the sample plots had rectangular shape and identified by marking plot boundaries with paint, starting by the second rows on each side, and leaving 4 m from the stand limits to the measured trees within the sub plots. In this case, the area of the resulting PSPs was nearly 0.09 ha (19 m x 46 m).

Measurements of total height at 1m accuracy were done for all stems within the plot, using a telescopic pole. The diameter at breast height was measured for all stems only with DBH equal and greater than 3 cm with 1 cm accuracy, and as a rule if a stem has forks or branches above 1.3 m, it was regarded as one stem, while if the forks existed below 1.30 m we considered two separated stems. Coppices of planted trees and natural regeneration of trees were not included in the measurements within a plot. Data recording and processing was recorded using Microsoft Excel Sheet. Mean annual increments in height and diameter were determined by dividing the heights and diameters with the respective age of the species.

Table 45 presents the survival rates of tree species and their growth performance in different plots at Ruhande Arboretum. In general, all tree species survived at a rate greater than 65%. The highest survival rates, greater than 80%, were observed on many tree species including *Eucalyptus tereticornis*, *Eucalyptus dunnii*, *Faurea saligna*, *Zanthoxylum gillettii* and *Cupressus funebris*. The lowest survival rates were observed for *Juniperus procera* and *Pinus caribaea* (plot 67) with 66.4% and 67% respectively.

Table 45: Survival rates of planted tree species in Ruhande Arboretum

Plot NO.	Tree species	Age(years)	Number of stems ha ⁻¹	Survival rate (%)	Average DBH (cm)	Average height (m)
543	<i>Eucalyptus dunnii</i>	3.5	1,775	71.0	6.2	8.9
541	<i>Pinus caribaea</i>	3.5	1,800	72.0	4.2	3.0
513	<i>Eucalyptus tereticornis</i>	5.5	2,300	92.0	5.9	7.0
536	<i>Cupressus funebris</i>	5	1,751	70.0	3.8	2.2
536	<i>Juniperus procera</i>	5	1,659	66.4	3.9	3.0
548	<i>Eucalyptus dunnii</i>	3.1	2,050	82.0	5.8	6.5
349	<i>Syzygium porvifolium</i>	10.4	1,775	71.0	7.9	8.8
397	<i>Maesopsis eminii</i>	9.4	1,275	76.1	12.0	13.4
381	<i>Maesopsis eminii</i>	9.4	1,225	73.1	10.9	12.7
386	<i>Eucalyptus dunnii</i>	3.1	1,425	85.0	7.0	7.1
404	<i>Faurea saligna</i>	5	2,150	86.0	4.5	4.1
231	<i>Zanthoxylum gillettii</i>	7	1,450	90.6	7.9	9.3
530	<i>Cupressus funebris</i>	5	2,100	84.0	4.8	4.5
434	<i>Pinus caribaea</i>	7	1,675	67.0	6.7	4.9

The preliminary results of growth parameters show that *Eucalyptus dunnii* has a faster initial growth in diameter and height than the rest of the tree species. It reached a height of 8.9 m and a DBH of about 8.9 cm, 3.5 years after planting. The 5- years old *Cupressus funebris* and *Juniperus procera* had smaller diameters than the other tree species of the same age. Indigenous species such as *Zanthoxylum gillettii* and *Faurea saligna* were relatively vigorous at the age of 7 and 5 years compared to other exotic tree species of the same age. The Mean Annual Increments (MAI) in diameter and height of the different tree are given in Table 46. Results showed that *E. dunnii* was a fast growing species in Ruhande arboretum with MAI in DBH ranging from 1.8 to 2.3 cm year⁻¹ while MAI in height was between 2.1 and 2.5 m year⁻¹. There was no large difference among the rest of the tree species in terms of MAI in DBH (0.8- 1.3 cm year⁻¹). Low MAI in height was found in species dominated by coniferous species including *Pinus caribaea* (0.7- 0.9 m year⁻¹), *Juniperus procera* (0.6 m year⁻¹) and *Cupressus funebris* (0.4 - 0.9 m year⁻¹). Lower growth rates in height of coniferous tree species could be due to their characteristics of developing many branches at early stage of growth.

Table 46: Comparison of Mean annual Increments (MAI) in diameter and height of the different trees species in plantation at Ruhande

Plot no	Tree species	Age(years)	MAI in DBH (cm year ⁻¹)	MAI in height (m year ⁻¹)
543	<i>Eucalyptus dunnii</i>	3.5	1.8	2.5
541	<i>Pinus caribaea</i>	3.5	1.2	0.9
513	<i>Eucalyptus tereticornis</i>	5.5	1.1	1.3
536	<i>Cupressus funebris</i>	5	0.8	0.4
536	<i>Juniperus procera</i>	5	0.8	0.6

548	<i>Eucalyptus dunnii</i>	3.1	1.9	2.1
349	<i>Syzygium parvifolium</i>	10.4	0.8	0.8
397	<i>Maesopsis eminii</i>	9.41	1.3	1.4
381	<i>Maesopsis eminii</i>	9.41	1.2	1.3
386	<i>Eucalyptus dunnii</i>	3.1	2.3	2.3
404	<i>Faurea saligna</i>	5	0.9	0.8
231	<i>Zanthoxylum gillettii</i>	7	1.1	1.3
530	<i>Cupressus funebris</i>	5	1.0	0.9
434	<i>Pinus caribaea</i>	7	1.0	0.7

In general, considering the survival rate, growth parameters and MAI, all tree species performed well. *Eucalyptus dunnii* appeared to be a fast growing species at juvenile stage compared to the rest of monitored tree species. Indigenous tree species such as *Zanthoxylum gillettii*, *Syzygium parvifolium* and *Faurea saligna* were promising to be among climax species that should be domesticated out of their natural habitat. These results remain preliminary and regular monitoring of growth and yield over many years will provide tangible results on growth performance and biomass yields.

Establishment of conservation plots and assessment of adaptability of indigenous tree species in Rubona Centre, Huye district, Rwanda

A few number of tree species dominate agricultural and forestry landscapes in Rwanda. The more common timber species in agroforestry is *Grevillea robusta*, while *Eucalyptus spp.* and *Pinus spp.* are more frequent in forest plantations and woodlots. However, Rwanda has a rich diversity of tree species in its natural forests or woodlands. Domestication strategies of these tree species could play a role in diversifying the range of high value tree species for use in agroforestry and forestry. Tree species diversification is vital because of a number of reasons:

- the needs of the population are diverse and need to be met by a diversity of species;
- different species perform differently under different site conditions and an increasing number of species are endangered and need to be raised artificially;
- the remaining natural forests need restoration after extensive deforestation and degradation as a result of socio-economic and climatic factors;
- ecosystems need to be restored and people need to be provided with a range of species for large scale reforestation or tree planting in agroforestry systems.

This study attempts to (i) domesticate indigenous and exotic tree species with high economic value for conservation and research purposes, (ii) compare the adaptability, growth rates and productivity of different tree species planted in Rubona Centre, (ii) compare the amounts of biomass and carbon accumulated in different tree species, and (iii) evaluate their potentialities in agroforestry systems for increased yield of crops/trees.

The experiment was established in Gakera site located in RAB Rubona Centre, Huye District, Southern province. Fifteen native and naturalized tree species from different agroecological zones of Rwanda were planted for domestication and conservation purposes. Planted tree species include *Podocarpus falcatus*, *Markhamia Platycalyx*, *Maesa lanceolata*, *Polyscias fulva*, *Harungana montana* *Croton megarcarpus*, *Bridelia Blidelifolia*, *Syzygium palyvifolium*, *Enthandrophragma excelicium*, *Ficus thonningii*, *Albizia adiantifolia*, *Faurea saligna*, *Zanthoxylum gillettii*, *Dombeya torrida* and *Maesopsis eminii* and *Pterygota mildbraedii*.

Seedlings of these tree species were raised in pots at Rubona nursery before field planting at Gakera site. Within the plots, weeding was done on quarter basis. The initial planting density of each tree species was 169 trees over an area of nearly 0.063 ha per replicate, translating an initial spacing of 2 m by 2 m. Each tree species was replicated three times, following the position in the landscape: hill top, middle, and bottom of hill). Adjacent replicates were separated by an array of 4 m on all sides. As the planted trees were very young, only the survival rate determined three months after tree planting.

Three months after field planting, the survival rates of the different tree species at Gakera sites were low ([Table 47](#)).

Table 47: Survival rates of the different tree species planted at Gakera site, Rubona Centre

No	Tree species	Total number of planted seedlings	Surviving tree seedlings	Survival rate %
1	<i>Podocarpus falcatus</i>	507	161	31.8
2	<i>Markhamia Platycalyx</i>	507	152	30.0
3	<i>Maesa lanceolata</i>	507	156	30.8
4	<i>Polyscias fulva</i>	507	266	52.5
5	<i>Harungana Montana</i>	507	142	28.0
6	<i>Croton megarcarpus</i>	507	279	55.0
7	<i>Bridelia Blidelifolia</i>	507	161	31.8
8	<i>Syzygium palyvifolium</i>	507	141	27.8
9	<i>Entandrophragma excelsum</i>	507	59	11.6
10	<i>Ficus thonningii</i>	507	256	50.5
11	<i>Albizia adiantifolia</i>	507	158	31.2
12	<i>Faurea saligna</i>	507	171	33.7
13	<i>Zanthoxylum gillettii</i>	507	11	2.2
14	<i>Dombeya torrida</i>	507	196	38.7
15	<i>Maesopsis eminii</i>	507	226	44.6

Overall, the survival rate was less than 60%. Compared to other tree species, *Croton megalocarpus* (55%), *Polyscias fulva* (53%) and *Ficus thonningii* (51%) recorded higher survival rates. In contrast, higher mortality rates were found for *Zanthoxylum gillettii*, *Entandrophragma excelsum*, *Syzygium palvifolium* and *Harungana montana* that had less than 30% of surviving trees. The main cause of low survival rates was an extended drought period that occurred three months after planting, and beating –up was unsuccessful.

In the future, more data will be gathered on growth parameters, productivity and biomass production in order to provide reliable information on that will guide the choice and use of these tree species in forestry and agroforestry development. The immediate need is now to restock the plots through beating-up and to carry out intense silvicultural activities to enhance survival and growth of the tree species.

Testing adaptability and biomass production of bamboo species

Bamboo is a versatile plant that is used for food, tools, musical instruments, brewing, making juices, furniture, shelter and medicine. It is also used for improving residential environment, and it is known to have high efficiency in carbon sequestration. As far as the livelihood of people is concerned, bamboo culms are used in construction and provide various traditional goods including baskets, beehives, mats, chairs, beds, etc. Bamboo stands play also a role in the conservation environment; as an example bamboo stands reduces emission of carbon dioxide in the atmosphere. Bamboo is also known as a good species for erosion control especially on land slid and riverbank protection.

In many areas of Rwanda, bamboo occurs in clusters on hills and farmlands, around homes and in gardens. Bamboo species are not diversified and only three species are commonly found in the country. These are *Bambusa vulgaris*, *Arundinaria alpina* and *Oxythenanthera abyssinica*. From 2005, research experiments conducted in Ruhunde Arboretum showed that *Dendrocalamus giganteus* was another bamboo species which perform well in Rwanda. Small clusters of bamboo species known as *Bambusa oreobambos* are found in Kigali and this species is mainly grown in gardens for ornamental purpose. In 2012, four new bamboo species namely *Bambusa textilis*, *Dendrocalamus barbatus*, *Dendrocalamus latiflorus* and *Dendrocalamus strictus* were introduced from China and are now field tested for their adaptability, growth and biomass production in Kicukiro, Huye and Nyaruguru districts.

Bamboo field test set up in Kanombe (Kicukiro district) were evaluated for their growth, and shooting ability. The experiment was set up in 2014 and included four bamboo species namely *Bambusa textilis*, *Dendrocalamus barbatus*, *Dendrocalamus latiflorus* and *Dendrocalamus strictus*. *Bambusa vulgaris*, a local adapted bamboo, was used as control. The growth of bamboo was evaluated by collecting data on culm diameter and height. Since bamboo coppices, the shooting ability was evaluated by recording shoot accounts on bamboo stools.

The diameter at breast height (DBH) and total height are key parameters in the evaluation of growth and adaptability of species in forestry and agroforestry. The performance of the four bamboo species in DBH and height of culms are presented in Figure 8 and Figure 9 respectively. Differences in diameter growth among *B. vulgaris*, *D. barbatus* and *D. latiflorus* were not significant but *D. barbatus* appeared to reach larger diameter (5.9 cm) than *D. latiflorus* (5.3 cm) and *B. vulgaris* (5.1 cm). The diameter of *B. textilis* was much smaller (2.3 cm), less than a half of the diameters of the other three bamboo species.

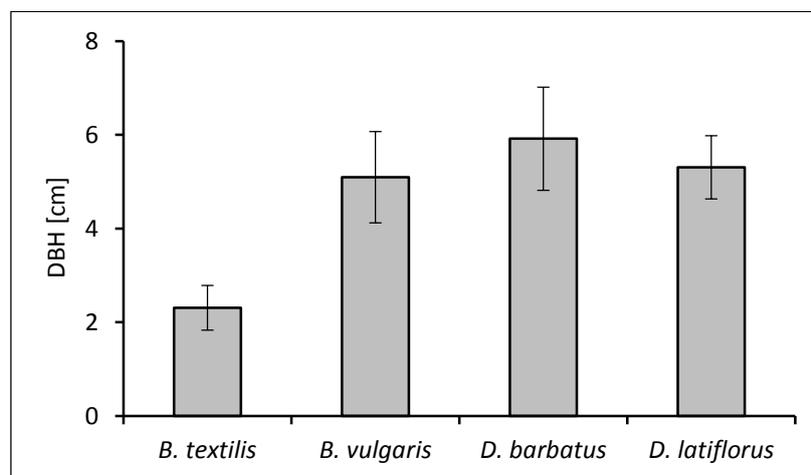


Figure 30: Growth in diameter at breast height (DBH) of four bamboo species grown in Kanombe site. Growth in height of the four bamboo species followed the same trend as their performance in diameter. Hence, taller culms were registered by *D. barbatus* (6.7 m), followed by *B.*

vulgaris (6.1 m) and *D. latiflorus* (6.0 m) and least for *B. textilis*. The smaller sizes of *B. textilis* make it suitable for use in erosion control practices, the production of stakes for climbing bean and use as small materials in the production of wood pellets as source of energy for cooking meals. The other three species could be alternative to eucalyptus in construction works.

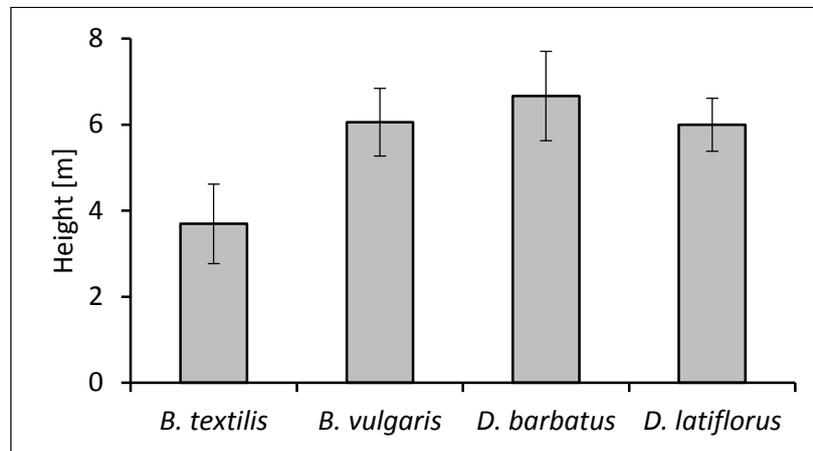


Figure 31: Growth in height of four bamboo species grown in Kanombe site

The shooting ability is important characteristic for highly productive bamboo species. [Figure 31](#) shows the sprouting rate of the four bamboo species planted in Kanombe. Results indicated that, *B. textilis* produced the largest number of shoots per stool (16 shoots/stool). It was followed far by *D. barbatus*, *B. vulgaris* and *D. latiflorus* that produced 9 to 11 shoots per stools. On hectare basis, the density of bamboo shoots were in the order of : 11,973 shoots ha⁻¹ for *B. textilis*, 8,213 shoots ha⁻¹ for *D. barbatus*, 7440 shoots ha⁻¹ for *B. vulgaris* and 5,600 shoots ha⁻¹ for *D. latiflorus*.

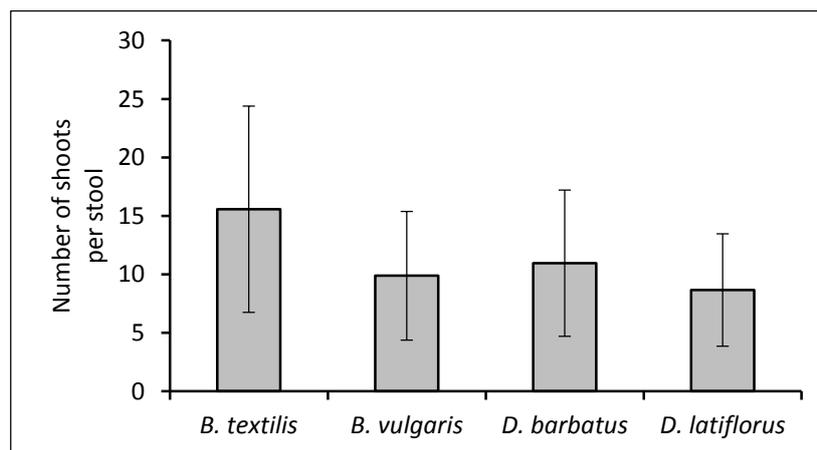


Figure 32: Average number of shoots produced by four bamboo species grown in Kanombe site

Determination of best pre-treatment methods for enhanced germination of selected indigenous tree species

Seed pre-treatment is anything that you do to the seeds before you plant them. This includes soaking, changing temperatures to imitate coldness/warmth, or even keeping them in the dark. Each type of seed has specific pre-sowing processes that will overcome dormancy, and allow germination to take place. Seed pre-treatment can either shorten germination period of treated seed or increase germination rate of this. The germination of seeds on many tree species in Rwanda is very low and efforts to increase their germination capacity have been made, with a focus on indigenous tree species.

Treated and untreated seeds of *Maesopsis eminii*, *Entada abyssinica*, *Polysias fulva* and *Harungana montana* were collected from different locations and sown in the tree nursery located in Rubona. *M. eminii* and *H. Montana* seeds were harvested at Nyungwe and both *E. abyssinica* and *P. fulva* were obtained from plantations at Rubona. The seeds were pre-treated by (i)soaking seeds in cold water for 48 hours, (ii) soaking seeds in hot water for 24 hours, (iii) removing the seed coat and (iv) soaking seeds in hot water for 24 hours. The seeds of each tree species were sown in the nursery. Each treatment was replicated three times and comprised 100 seeds.

For all the tree species, pre-treatment of seeds before sowing in seedbeds increased the germination rate (Table 48). Compared to the control, soaking seeds of *Maesopsis eminii* in cold water for 24 hours improved slightly the germination rate of the seeds. *Maesopsis* seeds germinated up to 57% when they were soaked in cold water for 24 hours while untreated seeds gave a germination rate of 49%. This pre-sowing treatment led to significant increase in the germination rate of *H. Montana* that registered 93%. The untreated seeds of this species gave a germination rate of nearly 66%, implying that cold water treatment increased the germination of the seeds by 28 % with a reference to the control.

Although seeds of *E. abyssinica* germinated satisfactorily (75%) without any pretreatment applied, soaking seeds in hot water for 24 increased the germination rate up to 83%. Hot water treatment before sowing increased the germination by 8% relative to the control. The removal of seed coat from seeds of *P. fulva* resulted in germination rate of 75% while the germination in the control treatment was about 69%.

Table 48: Germination per cent of four tree species under cold and hot water treatment and removal of seed coat

Species	Treatment	Number of germinated seeds out of 300 seeds	Germination %
<i>Maesopsis eminii</i>	Soaking in cold water for 48 hours	172	57.3
	Control	148	49.3
<i>Entada abyssinica</i>	Soaking in hot water for 24 hours	249	83.0

	Control	226	75.3
<i>Polysias fulva</i>	Removal of the seed coat	224	74.7
	Control	206	68.7
<i>Harungana montana</i>	Soaking in cold water for 24 hours	280	93.3
	Control	197	65.7

1.4 Cross-cutting research

1.4.1 Biotechnology

Biotechnology program at RAB conducts research for development a long two core themes. The first theme deals with plant tissue culture aimed at developing and/or optimizing protocols for mass production of disease-free planting materials of priority vegetatively propagated crops of direct relevance to food security. The second core theme that the program runs is development/optimization of efficient and cost-effective protocols on plant disease diagnostics/characterization. This facilitates indexing of plants raised in laboratory (tissue culture) for diseases to make sure that all the planting materials disseminated to end users are, indeed, disease free as well as diagnostics of other plant diseases, especially for epidemics. The program also runs some studies on plant diseases epidemiology on occasional basis.

In vitro mass production and dissemination of disease free planting materials

During the reporting period, the program was involved in mass production and dissemination of disease free planting materials for crops whose protocols have been finalized. In collaboration with different commodity programs, we were able to produce the following plantlets, which are at different growth and developmental stages:

- Banana: 20,399 plantlets, all of them on multiplication stage.
- Sweet potato (29,073 plantlets): 22,264 plantlets at multiplication stage and 6,809 plantlets at weaning stage.
- Multiplication of cassava clones from nucleus research materials that are presumed to be resistant to CBSD obtained from International Institute for Tropical Agriculture (IITA). In total, 28,135 plantlets are at the multiplication stage, although these came from IITA as plantlets on solid media. This means that they were multiplied on the basis of the existing partial protocol. Research to develop a full protocol for regeneration of cassava is reported in the section below.

Development/optimization of in vitro propagation protocols for priority crops

As reported last year, we initiated research into optimizing a coffee protocol that we had earlier developed for use in regenerating about 14 F1 hybrids, which were recently developed by the coffee sub-program. For protocol optimization, tissue explants for coffee hybrids (14

F1 hybrids) were cultured onto Murashige and Skoog (MS) artificial media supplemented with various levels of cytokinin phytohormones, after surface sterilization. These were subsequently, and regularly, transferred to fresh media for multiplication. Somatic embryogenesis (leaf as an explant) method was used.

A coffee F1 hybrids *in vitro* regeneration protocol based on somatic embryogenesis has been partially optimized. Explants collected from the F1 hybrids initiated on artificial media resulted in somatic embryos (1,345), which were transferred to fresh medium for multiplication. These were taken through regeneration stage, and later on, rooting stage. We have managed to successfully wean a total of 484 plantlets of such hybrids. Based on these results, we can say that the protocol to regenerate our recent coffee hybrids has been optimized, but with a weaning success rate of about 85%, depending on a variety (Photo 15), which we will further improve. However, since the process takes quite some time because of the nature of the coffee plant, we intend to start some research on the possibility of using different phytohormone combinations to quicken the regeneration process, especially at the somatic embryo stage. Apart from the work done on our coffee germplasm, coffee sub-program recently introduced germplasm from USA, which we collaborated on weaning them here in Rwanda. Thus, a total of 4,016 coffee accessions received from the USA were weaned at our facilities in Rubona. These will be used in trials across the country.



Photo 15: Regeneration of coffee F1 hybrids recently developed at RAB using optimized tissue culture protocol. Proliferated somatic embryos (left) were regenerated and sub-cultured on media (middle) before weaning, which showed a success rate of 85% (right)

We have not been having a full *in vitro* regeneration protocol for cassava; just multiplication part. The current cassava production trends in the country, however, necessitates a full working regeneration protocol for different reasons, but mainly two important ones: 1) Massively propagating the new CBSD tolerant clones introduced in the country for immediate deployment in our farming systems, and 2) rescuing some of our local cassava varieties (landraces) with proven good traits, which may be facing danger of genetic erosion or endangered. For protocol development/optimization, tissue explants for CBSD tolerant cassava varieties (NASE14, MM98/3567, MM 96/4271, NAM/130 and MM 96/2480) were

cultured onto Murashige and Skoog (MS) artificial media supplemented with various levels of cytokinin phytohormones, after surface sterilization. These were subsequently, and regularly, transferred to fresh media for multiplication. Nodal culture method was used.

Our results indicate that a near full protocol on cassava regeneration using tissue culture was developed/optimized. Plantlets raised from an initial initiation procedure comprising 167 explants on artificial media are now on multiplication stage. We have also been optimizing the weaning stage of cassava protocol, but using materials from our international research partners (mainly IITA). The results show a weaning success rate of about 70%, depending on a variety (Photo 16). Obviously, the weaning still needs to be optimized to come closer to 100 %, which we have started working on.



Photo 16: Optimization of cassava plantlets weaning protocol. Materials from international collaborators (left) were weaned with a success rate of 70% (right)

Plant diseases characterization/diagnostics

Most of the core research for development activities on plant diseases diagnostics/characterization reported in this biotechnology program section were conducted in the frame work of the project entitled “*Safeguarding livelihoods in Rwanda from the food insecurity threat posed by Maize Lethal Necrosis (MLN) through development of an integrated disease management system*”. Detailed activities are reported below.

Characterization of MLN-associated viruses

The characterization of MLN-associated viruses was carried out in collaboration with United States Department of Agriculture/Ohio State University (USDA/OSU). A total of 576 samples of maize and alternative MLN hosts (mainly napier grass and sorghum) were earlier tested using RT-PCR, which indicated that MLN in Rwanda is associated with Maize Chlorotic Mottle Virus (MCMV) as a principal virus and the two potyviruses: Sugar Cane Mosaic Virus (SCMV) and Maize Dwarf Mosaic Virus (MDMV), although MDMV could not be confirmed by RT-PCR probably because we used primers designed to a US isolate.

To better understand the MLN viruses complexity, we subjected representative samples to Next Generation Sequencing (NGS). Our bioinformatics work on RNASeq data obtained from the sequencing has so far revealed the existence of two new potyviruses in Rwanda. These viruses are Johnsongrass Mosaic Virus (JGMV) and a Polerovirus. We used a few other samples from our partners in East Africa to confirm the presence of these two viruses in the region. Detailed characterization studies, including plant bioassays, were carried out to confirm the potential role played by JGMV-East African isolate (JGMV-EA) in MLN development. JGMV-EA is distinct from previously reported isolates and infects maize, sorghum and Johnsongrass. It causes MLN in co-infection with MCMV and was present in MLN symptomatic plants in which the major East African potyvirus, SCMV, was not present (Figure 3). The findings, which are the first of their kind in Eastern Africa, will play a big role in re-designing MLN diagnostics and management in the region.

