SIERRA LEONE AGRICULTURAL RESEARCH INSTITUTE

2013 - 2018 Annual Report

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SIERRA LEONE AGRICULTURAL RESEARCH INSTITUTE

ANNUAL REPORT FOR 2013-2018

VISION

The Sierra Leone Agricultural Research Institute (SLARI) guiding vision requires the institute and its stakeholders and partners to stretch their future expectations, aspirations and performance to achieve "**improved and sustainable broad-based agricultural growth**".

MISSION

The mission statement that expresses the functional purpose of SLARI is **"to enhance sustainable productivity, commercialisation and competitiveness of the agricultural sector through generation and promotion of innovative agricultural technologies and empowerment of stakeholders**".

WHO WE ARE

The Sierra Leone Agricultural Research Institute (SLARI) is a national research organisation working in partnership with the Ministry of Agriculture and Food Security (MAFS), farmers, the private sector, civil society, and other rural development stakeholders to significantly and sustainably improve the productivity and incomes of resource-poor farmers in Sierra Leone. Beyond its local partners, SLARI also works with various international partners to reduce poverty and unleash the country's agricultural potential.

The SLARI, with its partners, is committed to generating and promoting innovative agricultural technologies and empowerment of stakeholders to enhance sustainable productivity, commercialisation and competitiveness of the agricultural sector.

THE CORE FUNCTIONS OF SLARI INCLUDE:

i. To provide information that will assist the government and other stakeholders in the development of agricultural policies for poverty alleviation, food security and improved livelihoods of the citizens of Sierra Leone.

ii. To formulate agricultural research policies and programmes taking into account the vision, mission, goals and objectives of the agricultural sector, in line with government policy, and views of stakeholders, especially those related to sustainable food security, and conservation of renewable resources of Sierra Leone.

iii. To research food and cash crops production, livestock production and health, fish production, land and water management, forestry production and conservation, food and nutrition management, technology and socioeconomics of postharvest activities, emerging technologies in agricultural science, bio-safety and environmental conservation.

iv. To establish a strong working relationship with extension agents in the public and private sectors in the transfer of technology.

v. To facilitate and provide the relevant training and manpower development to serve the agricultural needs of the country.

vi. To produce annual reports highlighting research findings, management, scientific training and financial aspects of the institute.

vii. To establish strong links with national, regional and international agricultural research institutions or agencies involved in science and technology development and transfer.

viii. To represent the country in regional and international fora.

ix. To enhance public awareness of the importance of scientific research to agricultural and economic development.

x. To disseminate knowledge on improved technologies to stakeholders.

xi. To monitor and evaluate the impact of the adoption of agricultural research on agricultural productivity.

xii. To process and forward to the government the annual estimates for funding.

xiii. To mobilise human, financial and capital resources from donors, the private sector and from within the institute to facilitate the work of SLARI.

MESSAGE FROM THE ACTING DIRECTOR GENERAL

Dear Colleagues,

I am thankfully grateful for your support accorded to the SLARI management during the periods of 2013-2018. I appreciate and commend your hard work, commitment to excellence and dedication to meeting SLARI's goals. Last year was fraught with numerous challenges for SLARI; however, we all rose to the occasion and made sure that the institute strives to meet its objectives and commitments. This shows the resiliency of staff and the organisational culture of excellence in SLARI. Management wishes to encourage all staff to contribute their very best in ensuring that SLARI meets its goals and objectives at all times. Everyone must contribute his or her share through individual and collective resolve to improve our performance and commitment to excellence at all levels.

THE FOCUS HAS BEEN ON:

1. Developing a stronger organisational structure with a redefined focus on research-for-development, partnership and capacity building.
2. Strengthening the SLARI centres, revamping the Freetown Fisheries Research Centre (**FFRC**) and establishing new ones; replacing retired, deceased and staff who have resigned, as well as recruiting new scientific staff and facilitating technical assistance contracts with IITA and AfricaRice through FSRP by mentoring our young scientists to become greater scientists for new and emerging programmes and projects.
3. Upgrading the knowledge and skills of our valuable technicians and scientists through short-term attachments in international research centres and in workshops and training programmes of our international partners.
4. Aligning our research programmes with that of the Government's Agricultural Development Agenda, and **CORAF/WECARD, FARA, ECOWAS**, as well as **CAADP**

principles for research for development and working more collaboratively with other scientists, centres and partners in the SLARI system.

5. Mobilising resources by tapping from traditional funding sources, and non-traditional funding sources such as FSRP, AfricaRice, EU, AGRA, NGOs, etc., to ensure that the institute is prepared to take on more challenges.
6. Building a stronger SLARI team and raising staff morale through energised efforts in striving for better conditions of service that are equivalent to or better than the universities, and striving to clear backlog salaries and benefits.
7. Building new relationships, forging and strengthening partnerships to ensure that the right technologies are developed, disseminated, and adopted by our end users.

All these will continue to result in a stronger organisation with a more relevant and focused science-based platform, responsive staff, and more effective institutional mechanisms to ensure effectiveness and efficacy in operations, proactive and more strategic relationships and networks and an increase in non-traditional resources, replacement and recruitment of more scientific staff that would facilitate the success of its research-for-development programmes.

The path ahead will continue to be fraught with challenges, but together, we will overcome them. Let us celebrate our successes, but at the same time continue to work harder together towards achieving our goals. I envision more productive years ahead and a stronger SLARI in the future.