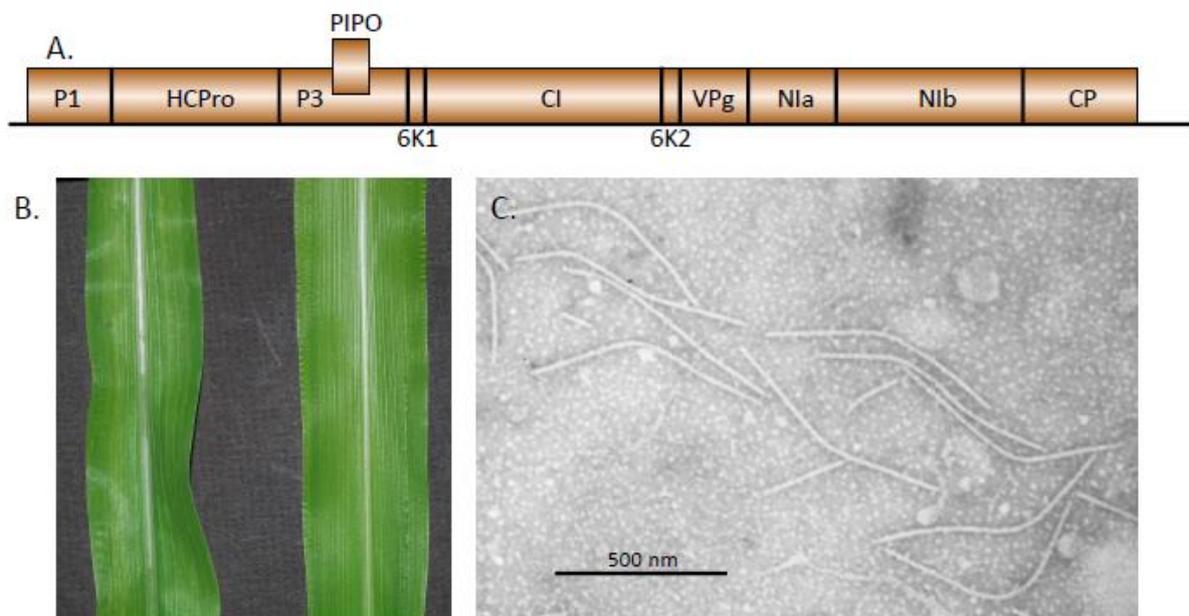


Photo 17: Johnsongrass Mosaic Virus East African isolate (JGMV-EA). A, Genome map; B, Symptoms in maize as shown on left compared to healthy control on right; C, Transmission Electron Microscopy (TEM) of virions

Testing the possibility of transmission of MLN viruses through seed

The possibility of MN disease transmission through seed was also investigated at the MLN regional facility in Naivasha, Kenya. We also tested the possibility of MLN transmission through infected soil as well as the role of mechanical (artificial) inoculation in enhancing disease development (Figure 4). Our results indicate that MCMV, the principal MLN virus, is transmitted by seed at a rate of 4.17%, which agrees with our earlier observations in Rwanda that the virus can be transmitted from parent to offspring for about three generations. These results suggest that seed movements from country to country need to be regulated in the region and seed testing be re-enforced. Within a country, quarantine programs targeting MLN hotspots should be established and policed.

The results also indicate that MCMV can be transmitted through infected soil. However, the mechanisms involved here are still elusive. Until conclusive experiments are conducted to unravel the mechanisms involved, we suspect that it could be due to the virus sticking to root or root hair debris instead of soil particles. Through delivery of a second virus into plants, healthy or infected with one of the MLN viruses, by using artificial inoculation, we were able to show that both MCMV and SCMV can be mechanically transmitted. Until now, most available reports had indicated that it is only MCMV that is mechanically transmitted. All these observations, especially the fact that potyviruses could also be mechanically transmitted, are a good resource, which we intend to use in re-designing and updating our MLN IPM package for use in Rwanda, but it also has a potential for use elsewhere in Eastern Africa.



Photo 18: Testing the potential MLN viruses’ means of transmission. Felix Gatunzi, technician in biotechnology program, inoculating young maize plants using a mechanical/artificial method (left), scoring and rating plants (middle) as well as testing of viruses in a lab (right). All these experiments were conducted at the Naivasha MLN centralized regional facility, Kenya, which is managed by CIMMYT

Screening maize germplasm for MLN resistance

Resistance screening for MLN disease is carried out in collaboration with the International Maize and Wheat Improvement Center, CIMMYT. Last year we reported that we had successfully screened a total of 305 Rwandan maize entries comprising hybrid varieties, locally developed inbred lines, commercial Open Pollinated varieties and breeding populations at the centralized MLN facility in Naivasha, Kenya. Out of these, we identified three hybrids with high levels of tolerance.

During this reporting period, we were pre-occupied with bulking of seed from these materials. For example, for the season 2018A, we have the three varieties at different stages of seed production as shown in table 1, with the most advanced stage being certified seed (last stage). This season we expect to get at least 30 MT (30,000 kg) of basic seed from the total acreage of 11.5 Ha and 200 MT (200,000 kg) of certified seed from the total acreage of 70 Ha. Together with the maize sub-program and RAB seed unit, we hope to disseminate these elite materials to farmers soon.

Table 49: Production of seed from three maize hybrid varieties with mild MLN resistance

Hybrid variety	Planted area for basic seed	Planted area for certified seed
----------------	-----------------------------	---------------------------------

RHM1407	4 Ha for female parent; 1.5 Ha for the male parent	50 Ha
RHM1409	2 ha for female parent; 1 ha for the male parent	20 ha
RHT 132	2 ha for female parent; 1 ha for the male parent	-

1.4.2 Genebank

There is a need to pay attention to genetic resources status by safeguarding the vast diversity existing in plant, forestry, animal and microorganisms. The Rwanda National Genebank safeguards genetic resources for current and future use through conservation. Currently, the main focus on conservation of genetic resources is on crop, forest and animal resources. During the 2016-2017 fiscal year, the Genebank activities involved collection, characterization and conservation of genetic resources.

Exploration and collection of plant genetic resources

Germplasm explorations and collections conducted from July 2016 to June 2017 focused on plant genetic resource landraces and orphan crops. Thus, a total of 105 accessions composed of 6 wheat landraces, 33 bean landraces, 6 soybean landraces, 14 pea landraces, 2 pigeon pea landraces, 1 rice landrace, 31 indigenous vegetables, 2 groundnut landraces, 2 finger millet landraces, 1 cowpea landrace, 2 maize landraces, 1 finger potato, 2 sorghum landraces and 2 passion fruits were explored, collected and conserved for further characterization, germination and moisture content tests. After collection, the accessions were registered, processed and assigned accession numbers.

Morphological characterization of different plant genetic resources

A total of 209 accession sets were morphologically characterized in three locations (Rubona, Rwerere and Karama RAB stations) representing middle altitude, high altitude, and low altitude agro ecological zone, respectively, using standardized descriptors. These 209 plant genetic resources consist of 11 amaranths, 10 eggplants, 9 hot peppers, 2 night sheds, 2 spider plants, 1 tomato, 1 sweet pepper, 11 pumpkins, 72 beans, 31 maize, 24 peas, 26 sorghum, 3 finger millets and 6 wheat. Figure 1 illustrates accessions of spider plant and beans being characterized in Rubona and Rwerere centers, respectively.



Photo 19: Morphological characterization of spider plant (left) and beans (right) using standardized descriptors

Characterization of local large stock (Inyambo and Inkungu)

In collaboration with large stock program, 20 local animal genetic resources (Inkungu) and 26 new calves of local genetic resources (Inyambo) were morphologically characterized (**Photo 20**).



Photo 20: Inyambo calves being morphologically characterized at Karama RAB station

Exploration and collection of forest genetic resources

To safeguard Rwanda's forest genetic resources, 22 accessions (*Chrysophyllum gorungosanum*, *Prunus africana*, *Faurea saligna*, *Macaranga kilimandscharica*, *Erythrina abyssinica*, *Syzygium parvifolium*, *Hagenia abyssinica*, *Podocarpus falcatus*, *Acacia gerrardii*, *Acacia hockii*, *Olea europea spp. Africana*, *Ozoroa reticulate*, *Combretum molle*, *Markhania platycalyx*, *Pterygota mildbraedii*, *Acacia polyacantha*, *Phyllanthus emblica*, *Carapa grandiflora*, *Croton megalocarpus*, *Dombeya torrid*, *Neoboutonia macrocalyx*, *Maesopsis eminii*) of genetic resources were collected and conserved. Like in plant genetic resources, the activity of collection was preceded by exploration, and after collection, the accessions were processed (sorting, drying, germination test, moisture content test, packaging) before conservation (**Photo 21**).



Photo 21: Seeds of *Croton megalocarpus* (left) and *Podocarpus falcatus* (right) in processing after collection

1.5.3 Socio-economics and biometrics

During the fiscal year 2016-17, the socio-economics and biometrics program up scaled the innovation platform approach, conducted different studies and contributed to the implementation of different projects.

Up scaling innovation platform approach

The operationalization of the existing and newly established innovation platforms consisted in trainings (Innovation system approach and its integration in the agriculture research for development; The concept of integrated agriculture research for development (IAR4D); Project design and management; Milk hygiene from farm to the MCCs; milk hygiene from MCCs to milk consumption); Linking IP to banking institutions and a study tour on value chain and IP management in Uganda.

One innovation platforms were initiated, one on wheat value chain in Gataraga sector/Musanze district and one on soybean value chain in Murundi sector/Kayonza district. It is in the framework of Enhancing Smallholder Wheat Productivity and Competitiveness to Reduce Wheat Import Bills (SWPSI) project that the wheat IP was initiated. A study conducted in Gataraga identified the following major wheat production and marketing constraints: (1) pests and diseases, (2) high cost of inputs, (3) low access to inputs, (4) small land holding, (5) Low soil fertility, (6) lack of improved wheat varieties, (7) low market price at harvesting time and other marketing constraints include (8) lack of market information, (9) lack of transport means, (10) difficulties in fixing prices, (11) substandard scales, (12) lack of appropriate storage facilities.

Smallholder wheat production and marketing cost structures in Rwanda

It is in the framework of Enhancing Smallholder Wheat Productivity and Competitiveness to Reduce Wheat Import Bills (SWPSI) project that this study was conducted in Rwanda to provide baseline information that would set the basis for measuring progress and impact of the project activities. More specifically the study aimed at estimating wheat production and marketing cost structures and look into specific production and marketing activities

constraining the competitiveness of smallholder wheat producers in Rwanda; estimating plot level wheat productivity and identify the attributes of different inputs and crop management practices to yield and estimating farm level contribution of wheat to household income and consumption. One hundred sixty (160) households randomly selected among 2017A season wheat growers from four (4) cells in Gataraga sector of Musanze district were interviewed using a structured questionnaire and data from the study were analyzed using descriptive statistics. Household land holdings in Gataraga sector are small the average landholding being 0.7 ha with a maximum of 8ha and a minimum of 0.015ha. The average land operated during the last season (Season 2016B), including rented in land was estimated at 0.5ha. Thirteen varieties were known by farmers in the surveyed area and twelve of them have been grown at least once. The most grown known varieties include Maroko, Gisukari, Sayire and Ingwizabukundu with 23.2%, 19.9%, 19% and 15.9% respectively. The main qualities that determine the preference of these varieties are mainly high yield (73.5%) and good taste (11.6%) while the main challenges include lodging (28.1%), susceptibility to disease (16.6%), low yield (14.3%) and low price (10.1%).

The data on wheat production revealed that 78.75% of the total surveyed households grew wheat in season 2016A while in season 2016B wheat production was done by 73.75%. the average area in both season was the same (0.2ha) and the average production was 260kg in 2016A and 241.8kg in 2016B and this means a productivity of 1300kg and 1207.5kg/ha respectively. The average selling price at harvest was around 330Frw/kg in both season (330.6frw/kg in 2016A and 332.9frw/kg in 2016B). Potato production occupied large area compared to wheat in the surveyed area with an average of 0.3ha in both seasons and the number of growers was a bit higher in season 2016B compared to that of wheat (141 potato growers against 118 wheat growers) while in season 2016A the number of potato growers was almost the same with that of wheat growers (121 potato growers against 126 wheat growers).

The average quantity of seed used was estimated at 119.5kg/ha and the average quantity of fertilizer used by wheat growers in 2017A season was estimated at 50.5Kg/ha of Urea, 86.5Kg/ha of DAP, 63kg/ha of NPK 17 17 17 and 2928kg/ha of organic fertilizer. Results of the study showed that women were more involved than men in wheat production activities and the reverse was observed in potato production where men were more involved than women. The utilization of wheat produce differs slightly from one season to the other but the major portion is sold to market with a proportion of 72% and 71% in 2016A and 2016B seasons respectively.

Wheat value chain in Cyumba innovation platform

The main actors of wheat value chain in Cyumba are: Producers, inputs dealers, collectors, wholesalers, retailers, processors, consumers, research extension and policy makers (Figure 33).

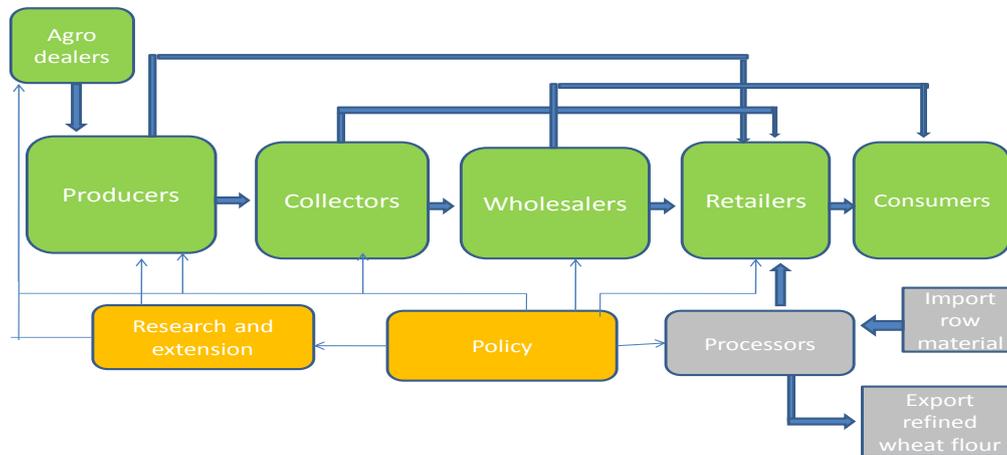


Figure 33: Map of wheat value chain actors in Cyumba sector

There is no strong relationship between actors and there is no link between producers and processing plants. The wheat production cost in Cyumba is high, reason why wheat produced locally are expensive compared to wheat imported. The selling price of local wheat is more than 250 Rfw while imported wheat cost less than 170 Rfw/kg. Therefore, big processors import wheat grain from Europe, USA and Australia. Wheat produced in Cyumba is bought by collectors carrying them at Gicumbi and Kigali market to be processed into flours made by small processors and this will be bought by consumers to be used as Ugali and porridge. Among all wheat value chain actors mapped; producers are the ones who gain less compared to others because farmers spend a long time in production added to the high production cost.

Gender based cost benefit analysis in innovation platform

This report presents the results from Gender based cost benefit analysis of participatory trials on use of lime for season 2017A. Three sites of Nyaruguru (Nyarwumba, Rohero and Cyahinda) and two sites of Nyamagabe (Nyabivumu and Remera) were considered. Three types of lime in six treatments: (1) Mashyuza burned and unburned, (2) Gishyita burned and unburned and (3) Mpenge burned and unburned were combined with Farm Yard Manure (FYM), DAP and Urea for beans and Maize production. Only maize is reported in Nyaruguru and climbing beans reported in Nyamagabe. Beans in Nyaruguru faced a long season drought while Irish potato faced diseases in Nyamagabe. The objective was to show the profit from the use of different types of lime in the production of maize and bean on the acidic soil and gender participation. The methodology used combined the crop assessment for the yield & input costs and the Focus Group Discussion (FGD) for the cost of labor.

The findings revealed that Mpenge unburned lime gave more profit than other types of lime on maize in the three sites of Nyaruguru while in Nyamagabe, the profit from climbing beans was high with Gishyita unburned lime where the yield was 4.07T/ha followed by Mpenge unburned with 4.03T/ha. The control treatments give negative return in all sites. Farmers themselves prefer the unburned lime in General. Considering the profit on these two crops, maize was more profitable than beans mainly because the cost of production of climbing beans is very high compared to the cost of production of maize.

Table 50: Summary of yield and profit of Maize in Nyaruguru District

Treatments	Yield S1 (T/ha)	Yield S 2 (T/ha)	Yield S3 (T/ha)	Average yield (T/ha)	Average cost (RwF)	Average revenue (RwF)	Average benefit (RwF)
Mashyuza burned	3.23	3.11	2.99	3.1	667666.7	1244000	576333
Mashyuza unburned	3.40	3.63	3.10	3.4	667666.7	1350667	683000
Gishyita burned	3.34	3.17	3.19	3.2	667666.7	1293333	625667
Gishyita unburned	3.59	3.69	3.29	3.5	667666.7	1409333	741667
Mpenge burned	3.41	3.33	3.57	3.4	667666.7	1374667	707000
Mpenge unburned	3.93	4.18	4.10	4.1	667666.7	1628000	960333
FYM + DAP+Urea	1.82	1.57	1.76	1.7	556666.7	686666.7	130000
Control	0.42	0.37	0.61	0.5	484000	186666.7	-297,333

Table 50 gives the image of yield in three sites of Nyaruguru, which are not significantly different. Mpenge unburned lime is the one that gives good results (4.1T/ha) followed by Gishyita unburned lime with 3.5T/ha. In general there is high loss where any input is applied (Control) to show that you cannot grow maize in Nyaruguru without using appropriate inputs.

Table 51: Profit analysis of beans in Nyamagabe sites

Treatments	Yield S1 (T/ha)	Yield S2 (T/ha)	Average yield (T/ha)	Average cost (RwF)	Average revenue (RwF)	Average Profit (RwF)
Mashyuza burned	3.86	3.67	3.51	1287500	1506000	218500
Mashyuza unburned	4.16	3.98	3.92	1287500	1628000	324500
Gishyita burned	3.85	3.55	3.70	1287500	1480000	192500
Gishyita unburned	4.35	3.78	4.07	1287500	1626000	340500
Mpenge burned	3.78	3.91	3.85	1287500	1538000	250500
Mpenge unburned	3.86	4.2	4.03	1287500	1612000	338500
FYM + NPK	2.59	2.65	2.62	1025000	1048000	23000
Control	0.45	0.95	0.70	937500	280000	-657,500

Table 51 shows that Gishyita unburned comes before with 4.07T/ha of yield followed by Mpenge and Mashyuza unburned with 4.03T/ha and 3.92T/ha.

Economic and financial analysis of the irrigation component of the Muvumba multi-purpose dam development project

The Government of Rwanda, through the Ministry of Natural Resources (MINIRENA), requested a support from KOICA to perform a feasibility study (F/S), including a detailed design (D/D), for the development of water resources through constructing a multipurpose dam on Muvumba River in Nyagatare District (Eastern Province of Rwanda). One of the major components of the Dam will be to supply irrigation water to drought-prone areas of Nyagatare District downstream of the Muvumba River. With respect to irrigation water supply, the Korean Engineering Consultants Corp (KECC) conducted an Irrigation System Feasibility Study for a total command area of 7,380 ha across 8 Sectors of Nyagatare District.

After reviewing the study, a RAB socio-economic team realized that the technical part of the study has been well developed and documented while the economic and financial analysis part had enough room for improvement. The team revisited then the later by using a spreadsheet to facilitate the analyses. The spreadsheet's calculations are attuned to economic and financial principles consistent with capital budgeting procedures enabling a comparison of projects.

The irrigation schemes are divided into two alternatives: Alternative A has canal lengths of 62 km in left side and 53 km in the right side; Alternative B has canal lengths of 62 km in the left side, but the canal in the right side will be divided into two parts; southern part and northern part according to the irrigation area, avoiding the right side canal passing the Nyagatare town.

In terms of cropping system for seasonal irrigation, maize is rotated with onion and these 2 crops are grown each twice a year. Rice is also cultivated twice a year but on the same land (Alternative A 650ha; Alternative B 820ha). When green beans are grown specifically in season C (June-August), avocado and banana occupy the land the whole year and are renewed each 10 years for avocado and 20 years for banana.

Results reveal that the 2 considered alternatives are economically acceptable with alternative B being superior to alternative A. In fact alternative B would contribute more to the national income by approximately 9 billion in forty years of the project life. The sensitivity analysis on cost and benefit was done under the following scenarios for Alternative A and B: (1) 0% inflation (2) 5% inflation per year (3) Increase by 1% in costs (4) Increase by 1.5% in costs (5) Increase by 2% in costs; (6) Increase by 2.5% in costs; (7) Decrease by 1% in benefits; (8) Decrease by 1.5% in benefits; (9) Decrease by 2% in benefits and (10) Increase by 1% in costs and decrease in 1% of benefits. [Figure 34](#) shows the effect of inflation on NPVs on alternatives A and B. These results show how alternative B would be more economically feasible. In fact,

alternative B is less sensitive to an increase in costs or a decrease in benefits. When inflation affects both costs and benefits (increased prices of both inputs and outputs), which is the case with scenario 1 and 2 the two alternatives A and B are not sensitive to change. However, a slight negative change (increase in input prices while no change on output price or a decrease in output prices while no change in input prices), which is the case for scenario 3 to 9, there is a free fall of NPVs. Things became worse when an increase in costs is combined with a decrease in benefits (scenario 10).

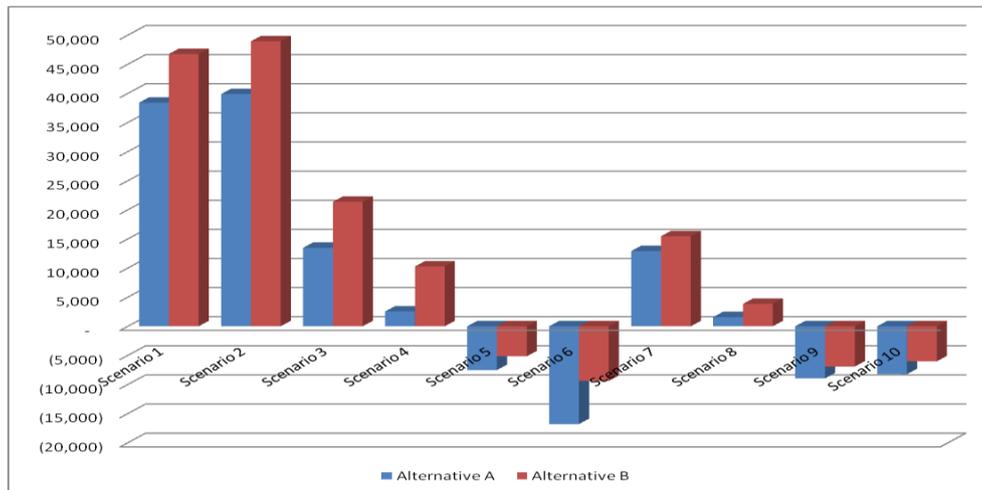


Figure 34: Sensitivity Analysis (Change in cost or/and revenue in 10⁶ FRw)

Capacity development for agricultural innovation systems (CDAIS) project

The project “Capacity Development for Agricultural Innovation Systems” (CDAIS) is an initiative launched in 2015 and implemented by the Government of Rwanda through the Ministry of Agriculture and Animal Resources (MINAGRI), the Food and Agriculture Organization (FAO), with financial support from the European Union (EU). The ultimate objective is to promote innovation that meet the needs of small farmers, small and medium-sized agribusiness and consumers. Draft capacity development plans were developed and validated by niche representatives in a validation workshop held on 7 December 2016. The outputs of the CNA and the CNA validation workshop were presented to capacity development providers and development organizations/partners on 8 December 2016 in an event known as a ‘Marketplace’ with a view to identifying synergies, complementarities and possible productive collaborations or co-financing opportunities (Photo 22).

Hand written posters for all niches and lists of capacities needed were prepared the day before by the niche representatives and posted at different locations on the walls of the workshop room. The posters contained a summary of the niche indicating the geographical location, opportunities, challenges, vision and objectives and key actors in the partnership of

each niche. The information on the hand written posters was captured by facilitators. The ‘World Café’ approach was used to share the information between workshop participants. One niche representatives stayed at the poster and presented the niche information to other participants who moved in their groups from poster to poster. The niches’ representatives provided more details on the niches through open discussions facilitated by NIFs.



Photo 22: Niche representative presenting at the information station for his niche

1.5.4 Postharvest

Fortification of cassava with orange-fleshed sweetpotato (OFSP) for improved retinol activity equivalents (RAE)

Cassava is a good source of energy as it contains high amounts of starch, which is a carbohydrate. Vitamin A deficiency is a public health problem in developing countries and the most vulnerable groups such as children, pregnant and lactating women are highly at risk. Cassava would be the right crop for fortification with orange-fleshed sweetpotato (OFSP), a rich source of β -carotene. In the current study, cassava flour and chikwangue (fermented cassava) were selected as the right product through which cassava would be fortified for improved retinol activity equivalence (RAE).

Preliminary trials on product development were conducted by researchers from the Postharvest and Nutrition program prior to subjecting them to a consumer acceptability test. The products ([Photo 23](#)) evaluated during the sensory analysis were prepared using a charcoal stove and tested by farmers to indicate the possibility of producing the same products without necessarily using electrical appliances. The products made from OFSP and chikwangue were exclusively prepared by using charcoal and stove. Seventeen products containing orange-fleshed sweetpotato and cassava were developed, seven of them being made based on cassava flour while the remaining ten were made on chikwange. The sensory analysis for these products was performed in Huye and Musanze Districts while products containing OFSP and cassava flour were evaluated in Muhanga and Musanze districts. Two

cassava flour based products had a score of 6 or above on general acceptability, while 10 chikwange based products had a general acceptability score of 6.



Photo 23: Product made based on chikwange with OFSP supplementation (left) and cassava flour with OFSP supplementation (right)

All the 17 products developed could be used as tools for combating vitamin A deficiency in Rwanda. These products can be prepared at home or in hotels and restaurants. Forty-three farmers were trained on the preparation of new cassava-OFSP products in Muhanga and Musanze.

Status of kitchen gardens in Southern province of Rwanda

Agricultural workers often lack sufficient income to meet their food and nutritional demands in terms of vegetables. Practice of kitchen garden farming could help them to improve consumption of vegetables. Thus, kitchen garden could be a principal source of household food and income during periods of stress, e.g. the pre-harvest lean season, harvest failure, prolonged unemployment, health or other disabilities suffered by family members or agricultural and economic disruption. Furthermore, the kitchen garden falls under bio-intensive and participatory innovation, which can provide year round availability, access and consumption.

The status of kitchen gardens in Southern province of Rwanda was assessed through a survey that was conducted in Huye district in four sectors using a stratified sampling methodology. About 85% of farmers interviewed have kitchen garden and the household who don't have kitchen garden are 15%. This shows today many households are willing to eat vegetables from their kitchen garden. About 59.6% of farmers use kitchen garden in plot design, 20% of the farmers use Nyamusozi kitchen garden and 5.4% use kitchen garden terraces design. About 49% of farmers do both cooking and selling the vegetables harvested and 51% of the farmers are consuming all the harvested vegetables. About 23.04% of farmers use vegetables to feed their children, while 18.14% of them use vegetables to improve the taste of food. 13.24% said

veggies help in digestion, and 12.25% said they improve eye health. A lower number of about 6.86% consider that vegetables are important in the prevention of diseases. Married people, women-headed households and off-farm employed household heads had significantly more kitchen gardens than unmarried people, men-headed households and unemployed off-farm household heads ($p < 0.05$).

The main challenge in growing vegetables was the lack of water during the dry season (74.01%), followed by insufficient and expensive manure and inorganic fertilizer (21.3%) and pest and disease (17.9%). About 10.4% of farmers reported that they do not face any challenge in growing vegetables.

1.6 Animal, fish and Insect research

1.6.1 Large stock

Large stock research is focused on selective cattle breeding through crossbreeding of exotic cattle and local Ankole for dairy. Breeding herds are located at Songa, Rubona and pure breed at Kinigi Center. Research studied seasonal growth of different crossbreeds and their seasonal milk production.

Seasonal growth of different crossbreeds

The seasonal growth of different crossbreeds was observed at RAB Songa. Mean live weights of the six cattle breed groups were recorded at birth, 3 and 6 months and weaning (Table 52). Birth weight was not affected significantly by any factor studied, except sex – males weighted heavier ($P < 0.05$). However, the calves of AF, ASS, ASJF, AFJ and ASF were heavier than calves of AA, AJ, and AJJ.

At three months, the weight of Ankole-Friesian crossbred calves (AFF) was significantly higher than other breed groups (Table 52, Figure 35). Calves born in short rain season were the heaviest. But the weaning weights across season 1 to season 3 did not differ significantly ($P > 0.05$). Male weaners ($125\text{kg} \pm 3.0\text{ kg}$) were heavier than female weaners ($119.27 \pm 2.5\text{ kg}$). We found that weaning weights differed ($P < 0.0521$). Calves Frisian x Sahiwal cross were significantly heavier at weaning than those of Jersey cross (Table 52). Weights of weaned calves of pure Ankole, cross of Jersey and Sahiwal were intermediate and not significantly different from each other.

At six months, weight of animals differed significantly by breed group ($P = 0.00001$), sex ($P = 0.0312$), (Table 52), while season ($P = 0.1053$) and its interaction with breed group ($P = 0.1004$) did not have influence on weaning weight. The heaviest weights were registered by breed groups AF and ASJ, but breed group ASJ was not significantly different in mature weights than breed group AJJ and AJ. The lowest weaning weights were registered in breed

group ASJF which was significantly lower than in all other breed groups ($P < 0.05$). At the same time, no differences were observed across seasons. Weaning during short rains has been adopted as a preferred management practice of at Songa and Rubona station to avoid weaning depression.

Table 52: Body weight of different breeds from birth to weaning age

Breed group	Body live weight (kg)			
	At birth	At 3 months	At 6 month	At weaning
AA	24a	58c	76c	119c
AF	26a	62b	96b	133b
AFF	24a	61b	86cb	142b
AFJ	27a	54c	72cd	142b
AJ	23.8a	62b	88cb	120b
AJJ	25a	51c	69cd	114b
AJJJ	26a	43c	65cd	120b
AS	26a	61b	81c	126.09b
ASS	27a	56c	91c	114.75b
AFFJF	24a	91a	148a	151a
AFS	24a	63b	88c	119b
ASSF	27a	58c	96c	130b
ASJ	24a	67b	151a	137a
ASJF	27a	64.5b	84c	99c
ASF	26a	63b	104b	137b

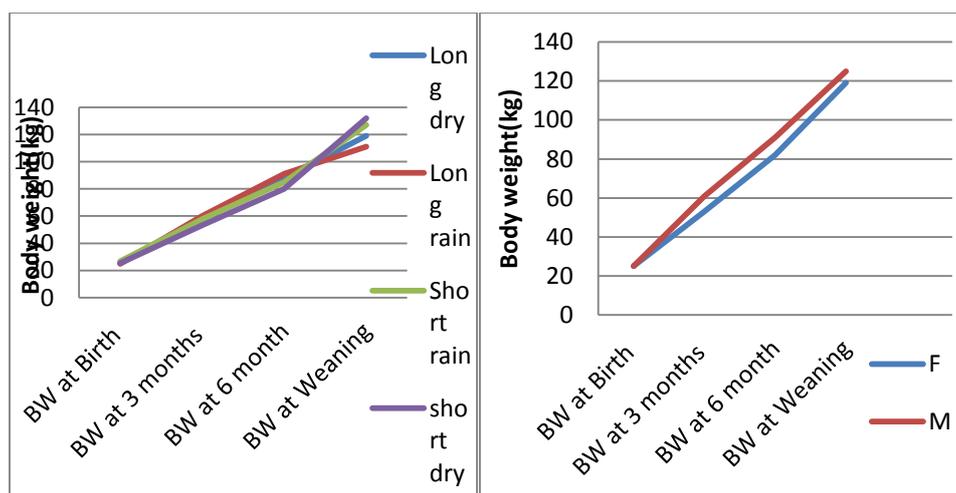


Figure 35: Effect of Seasons and sex on body weight (BW) of crossbred cattle

Note: AF = Ankole × Friesian; AJ = Ankole × Jersey; AS = Ankole × Sahiwal; AJJ = Ankole × Jersey × Jersey; AJS = Ankole × Jersey × Sahiwal; AJJJ = Ankole × Jersey × Jersey; ASS = Ankole × Sahiwal × Sahiwal

Effect of breed and season on milk production

The season is significantly affected the milk production $P=0, 0001$; breeding group it is also significantly affected. The milk productivity of 17 cattle genotypes reared at RAB stations is presented in Table 53. On average, the best performing genotype across the entire year was pure Frisian reared at Kinigi station, followed by AF, followed by AFF (Upgrades of AF when sired by Friesian), AFJ (upgraded when sired by Friesian and Jersey); followed by Fleckvieh; and then by AF and ASJJ (crossbred of Ankole and Sahiwal). Fleckvieh breed performed well. These animals need proper management for helping them to express their genetic potential. Milk production peaked in March, April and May (Figure 36). Milk produced per breed group, per day after feeding the calf (Figure 37).

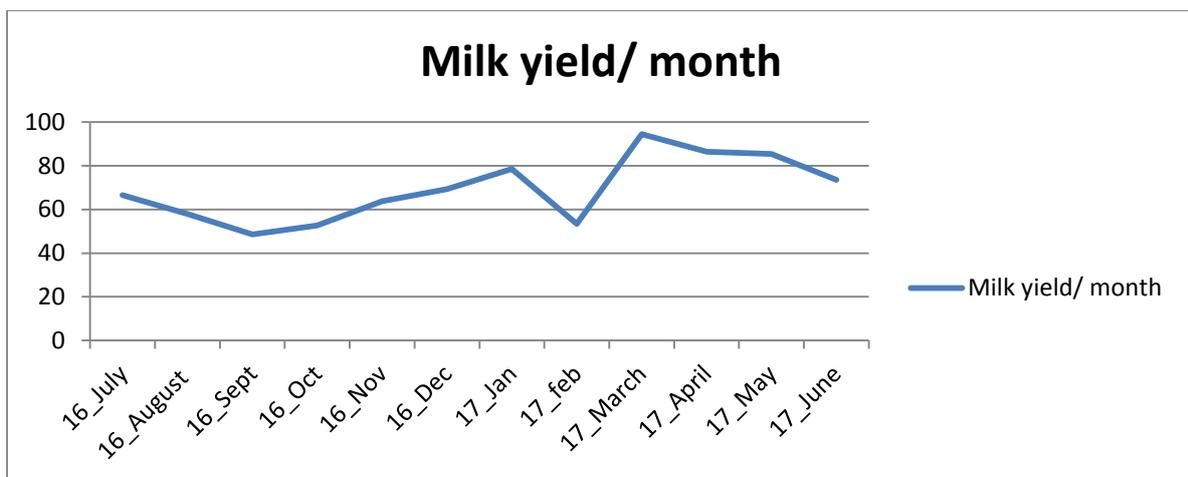


Figure 36: Milk yield per month

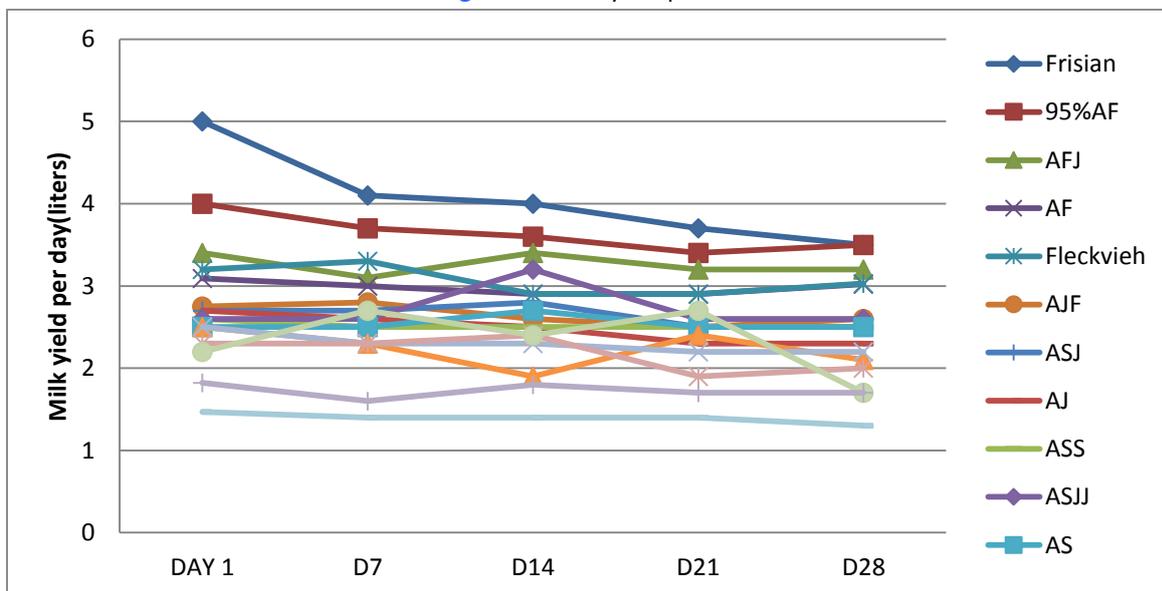


Figure 37: Variation in milk yield per cow and crossbreed at RAB Songa, Rubona and Kinigi

Milk yield was low. The best performing genotype was pure Friesian, peaked with 110 litres. The costs of housing, disease management and general care would not differ very much, but the cost of feeding would be a key factor. Thus it would be necessary to do a cost benefit analysis to determine the best system of production per genotype. In addition, the success rate of artificial insemination was reported to be 68% in RAB station during the 2016-2017 fiscal year.

1.6.2 Animal Nutrition

Animal nutrition research was focused on the study of the effect of untreated and ammoniated rice straw on different breeds steers growth performance; forage conservation; and study of trade-offs between income, soil nitrogen balances and greenhouse gas emissions and El Nino and Climate Change Resilient Livestock.

Effect of untreated and ammoniated rice straw on different breeds steers growth

The study compared the effect of feeding ammoniated total rice straw and untreated rice straw with beef concentrate on growth performance of three different steer breeds (Ankole, Friesian, and Fleckvieh). The ration tested were as follows: TRCA+ Beef concentrate; URCA (control) + Beef concentrate; TRCF+ Beef concentrate and TRCFF+ Beef concentrate. Where TRC is Total Rice Straw, TRCA is Ankole on treated rice straw, URCA is Ankole on Untreated rice straw, TRCF is Friesian on Treated rice straw and TRCFF is Fleckvieh on treated rice straw. Beef concentrate was made up with maize bran (40%), wheat bran (31%), soya (10%), palm cakes premix (13%), salt (1%), bone meal (3%) and premix vitamin (2%). Ammoniated rice straw with 46% urea was mixed with molasses after chopping rice straw.

The results on body weight gain of steers showed that Ankole s steers fed with untreated rice straws supplemented with commercial concentrates had a significant body weight gain as compared to other treatments (Figure 38).

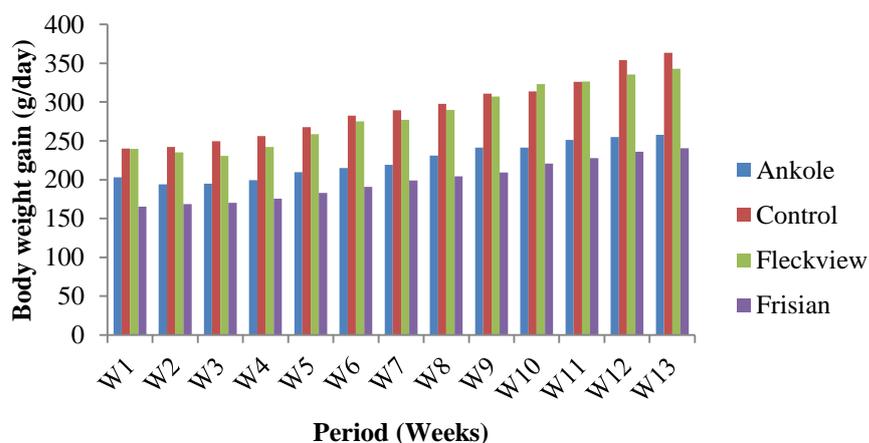


Figure 38: Growth of steers during 13 weeks of feeding trial

It was concluded that feeding untreated rice straw with concentrates increased body weight gain of Ankole steers compared to the steers fed on treated ammoniated rice straw. The use of

untreated and treated rice straw on the animal performance can lead to a better use of local resources for cattle by farmers in the rice based farming systems.

1. Fodder conservation

Fodder conservation is one of feed budgeting techniques, especially in drought prone areas. This is to mitigate feed shortages and avoid loss of animal during the dry period. From May to August 2017, a total number 14,819 bales equivalent to 444,570 kg of hay including *Chloris gayana*, rice straw and natural grass hay harvested at 21 farms was produced in Nyagatare district while it was 3,241 bales (97,230 Kg) of hay harvested from six farms in Gatsibo district (Figure 39).

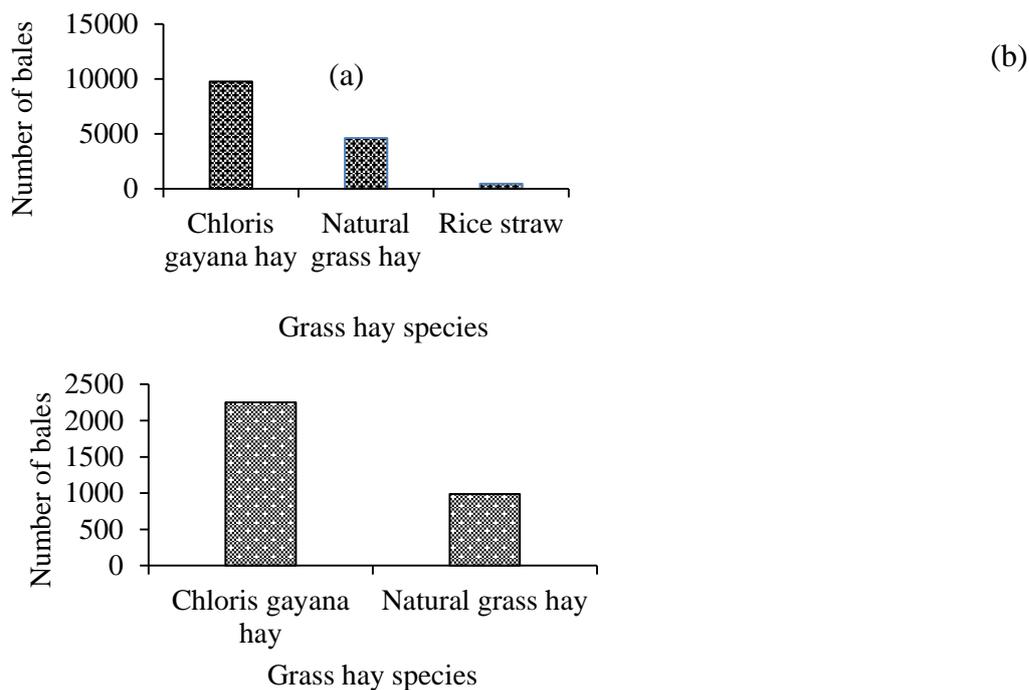


Figure 39: Number of hay bales produced in Nyagatare (a) and Gatsibo districts (b)

The results of dry matter harvested showed that the conserved grass hay could feed 872 and 3,987 TLU/cows for 92 days (during the dry season) in Gatsibo and Nyagatare districts, respectively. Knowing that Gatsibo district has a total number of 82,836 heads of cattle, only 1.05% of total cattle population can be provided with forages. Considering the number of farmers by types of hay; 67% of farmers have conserved improved forage variety namely *Chloris gayana*. Above a half of the total dry matter conserved in Gatsibo district was from *Chloris gayana*.

On the other hand, the conserved hay in Nyagatare district could feed only 3.7% of the total cattle population (106,822 heads of cattle). *Chloris gayana* was the most conserved hay (60%) followed by natural grass hay (38%) and only 2% of rice straw. Generally improved forages

were found to be more successful in forage production and conservation in both districts because they counted for 54% of the total conserved forages.

Hay making is the cheapest among other forage conservation techniques because any farmer, whether small or large can make it, even if he or she does not have a baler machine. Looking at the importance of forage conservation, it is advisable that farmers should be mobilized for forage conservation not only to cope with the dry season but also to increase feed availability year-round. It is hoped that farmers adopt the technologies and mobilization peer farmers in other district to eradicate feed shortage, especially during the dry season.

2. Pasture intensification in Rwanda: Trade-offs between income, soil nitrogen balances and greenhouse gas emissions

The FarmDESIGN model, which has been developed to perform multi-objective explorations of the solution space, to determine trade-offs between objectives at the same time developing promising alternatives for farming system have been used for multi-objective optimization and design of crop-livestock farming systems in Rwanda. This is done by coupling a bio-economical farm model that evaluates the productive, economic and environmental farm performance, to a multi-objective optimization algorithm that generates a large set of Pareto-optimal alternative farm configurations. In the first attempt FarmDESIGN was used for describing and explaining the outcomes of the current configuration of selected farms, as well as for exploring alternative farm configurations.

Case study farms were selected from contrasting agro-ecological zone, as well as with contrasting crop-livestock management systems. Four farms were selected as case studies for trade-off analysis with Farm DESIGN. Selected farms were i) a representative of large mixed farms (LM), that is to say the farm mixing grazing and cut and carry of forage systems, ii) a representative of small cut and carry farms (SCC), iii) a representative of small to medium cut and carry farms (SMCC) and iv) a representative of large grazer farms (LG). The LM farm had higher larger land area (16.2 ha) while SCC had both smaller land area (0.8 ha) and lower Tropical livestock unit (1 TLU). The LM farm had a TLU of 16.5. The SMCC farm and LG farms had 4.7 ha and 10 ha area of land and 8.5 and 22 TLU, respectively. The LM farm had mixed crop-livestock system while the LG farm had only livestock. However, the LM farm did not use crop residues as feeds for animal. The SMCC was an orphanage and it was much more complex than other farms in terms of feeds and feeding systems.

Principal component analysis (PCA) was performed on selected variables for 800 farmers to cluster Rwanda's farms. The PCA results highlighted 4 major clusters ([Table 53](#)). Cluster 1 was composed by farmers with cut and carrying of forages to feed more than 6 cattle. This cluster represents 0.18% of livestock farms countrywide. Cluster 2 comprised farmers with cut and carry, with one cow and the cluster represents 69.1% of livestock farms countrywide. Cluster 3 had farmers with grazing, and cut and carry, owning 2 to 6 cattle and the cluster represents

28.8% of livestock farms countrywide. Cluster 4 had farmers with big farms with grazing system and they represent 1.9% of livestock farms countrywide.

Table 53: Characteristics of clusters

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Min grazing time (hours)	0	0	0	7
Average grazing time (hours)	1.73	0.00028	0.0016	11.71
Max grazing time (hours)	6	2	1	12
Min # cattle	1	0	0	0
Average # cattle	6.54	0.30	2.47	7.76
Max # cattle	30	1	20	48
Min Land (are)	10.7	0.02	0.96	2.4
Average Land (are)	1000.03	48.17	113.58	357.3209
Max Land (are)	5074.05	364.8	956.07	5500

All farms had a positive N balance (Figure 40). However, SMCC and had higher N losses through exports of animal products indicating the extensive N mining and depletion. Farms which had cut and carry system, were the only farms which had the import of crop products as source of N. The LM and LG had main source of N as non-symbiotic fixation and deposition. Both LM and LG had the export of animal product as major output of N though LM had also export of household excreta as an output. In SCC and SMCC, the major output of N was export of household excreta. However, the export of crop and animal products also constituted as N output to the farms practicing the cut and carry of forage system. Large farms had minimum N dynamic compared to farms with cut and carry feeding system.

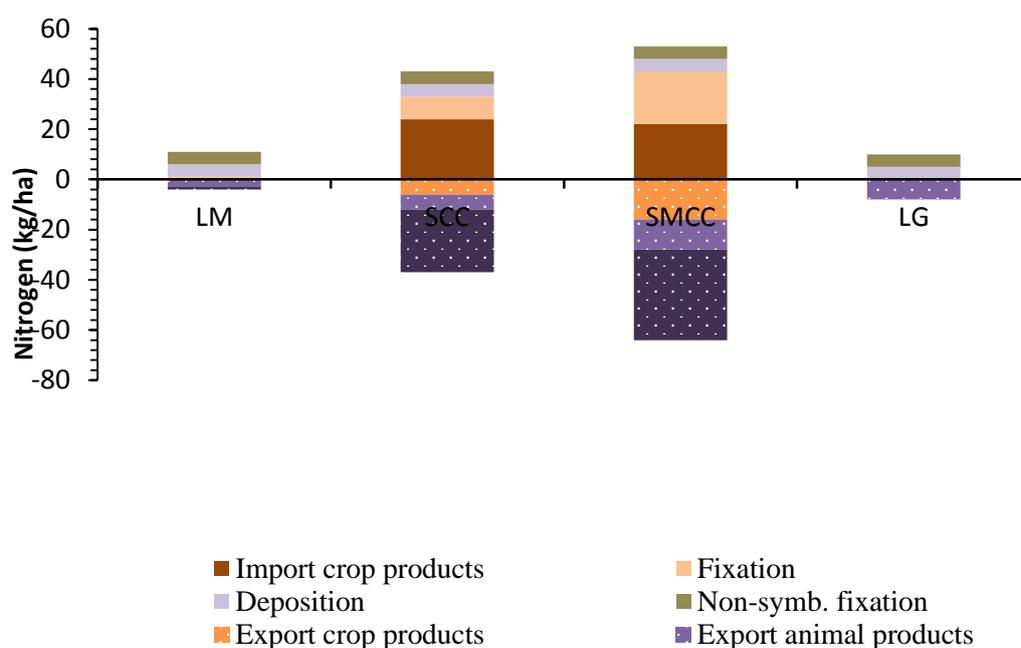


Figure 40: The N inputs and outputs at farm level (kg N/ha), values in positive side are inputs while values in negative side are outputs

In all farms, there was an internal cycling of N between soil, crops manure and household. The main losses of N in all farms was volatilization, as well as losses and accumulations but orphanage representing SMCC farms and SCC farms had crop products export and animal products as ways of losing Nitrogen in their farms. Crop N fixation was the external source of Nitrogen except from LG farms which had not crops. In addition, manure and crop product imports were also the source of external N for SMCC farm and SCC farm, respectively (Figure 41).

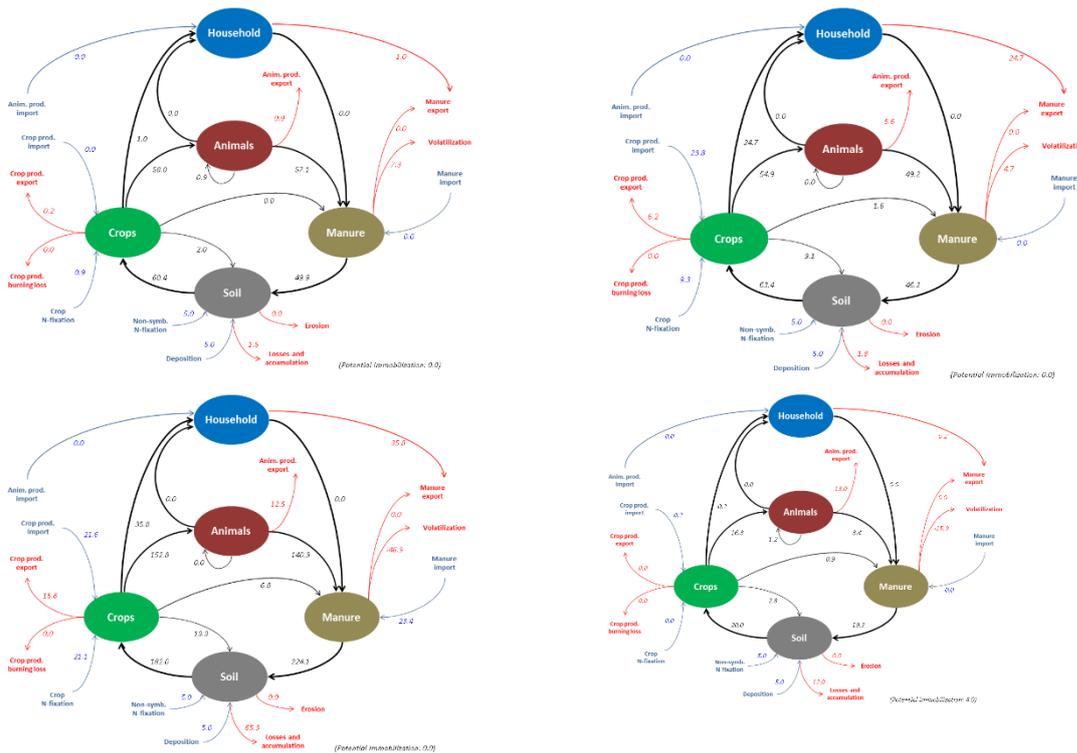


Figure 41: The N flows respectively from LM, SCC, SMCC and LG farms

The main source of organic matter was manure contributing 50% in all farms (Table 54). The major output of organic matter was manure degradation and SOM degradation. However, SMCC farm had the highest (1,849 kg/ha) SOM degradation output. The amount of stubble crops as a source of organic matter in SMCC farm was low (217 kg/ha) because farms used more crop residues as animal feeds than leaving them in the farm as green manure., There were a portion of crop residues left in the field, hence some green manure as a source of organic matter in LM, SCC and SMCC farms.