Thus, I encourage everyone to be diligent and make sure that SLARI succeeds in its goal of being the leading national research-for-development partner in Sierra Leone in finding solutions to hunger and poverty.

On behalf of the Management and Council of SLARI, I wish every staff member good health, wealth, happiness, and another successful year 2025. I look forward to a productive Annual Review and Work planning for 2025.

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OVERVIEW

The agricultural sector in Sierra Leone is not only the means of the livelihood of a significant portion of the population, but has the tremendous potential to serve as the engine for the socio-economic growth and development of the country. The performance of agriculture impacts heavily depend on nearly all other sectors of development. If such as huge socio-economic gain is to be realized, agricultural research unarguably has a vital role to play.

Agricultural research in Sierra Leone has made significant contributions towards improvement of the agricultural productivity and rural development in the past. In order to strengthen the role of and forestry sectors, agricultural research, the government established the Sierra Leone Agricultural Research Institute (SLARI) through an Act of Parliament in 2007 as the country's agricultural research and agricultural technology generating body for the benefit of the farming, fishing and forestry sectors. For its full operations, SLARI needs eight research centres spread throughout the country, of which, six are currently fully operational.

Considering the developmental strides at the national, regional and international levels, SLARI is currently revising the old strategic and operational plans (2012-2021). The revised documents will strategically position SLARI to continue to contribute significantly to the development of the agriculture sector with relevant emerging issues fully captured. From the regional and global perspectives, the Strategic Plan is in line with the Comprehensive African Agricultural Development Programme (CAADP), West and Central Council for Agricultural Research and Development (CORAF/WECARD); and the Millenium Development Goals (MDGs).

However, more than ever before, the institute is now required to go beyond research and become a vehicle for development. The SLARI guiding vision that requires the institute and its stakeholders and partners to stretch their future expectations, aspirations and performance is to see "**Improved and sustainable broad-based agricultural growth**". The Mission statement that expresses the fundamental purpose and business of SLARI is "**To enhance sustainable productivity, commercialization and competitiveness of the agricultural sector through generation and promotion of innovative agricultural technologies and empowerment of stakeholders**".

Given the institutional strategic direction, SLARI has identified five result areas that are necessary and sufficient to deliver on the institutional specific objective of generating and promoting innovative agricultural technologies and empowerment of stakeholders. Attainment of this Specific Objective will contribute to the realization of the overall institute's General Objective of **enhancing sustainable productivity, commercialization and competitiveness of the agricultural sector through generation and promotion of innovative agricultural technologies and empowerment of stakeholders**. The five results that are designed to position SLARI strategically as the key driver for **enhancing sustainable productivity, commercialization and competitiveness of the agricultural sector** include:

Result 1: Appropriate agricultural product value chains technologies and innovations **generated and promoted.**

Result 2: Appropriate markets and marketing strategies for enhancing agricultural value chains **developed and promoted.**

Result 3: Appropriate policy options for enhancing agricultural product value chains **facilitated and advocated.**

Result 4: Capacity for implementing agricultural product value chains research **strengthened.**

Result 5: Appropriate mechanisms for managing, sharing and scaling up agricultural knowledge, information and technologies **established and operationalized**.

In order to position itself strategically as a key driver in the transformation of the agricultural sector from subsistence to a commercial and profitable business enterprise, SLARI has adopted the Agricultural Product Value Chain (APVC) approach to research for development within the framework of Integrated Agricultural Research for Development (IAR4D). the adoption of this approach to research requires SLARI to shift focus from production of commodities to differentiated agricultural products including increased value addition to commodities within the rural areas and development and promotion of new products that fit the demands of the target market. This would require strengthening of capacity beyond the simple training and, therefore, a need for the development and operationalization of effective and efficient capacity development programme was identified during the development of the SLARI Strategic Plan. This need for strengthening of capacity for implementing APVCs research was subsequently addressed as one of the institutional level result areas. It is against this background that the Networking Support Function Four (NSF4) of Forum for Agricultural Research in Africa (FARA), in collaboration with the other FARA Networking Support Functions, initiated the capacity assessment of SLARI and its functional relationship with the wider Sierra Leone national agricultural research system.

ACHIEVEMENTS

Release of five rice varieties including NERICA L-19, NERICA L-20, ROK 35, ROK 36 and ROK 37.

Release of two soybean varieties (SLIBEAN 1-2), one OFSP (Mathutu), seven cassava varieties (SLICASS 7-14)

Rehabilitation of the water supply system at Kpuwabu

Solar electrification of the Kpuwabu senior staff quarters

Installation of a greenhouse at Kpuwabu Construction of multipurpose farm building at Pendembu

Construction of drying floor at Pendembu

Rehabilitation of conference hall and laboratory at Pendembu

Procurement of assorted laboratory tools and implements at Pendembu

Training of a one staff in the use of laboratory tools and implements at the IITA

Support to 150 cocoa farmers in Kenema and Kailahun districts for the establishment of 150 ha of cocoa (1 ha per farmer)

Support to 30 oil palm farmers in Bombali and Kambia districts for the establishment of 30 ha of improved oil palm planting materials that were imported from the Oil Palm Research Institute (OPRI) of Ghana

Administrative support to the KFTCRC for the procurement of office consumables

CAPACITY BUILDING

Two staff trained on semi autotrophic hydroponics (SAH) between 12th September and 24th September 2018 in IITA Ibadan, Nigeria.
Mr. Osman Nabay and Dr. Abdul Rahman Conteh trained on modernization and transformation of agriculture: technology adoption and impact assessment. The training was held in Dakar, Senegal on November 5 – 9, 2018.
A staff was trained on enhancing the concurrent selection and evaluation of biofortified and bio-enriched varieties derived from mutant rice, cassava and other crops at National Crops Resources Research Institute, Namulonge, Kampala –Uganda. 18th June 2018 to 17th August 2018. IAEA Project FS-SIL5020-1801894.

PEOPLE AND EVENTS

The visit by IITA team to SLARI and NARC on 2nd-4th July 2018 marks a promising beginning for a partnership aimed at transforming agriculture in Sierra Leone through innovative solutions. Dr Joseph Kargbo, DG, SLARI and management team received the TAAT team at the SLARI headquarters Conference room. Dr. Dixon introduced visiting team and highlighted the importance of NextGen for Sierra Leone in Phase II. He revealed that the TAAT Program is particularly targeting the youths and women in a way that they can make meaningful contribution to the growth and development of the Agricultural sector. He also disclosed a possible IrishAid plan to support vitamin A cassava interventions in Sierra Leone. The project aims at outscaling already developed technologies; seed production; and strengthening of seed systems. At NARC, Dr. Alfred G.O. Dixon introduced TAAT team. Dr. Chiedozie Egesi introduced Nextgen Cassava Phase 2. He revealed that the aim of the visit was to bring the breeding program to pace with technological progress in better experimental designs, data collection and management, germplasm exchange and collegiate knowledge exchange with other NextGen breeders across Africa. Peter Kulakow discussed new developments in IITA cassava breeding with emphasis on technologies that could be delivered in TAAT and opportunities for the new Community of Practice Partnerships (COPP) activities in Sierra Leone. Festus B. Massaquoi introduced SLARI past and current achievements in cassava breeding. Kumba Karim presented her work on high dry matter content and quality of high starch cassava. Isata Kamanda presented her work on biofortified cassava.

Figure 1. IITA Visitors to SLARI and NARC in July 2018. L- R: Drs Chiedozi Egesi, Peter Kulakov, and Alfred G.O. Dixon

Figure 2. SLARI-NARC wrap-up meeting at Njala, 4 July 2018 (notes prepared by Peter Kulakow)

Technical Meeting on Fall Armyworm (FAW) Management was held on 26th-27th of November 2018 at NARC conference hall. The purpose of the workshop was to develop workable management strategies of the FAW in Sierra Leone. Mr. Patrick Ngegba presented on the overview of FAW threat and economic impact on food security. The second presentation by Mr. Augustine Mansaray was done on the biology and ecology of fall armyworm. Significance of FAW in our economics, food security and export was presented by Dr. Alusaine E. Samura. harnessing bio-control as a major tool in combating FAW in Sierra Leone was presented by Mr. Charles Kattingu. Key action points from this workshop included (i) nationwide survey to produce a baseline data on the current status of FAW in Sierra Leone; (ii) to establish the Economic Injury Level and the Economic Threshold Level; (iii) study the biology and ecology of the FAW under laboratory and field conditions; (iv) to undertake classical biological control; (v) to generate, validate and promote IPM technologies for FAW in Sierra Leone; (vi) to build up the capacities of stakeholders in the management of FAW.

SUMMARY OF RESEARCH, TECHNOLOGY AND INNOVATION DEVELOPMENT ACTIVITIES FOR 2013-2018

This section of the report summarizes the research, technology and innovation development activities carried out from January to December of 2013-2018 by SLARI through its research programmes at the six functional centres. The detailed research, technology and innovation development activities are found in the annual reports of the different research centres. Other vital information on our activities can be found in summaries, briefing reports, extension materials and on various social media platforms such as LinkedIn, Facebook, etc.

A. ROKUPR AGRICULTURAL RESEARCH CENTRE (RARC)

The cereal crops research programme is implemented at the RARC. The programme is aimed at addressing challenges to enhance sustainable productivity, commercialization, and competitiveness of the cereal crops.

Enhancing rice varietal improvement and development for seed production for the upland and deep-water ecologies in Sierra Leone (Project Code: 2011 PASS 011)

Results obtained in the 2013 EVT are shown in Tables A1, A2, and A3 below. In Bo, none of the test lines significantly (P<0.001) outyielded the best check, Rok 24; the seven comparable yielders with ROK 24 (Table A2).

Table A1. Growth, grain yield and related traits of promising breeding lines tested in Elite Varietal Trial (EVT) at Rokupr, 2013 wet season

Variety	Yield (kgha^{-1})	Pan m^{-2}	PHT (cm)	FPF (d)	Mat (d)
TOX 3052- 39-1-2-1	1302	145	100	116	141
SIK 93	1213	145	119	142	136
IR 66298-5-3-3-B-1	1159	147	99	122	147
NIONO 2	1141	132	105	125	148
TOX 3233-46-52-3-3-3	1141	180	100	116	141
WAT 110-TGR 3-2-2	1106	120	118	123	148
SIK P7-1-18-5-1-4	1088	146	91	116	141
ROK 24 (BChk)	1024	134	99	122	147
Fpr	<0.001	0.001	0.04	<0.001	<0.001
$LSD_{0.05}$	167	3	27	7	2
C.V (%)	10.3	1.1	15.0	3.3	0.7