Table 54: Organic matter balance (kg/ha) in the study farms

Source/destination	Source/destination description	LM	SCC	SMCC	LG
Inputs	Crop Stubble	361	217	423	477
	Crop residues/Green manures	100	71	77	0

	Own manure	1,357	1,699	14,633	2,569
	Imported manure	0	0	0	0
Outputs	Manure degradation	1,227	1,492	13,284	2,297
	SOM degradation	592	495	1849	750
	Erosion losses	0	0	0	0
	Balance	0	0	0	0

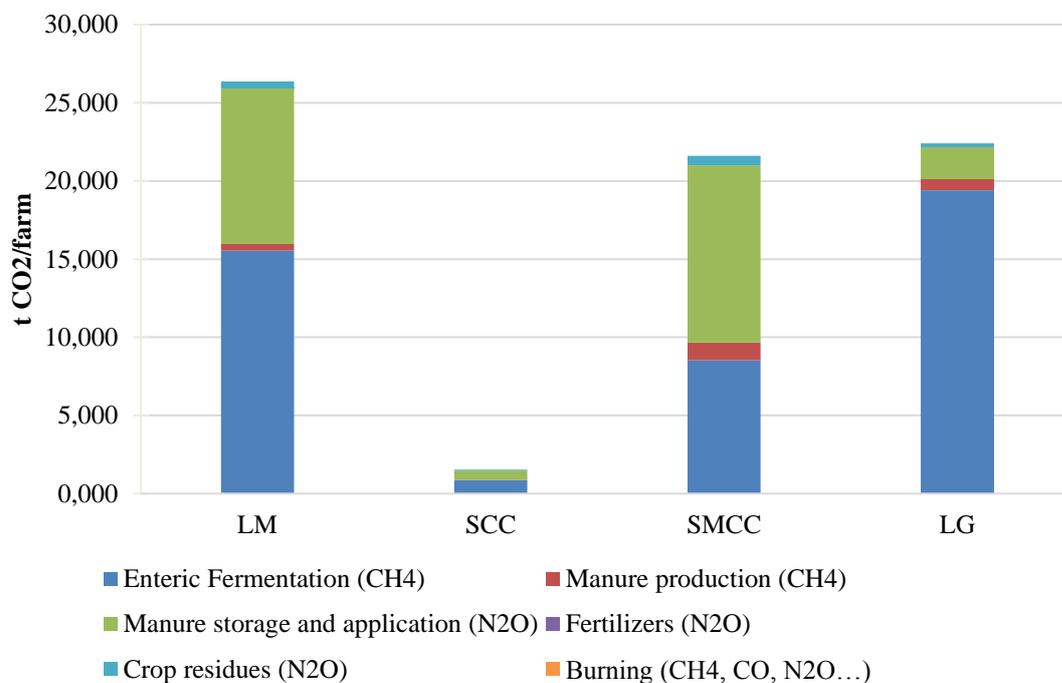
The SCC farm used only family labor because they had only 1 TLU and small portion of land (0.8ha) compared to other farms. In the other farms, most hired labor was more for livestock management than for crop management. All labor required, family labor contribution was less than 10%. In SMCC and LM farms, all types of labor were used for both crop and livestock management because they had various sub enterprises (Many crop lands and different types of livestock). The LG farm used less labor in crop management (<200 hr/ha/year) because natural pasture with less requirement of management activities. The SMCC farm had various crop and animal types and used the highest rate of labor which might be resulted from the inefficiency of people and this happen when a big number of people work together. Normally, the labor requirement should increase with the increase of the farm land but in this case the LG farm with 10 ha had more cumulative labor use than LM which had 16 ha.

The SMCC farm had higher operating profit than the rest of farms with, nevertheless, negative gross margin animals. The major cost in all farms was regular labor hiring. The LG farm had the least (USD 350) operating profit (+return family labor) while the highest (USD 14,767) operating profit (+return family labor) was observed in SMCC. Both LM and LG farms had a negative net income minus family labor costs whereas SCC and SMCC farmers had a positive net income (Figure 42). The LM farm was less profitable compared to other farms in terms of net income.



Figure 42: Net income from different farms

The LM farm had the highest greenhouse gases emission per farm while SCC had the lowest greenhouse gases emission per farm (Figure 43) which was in association with the number of livestock owned. The highest GHG was emitted from enteric fermentation in all farms, except SMCC farm which had high GHG emitted from manure storage and application (N₂O). The SMCC farm had a significant GHG emission per ha compared to other farms.



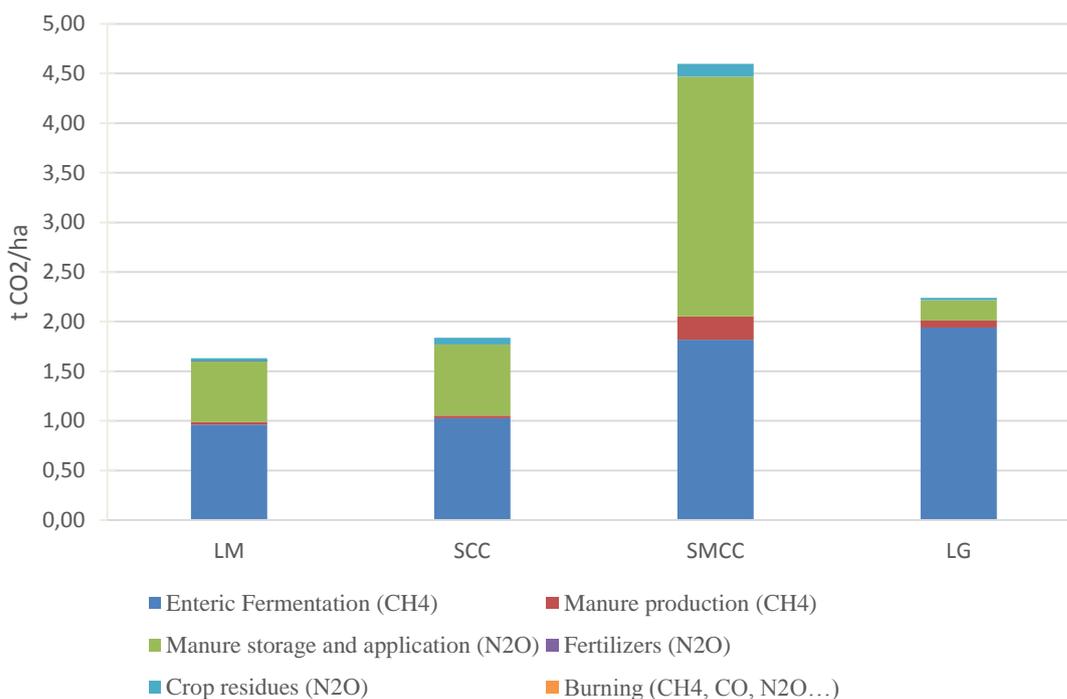


Figure 43: Greenhouse gases emission per farm

FarmDESIGN model highlighted an outstanding trade-off between farm profit and GHG emission. The LG farm had many options that would result in increased farm profit while reducing GHG emission compared to other farms. The LG farm had the least operating profit (+return family labor) while the highest operating profit (+return family labor) was observed in SMCC. The LM farm had the highest greenhouse gases emission per farm while SCC had the lowest greenhouse gases emission per farm which was in association with the number of livestock owned. Farm optimization highlighted that the SCC farm had few options to reallocate farm resources for resources use efficiency. The increase of farm profit would go up to 21.6% and GHG emission would be reduced by 25%.

3. El Nino and Climate Change Resilient Livestock

A decision support tool for sustainable intensification (SIDESS) and climate change resilient livestock was validated. The results identified and quantified significant opportunities for significant in yields, farm incomes, and gas emission intensity. In individual farms, implementing improved diets with 25% planted herbaceous legumes and higher feed intake in the long dry season results in productivity increases of between 30% and 215% (Table 55), and decreases in emission per kilogram of protein of between 8% and 45%.

Table 55: Average Daily Milk Yield and CO2eq per Unit Milk from one of Select Farms

Farm	Baseline	Improvement	% Change
Total land (ha)	0.3	0.3	0%

Total animals	2	2	0%
Kg milk/animal/day	3.31	10.42	215%
Kg CO2eq/Kg milk	1.52	0.83	-45%
Kg CO2eq/USD income	6.59	3.49	-47%
Total income (USD) from milk	247.57	710.22	187%

Scaling up these initial results to the national level suggests that a 50% adoption of the improved diets would lead to an estimated 40% increase in milk production nationally and for the mean farm. This rate of adoption would decrease emissions by about 20%, and would increase gross incomes per farm by about 28%. Adoption of improved diets by 100% of farms would increase milk production by an estimated 79%, would reduce emissions per kilogram of protein by about 32%, and would increase gross incomes by about 57% (Table 56).

Table 56: Scaling initial results to the national level according to different adoption rates of the improved diets

Parameter	Baseline	25% Adoption of Improved Diets	50% Adoption of Improved Diets	100% Adoption of Improved Diets
Animal Units (Units)	1,109,224	1,111,614	1,114,004	1,118,784
Bovine Animals (Unit)	2,856,384	2,870,833	2,885,281	2,914,178
Dairy Animals (Unit)	2,856,384	2,870,833	2,885,281	2,914,178
Total Live Weight (Kg)	499,150,642	500,226,203	501,301,763	503,452,884
Demand Crop Residues (Kg)	276,008,835	275,722,381	275,435,926	274,863,018
Demand Forage (Kg)	3,246,974,313	3,463,178,555	3,679,382,796	4,111,791,279
Total CO2eq (Kg)	1,889,025,575	1,950,257,967	2,011,490,359	2,133,955,142
Total CO2eq Beef (Kg)	738,842,182	703,947,028	678,209,990	644,323,215
Total CO2eq Milk (Kg)	1,150,183,393	1,246,310,939	1,333,280,368	1,489,631,927
Total CO2eq Net Emissions (Kg)	1,889,025,575	1,950,257,967	2,011,490,359	2,133,955,142
Emissions from Animals (Kg)	1,889,025,575	1,950,257,967	2,011,490,359	2,133,955,142
Income Beef (Unit)	134,538,786	141,307,641	148,076,496	161,614,207
Incomes Milk (Unit)	218,326,119	261,459,459	304,592,799	390,859,479
Total Income (Unit)	352,864,905	402,767,100	452,669,296	552,473,686
Total Beef (Kg)	138,042,791	145,130,231	152,217,670	166,392,549
Total Beef (Kg) Adjusted	138,042,791	145,130,231	152,217,670	166,392,549
Total Beef Protein (Kg)	10,146,145	10,667,072	11,187,999	12,229,852
Total Milk (Kg)	949,243,997	1,136,780,257	1,324,316,518	1,699,389,040
Total Milk (Kg) Adjusted	932,998,554	1,120,259,351	1,307,520,148	1,682,041,742
Total Milk Protein (Kg)	30,788,952	36,968,559	43,148,165	55,507,377

Total Protein (Kg)	40,935,097	47,635,631	54,336,164	67,737,230
Purchases of Concentrates (Kg)	30,825,825	46,786,159	62,746,493	94,667,161
Purchases of Grain Meal (Kg)	52,107,104	54,567,086	57,027,068	61,947,033

1.6.3 Animal health

1. The third component is on animal health which is focused on residual time of Permapy + 5% Piperonyl butoxide on tick-infested cattle

Residual time of Permapy + 5% Piperonyl butoxide on tick-infested cattle

Tick-borne diseases are a constraint to livestock production in many developing countries. Losses attributable to ticks are caused either directly, through tick worry, blood loss, damage to hides and udders and the injection of toxins, or indirectly through mortality or debility caused by the diseases transmitted by or associated with the ticks. This results in decreased production of meat, milk and other livestock by-products.

The most important tick-borne diseases of livestock in Rwanda are East Coast fever, ECF caused by *Theileria parva*, Anaplasmosis by *Anaplasma marginale*, Babesiosis by *Babesia bigemina* and *B. bovis* and Heartwater caused by *Ehrlichia ruminantium*. Of these, ECF is the most important cause of morbidity and mortality in cattle not only in Rwanda but through tropical Africa. Farmers in Rwanda mainly control ticks infesting livestock by application of aqueous emulsion acaricides. Other application methods include pour-on acaricide and grease-based formulations. Basing on veterinary and farmers' reports, resistance to some acaricides is increasingly being observed hence need to explore new acaricide formulations. Since 2015, the Veterinary and Laboratory Services Unit at Rubirizi has been working in partnership with AgroPy Limited in testing acaricides locally manufactured in Rwanda for efficacy and safety when used in controlling livestock ectoparasites. Here, we present results from field and laboratory-based investigations on a permethrin-based formulation Permapy containing Pyrethrins 1%, Permethrin 4% re-enforced with 5% piperonyl butoxide (PBO).

Tick infestation in selected animals on day 1 and 7 of the experiment

The mean tick counts on cattle sampled from at least two herds in each selected sector are shown in [Table 53](#).

Table 57: Mean tick counts on cattle

District	Sector	n	Mean tick counts		Mean tick counts	
			day 1 ± SEM	95% CI	day 7 ± SEM	95% CI
Bugesera	Gashora	6	41 ± 7	24-58	12 ± 2	7-16
	Rulima	6	35 ± 3	27-42	13 ± 1	10-15
Nyagatare	Matimba	9	40 ± 12	12-68	35 ± 10	13-57
	Rwimiyaga	8	66 ± 7	50-82	81 ± 10	59-103
Rutsiro	Boneza	5	58 ± 17	10-105	2 ± 2	-

Mukura	6	198 ± 47	78-317	0.5 ± 0.3	-
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Table 58: Responses on effectiveness of acaricides in use

District	Sector	n	Type of acaricide	Effectiveness of acaricide on ticks
Bugesera	Gashora	1	Amitraz	Susceptible
	Rulima	1	Amitraz	Susceptible
Nyagatare	Matimba	2	Amitraz	Resistant
	Rwimiyaga	2	Amitraz	Resistant
Rutsiro	Boneza	1	Cypermethrin	Susceptible
		1	Unknown	Susceptible
	Mukura	2	Amitraz	Susceptible

n= number of farms

On each selected farm, farmers were asked which acaricide they used to control ticks. They were further asked whether the acaricide they in use was effective in killing ticks (**Table 54**).

Tick species

The tick species recovered on sampled farms were as follows: apart from all the six animals sampled from Mukura Sector that were infested only with *B. decoloratus*, the rest (34) had *R. appendiculatus*. The cross tabulation of amitraz resistance and tick numbers on animals on day one and seven is shown in **Table 59**.

Table 59: Analysis of variance of tick numbers for amitraz resistance

Amitraz	Number of animals	Mean tick counts day 1 ± SEM	Mean tick counts day 7 ± SEM	Significance
Resistant	17	52 ± 8	57 ± 9	P > 0.05
Susceptible	23	84 ± 18	7 ± 1	P < 0.05

Mean tick numbers significantly reduced on day 7 in Amitraz-susceptible ticks while tick burdens in the resistant ticks did not significantly differ. In reference to **Table 59**, reduced susceptibility was observed in Matimba and Rwimiyaga sectors, a phenomenon that was not observed in other sectors where the exercise was done. The tick species found infesting animals on day seven were all *R. appendiculatus* species. *Boophilus* re-infestation had not occurred at day 7.

Preliminary in vitro female ticks' reproductive efficiency tests

Engorged female tick samples from Bugesera collected from cattle in vicinity of test herds were subjected to reproductive efficiency tests. Tick samples were incubated in the dark in humid state. The results were read five weeks later. The effective doses of Permapy on reproductive efficiency of female engorged ticks are shown in **Table 60**.

All the negative control ticks laid eggs and by 5 weeks after commencement of experiment, *B. decoloratus* and *R. appendiculatus* had hatched larvae. When treated with a standard

concentration none of the *R. appendiculatus* and *B. decoloratus* laid eggs; however ticks that were exposed to half standard concentration had one 1/3 ticks laying eggs (67%). All larvae that hatched from eggs were 100% viable.

Table 60: Reproductive efficiency response of ticks to Permapy on ticks from Bugesera

Reproductive state five weeks after treatment								
	n	Negative control	Comments	Half Conc	Comment	Standard conc	Comment	
<i>A. variegatum</i>	3	3	Not yet hatched	0	-	2	Not yet hatched	
<i>B. decoloratus</i>	4	4	Hatched, 100% larval motility	1	Not yet hatched	0	-	
<i>R. appendiculatus</i>	4	4	Larvae, 100% larval motility	1	Larvae, 100% larval motility	0	-	

Overall, Permapy + 5% PBO effectiveness in killing ticks was demonstrated in live feeding ticks in Bugesera and Rutsiro districts. The perception of farmers on effectiveness of the new acaricide was obtained two days after spraying. In addition, we examined the animals to confirm the farmers' reports. The acaricide effect was appreciated in Gashora, Rulima, Mukura and Boneza sectors. In Matimba and Rwimiyaga sectors, the farmers who participated in the experiment were not satisfied and instead reported '*the new acaricide is not effective in killing ticks*'.

Seven days after application of Permapy + 5% PBO, revisits were made on all farms where the experiment was performed. All ear-tagged animals were examined for tick infestation. Significant reductions were observed in Gashora, Rulima, Mukura and Boneza; conversely, heavier infestations were observed in Matimba and Rwimiyaga farms.

Basing on the results in this study, Permapy + 5% PBO can effectively protect sprayed animals up to 7 days, implying that weekly spraying intervals are sufficient in killing ticks. In a separate *in vitro* study report (results not shown here), half (2.5 ml in 1,000 mls of water) the standard recommended rate of 5 mls in 1,000 mls of water) mixing was equally effective as the standard rate. These results are supported by the reproductive efficiency studies of female ticks of *R. appendiculatus* and *B. decoloratus*.

Our observations show that Permapy is not effective where farmers have reported reduced efficiency / resistance of Amitraz as was shown in the two sectors in Nyagatare district. This observation demonstrated cross resistance between Permethrin-based formulations and Amitraz.

Recommendations

Permapy + 5% PBO can protect cattle against tick infestations for at least 7 days. In fact, the interval could be extended beyond 7 days because in Mukura, despite being a rainy season and 7 days after application, tick re-infestation had not occurred. In addition, the tick species in Mukura that infested cattle were all Boophilus species which are one host-ticks.

The trials provided sufficient scientific evidence of effectiveness of Permapy formulations in protecting livestock from ticks within the limits of the experiment. No adverse effects in form of skin reactions/ swellings were observed. We recommend that Permapy + 5% PBO be licensed for use for control of livestock-infestive ticks in Rwanda particularly in areas where amitraz resistance has not yet developed.

Training of Embryo transfer and embryo recovery

The theory and demonstration of materials used in MOET was showed to participant ([Photo 24](#)). Theory was attended at Rubilizi by all animal breeding staff and the practical was done at Kinigi on two cows. The protocol for embryo transfer was prepared ([Table 61](#)) and done as follow:

Table 61: Protocol of multiple ovulation and Embryo transfer (MOET)

		Day	Donor Cows		Recipient Cows
	11	01/12/2016		Prid delta P4	Prid delta P4
	10	02/12/2016			
	9	03/12/2016			
	8	04/12/2016			
	7	05/12/2016			
	6	06/12/2016			
	5	07/12/2016			
	4	08/12/2016	Folligon*2 (AM 700 IU, PM 700 IU)	(9 days Prid delta P4)	(9 days Prid delta P4)
	3	09/12/2016	Folligon*2 (AM 500 IU, PM 500 IU)	Inject PGF2α (enzaprost)	Inject PGF2α (enzaprost)
	2	10/12/2016	Folligon*2 (AM 200 IU, PM 200 IU)	Removal P4 + PMSG	Removal P4 +PMSG
	1	11/12/2016	Folligon*2 (AM 100 IU, PM 100 IU)		
	0	12/12/2016	Heat detection AI (PM)		Heat detection(no AI)
21 Days	7-8 Days	Day1; 13/12/2016	AI (AM); AI (PM)		Heat detection(no AI)
		Day2; 14/12/2016			
		Day3; 15/12/2016			

		Day4; 16/12/2016				
		Day5; 17/12/2016				
		Day6; 18/12/2016				
		Day7; 19/12/2016	Embryo flushing and recovery		Embryo Transfer (ET)	
	33 Days	Day8; 20/12/2016	Embryo flushing and recovery		Embryo Transfer (ET)	
						Checking the return of estrus
						PD (40 days)



Photo 24: Embryo transfer equipment and staff conducting flushing

Training of farmers on feed conservation

Training of farmers on forage on conservation and crop residues treatment were conducted both at on-farm and on-station.

Eighty (80) farmers from Ruhango, Muhanga and Kamonyi districts ([Photo 25](#)) were trained on the techniques of tube silage making and hay making as ways of conserving the forage. They were also taught how to treat and feed the crop residues were trained on the techniques of hay and silage making. The same techniques were taught to seventy (70) farmers from Huye district ([Photo 26](#)) who came to Rubona station. The farmers were shown how the bean residues are treated and witnessed how the animals eat bean residues treated with molasses. They were also able to compare handmade hays with bailer made hays of *Chloris gayana*.



Photo 25: Farmers observe fodder species under conservation (left); farmers learn how to make hay using hay boxes (right)



Photo 26: Farmers performing themselves silage making using silage tubes

1.6.4 Goats

Goats are valuable genetic resource that is good for low-input agricultural production systems. They require low inputs and are easy to manage, making them suitable for the resource poor rural households. Karama in Bugesera District is research centre under Rwanda Agriculture Board where different breeds of goats are kept for selection and breeding (pure Galla (GxG), pure Boer (BxB), pure Local (LxL), and their crossbreds (GxL) and (BxL)) for suitable goat genotypes.

Evaluation of goat genotypes reared under range grazing at Karama Center

The aim of this study was to evaluate the growth performances of goat genotypes at Karama Research Centre in the fiscal year 2016-2017. Genotype significantly influenced weight at ages

of 6 months to 16 months (Figure 44). The second generation Boer cross local and pure galla goats had the best weights (13kg) all through while pure local goats cross with Boer had the lowest values. The mean weight at 16 months were 27kg (BB), 24.5 (GG), and 20 kg (LL). It is concluded that pure Boer and pure Galla goats performed best during the study, management of the goats must be very good so as to sustain the performance, otherwise, local goats are hardy and always come handy under challenge of disease and lack of feed. Therefore the best bet combination for eastern Rwanda would be crossbred of local goats to Boer or Galla, so as to take advantage of the two gene pools.

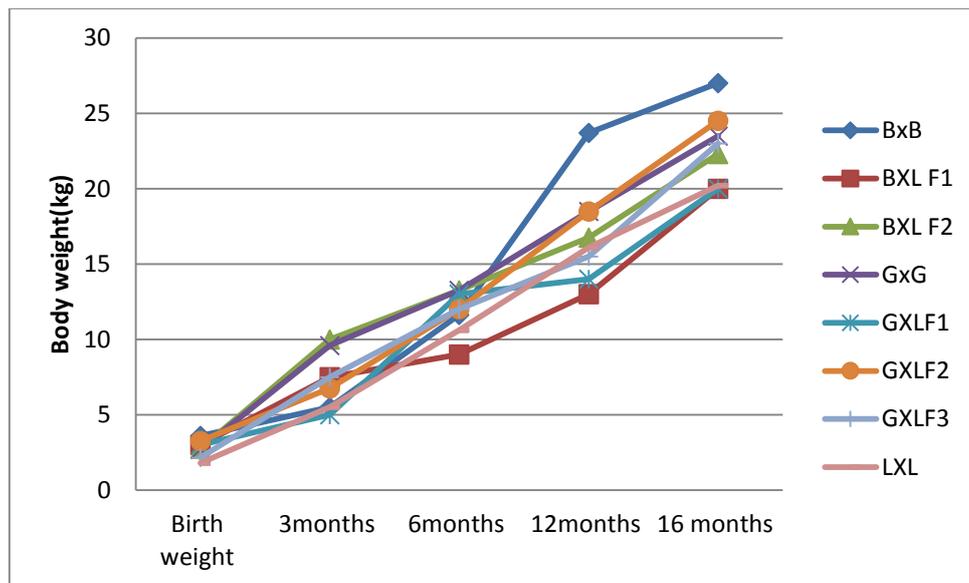


Figure 44: Effect of genotypes on body weight of goats

1.6.5 Poultry

The purpose of the research in chicken was to evaluate the weight of eggs from different chicken breeds

Egg weight

Egg weight was measured for Kuroiler, local breed and their crosses (Photo 27). The results shown that egg weight found to be affected by breed. Those data were collected on Pure Kuroiler, Local and 75%Kuroiler with local crosses. Egg weight between breed show to be significantly different ($P < 0.001$) with average weight for pure Kuroiler are 65,75gr, local 45.5gr and 75%Kuroiler local crosses 55gr.



Photo 27: Egg production at Songa

1.6.6 Aquaculture and Fisheries Research

The research in aquaculture and fisheries focused on diversification of fish species ; establishment of limnological database in lakes kirimbi and gaharwa and selective breeding of *Oreochromis niloticus* at Kigembe center

Diversification of fish species to be grown by Rwandan fish farmers

In Rwanda, now, one species namely *Oreochromis niloticus* (*Tilapia nilotica*) is available but there is a need to diversify aquaculture fish species, at least to have four fish species from different families in use. The fish families we can get species from are as follows: Cichlidae (*Tilapia nilotica*), Clariidae (*Clarias gariepinus*), Cyprinidae (different genera), Salmonidae (different genera).