BChk = Best Check

Table A2. Growth, grain yield and related traits of promising breeding lines tested in Elite Varietal Trial (EVT) at Bo, 2013 wet season

Variety	Yield (kgha^{-1})	Pan m^{-2}	PHT (cm)	FPF (d)	Mat (d)
SIK P5-04-3-5-2-4	4351	111	140	111	143
BG 1370	4030	116	144	111	143
ROK 24 (BChk)	**3923**	138	141	114	147
NIONO 2	3852	156	120	103	134
WAR 115-1-2-2-1-2-B	3852	189	96	107	139
SIK P7-1-18-5-1-4	3567	173	111	96	127
GAMBIAKA	3531	139	122	96	127
IR 66298-5-3-3-B-1	3388	151	137	113	144
Fpr	**<0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
$LSD_{0.05}$	**708**	**33**	**11**	**9**	**9**
C.V (%)	**12.5**	**12.7**	**5.5**	**5.1**	**1.7**

BChk = Best Check

At Blama, the seven top yielders (1177-2818 kgha^{-1}) were all superior to the best check, ROK 24 with yield of 820 kgha^{-1} (Table A3).

Table A3. Growth, grain yield and related traits of promising breeding lines tested in Elite Varietal Trial (EVT) at Blama, 2013 wet season

Variety	Yield (kgha^{-1})	Pan m^{-2}	PHT (cm)	FPF (d)	Mat (d)
NIONO 2	2818	310	102	96	126
SIK 93	1890	266	120	94	135
WAR 115-1-2-2-1-2-B	1676	235	102	108	155
IR 66298-5-3-3-B-1	1569	220	122	109	139
SIK P5-04-3-5-2-4	1462	266	122	104	134
TOX 3233-46-52-3-3-3	1373	195	114	93	123
WAT 110-TGR 3-2-3	1177	179	97	85	115
ROK 24	**820**	136	118	114	128
Fpr	**<0.001**	**-**	**<0.001**	**<0.001**	**<0.001**
$LSD_{0.05}$	**220**	**-**	**16**	**8**	**20**
C.V (%)	**12.1**	**-**	**8.8**	**4.5**	**8.8**

BChk = Best Check

The best check, **ROK 14** (2247 kgha^{-1}) was superior to all the tested breeding lines except JAMKO 11 which exhibited grain yield of 2140 kgha^{-1} (Table A4). The breeding lines with at least 1500 kgha^{-1} were included in the 2014 EVT.

Table A4. Growth, grain yield and related traits of promising breeding lines tested in Advanced Varietal Trial (AVT) at Rokupr, 2013 wet season

Variety	Yield (kgha^{-1})	Pan m^{-2}	PHT (cm)	FPF (d)	Mat (d)
ROK 14 (BChk)	**2247**	146	73	119	145
JAMKO 11	2140	142	121	111	136
WAS 161-B-4-B-1-TGR	2069	173	91	106	131
DKA 11	1694	182	96	106	131
JAMKO 1	1676	168	106	94	119
JAMKO 2	1658	157	86	98	123
JAMKO 9	1552	133	102	111	136
DKA M4	1534	168	65	74	99
Fpr	**<0.001**	**0.03**	**-**	**<0.001**	**<0.001**
$LSD_{0.05}$	**164**	**-**	**14**	**-**	**1**
CV(%)	**6.5**	**-**	**8.4**	**-**	**0.6**

BChk = Best Check

Similarly, in the PYT, tested breeding lines with comparable grain yield with the best check, ROK 24 (1248 kgha^{-1}), which outyielded all the test lines (Table A5), were advanced to 2014 AYT.

Table A5. Growth, grain yield and related traits of promising breeding lines tested in Preliminary Varietal Trial (PVT) at Rokupr, 2013 wet season

Variety	Yield ($kgha^{-1}$)	Pan m^{-2}	PHT (cm)	FPF (d)	Mat (d)
ROK 24 (BChk)	**1248**	154	134	115	140
WAC18-WAT65-1-1-2	1213	139	122	152	177
DKA M7	1159	135	120	104	129
WAC 33-TGR 1-WAT 1-TGR 1	1124	154	83	125	149
WAC 13-WAT 32-2-3-1	1141	144	108	98	125
SIK 353- A 10	1106	109	101	104	129
KHAO-DHARK MALI 105	1070	134	95	105	129
DKA M 13	963	137	95	110	135
Fpr	**Ns**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
$LSD_{0.05}$	**708**	**33**	**11**	**9**	**9**
CV(%)	**12.5**	**12.7**	**5.5**	**5.1**	**1.7**

BChk = Best Check

The breeder seed harvested in 2013 were used to produce 2014 foundation seed both on- and out-stations through the funding aid by our partners namely: BRAC SL, Genesis Farm, and SMP, etc. (Table A6).

Table A6. Breeder Seed Production (BSP) at Rokupr, in 2013 wet season: Joint Effort (WAAPP/AGRA/BTF)

Variety Designation	Area (m^2)	Seed Harvested (Kg)
TOX 3805-38-2-1-2	55	5.3
TOX 3931-22-1-2-3-2	25	4.9
BUTTER CUP	30	2.5
TOX 3233- 46-52-3-3-3	20	2.4
WAB 2060-FKR4-WAC1-TGR5-B	20	2.0
WAB 2095-WAC1-TGR1-B	20	2.6
WAB 2061-2-FRKR1-WAC2-TGR4-B	25	2.9
ITA 212	35	5.0
SWARNA	25	2.6
SWARNA +Sub 1	35	4.0
NERICA L-19	70	6.8
NERICA L-20	35	3.8
ROK 24	35	3.4
ROK 10	35	4.3
No. 1 B.P. (148)	35	1.2
WAS 49-B-B-9-1-4-4	35	1.0
Totals	**535**	**54.7**

Elite putative breeding lines recommended for the upland and lowland ecologies are presented in Tables A7 and A8, respectively.