The results shown that the temperature of most water bodies in the northern part of Rwanda is between 14°C and 22°C, the pH is between 6.5 and 8.8; the dissolved in water oxygen is between 8.5 mg/l and 6.6 mg/l. Eighty(80) carps, *Cyprinus carpio*, have been fished from Nasho fishinfg zone and put in ponds for adaptation and preparation for artificial reproduction.

Now, 12 of them are ready for artificial reproduction. Sixt four (64) *Clarias gariepinus* were intensively fed with aim of getting fingerlings and to have broodstock for artificial reproduction of *C. gariepinus*.

Carp and Clarias were fished from Nasho fishing Zone and stocked for adaptation in Kigembe and Kamisave fish farming stations: 20 carps and 11 clarias broodstock were collected from Nasho fishing Zone, Kirehe District, Eastern Province and stocked in the ponds at Kamisave Station in Musanze District, Northern Zone for adaptation.

Establishment of limnological database in lakes Kirimbi and Gaharwa

The study shown that the Kirimbi and Gaharwa lakes are shallow waters which are fairly low mineralized and water columns are not stratified in term of temperature. The temperature of both littoral and pelagic zones was fluctuating between 26°C and – 21°C throughout the day. Knowing that in most tropical water systems, species grow best at 20°C and 32°C. The recorded temperature range is favorable for aquatic life. It is observed that Lakes Kirimbi and Gaharwa are slightly alkaline in all selected sites with 7.7 as the highest pH and 7.2 as the lowest one. The pH range in littoral and pelagic areas varies within the favorable range for tropical fish production. Water transparency observed in littoral zones was lower than that of pelagic zones. Both suspended solids concentration and turbidity affect the light penetration which could be expressed by the level of water transparency.

As conclusion, results of the exploratory campaign in these two water body shown that different parameters are within what is considered to be safe for survival and production of aquatic organisms.

Selective breeding of oreochromis niloticus at Kigembe center

In Selective breeding , the scientist are focusing on improvement of the breeding value of **Oreochromis niloticus** . The selection is based on selecting the best fish (largest, heaviest, those with the desired colour, etc.) It is hopefully that the select brood fish will be able to transmit their superiority to their offspring. If this occurs, the next generation will be more valuable (better growth rate , increase yields; lower feed costs, which will increase their market value. The preliminary results for the selective breeding is shown in the [Table 62](#); [Figure 45](#).

Table 62: Selective breeding preliminary results

Families	Number of eggs	Fecundity rate	Number of eggs	Hatching rate	Number of fries hatched	Number of fries in happa	Survival rate	Number of fries grown in happa	G(%of Initial weight
F1.1	21000	99%	20790	80	16632	486	90%	438	17560
F1.2	21000	99%	20790	80	16632	736	90%	663	21407
F1.3	21000	99%	20790	80	16632	511	90%	460	21328
F1.4	21000	99%	20790	80	16632	415	90%	374	23135

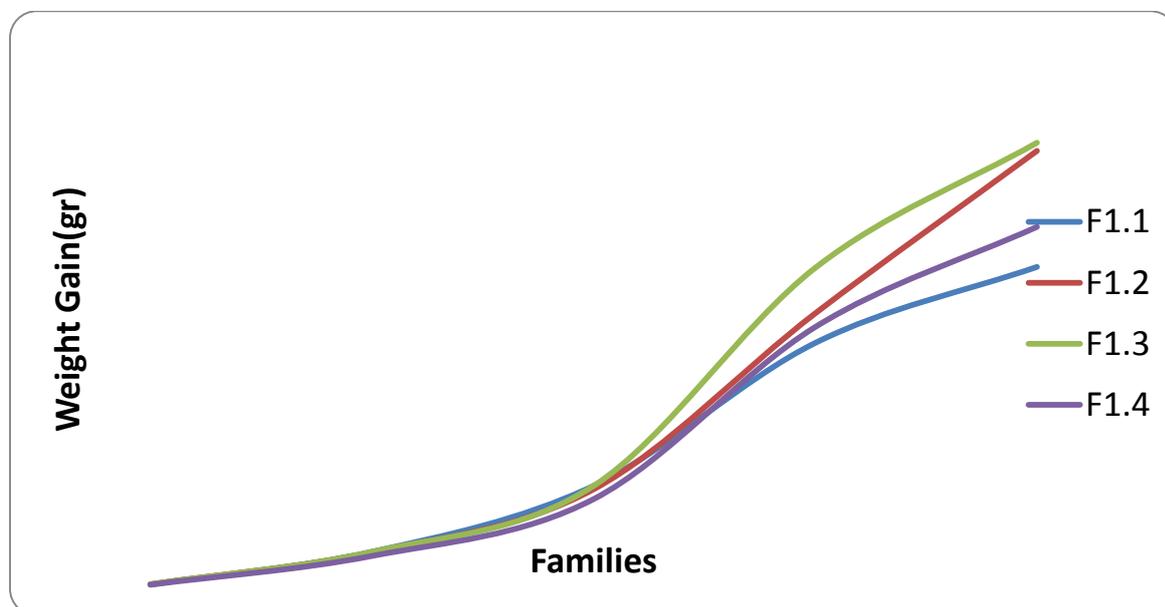


Figure 45: Weight gain of first generation in 4 families

1.6.7 Apiary

Evaluate honey quality from different agro-ecological zones carried out

The results shown that Honey from Ibis bya Huye had the highest values of specific gravity, total acidity, free fatty acid content, diastatic number, overall acceptability, and lowest hydroxymethyl-furfural (HMF) level as compared to honey samples from other areas (Table 59). There was no significant difference ($p > 0.05$) in terms of HMF in the other honey samples from Nyamagabe, Nyaruguru, Nyanza, Muhanga, Ruhango and Kamonyi. HMF levels in all

honey samples were far below the maximum acceptable level of 40 mg/kg as recommended by the Codex Alimentarius Commission Standards before storage for 5 months (Figure 36). No traces of streptomycin and phenol were detected in all honey samples. It was concluded that according to the values of the studied quality parameters, the types of Rwanda honey obtained from the popular honey producing areas may be judged to be of high quality.

Table 63: Acceptability and physical properties of honey samples harvested from different areas

Geographic origin of honey	Suspended of colloids (mg/100g)	Specific gravity (g cm-3)	Diastatic number	Moisture (%)	Color (OD) at 420 nm	Acceptability
Nyamagabe	1.53a	100a	22.8b	22.7b	1.6 a	7.0 b
Ruhango	1.50a	100a	22.2a	22.6b	1.6 a	6.2 a
Muhanga	1.55b	200a	23.3b	22.6b	1.6 a	7.2 c
Kamonyi	1.52a	150a	22.6a	22.8b	1.7 b	6.7 b
Huye	1.62c	200b	32.6c	21.6a	2.0 b	8.2 c
Nyanza	1.51a	100a	22.1a	22.7b	1.6 a	6.2 a

Note. Data in the same column followed by identical superscript do not differ significantly ($p < 0.05$). High-ranked letters are significantly different from lower ones in this order $c > b > a$. (n = 5).

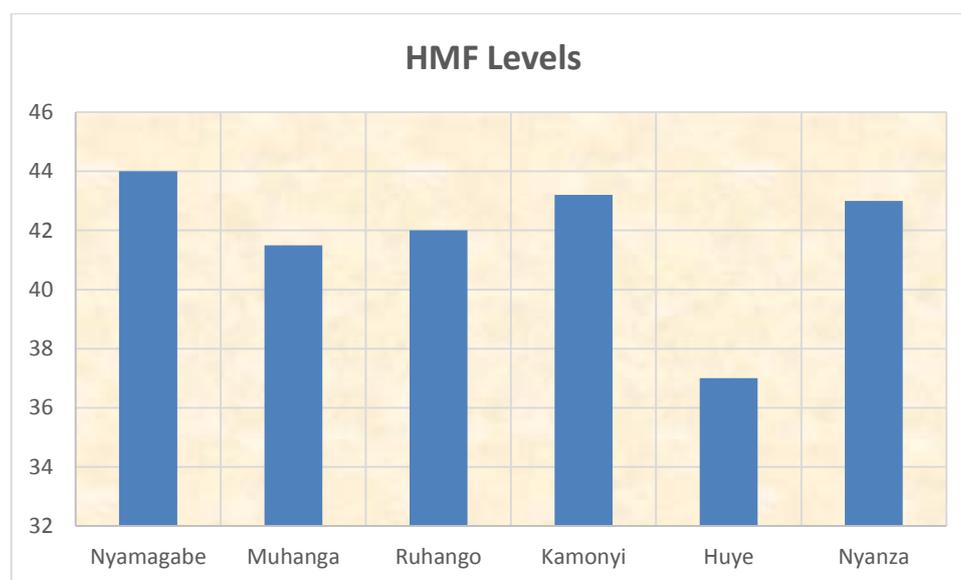


Figure 46: Levels of HMF in different samples of honey stored over a period of 7 months

It is shown that total acidity of honey samples obtained from Nyamagabe was significantly higher ($p < 0.05$) than the samples from other areas. Total acidity values of honey samples from Muhanga, Ruhango, Nyanza, Huye, and Kamonyi did not differ significantly ($p < 0.05$) (Table 64). Honey sample from Huye had the highest free fatty acid content of 26.6 meq/kg against lowest value of 10.4 meq/kg in the Huye sample. Lower values were of 10.6 meq/kg and 10.8 meq/kg were also obtained for Nyamagabe and Nyanza samples, respectively.

Table 64: Chemical properties of honey samples collected from different areas

Geographic origin	pH	Total acidity	Free fatty acid (meq/kg)	Streptomycin (meq/kg)	Phenol
Nyamagabe	4.20 a	41.6 c	10.6 a	ND	ND
Muhanga	4.63 b	33.2 b	14.2 a	ND	ND
Ruhango	4.41 b	34.4 b	10.4 a	ND	ND
Kamonyi	4.72 c	32.4 b	14.5 b	ND	ND
Huye	4.87 c	29.1 a	26.6 c	ND	ND
Nyanza	4.40 b	31.5 a	10.8 a	ND	ND

Note. Data in the same column followed by identical superscript do not differ significantly ($p < 0.05$). High-ranked letters are significantly different from lower ones in this order $c > b > a$. (n = 5). ND = Not Detectable

It is observed that low levels of initial HMF in all honey samples may also be attributed to low pH values, ranging from 4.20–4.87 (Table 64). Upon storage for up to 7 months at 28°C, the HMF in all honey samples increased progressively with Huye sample showing the least HMF level. With the exception of Huye sample, all other honey samples were either very close or have exceeded the maximum allowed level of HMF of 40 mg/kg in the new European Council draft, this is clear indication that at such a high storage temperature, honey should not be kept for more than 6 months. It could be concluded that the honey produced in the popular honey-producing areas in Rwanda is of acceptable quality standards as most of the quality parameters fall within the recommended limits. The storage temperature of honey should be carefully controlled to preserve its quality. At its best, honey should be consumed within 6 months following its harvesting.

1.6.8 Sericulture

During this fiscal year (FY 2016-2017), Sericulture activities were mainly focused on characterization of both mulberry varieties/silkworm breeds and Screening of both highly productive mulberry varieties/silkworm breeds.

Characterizations of both mulberry varieties and silkworm breeds

The characterization of germplasm accessions is carried out using morphological, biochemical and physiological characters, rooting ability of stem cuttings, leaf yield, leaf moisture, protein and sugar contents, photosynthetic efficiency, physiological water use efficiency etc. These traits will help breeders to select parent varieties with desired traits for further breeding programs. It is in that context that 10 mulberry varieties from the National Genetic Resources of mulberry were characterized based on their morphological characteristics. These varieties include Rubona-03.11 (H), Polyploid-01/03 (lob), SF" Gift"-11 (K), SF" ISAR"-09 (H), MSF-02 R, ISAR HW-3 (lob), M-600/13, CV-1, CV-2, TPGF-4. The two mulberry varieties, CV-1 and CV-2 are new and further research on them will be conducted. Results obtained from this study have shown that these varieties were morphologically different. Considering their leaves characteristics, varieties such as CV-1, CV-2, and TPGF-4 have tender leaves whereas Polyploid-01/03, and Rubona-03.11 have rough leaves (Photo 28).



Photo 28: Leaf of polyploidy-01/03 variety (left) and CV-1 variety (right)

This study has also shown that some varieties had leaves with light green color whereas others had dark green color. This is ongoing activity since all mulberry varieties conserved in the National Genetic Resources of Mulberry at Rubona have not yet fully characterized.

Characterization of mulberry varieties based on water loss

The moisture content of mulberry leaf is one of the key constituents determining the quality of the feed. It has a positive influence on the growth of silkworm larvae. Mulberry genotypes namely Diamond, M600/13, Sangilppong, RSC-2, and Kanva2 were taken up for this study. Leaves of each category were randomly sampled. The moisture content of the leaf was determined on dry weight basis. One hundred fresh leaves, comprising of tender, medium and coarse leaves were harvested earlier in the morning and weighed immediately. The leaves were then dried in hot air oven at 60 °C for 48 hours. The dry weight was recorded and the moisture content and the moisture retention capacity calculated as per following formula:

$$\text{Moisture content (\%)} = \frac{(\text{Fresh weight} - \text{Dry weight})}{\text{Fresh weight}} \times 100$$

$$\text{Moisture retention} = \frac{(\text{Weight after 6 hrs} - \text{Dry weight})}{\text{Capacity after 6 hours}} \times 100$$

$$(\text{Fresh weight} - \text{Dry weight})(\%)$$

$$\text{Moisture retention} = \frac{(\text{Weight after 12 hrs} - \text{Dry weight})}{\text{Capacity after 12 hours}} \times 100$$

$$(\text{Fresh weight} - \text{Dry weight})(\%)$$

The results shown that moisture content in fresh leaves was maximum (61.7%) in Sangilppong (Table 65), which was significantly higher than the remaining varieties, whereas, it ranged from 53.7 percent in RSC-1 to 47.4 percent in Diamond. Moisture retention capacity (%) after six hours was high (90.9 %) in Diamond, being significantly more than the remaining genotypes where the values ranges from 89.4 % in Sangilppong to 85.7 % in Kanva-2. Moisture

retention capacity after 12 hours again it was maximum in Diamond (83.0 %). Kanva-2 varieties has shown the lowest moisture retention capacity (74.7%) after 12 hours.

Table 65: Leaf Moisture Status of Different Mulberry Varieties

Variety	Moisture content (%)	MRC after 6 hours (%)	MRC after 12 hours (%)
Sangilppong	61.7	89.4	79.3
RSC-1	53.7	88.2	76.9
Diamond	47.4	90.9	83.0
Kanva-2	49.0	85.7	74.7
M600/13	48.4	86.2	75.2

MRC: Moisture Retention Capacity

The moisture content in mulberry leaves and its retention for longer periods play a very important role in improving the palatability of these leaves to silkworm. Experiment revealed that, all the genotype under this study possessed less than 70 percent moisture content. It has also revealed that, mulberry variety Diamond established its nutritional superiority with respect with Moisture Retention Capacity after 6 and 12 hours. It is still very earlier to draw a conclusion from these data obtained since this research is an ongoing activities and many other parameters such as different seasons and so on has to be taken into consideration. Once this study completed, it will help in the development of proper mulberry leaves post-harvest preservation technology

Characterization of silkworm breeds

Region specific studies of Silkworm, *Bombyx mori* L. are of great importance in identifying and understand the adaptability of silkworm genotypes, which are largely influenced by many factors such as climate. Silkworm is one of the most important domesticated insects where the growth and development is greatly influenced by environmental conditions. Success of silkworm breeds/hybrids largely depends on their adaptability to the environment in which it is destined to be reared. The biological as well as cocoon-related characters are influenced by ambient temperature, rearing season, quality mulberry leaf, and genetic constitution of silkworm strains. It is in that context that maintenance should be done periodically in order to conserve their original characteristics. Based on the above assumptions, 21 silkworm breeds; HA-8/13; PN 7/85; V5 (B); V5 (W); N2B (SL); LB-7 (SL); LB-8 (SL); BZ (SL); BE (W); BE (B); ED-21 (SL); YP (w); YP (B) LB-6 (W); LB-6 (B); AN; LB-9 (B); LB-9 (W); Kigali-015; Butare (W); were maintained and during maintenance data on quantitative and qualitative characteristics were recorded ([Photo 29](#)). Among these breeds, seven are sex-limited breeds (sex-limited on larvae and on cocoon). The crossbreeds in general practice are prepared in commercial silkworm seed production center through mating females of one silkworm breed with males of another breed in order to avoid inbreeding. Effort were also made to sex separate at cocoon stage based on weight differences as average weight of female cocoon is usually

higher than the male cocoon and this mechanical method was practically difficult and failed due to negligible variation or overlapping cocoon weight of opposite sexes either as a result of rearing lapse or racial characteristics. In this context, sex limited silkworm breeds developed at Rubona Research station assume great significance of practical utility to the sericulture industry in Rwanda, especially for silkworm seed production units.



Photo 29: Sex-limited breeds: on larvae and on Cocoon

Beside the qualitative characteristics, two quantitative characteristics namely cocoon shell weight and cocoon weight of the two years (2015 and 2016) were evaluate in order to check out the performance of these breeds. [Figure 47](#) shows the comparative data of two breeds, V5 (B) and V5 (w), on the two main quantitative characteristics: cocoon shell weight and cocoon weight.

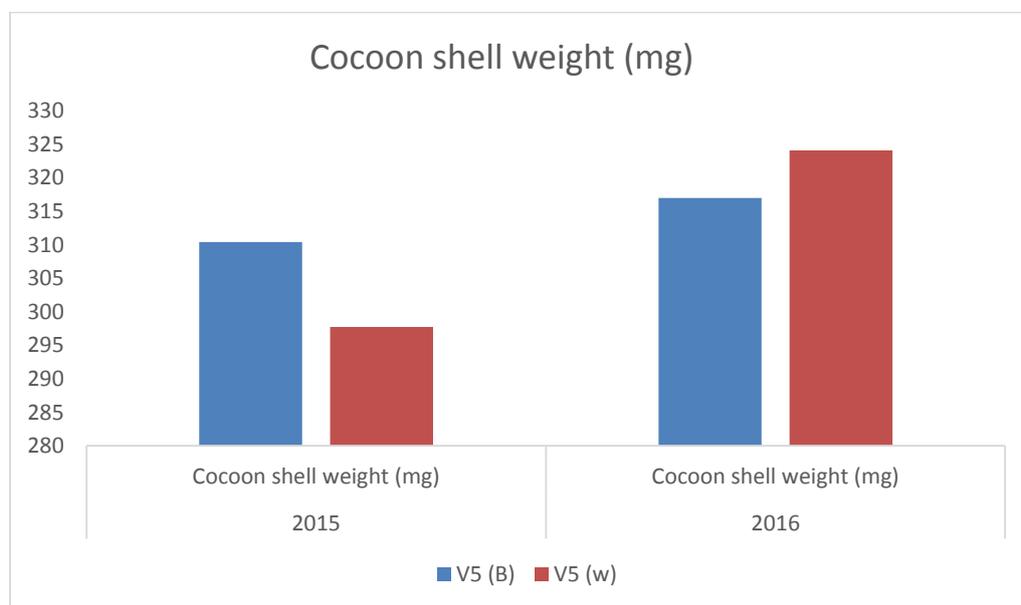


Figure 47: Cocoon shell weight of two breeds

To determine the performance of breeds during two years, we examined the cocoon shell weight of the two breeds, V5 (B) and V5 (W). As shown in [Figure 48](#), the cocoon shell weight of V5 (B) was high compared to V5 (W) during the first year and during the second year V5

(W) had high cocoon shell weight compared to V5 (B). In general, the cocoon shell weight increased in 2016 compared to 2015 in all breeds. The weight of silk shell is the most consequential factor as this measure forecast of raw silk yield. Therefore, much attention should be paid on these characteristics in order to produce high quality cocoon.

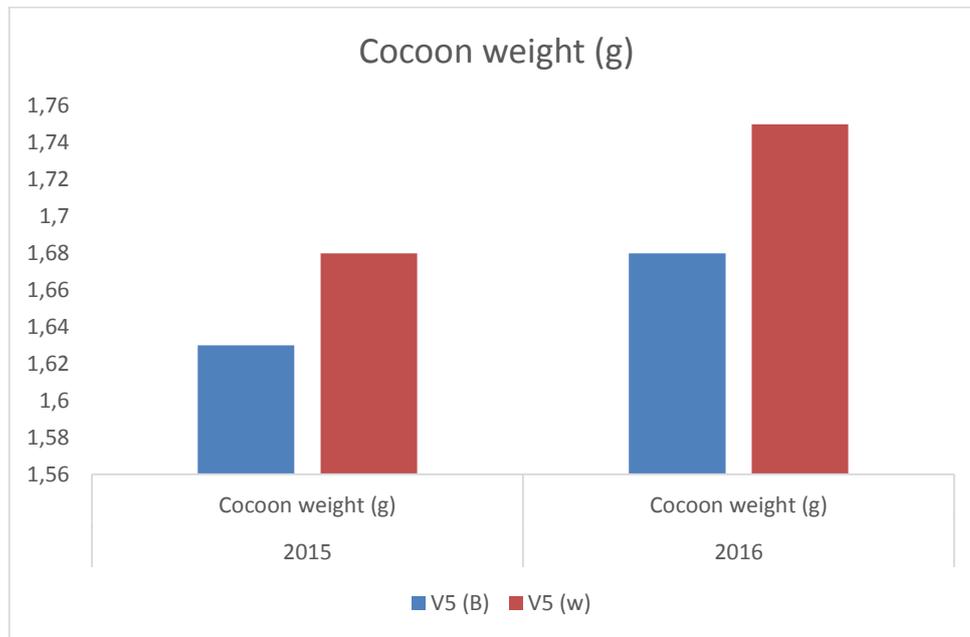


Figure 48: Cocoon weight of two breeds

Cocoon weight of the two breeds (Figure 48) increased from one generation to the other generation. V5 (W) had a high cocoon weight compared to V5 (B) in all the two years. Cocoon weight is the most significant commercial feature. Cocoons are sold in the marketplace based on weight as this index signals the approximate quantity of raw silk that can be reeled. Hence, more generations should be produced in order to reach the full capacity of breeds. Since these data were recorded on the 4th and 5th generations, it is clear that the characteristics of these breeds have not yet reached their peak. Different researches have shown that characteristics of an organism in different environmental conditions from the original are stabilized after 8 generations at least. Therefore, maintenance will continue until their original forms are reached.

Maintenance of both mulberry varieties and silkworm breeds

Production of silkworm hybrids eggs for cocoon production and delivery to farmers: During this fiscal year (2016-2017), 800 boxes of silkworm hybrid eggs were produced and among those boxes, 178 boxes were delivered to National Sericulture Center (NSC). Eighty-five (85) silkworm hybrid eggs were distributed to different farmers in various districts. Normally in most of the sericulture countries, the average production per box is 20 kg. The data received

from farmers on the yield obtained show that the cocoon yield per box still very low (Figure 49).

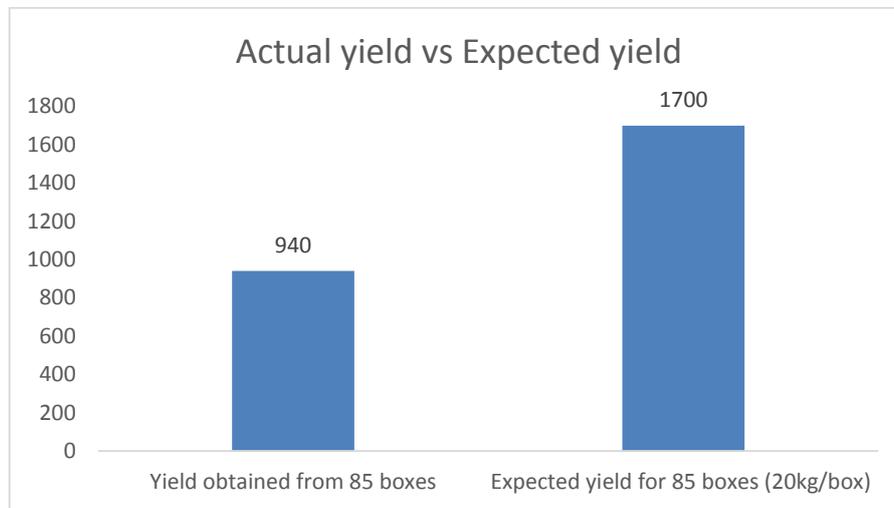


Figure 49: The cocoon yield obtained compared to expected yield

This is due to many factors such as lack of equipment, adoption of sericulture rearing technologies, training of farmers and so on. In order to increase the production, proper extension activities for the transfer of new technologies from laboratory to land play a major role in the adoption of new practices. The extension activities should be in such way that farmer should get convinced about the benefits of the improved techniques.

Screening of both highly productive mulberry varieties and silkworm breeds

Nutrigenetic screening strains of silkworm for nutritional efficiency: The purpose of this study was to obtain new data about screening for nutritional efficiency in silkworm breeds maintained at Rubona research station. This will not only increase the current knowledge on gene interaction between nutrition efficiency conversion and quantitative traits, but also will provide valuable information that will allow identification of nutritionally efficient silkworm breeds based on the standard gravimetric analysis of important economical nutrigenetic traits as 'biomarkers'.

The five silkworm breeds used were IS-2, R-50H, NGL-13, H-50, and GH-2. The morphological differences were found between germplasm breeds with respect to eggs, larva and cocoon traits. The chorion was pigmented in dark grey in three breeds (R-50H, H-50, NGL-13), and ash color in two breeds (GH-2, IS-2) and the egg serosa was white in all the five breeds (Photo 30). The five breeds spun elongated cocoon in shape (Photo 30). Among these five breeds, two of them, GH-2 and R-50H, are sex-limited.

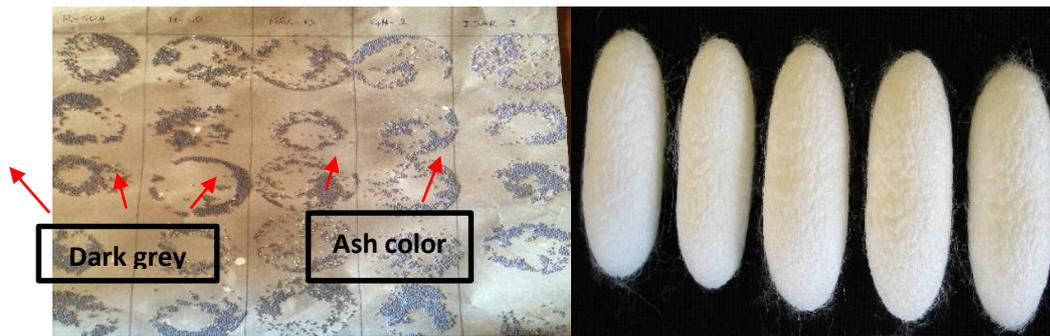


Photo 30: Eggs color of five breeds (left) and cocoons of five breeds (right)



Photo 31: Sex-limited breed (GH-2 breed: left: male, right: female)

Photo 31 shows male and female larvae of the sex-limited silkworm breed (GH-2). The sexes of this breed can be easily distinguished by body markings (carpet: female, Normal markings: male) in the fourth and fifth larval instar. The discrimination of these larvae based on sex-limited markings is advantageous in practical use. It is possible to reduce 20 % of labour with these strains and saving of time and labour for discrimination in male pupae production.

The nutrigenetic traits estimation study was carried out between July 2016 and September 2016. Silkworm rearing was conducted following the standard method under the recommended temperature and relative humidity until the 4th molt. On the 1st day of fifth instar, 50 healthy silkworm larvae per breed in three replications of 150 larvae each were selected for estimation on nutritional traits analysis. Accurately weighed fresh mulberry leaves were fed 2 times a day to the experimental batch. The left over leaves and excreta were collected on each subsequent day, separated manually and dried in a hot air oven daily at about 80 °C until they reached constant weight using electronic balance. The dry weight of left over leaves, excreta, larvae, cocoon, and shell in each of the breed were recorded.

The larvae weight of all five breeds increased from the first day of the fifth instar and reached the peak on the sixth day (**Figure 50**) and from the seventh day, the larvae weight started to

decrease. This is due to the fact that at that particularly period the appetite of larvae decrease because they are about to start spin cocoons.

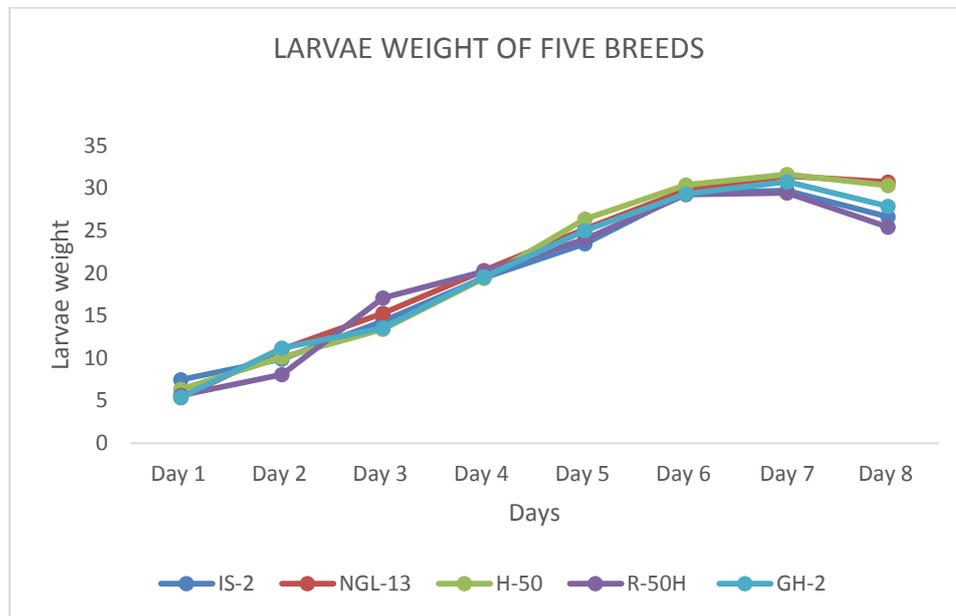


Figure 50: Larvae weight comparison of five breeds

The highest growth rate was found in H-50 (30.35 gr), followed by NGL-13 (29.77 gr). Silkworm larvae in fifth instar feed voraciously on mulberry leaves and display a very high rate of growth. After reaching the peak growth level they become mature larvae. The extent of this growth varies with the silkworm breed. Besides, it also varies with the nutrition condition, external conditions and other related factors. During this study, silkworm larvae of different breeds were fed the same amount of mulberry leaves (Diamond) and reared in the same conditions in order to compare their growth rate. The 5th instar, is very important because the larvae have enough nutrient for growth, development, and silk production. Data on left over and excrements in each replication were recorded and analyzed (Figure 51 and 52).

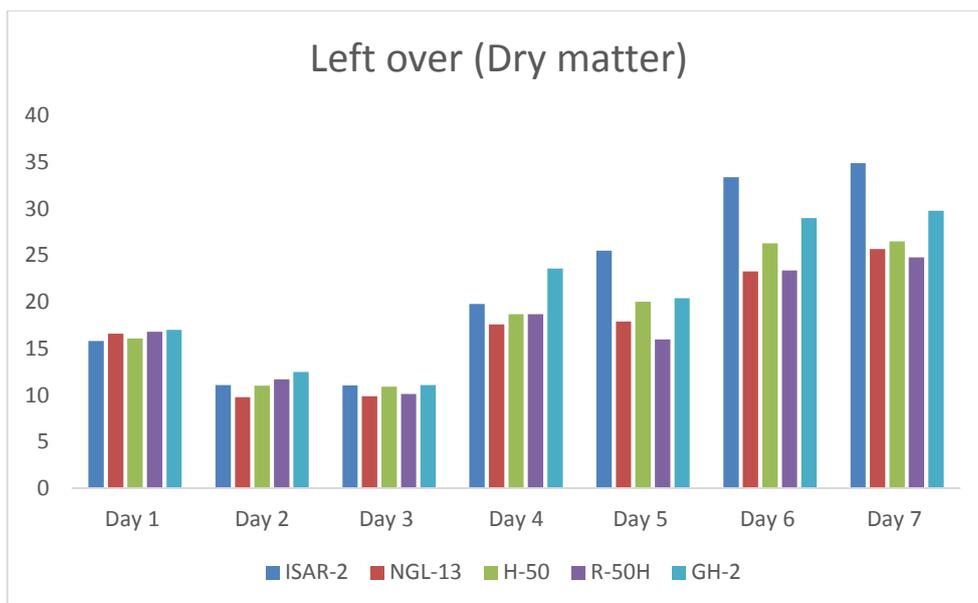


Figure 51: Silkworm excrements

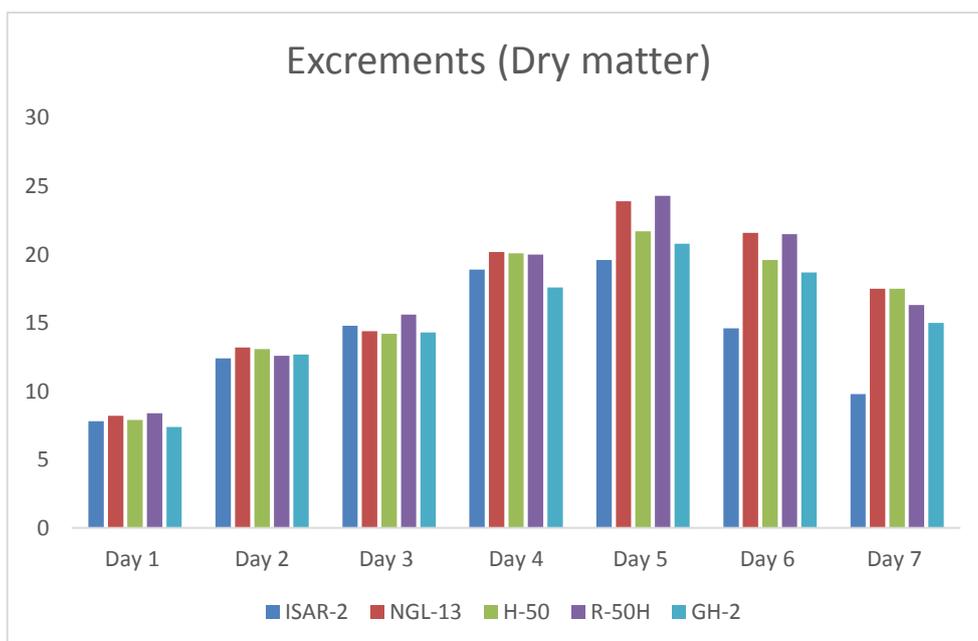


Figure 52: Mulberry left over

The left over increased from the first day of the fifth instar until the sixth day. The highest rate of consumption was found in ISAR-2 followed by GH-2, H-50, NGL-13, R-50H. The excrements increased from the first day and reached the peak on the fifth day. After the fifth day, the amount of excrements decreased in all breeds. The highest amount of excrements was found in R-50H followed by NGL-13. These preliminary data analyses have shown that there is difference in mulberry leaves consumption between five breeds but further analysis on 19 other nutrigenetic traits will determine breeds with nutrition efficiency conversion.

Screening silkworm breeds for nutritional efficiency is very essential in order to produce crossbreeds under limited area of mulberry production.

Part 2. CROP PRODUCTION AND EXTENSION

2.1 Crop Intensification Program

Crop intensification program was set to boost the productivity of main priority crops through decentralized seed and fertilizer supply. In earlier years, many efforts were concentrated on land consolidation and community sensitization to reach agreements for single cropping in consolidated CIP sites. During FY 2016-2017 the main activities of the CIP focused on seed distribution for maize, soybean, cassava, Irish potato and wheat; mineral and organic fertilizers and lime supply and distribution, and monitoring of crop yields.

Use of inputs concerned the use of improved seeds, local seed produced, mineral fertilizers, compost and lime (Table 66).

Table 66: Inputs used during 2016/2017 Fiscal Year

Inputs	Baseline	Annual targets	Quantities distributed
Improved seed	Cassava cuttings: 6.7 million Maize: 2,000 MT Soya: 600 MT	Cassava cuttings: 200 Millions Maize: 3,100 MT Soya: 100 MT	Hybrid Maize: 2, 399 MT OPV: 213 MT Soybean: 237 MT Wheat: 549 MT
Local seeds produced	Hybrid maize: 300 MT Soybean: 100 MT Cassava: 6.5 Millions of cuttings Irish Potato: 3,000 MT	Hybrid maize: 1000 MT Soybean: 500 MT Cassava: 200 Millions of cuttings Irish Potatoes: 9,500 MT	OPV/Maize: 350 MT Soybean: 164 MT Irish potato: 1,045 MT
Subsidized fertilizers	Food crops :43,516 MT	43,566 MT	Seasons A&B 17(kg) DAP: 9,827,323 UREA : 5,608,349 NPK: 16,366,887 KCL: 111,180 Blends: 142,825 TOTAL: 34,056,564
Lime	19,012 MT	26,421 MT	24, 362.6 MT
Compost	NA	44,240 MT	146,652 MT of compost were produced and used by farmers

2.2 Twigire Muhinzi extension model

In 2013, the Rwandan government through its Ministry of Agriculture and Animal Resources (MINAGRI) invited One Acre Fund into an official partnership to operate an agricultural training program through its nationwide extension network. Through this partnership, we

developed Twigire Muhinzi (meaning “self-sufficient farmers” in Kinyarwanda), where One Acre Fund’s agricultural training curriculum and training methodology – which has been used with smallholder farmers in Rwanda since 2007 and covers 19 crops – was adapted for implementation via Rwanda’s agricultural extension system. Since 2013 we have successfully operated this training program in partnership with MINAGRI through its implementing agency, The Rwanda Agriculture Board (RAB) by training government agronomists at multiple levels to train a nationwide network of ‘farmer promoters’, who ultimately train farmers in villages across Rwanda.

Main activities realized: The key achievement of this partnership has been developing the capacity of farmer promoters to act as frontline extension agents. This was done through practical demonstrations, printed extension materials and Training of Trainers (TOT) sessions. The training sessions were aligned to the seasonal cropping schedule. In total, partnership activities reached 14,200 farmer promoters out of 14,817 which are the total number in the whole country. Since last year, the partnerships team has also trained Farmer field school facilitators and 1,300 have been trained this year. A total of 774,178 farmers were reached through Twigire Muhinzi program and Farmer Field Schools (Table 67).

The extension materials produced and disseminated include: a Farmer Promoter Checklist; a guide on establishing demonstration plots; guides on compost making; and guides explaining good agricultural practices (planting, pest and disease management and post-harvest modern techniques) for ten Rwanda priority crops (maize, beans, rice, cassava, rice, wheat, soya, Irish potatoes, fruits and vegetables).

The partnership provided all 14,200 farmers promoters with a uniform package consisting of a distinctive t-shirt, cap, and gumboots so they would be visible in their communities. Farmer field school facilitators, Social Economic Development Officers (SEDOs), Sector and District Agronomists, and RAB staff were also given uniform shirts and extension materials.

The partnership supported TOT sessions where the RAB team trained farmer promoters, FFS facilitators, SEDOs and Sector agronomists on good agricultural practices for the eight priority crops. Those trained in turn trained farmers at the local level. Increasingly, more farmers were learning improved farming techniques from their respective farmer promoters and FFS facilitators, and increasing the overall adoption of best practices that increase yields and raise household incomes.

Table 67: Twigire Muhinzi Achievements 17A and B Seasons

Province	District	# Sectors	# Demo plots established	# FFS plots established	# TWIGIRE groups formed	# FFS groups formed	Total # farmers in TWIGIRE & FFS groups (# Farmers reached)
East	Bugesera	15	788	241	725	168	18 130
	GATSIBO	14	536	51	1 305	51	1 014
	Kayanza	12	354	59	1 021	59	1 129
	KIREHE	12	488	102	1 363	102	1 871
	NGOMA	14	470	66	1 085	66	1 241
	NYAGATARE	14	626	85	1 390	85	1 526
	RWAMAGANA	14	793	276	1 241	46	22 206
East Total		95	4 055	880	8 130	577	47 117
Kigali City	Gasabo	9	329	102	638	48	11 603
	Kicukiro	7	102	15	170	15	1 849
	Nyarugenge	4	536	216	203	19	2 906
Kigali City Total		20	967	333	1 011	82	16 358
North	Burera	17	632	179	3 250	179	51 280
	Gakenke	19	486	169	2 940	436	54 135
	Gicumbi	21	678		1 746		35 419
	Musanze	15	90	28	949	28	13 959
	Rulindo	17	378		1 186		24 002
North Total		89	2 264	376	10 071	643	178 795
South	Gisagara	13	586	50	1 042	54	16 384
	Huye	15	541	141	1 250	98	23 717
	Kamonyi	12	353	107	672	75	15 925
	Muhanga	12	598	56	1 280	38	15 399
	NYAMAGABE	17	576	151	2 510	119	44 198
	Nyanza	10	666	145	1 844	85	38 062
	NYARUGURU	13	565	112	1 863	122	40 623
Ruhango	9	797	231	1 363	241	29 456	
South Total		101	4 682	993	11 824	832	223 764
West	Karongi	13	500	25	3 153	25	56 615
	NGORORERO	13	466	103	2 107		25 942
	NYABIHU	12	794	78	2 073	61	32 610
	Nyamasheke	15	331	58	2 098	58	32 137
	Rubavu	12	347	60	2 313	60	37 551
	Rusizi	18	590	47	3 209	44	70 936
	RUTSIRO	13	426	83	2 778	74	52 353
West Total		96	3 454	454	17 731	322	308 144
Grand Total		401	15 422	3 036	48 767	2 456	774 178

Distribution of extension material

The number of materials were distributed in districts over 2017B season (Table 68). All of these materials were distributed and reached extension agents.

Table 68: Summary of extension agents, FFS facilitators and extension material distributed per district in 2017B season

Districts	Number of SEDOs	Number of Far-mer Promoters	Number of Extension Materials delivered in Districts		
			Number of FFS Facilitators	Booklets	FP Checklist
Gatsibo	69	605	82	755	616
Kirehe	60	612	104	788	788
Bugesera	72	570	151	808	570
Nyagatare	106	629	67	816	629
Rwamagana	82	474	69	639	474
Kayonza	50	418	78	558	418
Ngoma	64	473	56	607	473
Kicukiro	21	131	13	175	131
Gasabo	55	286	7	357	286
Nyarugenge	17	113	19	153	118
Gicumbi	109	630	124	884	630
Gakenke	107	617	148	872	617
Musanze	68	432	106	621	432
Burera	69	571	102	759	571
Rulindo	71	494	137	723	494
Nyanza	52	420	91	573	420
Huye	77	508	68	667	508
Nyaruguru	72	332	67	485	332
Nyamagabe	92	536	110	755	536
Gisagara	59	525	66	663	526
Ruhango	59	534	110	712	534
Muhanga	63	331	42	448	331
Kamonyi	59	314	57	450	322
Karongi	88	538	45	684	538
Rutsiro	62	477	87	565	368
Nyabihu	73	472	66	623	427
Rusizi	93	590	54	755	482
Nyamasheke	68	588	59	730	517
Rubavu	74	455	67	608	406
Ngororero	73	419	104	609	419
Total	2,084	14,094	2,356	18,842	13,913

One of the training models for farmer promoters was focused to establishing ‘training trials’. These consist of establishing a demo plot with right varieties, inputs, sowing dates etc., then conducting regular training sessions with farmer promoters, individual farmers or their groups, farmer cooperatives and getting their feedback and input all along the cropping cycle. Various training trials are shown in [Table 69](#).

Table 69: Seasonal 2017B learning trials (290 Sectors)

Trial description	Hypothesis
60 Normal pilot sector training trial: Provision of quick fire theory session (for 3hours) on all the booklet to FPs	This is the standard training provided in previous season; it is the control
60 Active Learning Strategies (ALS) trial: combination of active learning theory and practical training sessions in fields using a trainer script	Class based theory training results in limited knowledge transfer. Participatory, practical & shorter training will increase transfer and motivation
60 Active learning + manual for group leaders trial: Like ALS, but provision of short planting guide for Twigire group leaders	Twigire group leaders will be activated to support FP train and reach more farmers
60 Active Learning + individual FP Inputs for demo trial: Like ALS, but additional provision of fertilizers to FPs to be used in demonstration plots	Inputs will ensure FPs will establish demonstration plots with improved input
50 Farmer Promoter cooperatives trial: provision of inputs (seed and fertilizer) to FP cooperatives	Incentivizes encourage FP to improve R&R & strengthening or form cooperatives

Farmer Promoters Success Stories

Leonidas Mbaraga is a 38 year-old man, married with two children. He lives in Murundi Sector, Akanyerezo Village ([Photo 32](#)). His is a smallholder farmer, growing all the food his family eats and selling whatever surplus harvest he has as his only source of income. He started farming in 2008, but used traditional methods that made it difficult for him to grow enough to feed his family. In 2012, he formed his neighbors into a cooperative with 45 members, but all of them used low-yielding traditional methods that tied them to a life of subsistence agriculture.



Photo 32 Farmer Promoter Leonidas Mbaraga (left) with Asma Munyana, a Twigire Muhinzi Field Coordinator

In 2014, Leonidas was nominated as farmer promoter in his village to serve in a new program called Twigire Muhinzi. Through the program, the Rwanda Agriculture Board provided him with training on good agriculture practices. He shared the training on modern agriculture with his fellow farmers after he organized them into Twigire groups, and many of the farmers began to achieve dramatically higher yields after adopting the methods.

Murundi Sector is one among twelve sectors in Kayonza district. It is about 25 km from Kayonza city to the sector office. This sector is among many in the area that face problems of prolonged drought, water shortage, and government food assistance to aid vulnerable people affected by famine. However, all these problems are all in the past for Leonidas and his group, who all climbed out of poverty solely through adopting new growing techniques and achieving higher yields.



Photo 33: TWUNGUBUMWE Cooperative members

In 2017A, Leonidas' cooperative TWUNGUBUMWE grew maize on 8 hectares and harvested 35.8 tons. After selling their harvest, the members earned 9.42 million Rwf while still keeping 2 tons for household consumption. In 2017B, the cooperative is now rotating the crops in their field, and are planting soybeans, tomatoes and cabbages ([Photo 33 and 34](#)).



Photo 34: TWUNGUBUMWE cooperative members preparing their 2017A harvest

The cooperative also managed to buy small-scale irrigating machines at a subsidized cost, and also received support from MINIMEX (a major maize flour production company in Rwanda) to purchase a maize shelling machine (Photo 4). These machines improve their growing as well as post-harvest processing, since the irrigation machines allow them to keep their fields watered during drought and the shelling machine enables them to process their own maize before selling it to MINIMEX.



Photo 35: The cooperative's shelling machine (left) and one of their small-scale irrigation pumps (right)

Bernadette Muhawenimana, a member of cooperative expresses her thanks for the training she has received, "We give many thanks to those who trained our cooperative's president on good agricultural practices, which he in turn taught us. Had it not been for the existence of the Twigire Muhinzi extension system, we would have remained in a miserable life without enough to eat" (Photo 36).



Photo 36: Bernadette Muhawenimana in her soybean field

Improving the lives of smallholder farmers through improved training is one of Twigire Muhinzi's main objectives. Thanks to hard-working farmer promoters like Leonidas, Twigire Muhinzi is helping villages across the country increase their productivity and transition from subsistence farming to profitable market agriculture.

Program Impacts: Evidence from previous pilot sectors that were trained in TWIGIRE MUHINZI:

- Improved Agriculture Practices: Farmer Promoters in pilot sectors applied more GAP than those in non pilot sectors
- Improved farmer impact: Trained farmers in pilot sectors had higher yields than farmers trained in non pilot sectors
- Increased farmers trained: Farmer Promoters in pilot sectors trained more farmers compared to non pilot sectors

2.3 Crop Protection

Crop protection unit operates under Crop Production and Food Security Department and is in charge of follow up of crop health at country level, identification and addressing main crop pests and disease epidemics, assisting with pesticides provision and supply, as well as delivering technical advice for integrated pests and disease management in crops. During FY 2016-2017, the major pest emergence was appearance and rapid spread of army worm that affected the yield of nearly all major crops. RAB in collaboration with other partners has taken rapid action to address pest problem and to manage it sustainably.

2.3.1 Control of armyworm outbreak in 2017B cropping season

Armyworms are among serious migratory insect pests affecting crops. They can cause up to 70% of yield loss if are uncontrolled. Affected crops grass family such as maize, sorghum, rice, wheat, and other grasses (e.g. Napier grass). There are several species of armyworm but the most known devastating armyworms are the African armyworm (*Spodoptera exempta*), which is native to Africa, and the fall armyworm (*Spodoptera frugiperda*) native to both North and South Americas. The fall armyworm is more destructive than the African armyworm. The FAW was reported in Southern Africa-Zimbabwe, Malawi, Mozambique, Namibia, South Africa and Zambia late 2016. It was in January 2017 that the pest was suspected in East African countries, and confirmed in Rwanda at the end of February 2017 in Mushishito marshland located in the sectors of Uwinkingi and Kibilizi in Nyamagabe District ([Photo 37](#)). On the 9th March 2017, RAB entomologists confirmed that the pest was Fall Army Worm (FAW: *Spodoptera frugiperda*). The transmission mode of this pest is still under investigation but in general, the FAW moth is known to be spread by prevailing winds.



Photo 37: Army worm feeding on maize leaves

MINAGRI, MINALOC and farmers: Prior to the identification of the pest on 9th, RAB started control campaign on the 4th March 2017 in Mushishito Marshland, Nyamagabe District, where the pest outbreak was first observed on maize. The campaign has produced positive results as the pest was controlled.

However, due to the nature of spread, it was noted that by the 24th April 2017, the pest had spread to all 30 districts of the country. So far, the infested area is estimated at 17,521 ha, mainly of maize crop, out of 63,495 ha planted with maize in season 17B, equivalent to 28% of the total maize acreage (Table 70).

Overall the percentage of crop recovery varies between 40 to 70 %, depending on when the pest is reported. The highest rate of recovery is in consolidated sites where surveillance and interventions have been much easier. The Annex indicates the level of pest distribution.

The following collaborative interventions and measures have been instituted and bearing good results:

- **Research:** RAB has started evaluation of different types of pesticides for FAW control. Efficacy trials have indicated that pesticides in the “organophosphate” group, such as “Roket” have been more effective in controlling FAW than pesticides based on pyrethroids (e.g. “Lambda-cyhalothrin”, “Pyrethrum 5EW”). Furthermore, actually RAB is conducting trials of a wide range of pesticide types and differing concentrations for efficacy, and has started research collaboration with advanced research institutions: Centre for Agriculture and Biosciences International (CABI) and the University of Lancaster in the UK for genetic characterization FAW in order to determine the most appropriate and sustainable control options.
- **Awareness campaign:** MINAGRI and RAB organized intensive awareness campaign at national, provincial and district levels. Local leaders, agronomists and farmers were

trained on the new pest, its negative impact and method of control. MINAGRI and RAB initiated radio talk shows to sensitize the public about the new pest.

- **FAW surveillance:** RAB senior technical staff intervened in affected areas, carried out field surveillance to confirm the identity of the pest, its incidence, and advised on the appropriate chemicals and other Integrated Pest Management (IPM) measures including picking and destruction, which have yielded positive results.
- **Provision of pesticides and field equipment:** RAB provided appropriate chemicals to the affected. So far, 7,600 litres of pesticides and 1,422 spraying pumps have been availed to farmers, especially the small-scale farmers. Large-scale farmers, farmer cooperatives and individuals have taken up the initiative to purchase their own chemicals from agro-dealers. Insecticides that have shown successful results last season are recommended for this season and alternate with systemic insecticides: 1) Cypermethrin 4% + Profenofos 40%; 2) Lambdacyhalothrin 50g/l EC; 3) Imidacloprid (systemic insecticide); 4) Pyrethrin EWC+ & 5EW.

MINAGRI, RDF, RNP, MINALOC collaborative efforts: Given the magnitude of the rapid spread of the pest within a short time, it was imperative that MINAGRI requested for support from Rwanda Defense Force/RDF, Rwanda National Police/RNP in collaboration with farmers. RDF and RNP joined the campaign with efficiency and rapidity effective from 13rd April, 2017. RDF has assisted by providing rapid distribution of the pesticides in different locations countrywide (4,000 litres of pesticides from SOPYRWA were distributed by RDF), in addition to the mobilization of farmers, spraying and picking the pest along with the farmers.

Impact of pest on production The expected maize production for 2017B was 192,459 metric tons. The total lost area is 3,445 ha which implies that the total loss in production is estimated to 10,336 metric tons.