Table A7. Upland rice varieties nominated for release in Sierra Leone in 2013

Variety designation	Original name	Ecology
ROK 34	NERICA 2	Upland
ROK 35	NERICA 3	Upland
ROK 36	NERICA 4	Upland
ROK 37	NERICA 6	Upland
ROK 38	NERICA 15	Upland
ROK 39	NERICA 16	Upland
ROK 40	NERICA 18	Upland
ROK 41	WAB 450-24-2-4-P33-HB	Upland
ROK 42	WAB 450-I-B-P-32-HB	Upland

Table A8. Lowland rice varieties nominated for release in 2013

Variety designation	Original name	Ecology
ROK 43	AS 781-1	Inland Valley Swamp
ROK 44	BG 1370	Inland Valley Swamp
ROK 45	GIBOB	Inland Valley Swamp
ROK 46	NERICA L-19	Inland Valley Swamp
ROK 47	NERICA L-20	Inland Valley Swamp
ROK 48	TOX 3817-42-3-1-2-3-2	Inland Valley Swamp
ROK 49	WAS 49-B-B-9-1-4-4	Inland Valley Swamp
ROK 50	Pa Kiamp	Inland Valley Swamp/Upland
ROK 51	Pa Bangura	Mangrove
ROK 52	WAR 73-1-M2-1	Mangrove
ROK 53	WAR 77-3-2-2	Mangrove

The F_1 hybrid seeds collected crosses were used to raise the F_1 population in 2014, from which F_2 seeds were collected (Table A9). This was a collaborative activity, jointly sponsored by WAAPP, AGRA, and Africa Rice Breeding Task Force.

Table A9. Varietal development- new crosses made at Rokupr, in 2013 wet season

Date	Cross #	Female (♀)	Male (♂)	Pan-Emas	Pan-collected	F1 seeds collected
12/11/13	16	BR 11 + SUB 1	ROK 16	4	4	51
13/11/13	17	ROK 16	BR 11 + SUB 1	3	3	32
13/11/13	18	GIGANTE	ROK 24	4	4	20
14/11/13	19	ROK 24	GIGANTE	3	1	1
19/11/13	20	SAMBA MASHURI + SUB 1	ROK 16	5	5	150
25/11/13	21	OM 5886	ROK 24	4	4	18
26/11/13	22	SAMBA MASHURI 2 + SUB 1	ROK 24	4	4	11
26/11/13	23	NIL 2	ROK 24	5	4	57
27/11/13	24	TDK 1 + SUB 1	ROK 24	5	5	29
27/11/13	25	NIL 130	NERICA L-19	4	3	19

A total of 50 plant selections were made as specified in the table 12, which shows how the hybridization work has been progressing since 2010 when the crosses were made (Table A10). The plant selections will be used to raise the F_{4-5} populations; ensuring that the plants selections per cross are used to raise the F_{4-5} populations of that particular cross each separately in 2014 wet season, according to the objective of selection.

Table A10. F_{3-4} segregating populations maintained at Rokupr, in 2013 wet season

Cross	Objective/s	F1-2 seeds [2010]		Number of Plants Selected		
		Pan	Seeds	F_{2-3} [2011]	F_{3-4} [2012]	F_{4-5} [2013]
ROK 32/ROK 24	For iron tolerance, improved tillering and good grain and plant type.	5	120	6	26	20
CISADANE/ROK 24	For gall midge resistance, good grain and plant type, and iron tolerance.	4	69	10	13	9
No. 1BP(148)/ ROK 24	For good grain quality, aroma and iron tolerance.	3	24	4	19	13
WAB 450.I.B.P32-HB/ROK 30	For blast resistance, and good grain and plant type.	1	27	8	18	8
					Total	50

VARIETAL DEVELOPMENT -2014 HYBRIDIZATION CROSSES

Submergence tolerance breeding lines acquired from IRRI through AfricaRice breeding Task Force STRASA activities were used in the 2014 crosses; F1 seed harvested were grown in January, 2015, and F2 seeds harvested from the F1 plants will be raised as F2-3 segregating population in 2015 cropping season (Table A11).

Table A11. F_{3-4} segregating populations maintained at Rokupr, in 2013 wet season

Cross #	Female ♀	Male ♂	No. of Pan		No. of Seeds	
			B. Env	G. Env	B. Env	G. Env
1	IR 64 + Sub 1	ROK 16	3	4	33	27
2	ROK 16	IR 64 + SUB 1	1	3	0	22
3	NIL 130	NERICA L-19	-	2	-	8
4	NERICA L-19	NIL 130	1	2	4	7
5	GIGANTE	NERICA L-19	2	2	13	0
6	NERICA L-19	GIGANTE	1	3	5	7
7	NIL 2	NERICA L-19	1	3	1	24
8	NERICA L-19	NIL 2	2	2	7	2
9	TKD 1 + SUB 1	ROK 16	2	2	54	31
10	ROK 16	TKD 1 + SUB 1	2	2	12	4

11	Swarna + Sub 1	ROK 16	3	4	4	0
12	SAMBA MASHURI + SUB 1	ROK 24	1	2	7	31
13	ROK 24	SAMBA MASHURI + SUB 1	2	1	39	0
14	SWARNA + SUB 1	ROK 24	1	3	46	109
15	TKD 1 + SUB 1	ROK 24	4	-	17	-

BREEDER SEED PRODUCTION OF UPLAND AND LOWLAND RICE VARIETIES

During the 2014 wet season, 77.5 kg of breeder seed or pre-basic seed (G3) of four upland rice varieties and 208.5 kg of nine lowland rice varieties were produced at Rokupr (Table A12). According to the ECOWAS Seed Regulation of 2008, pre-basic seed (G3) can be used for the production of foundation seed or basic seed (G4). The seeds were delivered to the Farm Management Unit for the production of foundation seed during the 2015 cropping season. Figure A1 shows the different sizes and colours of the grains of four upland and nine lowland varieties.

Table A12. Grain weight of four upland and nine lowland rice varieties produced as breeder seed, Rokupr, 2014 wet season

Upland rice variety	Grain weight (kg)	Lowland rice variety	Grain weight (kg)
ROK 34 (Pa Kiamp)	33.0	ROK 10	31.0
ROK 3	24.5	ROK 21	27.5
NERICA 3	13.5	ROK 5	27.0
ROK 16	6.5	ROK 24	23.5
-		ROK 22	22.5
-		Indochine Blanc	21.0
-		NERICA-L-19 (Medium grain)	20.0
-		NERICA-L-19	20.0
-		NERICA-L-19 (Long grain)	16.0
Total	**77.5**		**208.5**

		
ROK 3	**ROK 16**	**NERICA 3**
		
ROK 34 (Pa Kiamp)	**ROK 5**	**ROK 10**
		
ROK 21	**ROK 22**	**ROK 24**
		
Indochine Blanc	**NERICA-L-19 (Long grain)**	**NERICA-L-19 (Medium grain)**
		
NERICA-L-20		

Figure A1. Sizes and colours of upland and lowland rice grains

DEVELOPING MULTIPLE-STRESS TOLERANT RICE VARIETIES FOR THE MANGROVE SWAMPS

The objectives of this study were: (i) to develop and/ or identify and select appropriate new rice varieties with high yield potential and well-adapted to mangrove swamps- (resistant to or tolerance of adverse soil conditions (salinity, sulphate acidity, iron toxicity, submergence), diseases and pests (weeds, blast, RYMV, brown spot, stem borer, crabs, gall midge) with consumer acceptable qualities (Milling, Cooking, Eating/Taste, Keeping); and (ii) to enhance varietal release and farmers' access to quality seeds of recommended, improved high yielding released and pre-released rice varieties.

The research activities conducted during 2013-2015 were:

i. Screening and evaluation of available exotic accessions/local collections, in conventional screening trials: Observational Yield Trial (OYT), Preliminary Yield Trial (PYT), and Advanced Yield Trial (AYT) at RARC, Rokupr- on-going activities in the breeding programme.
ii. Varietal Development: Hybridization crosses were made (2010, 2013 and 2014) to develop appropriate and desirable stress-tolerant plant types/rice varieties for the mangrove swamps and the rainfed lowland systems in Sierra Leone in general.
iii. Genetic Diversity study in mangrove rice, WAAPP intervention enabled us, in 2013, to carry out agro-morphological characterization of local rice collections made in 2011 with the support of both AGRA and AfricaRice BTF-STRASA Projects. WAAPP project continued to collect mangrove rice germplasm in 2014/15.
iv. Maintenance of a genetic stock/field genebank- in the absence of a functional cold room facility- comprising of all rice accessions i.e. introductions and collections available at RARC- a measure to prevent genetic erosion, preserve the identity and genetic purity of a variety and serves as a reference stock and source of true-to-type panicles used in breeder seed production (G1).
v. Breeder Seed production/multiplication of seed rice of stress-tolerant rice varieties (STRV)- it is an on-going activity in the breeding programme.

- ✓ To maintain the genetic purity and variety identity and
- ✓ Expedite foundation seed production, farmers' access to certified quality seed rice and varietal release- especially of outstanding pre-released and released varieties in high demand by seed growers/farmers.

Table A13 presents summaries of growth, grain yield and related traits of breeding lines tested in Advanced Yield Trial (AYT), 2015 wet season in the mangrove swamp ecology of RARC, Rokupr. Mean grain yields were below 1tha^{-1} and were non-significant among genotypes, but significantly varied for the other measured traits.

Table A13. Growth, grain yield and related traits of promising breeding lines tested in Advanced Yield Trial (AYT), 2015ws, long season Mangrove, Rokupr

Variety	Yield ($kgha^{-1}$)	Panicle m^{-2}	Plant height (cm)	50% flowering (d)	Days to maturity (d)
ROK 5	695a	101a	101c	160a	180a
WAR 36-37-3-3-1	659a	100a	97d	145c	165b
ROK 37	659a	102a	81f	143c	163b
Rohyb 173-B-1-B-2	649a	87b	104bc	160a	180a
Rohyb 162-B-3	648a	97a	112a	151b	180a
WAR 115-1-2-4-9-B-B-7	577a	101a	107b	161a	181a
Pa Brima Samura	577a	85b	102c	162a	182a
WAR 90-4-5-B-1-B-B-B-1	553a	101a	94e	145c	165b
CV (%)	25.4	3.1	0.4	0.4	1.5