Way forward There is a progressive recovery of maize crop and a consecrated effort and collaboration of all stakeholders is still required to overcome the pest. MINAGRI advised the Districts to use transferred funds to purchase pesticides that are required by farmers.

Table 70: Effect of Fall Armyworm Pest on maize production during 2017B season

Province	Districts	Area planted (ha)	Area affected (ha)	Area treated (ha)	Area recovered (% per ha)	Area recovered (ha)	Area lost (ha)
Kigali city	Kicukiro	312	304	304	84.0	254	50
	Gasabo	1,666	164	148	83.0	138	27
	Nyarugenge	1,082	117	117	71.0	98	19
	Subtotal	3,060	585	569	79.0	490	95
South	Kamonyi	1,247	304	322	80.0	254	49

	Muhanga	830	264	518	80.0	221	43
	Ruhango	1,072	342	342	81.0	286	56
	Nyanza	1,217	301	310	80.0	252	49
	Huye	1,015	789	789	80.0	660	129
	Gisagara	287	279	239	70.0	233	45
	Nyamagabe	217	235	168	80.0	197	38
	Nyaruguru	1,726	1,554	1,293	75.0	1,301	253
	Subtotal	7,611	4,066	3,981	78.0	3,404	663
West	Nyabihu	4,819	548	533	90.0	458	89
	Nyamasheke	623	210	210	85.0	176	34
	Ngororero	5,165	1,973	1,944	83.8	1,651	322
	Rutsiro	3,556	691	690	85.0	578	113
	Rusizi	257	242	236	75.0	203	39
	Karongi	316	316	316	80.0	264	52
	Rubavu	8,310	1,727	1,727	89.0	1,446	282
	Subtotal	23,046	5,706	5,656	84.0	4,776	930
North	Musanze	1,341	217	723	94.0	182	35
	Gakenke	1,684	412	476	95.0	345	67
	Burera	484	130	660	95.0	109	21
	Rulindo	528	391	546	71.0	327	64
	Gicumbi	1,387	273	273	95.0	229	45
	Subtotal	5,424	1,423	2,678	90.0	1,191	232
East	Bugesera	7,771	1,216	942	82.0	1,018	198
	Gatsibo	1,726	213	213	95.0	178	35
	Kayonza	2,643	1,298	1,085	87.0	1,086	212
	Kirehe	1,233	2,466	875	82.0	2,064	402
	Ngoma	559	513	430	82.0	430	84
	Nyagatare	10,367	3,316	3,174	84.0	2,775	541
	Rwamagana	713	334	328	97.0	280	54
	Subtotal	25,012	9,356	7,047	87.0	7,831	1,525
	Total	64,153	21,138	19,931	83.7	17,692	3,445

2.4 Seed inspection and certification

Seed quality control included seed inspection, sampling, Irish Potato seed control in stores and field visit to the seed multiplier candidates, as well as seed testing in the laboratory. A total of 3862.428 ha of field area for maize, rice, wheat, bean, soybean, peas, cassava and sweet potato were inspected, and 84.13% complied to the seed production standards. A total of 660,749 tons of potato seed was controlled in stores. A total of 913 seed producers were certified, including 72 new producers.

2.5 Kitchen gardens

RAB in close collaboration with districts has conducted the program of expansion of kitchen gardens to improve human nutrition and increase consumption of vegetables grown in close

proximity to households. The establishment and management of new kitchen gardens was monitored by district agronomists with target of covering the selected districts with high level of malnutrition according to DHS 2015. The promotion of kitchen garden has started in 2011 in different sectors in order to fight against malnutrition in the country. At district level DASO were contracted to assist in constructing kitchen gardens for most vulnerable families Others partners such as World Vision, UNICEF in Health were involved in promoting kitchen garden and have contributed a lot to the program in their intervention areas such as Gisagara and Muhanga districts.

The RAB staffs were communicating with the district staff precisely Director of Agriculture and Director of Health to whom they are in charge of kitchen garden meanwhile, the field visit were applied to know the status of kitchen garden are and to validate the requirement need to rehabilitate and install new kitchen garden. RAB staff were identified the kitchen garden status by visiting the sampled household mainly the families with malnutrition with a purpose of get a sight on the kitchen garden’s situation in districts and the causes of malnutrition.

- Collaboration with District staff for kitchen garden implementation per each household
- Kitchen garden assessment
- Training on kitchen garden establishment of ToTs
- Training on Nutrition via cooking demonstration
- Mobilization on family planning
- Distribution of vegetables seeds founded by kitchen garden project

Trainings: The families with malnutrition in selected district with high malnutrition were trained on kitchen garden implementation and balanced food preparation. These trainings were done at health centers with the in charge of nutrition at health centers, sectors agronomist and the vulnerable families with their children. After kitchen garden installation for demonstration and cooking, they feed their children the prepared balanced foods. RAB staffs were also focused on family planning because it was shown that those families have a big number of children. After training the participants were told to RAB staff that they are going to make practice at home from the improved knowledge acquired in training.

Distribution of vegetable seeds and installation of demo kitchen garden: RAB staff after training those families, they were distributing vegetables seeds for those trained families in ten selected districts with high malnutrition. The selected districts were Kirehe, Kayonza, Bugesera, Nyabihu, Huye, Gisagara, Nyaguguru, and Nyamasheke. The distributed vegetable seeds were amaranths, cabbage, carrots, spinach and soybean. RAB staff installed kitchen garden for demonstration in Murori site. This site is used for training other trainers and it is managed by malnutrition vulnerable family and households in first category (ubudehe) from Huye and Gishamvu. The target for 2016-17 was achieved at 100 % (Table 71).

Table 71: Performance Indicators for Kitchen Gardens and Targets per district in 2016/17

Districts	Kitchen Gardens Targeted	Kitchen Gardens Constructed
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Bugesera	68,753	69,057
Burera	88,289	88,595
Gakenke	83,897	84,202
Gasabo	37,405	37,708
Gatsibo	61,787	62,091
Gicumbi	68,602	68,909
Gisagara	73,448	73,752
Huye	56,184	56,489
Kamonyi	66,027	66,331
Karongi	60,878	61,181
Kayonza	59,364	59,664
Kicukiro	38,011	38,317
Kirehe	60,654	60,955
Muhanga	64,210	64,515
Musanze	95,861	96,163
Ngoma	70,570	70,871
Ngororero	87,683	87,986
Nyabihu	84,654	84,955
Nyagatare	63,907	64,212
Nyamagabe	70,116	70,418
Nyamasheke	72,085	72,386
Nyanza	65,422	65,725
Nyarugenge	35,134	35,434
Nyaruguru	58,304	58,610
Rubavu	78,445	78,746
Ruhango	56,790	57,093
Rulindo	52,398	52,701
Rusizi	75,871	76,171
Rutsiro	85,563	85,864
Rwamagana	38,618	38,926
Total	1,978,930	1,988,027

2.6 China-Rwanda Agricultural Technology Demonstration (C-RATDC)

The China-Rwanda Agricultural Technology Demonstration (C-RATDC), located at Rubona RAB station, promotes improved agricultural technologies for soil and water conservation, rice and mushroom production as well as sericulture. This is done through production of high quality seeds, agricultural production and processing, demonstration, technology transfer and training.

During this reporting period, the center produced 136,723 mushroom tubes and 5639 spawn. Since one spawn yields 50 mushroom tubes, a total of 418,643 tubes were produced and disseminated to farmers. Mushroom production infrastructure was upgraded by constructing five sheds in Muhanga, Huye, Gatsibo, Bugesera, and Rulindo. Furthermore, apart from the farmers who normally make field visits to RATDC for study tours, 356 individual farmers were trained on JUNCAO mushroom technology (theoretically and practically) and 10 farmer cooperative representatives were supported to participate in a 21 days JUNCAO Mushroom training workshop in China. Five hectares of intercropped mulberry trees and crops were also maintained.

The China-Rwanda Agricultural Technology Demonstration (C-RATDC), located at Rubona RAB station, promotes improved agricultural technologies for soil and water conservation, rice and mushroom production as well as sericulture. This is done through production of high quality seeds, agricultural production and processing, demonstration, technology transfer and training.

PART III. ANIMAL RESOURCES EXTENSION

The Animal Resources Department aimed at improving animal resources in the country through extension services. The department oversees operations of Animal Genetic Improvement, Animal nutrition, Veterinary and Laboratory Services Unit (VSLU), Bee keeping, Fisheries and Aquaculture, Veterinary Products Inspection, and Special Government programs *namely* One Cow per Poor Family 'Girinka' and One Cup of Milk per Child Programs.

3.1 Cattle genetic improvement

The animal genetic improvement focused on management, replacement of bull, Avail semen, Liquid nitrogen and other inputs and Bovine artificial insemination and capacity building.

Management and replacement of bull stud

Masaka Bull station hosts a team of 13 best bulls selected to produce semen in order to ensure fast dissemination of superior genetics and faster genetic improvement and conservation of local breeds (Photo 37). In the fiscal year 2016/2017, three young bulls (Friesian, Jersey and Simmental) selected basing on their genomic information were acquired from Ireland through partnership between RAB and Bothar. The work focused on the management of bulls and training of young bulls on semen production and two of the bulls have started giving quality semen while the third bull is still under intensive training.



Photo 38: Sample Bulls of different breeds kept at Masaka Bull Station for semen production

Availability of Semen, Liquid Nitrogen and other inputs

Semen and other inputs necessary to ensure a good artificial insemination service delivery are availed by RAB and are accessible to all stakeholders (Photo 38). In FY 2016/2017 a total of 87,732 semen doses from 7 bulls were produced, processed and stored. This achievement was less than our initial target mainly due to shortage of liquid nitrogen in the first four months of the fiscal year. 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.



Photo 39: Semen production, Liquid Nitrogen production and other inputs availability

Bovine artificial insemination and capacity building

In the 2016-2017 fiscal years, the achievements were 77,221 cows inseminated and 27,386 AI calves identified (Figure 53). This was below our initial targets mainly due to breakdown of the liquid nitrogen plan and some other shortcomings in the AI service delivery chain. In this fiscal year, 287 animal sciences technicians have been trained on bovine artificial insemination technique and qualified as Inseminators. Also, existing AI technicians and District Veterinary Officers (DVOs) have been given refresher courses on use PRID Delta protocol for estrous synchronization, liquid nitrogen handling and cattle reproductive management (Photo 39).

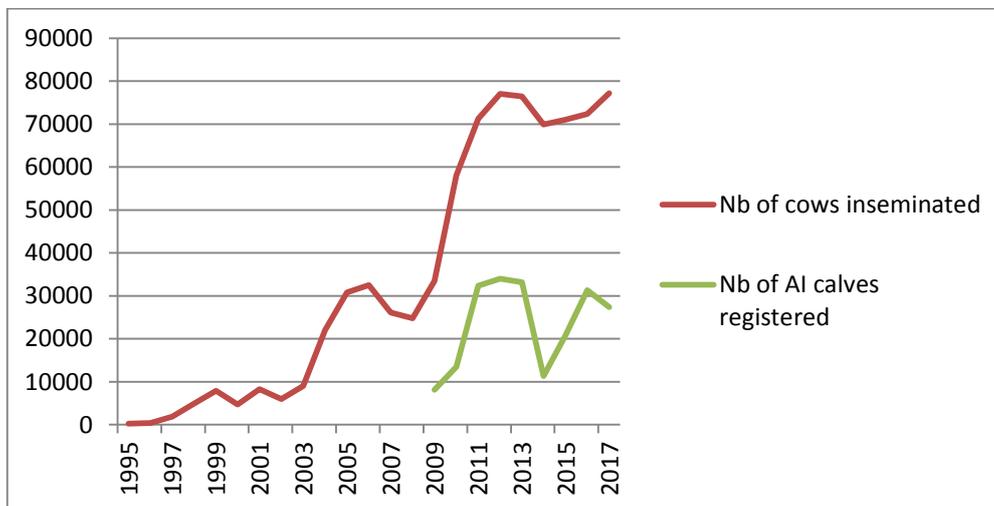


Figure 53: Annual achievements of Bovine artificial insemination since 1995



Photo 40: Technician training and refresher courses

3.2 Pig genetic improvement

To strengthen pig industry, RAB supports pig breeders and farmers to acquire and disseminate the best pig genetic materials. In the 2016-2017 fiscal year, RAB worked with farmers to improve pig husbandry and genetics through support to artificial insemination and recording of piglets born on AI (Photo 40, 41). Specifically, RAB have provided 8 exotic boars to three breeding centers (CPPA Kisaro, UR-CAVM Busogo campus and APTC Ltd) to improve availability and access of quality pig genetics. RAB helped to operationalize the pig AI center of UR-CAVM and now we count 2 pig AI centers with the one at CPPA Kisaro. In partnership with the centers we have carried out two pig AI campaign, inseminated more than 200 pigs and trained 11 technicians.



Photo 41: Pig semen production (left) and artificial insemination (right)

3.3 Animal nutrition

During the fiscal year 206/17 a new animal feeds factory have been constructed in Huye district with a capacity to produce 45 tons of feeds per day. It could significantly contribute toward increasing animal resource production in addition to other few factories already established in the country.

An awareness campaign for forage cultivation & renovation of grazing pastures have been organized where 550 Ha of land have been cultivated for improved forage grasses & leguminous (Photo 42, 43).



Photo 42: Improve forage (Chrolois gayana & Desmodium) cultivated in Eastern Province

Farmers were urged to conserve forage and rain water harvesting to cope with the drought challenges where 541.8 tons hay which is equal to 18,060 bales have been harvested and conserved



Photo 43: Awareness campaign on animal nutrition to implement mitigation measures for the dry season in Eastern Province

3.4 Small stock

This project was initiated under the auspices of RAB/MINAGRI to harness the potential of small stock based on agro-ecological zones and species adaptability in Rwanda. The project is implemented by districts through earmarked fund. RAB provide technical assistance required to design specification for procurement of small stock and also carry out monitoring and evaluation on the progress of the project. Thereafter, small stock and training package are given to the beneficiaries (Photo 44). The selected districts were based on the level of poverty and the potential to increase the market of animal product (Table 72) (Example: Poultry product at DRC border)



Photo 44: Small stock & package given to beneficiaries

Table 72: Selected district, Performance Indicators and Targets FY 2016/17

District	Number of beneficiaries trained	Number of communal shed(CS) or Hen house constructed according to standard	Number of small stock distributed
	Target 2016/17	Target 2016/17	Target 2016/17
Rusizi	18 unemployed youth coop.	18 hen houses	18,000 Layers
Nyamasheke	9 unemployed youth coop. + 500 HH (Cat 1&2 Ubudehe)	9 hen houses + 50 CS	9,000 Layers and 550 Pigs
Bugesera	500 HH (Cat 1&2 Ubudehe)	100 CS	1,100 Goats
Nyaruguru	1,000 HH (Cat 1&2 Ubudehe)	100 CS	1,100 Pigs
Total	-	27 hen house and 250 CS	27,000 Layers 1,650 Pigs 1,100 Goats

N.B: 1,100 Pigs or Goats (1,000 females, 100 males) →100 community shelters of 11 pigs & goats each one (10 female & 1 male) for 1,000 beneficiaries. This initial stock will be able to produce gilts to supply subsequent batches of beneficiaries within two year under pass-on arrangement.

3.5 Veterinary and Laboratory services

The VSLU is focusing on implementation national veterinary services policy and animal health laws. One of the major roles is to control animal diseases by implementing strategies meant for ensuring prevention, protection, diagnosis and treatment of animal diseases including transboundary diseases and zoonoses. The unit collects and publishes animal diseases' statistics at national level.

Control of transboundary animal diseases

The control of transboundary animal diseases (TADs) is an activity that was taken on from the financial year 2016/17, the country made significant progress in controlling TADs. Those of interest include lumpy skin disease (LSD), African swine fever (ASF), peste des petit ruminants (PPR) and contagious bovine pleuropneumonia (CBPP). World Animal Health Organization

(OIE) progressive control pathway staging of FMD status in Rwanda is stage 4 on 5-stage pathway and the country is set to apply for certification to stage 5 .

During 2016/17, 76 at risk cattle around FMD high risk areas were vaccinated. These areas include districts bordering Tanzania and Uganda; and among these are; Kirehe, Kayonza, Gatsibo, Nyagatare and Ngoma districts. Outbreaks of LSD were reported in various districts and 493,350 cattle were vaccinated. There were no clinical cases of ASF, PPR and CBPP. 390,500 heads of cattle were vaccinated against black quarter.

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, Some abortion outbreaks in cattle were reported in the eastern province in Rwanda and Rift Valley fever (RVF) was confirmed in the laboratory on serum samples from affected animals as the cause. Since the disease is known to be transmitted by mosquitoes, livestock reared near large expanse swampy areas were considered to be at high risk. Along the Nyabarongo, Akanyaru, Akagera and Muvumba rivers, 76,800 cattle were vaccinated. In the control of brucellosis 3,670 cattle were vaccinated. A total of 9,800 dogs and cats vaccinated ; in addition, 2,863 stray dogs were destroyed.

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 animal and animal products. The traffic of animal and animal products is shown in [Table 73](#).

Table 73: Movement of the animals

Species/Item	Import	Export
Cats	73	60
Dogs	271	208
Cattle	2652	1708
Goats and Sheep	1763	3186
Pigs		15457
Hides and Skin		7, 600 T
Eggs and Day old chick	987,560	1.752 T eggs
Fish	8675 tones	10,000 T

In addition, 170,000 cattle and 248,000 small ruminants were identified for sale in the livestock markets; 1700 inspection books, 3180 movement permits books for large and small animals were produced and distributed to different districts in the country. Furthermore, out of six border and quarantine posts in the country, only four are operational.

Issuing permit of importation of veterinary drugs, animal feeds and equipment.

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

Laboratory diagnostic services

The National Veterinary Laboratory at Rubirizi provides confirmatory diagnostic services for different animal diseases in the country. Samples analyzed were collected by laboratory staff on request by animal owners. Samples were also submitted by field veterinarians.

Additional samples were collected by laboratory staff during epidemiosurveillance of animal diseases aimed at estimating different disease burden. The laboratory is divided into sections namely Protozoology, Serology, Bacteriology, Virology, Helminthology and Gross pathology.

Protozoology section

Experimental trial on the Immunization against East Coast fever in Rwanda

East Coast Fever

East Coast Fever (ECF) is a cattle disease caused by a protozoan parasite, *Theileria parva*, and transmitted by the brown ear tick *Rhipicephalus appendiculatus*. Climatic conditions in Rwanda are favorable for a year round presence of the three major tick species (*Amblyomma spp*, *Boophilus spp* and *Rhipicephalus spp*) recorded in Rwanda. ECF is prevalent in all regions of the country except in the mountainous volcanic regions. ECF incidence rates of 70% to 80% were recorded in calves less than one year old with corresponding fatality rates of 30-40%.

Immunization trials have been carried in Rwanda aiming at elucidating the levels of protection conferred by the Muguga cocktail vaccine under local epidemiological conditions. The protection conferred by the Muguga cocktail vaccine (MCL01) is slightly high, for that during 2016/2017, 216 cows was immunized against East Cost Fever ([Photo 45](#)).



Photo 45: Vaccination Against East Cost Fever

Bacteriology section

Analytical tests were mainly performed on milk for bacteria culture (isolation) and identification. Antimicrobial sensitivity tests were performed when necessary. In addition, tissues from necropsy were submitted and the bacteriological tests performed involved Gram staining and biochemical characterization ([Photo 46](#)).

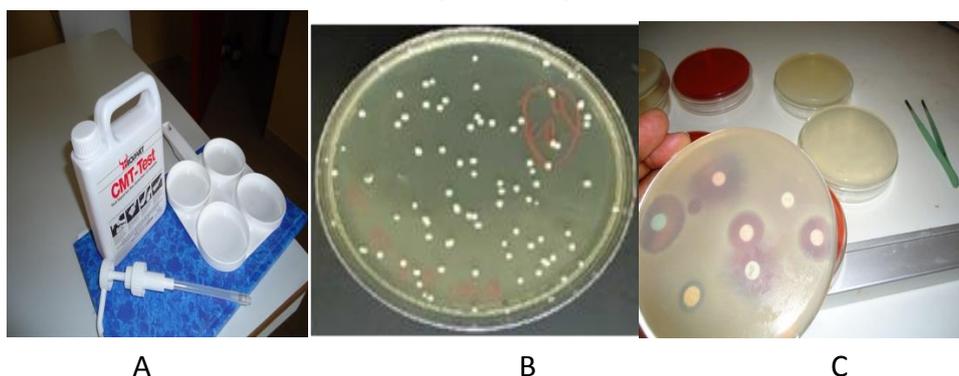


Photo 46: Instruments and materials used in mastitis testing at Rubirizi. A: California mastitis test (CMT) kit, B: bacteria culture plate, C: antibiotic sensitivity test plate

Screening dairy cattle for subclinical mastitis: most of the milk samples were collected from farms located at Muhanga, Ruhango, Kayonza and Gasabo. Milk from each quarter was collected in separate sterile glass tubes. California mastitis test was utilized in screening cows for subclinical mastitis ([Table 74](#)).

Table 74: Subclinical mastitis screening and Samples collection

N°	Districts	Nbr of farms	Nbr of cows	Nbr of samples	Negative	Pos+	Pos++	Pos+++	Total pos	%
1	Muhanga	28	65	259	181	36	32	10	78	30,1
2	Ruhango	3	24	89	37	21	23	8	52	58,4
3	Kayonza	18	49	196	144	31	13	8	52	36

4	Gasabo	2	17	68	25	27	9	6	43	63,2
TOTAL		55	160	636	387	115	77	32	225	35,3

Antimicrobial resistance testing

Antibiotic resistance tests on milk samples: the antibiotics bacteria were sensitive to were tested in 29 milk samples collected. Gentamycin and Erythromycin showed susceptibility to all bacteria while high degree of resistant was read toward Streptomycin and Cloxacillin. Penicillin was intermediate (Table 75).

Table 75: Susceptibility of bacteria towards various antibiotics from cultured milk samples

Antibiotic	Peni- cillin G	Linco- mycin	Genta- mycin	Cloxa- cillin	Strepto- mycin	Ciproflo- xacin	Tetracy- cline	Erythro- mycin	Cepha- lexin
Species									
Bacillus	18	22	20,6	8,3	13,6	14,5	8,7	24	25,7
Coliform spp	17,2	15,8	24,6	9,5	8,7	25,5	23,9	25,5	20,1
CN Staph.spp	13,1	11,25	26,9	4,9	22,3	32,3	25,75	23,6	16,1
Staph.aureus	19	16,8	26,2	17,8	2,2	27,4	21	28,1	16,1
Other Staph.spp	21,3	21	31,3	20,3	0	31	24,6	22,6	10,3
Strep.spp	7,7	16,7	22,2	24,2	1,5	27,5	24,2	30,4	15,5

Virology section

The activities involved making epidemic surveillance of the zoonotic Rift Valley fever (RVF), Newcastle diseases; Foot and Mouth disease (FMD) outbreak and Staff also performed proficiency testing for rabies.

Epidemic-surveillance of FMD and RVF: 3ABC FMD antibody test kits were used in identifying exposure of cattle to FMD virus while competitive ELISA test kits containing anti-RVF antibodies were used in testing for exposure of the animals to RVF (Table 72; Photo 46).

Table 76: Epidemic-surveillance for of the zoonotic Rift Valley fever (RVF), Newcastle diseases and rabies

Zoonotic Diseases	Number of cattle bled	Number of positive	%positive
Rift Valley Fever	79	10	12.6
NewCastle	163	0	0
Rabies	103	6	5.8%

Proficiency testing for rabies: The proficiency test to confirm rabies infection in animals was conducted in partnership with the Agriculture Research Council-Onderstepoort Veterinary Research, University of Pretoria, South Africa which is an accredited rabies laboratory.

Fluorescent antibody technique was used and the results generated from 10 test samples; 20% were positive. It is now confirmed that National veterinary laboratory has the capacity to do the test.

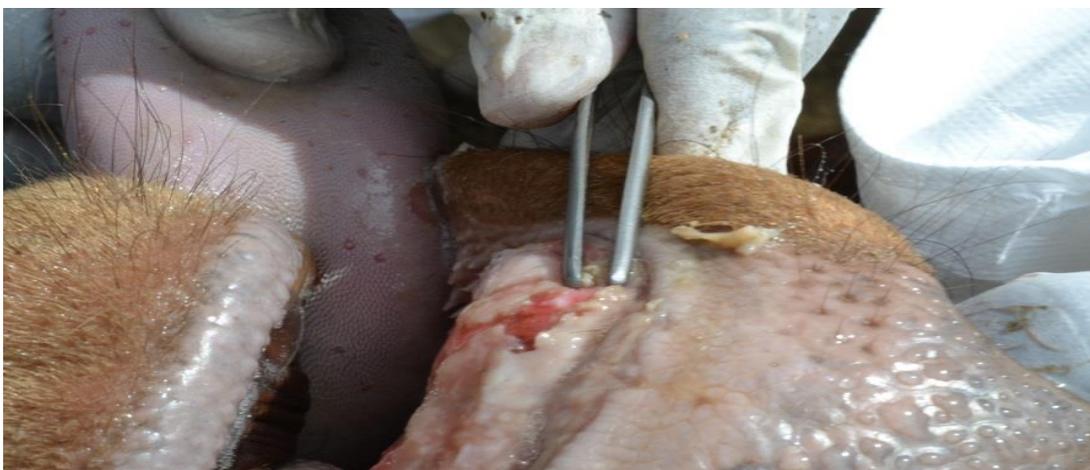


Photo 47: Sample collection from cows infected for Foot and Mouth Disease

Serology section

This section supports animal health care by testing samples using serological techniques. The commonest techniques used are enzyme linked immunosorbent assay (ELISA). In the test for brucellosis, Rose Bengal plate test is used. Most of the blood samples of cattle and goats were collected as a pre-requisite of screening all animals for re-stocking before being handed over to beneficiaries.

The total samples tested from July 2016 to June 2017 were 8880, it was discovered that 7 cattle were positive, which is 0.08%. The other animal species tested were goats (6297); Pigs (3547) and Sheep (584).

Helminthology section

During 2016/2017 fiscal year, an epidemio-surveillance was conducted to examine the status and distribution of helminthes in cattle and goats in different districts of Kicukiro, Nyagatare, Bugesera, Huye and Gatsibo. A total of 395 samples from cattle were collected with prevalence of 20.5% of various species of helminthes (Table 77). In all sampled districts, Huye had the highest prevalence of helminthes followed by Gatsibo.