The tidal mangrove grain yields obtained in 2015 cropping season are lower than 2014 for most of the test breeding lines probably due to change of trial sites, but interestingly the same trend in grain yields was again observed-better in the shorter salt-free period catenae than in the long season mangrove with the longest salt-free period (> 6 months). However, better grain yields could be obtained above the 1970s recommended applied inorganic fertilization dose of 60:40:40 N, P_2O_5, K_2O $kgha^{-1}$. Pa Brima Samura, the local variety used as check at both locations was only significantly out-yielded ($P<0.05$) by Rohyb 181-B-10-5 (1284 $kgha^{-1}$) at Rokel (Table A14). At the PYT breeding stage, genotype Pa Three Months had the highest grain yield of 2574 $kgha^{-1}$, Kabba Forreh had the lowest of 2085 $kgha^{-1}$ similar to all the breeding lines tested under Mangrove Associated Swamp condition, Rokupr (Table A15).

Table A14. Growth, grain yield and related traits of promising breeding lines tested in Advanced Yield Trial (AYT), 2015ws, Medium Season Mangrove, Rokel

Variety	Yield ($kgha^{-1}$)	Panicle m^{-2}	Plant height (cm)	50% Flowering (d)	Days to maturity (d)
Rohyb 181-B-10-5	1284a	124d	111e	135a	150b
Rohyb 162-B-3	1261a	131c	124c	136a	162a
Pa Brima Samura	1059b	113e	127b	136a	161a
Rohyb 186-B-6-B-1	997b	154a	109f	112c	138d
ROK 5	940b	112e	129a	136a	161a
Rohyb 194-B-7-B-1	917b	145b	116d	117b	142c
ROK 36	894b	83f	130a	111c	137d
FKR 28	871b	75g	83g	136a	150b
CV (%)	19.7	6.9	0.4	0.6	0.6

Table A15. Growth, grain yield and related traits of promising breeding lines tested in Preliminary Yield Trial (PYT), 2015ws, at Mangrove Associated Swamp, Rokupr

Variety	Yield ($kgha^{-1}$)	Panicle m^{-2}	Plant height (cm)	50% flowering (d)	Days to maturity (d)
Pa Three Months	2574a	151b	151d	119j	139h
Thaylor	2471a	146bc	147e	131h	151f
Pa Brima Samura	2471a	144c	160a	151d	171c
Kapengie	2420a	151b	157b	153cd	172bc
ROK 24	2420a	153ab	155c	125i	146g
Pubei	2214a	155ab	159ab	140f	160d
Pa Musleme	2188a	147bc	160a	150de	170c
Gbobe (1)	2137a	158a	152d	130h	150f
Kabba Forreh	2085a	151b	148e	134g	154e
Pa Maseray	2085a	144c	158b	155c	174b
Black Zoro	2059a	155a	159ab	130h	150f
Korgbati	2034a	150bc	159ab	133g	153e
Pa Black (2)	2008a	142c	12g	164b	184a
Kolma Figeh	2008a	141c	121f	165ab	185a
Black Rice	2008a	145c	119g	167a	185a
CV (%)	24.7	2.0	0.6	1.0	0.6

No significant differences were observed in grain yields for rice grown under 60:40:40 N, P_2O_5, K_2O $kgha^{-1}$, but higher grain yields could be obtained at higher levels of applied inorganic fertilization. The local variety, Pa Brima Samura, used as check in the study was only slightly out-yielded by four test entries (Table A16).

Table A16. Growth, grain yield and related traits of promising breeding lines tested in Advanced Yield Trial (AYT), 2015ws, Mangrove Associated Swamp, Rokupr

Variety	Yield ($kgha^{-1}$)	Panicle m^{-2}	Plant height (cm)	50% flowering (d)	Days to maturity (d)
WAR 2155-TGR2-WAT 3-2-1	2046a	199a	78g	99d	119c
KHAO DHARK Mali 105	2045a	175d	118b	120c	140b
DKA 23	1931a	161e	114c	92e	112d
DKA 1	1908a	195b	91f	122b	142b
Pa Brima Samura	1827a	183c	117b	160a	180a
WAC 13-WAT32- 2-3-1	1666a	124f	103e	98d	118c
SIK 353- A10	1655a	103g	107d	120c	140b
JAMKO 11	1504a	103g	131a	93e	113d
CV (%)	36.2	1.2	0.5	0.4	1.3

ROK 5, Rohyb 4-WAR 1-3-B-2, and Rohyb 186-B-6-B-1 appeared to be fertilizer responsive, because they returned higher grain yields under applied inorganic fertilization (>60:40:40 N,$P_2O_5K_2O$ $kgha^{-1}$, based on RARC recommendations since the 1970s) (Table A17).

Table A17. Mean grain yields ($kgha^{-1}$) obtained in PVS trial across the three Mangrove Swamps Catenae

Variety	Long season	Medium season	Long season
ROK 5*	1543	823	755
Rohyb 4-WAR 1-3-B-2*	514	514	518
IR 65192-4B-11-3	720	617	823
ROK 37	1028	514	617
IR 65192-4B-13-2	514	720	1028
Rohyb 186-B-6-B-1*	617	720	514

Breeding lines that out-yielded both the improved and local standard varieties, ROK 5 and Pa Brima Samura, respectively, were included in the 2016 Rice Garden established in the mangrove swamp rice hub to allow joint assessment by stakeholders in the mangrove Innovation Platforms. The local mangrove rice cultivars collected (400) in 2014/2015 were also maintained in the long season mangrove at Rokupr, in 2015 cropping season (Table A18).