Table 77: Prevalence of Helminthes in six districts

Districts	Species	No. Samples	No. of positive samples	Prevalence (%)
1 Kicukiro	Bovine	7	0	
2 Nyarugenge	Bovine	59	20	33.9

3	Bugesera	Bovine	13	0	0
4	Huye	Bovine	40	29	72.5
5	Nyagatare	Bovine	158	12	7.6
6	Kabarore	Bovine	118	20	16.9
	Total		395	81	20.5

Trainings, Internships & Agrishow

Two hundred twenty three community animal health workers (CAHW) were trained and equipped with basic veterinary kits that helps them to execute their work . The training took place at Muhanga, Ruhango, Nyanza and Huye district. In addition, 975 CAHW were evaluated and had a refresher training course in the management of animal diseases. Veterinary and laboratory Services conduct farmers training on animal diseases impacting on the production and quality of milk (mastitis, brucellosis and tuberculosis) in Muhanga, Ruhango, Nyanza and Nyaruguru Districts.

Agrishow

RAB technicians in Animal resources department participated in the preparation and flow of 12th National Agricultural show held at Mulindi, Gasabo District from June 22th up to 27, 2017 (Photo 48).



Photo 48: Animal Ressources stand at 12th National Agrishow, June 2017

3.6 Veterinary inspection

In the fiscal year 2016/2017, emphasis has been put on veterinary registration and veterinary inspection of livestock products and veterinary products, including vaccines and pharmaceuticals.

Veterinary registration: The registration of veterinary pharmacies kicked off in Kigali, and in total 47 veterinary pharmacies out of 84 found in Kigali, met the registration requirements and was registered (Photo 49). Other 41 pharmacies were urged to meet the registration conditions in order to improve their services and play their role in products quality improvement and availability across Kigali. The registration continued with campaign of awareness on the need to comply with veterinary pharmacy requirement and register their

businesses, in the four Provinces (Rwamagara, Karongi, Musanze, Huye). In total 350 peoples were sensitized in veterinary pharmacy registration.



Photo 49: Veterinary pharmacy, Kigali

Animal products and veterinary products inspection

The quality of veterinary products sold in Rwanda was monitored through a strict control of importation conditions and the enforcement of the Ministerial Order N°008/11.30 of 18/11/2010, which determines the organization of veterinary pharmacy practice. In total 285 inspection interventions on selling points of veterinary products were performed in the 2016/2017 Fiscal Year ([Photo 50](#)). Official meat inspection stamps were distributed to 9 registered abattoirs, in order to ease to separate inspected meat from non-inspected meat. In total 34 District and Sectors veterinarians have been trained in meat veterinary inspection and good slaughterhouse practices. Companies in meat processing, beef production and slaughtering have been trained on HACCP system and are ready to implement it.



Photo 50: Meat handling at abattoir, Kigali

Veterinary public health: In order to reduce the impact of veterinary on public health (resistance of products and products residues), a training on prudent use of veterinary products was organized, in collaboration with Trade Mark. 56 veterinary pharmacies were trained during 3 days on different themes including prudent use of veterinary products. 89 Milk selling points, MCCs and other kiosk for milk selling have been inspected and the hygiene condition, the inspection, the transport and milk collection activities have been followed and monitored. Farmers, milk collectors, MCC agents have been trained in hygienic and safe production, transport, collection and milk reception at MCC



Photo 51: Milk hygiene at MCC

The acceptability of milk at dairy level has been increased, following a training conducted in Gicumbi for 63 farmers, milk collectors, and MCC agents. The training focused on safe and hygienic handling of milk and reducing different cause of milk rejection of milk by diaries (Products residues, number of cell in the milk, less hygiene along milk collection chain and miss handling before reaching the cooler at MCC level ([Photo 51](#)).

3.6 Beekeeping

In Rwanda, beekeeping plays a major role in socio-economic development and environmental conservation. It is a source of food (e.g. honey, pollen and royal gelly), raw materials for various industries (e.g. beeswax candles, pharmaceutical), source of medicine (honey, propolis, beeswax and bee venom) also a source of income for beekeepers.

RAB interventions in Apiary sub-program were inspired by its Strategic Action Plan 2016-2017, which places particular emphasis on the promotion of beekeeping oriented entrepreneurship and that may play an important role in reduction of rural poverty in particular and the welfare of the Rwandan population in general.

Distribution of Queen breeding and other beekeeping equipment to farmers

Equipment's for queen rearing and other equipment such as bee suits, gloves, smokers, honey extractors, bees wax processing machines and maturators were provided to advanced beekeepers cooperatives from Rusizi, Nyamasheke, Nyamagabe, Huye, Gatsibo ([Photo 52](#)). Nyagatare, Musanze, Burera and Rubavu in other to disseminate techniques of raising queens for honey production.



Photo 52: Cooperatives from Karongi (left) and Nyamagabe (right) receiving bee keeping equipment



Photo 53: Beekeeping equipment distributed to beekeepers from UNICOAPIGI union (Rubavu) and UCOAPIRU (Rusizi)

Beekeeping equipment's for honey quality and queen breeding were distributed to beekeepers' cooperatives under UNICOPAV (Union of Cooperatives around Virunga Zone), UNICOAPIGI (Union of Cooperatives around Gishwati Zone) and Rusizi union ([Photo 53](#)). The equipment included: Mini Mating nucs, bee suits, gloves, Honey extractor, Honey processor, bees wax processor and others for queen rearing. The Head of Beekeeping Program, Mwiza Willy, explained that the purpose of the equipment's is to improve the quality of honey, wax, to raise queen and to multiply honey bees' colonies.

Training of stakeholders on Queen breeding on FFS

Practical training of master beekeepers on queen breeding were organized in different unions from Rusizi, Nyamasheke, Nyamagabe, Huye, Gatsibo. Nyagatare, Musanze, Burera and Rubavu to use queen rearing equipment to produce high value queens and royal jelly ([Photo 54](#)).



Photo 54: Practical queen rearing in Rubavu (left); Queens produced in Ibisi bya Huye (right)

Training of stakeholders on bee diseases

100 beekeepers from Rubavu, Rutsiro, Rusizi, Musanze and Burera were trained on Periodic Colony Inspections, how to recognize signs of bee diseases and pests. Differentiate between serious and not so serious, know some corrective actions for each case ([Photo 55](#)).



Photo 55: Master beekeepers from Rusizi were trained on bee health

Consultative meetings for harnessing and harmonizing value Chain

2 consultative meetings were organized in quarter 1 at RAB headquarters and Nobleza hotel to organize the Rwanda Apiculture Multistakeholders Platform in collaboration with NAEB.

The Third General Assembly of the African Apiculture Platform (AAP) on Honey Production, Bee Health and Pollination Services, was held from 21st-23rd September 2016 at the Kigali Conference and Exhibition Village, Kigali, Rwanda. The theme of the General Assembly was **“Promoting Intra and Inter Regional Trade of Honey and Other Beehive Products in Africa”**. This theme is well aligned to the Malabo Declaration Agricultural Transformation Agenda which aims to triple intra-African trade as a means to address food insecurity and youth unemployment, and to increase incomes and economic growth.

The Third General Assembly of the African Apiculture Platform on Honey Production, Bee Health and Pollination Services was held in Kigali on 10 October 2016 ([Photo 56](#)).



Photo 56: Group photo of the general assembly

3.7 Aquaculture and fisheries

Rwanda is endowed with enormous potential for fisheries production to become self-reliant and even build capacity to export. 26,528,977 kg in 2016/17 registering a 21% increase. Capture fisheries increased from 20,541,950 kg to 25,012,878 kg which was 21.8% increase while Aquaculture production increased from 1,363,130kg to 1,579,454 kg registering only 16% increase.

The activities that contributed to the increase in production were all based on transforming Aquaculture and fisheries into a productive, high value, market oriented sector that is spearheaded by the private sector. In capture fisheries, over and above the usual surveillance to combat illegal fishing, fishers also saw a great advantage in fishing the Haplochromis (Photo 57) whose production greatly increased as it was being used by fish feed manufacturers.



Photo 57: Haplochromis catch from one of the Lakes

The other activities that contributed to the increased production were: i) Improvement of lakes management through the implementation of strict surveillance missions to control illegal fishing, the closure of lakes for a period of 2 months to enhance reproduction and production and the sensitization and training of fishers to become better managers of their ecosystem;

ii) Improved management of ponds using on site trainings especially in feeding, the rearing of monosex and the better construction of ponds to the newcomers into the new sector entrants. This activity was however hampered by the lack of adequate feeds and planned incentives to fish farmers leading to non-attainment of the desired aquaculture production target that was to reach 5,000 tons.

At the level of lakes management, monthly surveillance missions were organized on lake Kivu and only on the lakes in the Northern fishing zone (Burera and Ruhondo) in collaboration with the Police Marine. During this activity 3,423 illegal nets were captured, this included the notorious kaningini, mosquito nets and fry nets commonly known as “ibikuruzo” and “Ibingumbi” which are used in the reproductive zones, all these were impounded and destroyed (Photo 58).



Photo 58: Illegal nets ibingumbi (up) kaningini (down) captured by surveillance mission

In cage fish farming we saw the entrance of 3 big companies namely KIVU TILAPIA FARM that is located in Rusizi District, LAKE KIVU AQUACULTURE COMPANY Ltd that is located in Karongi District and FREFISH that is located on Lake Muhazi. These are using HDPE circular cage types that have a capacity of producing up to 35tons per cycle, production from these companies will be realized in the next financial year (2017/18). As compared with 2011, fish production has significantly improved (Photo 59-61; Table 78).



Photo 59: Aquaculture progress since 2011 to 2017



Photo 60: Part of the modern Clarias hatchery installed at Kigembe fish centre

Table 78: Fish production in Kg for the year 2016-2017

Fishing/Aquaculture Zone	Q1	Q2	Q3	Q4	TOTAL
1.1. Burera - Ruhondo Zone					
L. Ruhondo	53,913	58,903	58,778	25,965	197,559

L. Bulera	84,499	86,529	85,689	28,413	285,130
S/Total 1.1	138,412	145,432	144,467	54,378	482,689
1.2. Gisaka-Bugesera Zone					
L. of Gisaka	152,721	210,996	195,223	189,367	748,307
L. of Bugesera	115,467	114,406	115,467	111,765	457,105
S/tot 1.2	268,188	325,402	310,690	268,633	1,205,412
1.3. Nasho – Akagera Zone					
Lakes in the Nasho Valley	73,303	106,210	116,332	117,816	413,661
Akagera National Park	-	-	-	-	-
S/tot 1.3	73,303	106,210	116,332	117,816	413,661
1.4. Zone Muhazi					
L. Muhazi	137,515	152,709	147,915	127,540	565,679
1.5. Zone Kivu					
- Rusizi	767,954	652,992	1,417,563	1,393,417	4,231,926
- Nyamasheke	941,570	839,424	1,601,242	1,502,755	4,884,991
- Karongi	659,241	674,711	1,463,577	1,293,759	4,091,288
- Rutsiro	700,857	701,339	1,578,947	1,553,285	4,540,428
- Rubavu	462,951	752,068	1,665,923	1,693,605	4,574,547
S/tot 1.5	3,532,573	3,626,534	7,727,252	7,436,821	22,323,180
S/tot Gasabo Capture	5,674	5,992	5,850	4,741	22,257
Total Capture	4,155,665	4,362,279	8,452,506	8,042,428	25,012,878
Aquaculture					
Dams	65,847	67,028	71,355	57,963	262,193
Ponds	166,097	166,318	293,185	200,845	826,445
Cages	107,182	87,082	190,219	106,333	490,816
S/tot Aquaculture	339,126	320,428	554,759	365,141	1,579,454
Grand Total (Capture and Aquaculture)	4,494,791	4,682,707	9,007,265	8,407,569	26,592,332

3.8 One Cup of Milk per Child program

The main objective of the One Cup of Milk per Child program is to fight against malnutrition among children using the approaches of giving milk to school going children in designated schools. Till the end of June 2017, the program was implemented in 112 schools from 15 districts namely Rubavu, Rutsiro, Ruhango, Ngororero, Nyanza, Ngoma, Gisagara, Nyaruguru, Nyamagabe, Kamonyi, Bugesera, Ngoma, Gakenke, Nyamasheke and Karongi.

The milk from Inyange and Nyanza Milk Industries Limited, are given to pupils and the target group were the pupils from nursery up to primary three. Pupils are given milk twice a week, by taking half liters per day.

By the end of June 2017; the program had 85,953 pupils from 112 schools within 15 districts and they have received **2,094,573** liters of milk. RAB has been focusing on the purchase and distribution of milk to pupils through contract signing with Dairy processing plants and the monitoring and evaluation of the program activities.

3.9 One cow per poor family

Cows distributed to poor families during FY 2016-2017

Through the stride proliferation of distributed cows and tangible support of distinctive stakeholders of Girinka program, the following cows have been distributed to the poor families during the fiscal year 2016-2017 (Table 79).

During the reporting year, a target of distribute **34777** cows was set, and RAB has achieved this target on 97% as 33902 cows have reached the new beneficiaries in each of Rwanda provinces and districts (Table 79).

Table 79: Target achieved during FY 2016-2017

Province	District	Number of cows distributed	Achievement(%)
EAST	BUGESERA	1637	98
	GATSIBO	1423	88
	KAYONZA	772	98
	KIREHE	1410	99
	NGOMA	721	91
	NYAGATARE	833	67
	RWAMAGANA	1240	112
S/TOTAL		8036	93
SOUTH	GISAGARA	1766	112
	HUYE	1171	74
	KAMONYI	1636	111
	MUHANGA	1029	85
	NYAMAGABE	1433	78
	NYANZA	1143	103
	NYARUGURU	1337	68
	RUHANGO	1614	98
S/TOTAL		11129	91
WEST	KARONGI	804	75
	NGORORERO	1169	100
	NYABIHU	634	116
	NYAMASHEKE	1188	106
	RUBAVU	673	102
	RUSIZI	1369	97
	RUTSIRO	1081	112
S/TOTAL		6918	101
NORTH	MUSANZE	873	104
	BURERA	1415	95
	GICUMBI	1701	108

	RULINDO	1747	257
	GAKENKE	1257	99
	S/TOTAL	6993	133
	GASABO	366	103
	KICUKIRO	183	66
CoK	NYARUGENGE	277	100
	S/TOTAL	826	90
	G/TOTAL	33902	97

The total number of cows distributed during the fiscal year 2016-2017 was 33,902.

PART IV. LAND HUSBANDRY, IRRIGATION AND MECHANIZATION

The land husbandry, irrigation and mechanization (LIM) department of RAB has the mandate of sensitizing and mobilizing farmer beneficiaries and marketing entrepreneurs to implement irrigated and commercial agriculture; developing comprehensive land husbandry works on rain-fed command-area catchments and irrigable land; providing and installing the entire irrigation infrastructures on small, medium and large scales; commanding area management including operation and management of irrigation infrastructure; promoting appropriate farm mechanization options to the farmers; and increasing access of farm machinery to the farming community. A number of interventions (Land husbandry, Irrigation and Mechanization) have been carried out during the 2016/2017 FY with aim of supporting the fulfillment of this mandate.

4.1 Land husbandry

The department (LIM) had planned to implement 200Ha of radical terraces and 400Ha of progressive terraces through a contract signed between RAB and MINADEF. However, due to budget cuts implementation was postponed to 2017/218FY.

4.2 Agricultural Irrigation

Three companies conducted marshland studies:

1. SOCOSE Ltd: Urwonjya (133Ha) in Nyaruguru and Nzavu (107Ha) in Nyamagabe districts
2. FES Ltd company: Makera (109ha) in Muhanga district
3. COCA Ltd company: Mwura-Gatare (101Ha) in Gisagara) and Rubuyenge –Burakari (416Ha) in Nyanza-Ruhango districts.

Commissioned studies have been completed as planned and all their detailed reports have been submitted and validated.

Eight studies were commissioned for hillside irrigation but planned targets haven been achieved for 5 of them: Rilima, Rweru, Cyohoha South, Mpanga and Mahama-1. Their inception reports have been submitted and validated. For Mahama-2, the DPR has been submitted but not yet approved. For Gabiro study, the progress is at 87% instead of the planned 100% due to an increase in the area of study for potential area from 5000Ha to16,000Ha, delays in payments to the contractor and delayed decision on water source. For Rukumberi, it had been planned to use the EPC approach and the progress is 10% instead of the planned 50% by end of 2016/2017FY. This was due to budget unavailability. Achievements on hillside irrigation development, marshland irrigation development, small scale irrigation technology (SSIT) and irrigation water users organizations (IWUOs) are presented (Tables 80-83).

Table 80: Hillside Irrigation Development in FY 2016-2017

Output	Target	Achievement (ha)	Comments
Increased Irrigation Infrastructures' Construction	-Ngoma 22: 100% -Rukumberi (600Ha): 30% -ETI-Mpanga: 40% -ETI-Mahama lot-1: 25% -ETI-Mahama lot-2: 25%	-Ngoma_22:100% completed -Rukumberi (600Ha): 10% -ETI-Mpanga: 20% -ETI-Mahama lot-1: 10% -ETI-Mahama lot-2: 5%	Only Ngoma22 project (265Ha) was completed by end 2016/2017FY as it had been planned. For Rukumberi project, progress has been limited by budget unavailability. For ETI project the contract for Mpanga was signed while Mahama 1&2 are still in procurement. All causes of delays have been detailed under ETI project progress report.

Table 81: Marshland irrigation development

Output	Target	Achievement (ha)	Comments
Ha of Marshland under Irrigation	500	225 (53%)	Development has been limited by budget cuts
Ha Rehabilitated in marshland irrigation schemes	300	298.2 (99.4%)	Completed by the Reserve Force as per the mapped area.

Table 82: Small Scale Irrigation Technology (SSIT) in FY 2016-2017

Output	Target	Achievement (ha)	Comments
Newly developed Ha under SSIT	1,100	2,130 (195%)	Due to the prolonged dry periods across the country, more emergency interventions were conducted. This also INCREASED the SSIT activities such as trainings and demonstrations.
SSIT demonstrations	124	165 (125%)	SSIT team has also actively participated in the national army week interventions and this has led to an increase in the

sessions conducted			number of farmers purchasing the SSI kits. Information sharing/Reporting was not effective during the ended fiscal year.
Farmers (F) and Technicians(T) trained on SSIT	520	580 (110%)	It is expected that with the decentralization of SSIT activities, information sharing will be improved, specifically through the guidelines developed by RAB/MINAGRI.

Table 83: Irrigation and Water Users Organizations (IWUOs) in FY 2016-2017

Output	Target	Achievement (ha)	Comments
Water Users Organizations to be established	24	19 (79.2%)	IWUOs were created in Cyogo, Rufuka, Nyagafunzo-Nyamigogo, Ruvungirana, Mushishito, Murori, Rumira-Urukunga, Rwamamba, Kigaga-Kabogobogo, Nyakagezi and Akagera marshlands, Nyamigogo, Rwakaganza& Ngoma-22, Akaboti, Agatare, Kibugazi, Umusizi and Kanyegeyege Marshlands
Water Users Organizations to be registered with RDB	10	9 (90%)	Two IWUAs registered in Nyiramageni&Umwaro Marshlands.; two IWUAs registered in Jabana and Bahimba; two IWUAs in Urwonjya&nyakanyeri IWUAs registered and three IWUAs registered in Mukinga, Nyagisenyi-Rufigiza and Kajevuba
Water Users Organizations members to be trained	2,800	2,814 (100%)	Training is done by Service providers through sit training and onsite training using FFLS Approach. A total of 2,814 members have been trained.
Water Users Organizations to be supported	34	34 (100%)	23 IWUAs are supported by field officers recruited under contract between RAB and HoReCo. The contract for 11 IWUAs supported under contract between RAB with Inades Formation Rwanda, STAR Construction and Consultancy and COCA Ltd was not renewed, these marshlands will be taken over by HoReCo and the document is in RPPA for approval.
Hillside Irrigation Schemes with Farm Managers	6	3 (50%)	Kagitumba, Matimba and Mpanga are covered under contract between RAB and HoReCo signed on 2 nd January, 2017

4.3 Agricultural mechanization

The main achievements of agricultural mechanization were expansion of irrigated land, training of machine operators and farmers and demonstrations of farm machinery (Table 84).

Table 84: Agricultural mechanization achievements for FY 2016-2017

Output	Target	Achievement (ha)	Comments
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Land to be mechanized	4,000	4,400	Land preparation increased due to prolonged rainy season and Army week
Percentage increase of mechanized farm operations	7%	6.2%	Farm operations under consideration are: Land development & land preparation, planting, crop treatment, harvesting, post-harvesting and agro-processing
Machine Operators to be trained	30	35	Tractor operators trained in collaboration with service providers and machinery dealers
Agro-mechanics Technicians trained	10	13	Agronomists were trained on the importance of using farm machinery / post-harvest equipment
Farmers to be trained	100	100	Farmers trained on operation of post-harvest equipment and machinery
Farm Machinery Demonstrations	4	12	Demonstrations on post-harvest machinery done to improve post-harvest handling in collaboration with local manufacturers

PART V. SUPPORT SERVICES

5.1 Planning, monitoring and evaluation unit

The planning, monitoring and evaluation unit has the mandate of, among other thing, developing technical tools for planning and managing data collection, analysis, and use. The PM&E process expands the Log frame to identify key information requirements for each indicator and summarizes the key monitoring and evaluation tasks for the existing strategic plan (2013-2018). It helps staff to determine if the proposed indicators can effectively measure the results linked to the single action plan. A good application of monitoring and evaluation rules helps the institution to tackle accurate information from achieved and under implementation activities; information that are used for further planning, learning and accountability. [Tables 85 and 86](#) below shows the calendar of PM&E activities during 2016-2017 fiscal year.

Table 85 : Planning ,Budgeting Monitoring and Evaluation Calendar 2016- 2017

Period	Planned activities
October	Issuing of the 1st PBCC from MINECOFIN, Quarterly reporting on Action Plans ,Imihigo and budget execution
November	Investments plans (PPDs and OPAFs Submitted to MINECOFIN) RAB action plans submitted to the Mother Ministry
January	2 nd PBCC from MINECOFIN to Publics institutions

	Quarterly reporting on Action Plans, Imihigo and budget execution
February	Data entry in IFMIS Received budget Ceiling from MINECOFIN
March	Budget consultation/ defense, Budget allocation (departments, programs, support services...)
April	Internal budget ceiling (departments. Programs, Projects) Quarterly reporting on Action Plans, Imihigo and budget execution
May	Elaboration of Annual Work Plan and Budget for FY 2017/2018 Elaboration of Joint & individual Imihigo for FY 2017/2018
June	Development of End Year (2016-2017) reports Staff Performance contracts entry in RBM/IPPIS

Table 86: RAB reporting Framework

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

5.2. Legal advisory services

The role of legal advisory services is to advise the senior management of the organization/ institution to comply with regulations in force in order to prevent unnecessary legal issues

and provide equal treatments to beneficiaries. The following tasks have been executed during this financial year by RAB legal advisory services during 2016-2017 fiscal year:

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

All the above mentioned activities were successfully.

5.3 Human resources management

The main role of Human Resources Management unit in RAB is to make sure that rules and regulations governing public servants, ethics, entitlements and conditions of service as well as standard operational procedures regarding their daily responsibilities are respected.

To ensure the effective Human Resources Management, RAB top Management organized different meetings during 2016-2017 FY whereby HR related issues were raised and solved. The performance appraisals for all RAB staff for the fiscal year 2016-2017 were conducted at 54%.

The number of RAB permanent staff in October 2016 was 441. In September 2017 two of them had retired while 2 others had resigned, making the total permanent staff reduced to 438 (Table 87). RAB has also 187 contractual staff some of them being paid on RAB revenues while others are paid by externally funded projects. The table below provides more information of RAB permanent and contractual staff.

Table 87: RAB staff in FY 2016-2017

	Total number, October 2016	Total number, September 2017
Permanent staff	441	438
Contractual staff	180	187
TOTAL	621	625

To date, RAB has 24 PhDs and 112 MScs. Forty three (43) staff went for a long term training, 22 on PhD and 21 on MSc. RAB hosted 350 professional internees in 2016-2017 fiscal year. During the 2016-2017 fiscal year, 8,658 incoming documents were received and 2,854 outgoing documents were sent by RAB central secretariat. All these documents are electronically registered and hard copies are filed using numerical filing system to insure easy access and security.

5.4 ICT Unit

The ICT unit is one of four support Units forming RAB's Corporate Services Division and has the following roles and responsibilities.

- Planning, implementing ICT infrastructure that includes (Setting and supporting Local Area Networks(LAN), Wide Area Network (WAN)s,);
- Responsible for the overall functioning and effective management of RAB's systems and related technology.
- Developing an IT strategy on data security, back up and support systems;
- Participate in elaboration of ICT sector strategic plan, RAB national ICT policy, annual action plans as well as operational plan;
- Plan for capacity building for RAB staff in Knowledge of computer hardware/software technologies.
- Develop specifications for procurement of systems/software and IT equipment;
- Ensure network connectivity throughout RAB's LAN/WAN infrastructure is realized;
- Ensure the maintenance of RAB's network facilities in individual machines, such as drivers and settings of personal computers as well as printers;

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

Purchase of IT equipment:

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

ICT infrastructure development:

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

The unit implemented a full and modern network IT infrastructure in the new constructed RAB new Headquarters with full applications and domain servers operational and optimized high-speed internet access through fiber optic terminals; with powerful surveillance cameras at every single corner of the premise, modern IP handsets to enable internal voice call.

These infrastructure are also highly protected by powerful cyber security equipment which meets the National cyber security requirement and standards. In the same line RAB purchased a good number of 4G LTE wireless routers and single point connectivity (Modems) to facilitate staff with full mobility of data connectivity.

Through ICT unit and in partnership with Rwanda Development Board (RDB) end users, administrative assistants were trained on the use of document tracking Management System, specifically on omni scan and omni flow platforms.

With the aim of facilitating communication among RAB staff based in different parts of the country, RAB implemented closer user group (CUG) communication facility with latest smart phones with mobile data connectivity, where RAB staff are making calls among themselves. Furthermore RAB toll free line 4675 up and running where farmers from different parts of the country and abroad call in for various queries on matters related to agriculture and get interactive responses. RAB has implanted ICT policies, procedures and disaster recovery plan manual by hosting RAB systems in the National Data centers to make sure that government data and information are hosted in safer environment.

PART VI. SCIENTIFIC COMMUNICATION

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