Table A18. Mangrove rice germplasm collections in 2014/15 dry season

Collector	**Village**	**Reg. Farmers**	**Number of germplasm collected**
Unis T. Bangura	Robombeh (LSM)	26	48
	Rokon (LSM)	12	26
	Rosinor (MSM)	19	30
Alpha Sesay	Robat (LSM)	32	49
	Romankneh (LSM)	16	31
	Magbolontor (MAS)	9	11
Edward M Munu	Balancera (SSM)	39	58
	Rokel (MSM)	19	24
	Kychom (MSM)	48	59
Mohamed Sumah	Rolal (SSM)	41	64
	Total	**261**	**400**

STATUS OF VARIETAL DEVELOPMENT FOR ABIOTIC AND BIOTIC STRESS TOLERANCE

Table A19 shows number of hills selected from each of the $F_{5\text{-}6}$ plots; for example, from Cross # 1, ROK24/ROK32, 28 plots were grown comprising 2360 hills/plants, out of which 28 desirable plants were selected in 2015 cropping season. This implies that, 13, 19 and 10 desirable plant types were selected from 1560, 2280, and 1200 hills in cross numbers 2, 3, and 4, respectively.

Table A19. Maintenance of $F_{5\text{-}6}$ segregating populations of 2010 crosses, 2015 cropping season

Cross #	**Parents** [(♀) / (♂)]	**Objective**	**# of Hills selected**
1	ROK24/ROK32	To obtain Fe-Tox plant types with good grain.	28 (28 plots- 2360 hills)
2	ROK24/Cisadane	To obtain Fe-Tox plant types with good grain that are resistant to AfRGM.	13 (13 plots- 1560 hills)

3	ROK24/ROK36	To obtain Fe-Tox plant types with good grain and aroma.	19 (19 plots - 2280 hills)
4	ROK30/WAB 450-I-B-P-32-HB	To obtain early, blast resistant plant types with good grain.	10 (10 plots - 1200 hills)
		Total	**70**

Table A20 presents number of hills selected from each of the $F_{2\text{-}3}$ plots' hills; for example, from Cross # 1, IR 64 + Sub 1/ROK 16, 2 plots were grown comprising of 240 hills/plants, out of which 2 desirable plants were selected in 2015 cropping season. This implies that, 2, 2, 4, 13, 12, 11, 24, and 3 desirable plant types were selected from 240, 480, 120, 720, 720, 960, 720, and 360 hills in Cross numbers 2, 3, 4, 5, 6, 7, 8, and 9, respectively.

Table A20. Maintenance of $F_{2\text{-}3}$ segregating populations of 2014 crosses

Cross #	Parents [(♀) / (♂)]	Objective	No of hills selected
1	IR 64 + Sub 1/ROK 16	To obtain early sub-saltol plant types	2 (2 plots - 240 hills)
2	ROK 16/IR 64 + Sub 1	To obtain early sub-saltol plant types	2 (1 plot - 240 hills)
3	NIL 2/NERICA L-19	To obtain Fe-toxicity RYMV plant types with good grain	2 (4 plots - 480 hills)
4	NERICA L-19/NIL 2	To obtain Fe-toxicity RYMV plant types with good grain	4 (1 plot - 120 hills)
5	ROK 16/TKD 1 + Sub 1	To obtain early sub-saltol plant types	13 (6 plots - 720 hills)
6	Samba Mashuri 2 + Sub 1/ROK 24	To obtain medium duration sub-Fe-toxicity plant types	12 (6 plots - 720 hills)
7	ROK 24/Samba Mashuri 2 + Sub 1	To obtain medium duration sub-Fe-toxicity plant types	11 (8 plots - 960 hills)
8	ROK 24/Swarna + Sub 1	To obtain medium duration sub-Fe-toxicity plant types	24 (6 plots - 720 hills)
9	ROK 24/TKD 1 + Sub 1	To obtain medium duration sub-Fe-toxicity plant types	3 (3 plots - 360 hills)
		Total	**73**

In 2016 cropping season, panicles of each hill selected constituted a plot/breeding line, implying that 70 plots/breeding lines could emerge from the 2010 crosses; 2015 plots were observed to be highly homogenous. Table A21 reveals breeder seed production of 12 rice varieties, demo plots

Table A21. Breeder seed production of 12 rice varieties, demo plots

Variety	2013 Seed (kg)	2014 Seed (kg)	2015 Seed (kg)	Total seed (kg)
TOX 3805-38-2-1-2	5.3	1.5	-	6.800
TOX 3931-22-1-2-3-2	4.9	1.5	-	6.400
TOX 3233- 46-52-3-3-3	2.4	2.1	-	4.500
WAB 2060-FKR4-WAC1-TGR5-B	2.0	2.0	-	4.000

WAB 2095-WAC1-TGR1-B	2.6	1.3	-	3.900
WAB 2061-2-FRKR1-WAC2-TGR4-B	2.9	1.7	-	4.600
WAS 49-B-B-9-1-4-4	1.0	1.0	-	2.000
ITA 212	5.0	1.8	2.445	9.245
SWARNA	2.6	1.4	1.630	5.630
SWARNA +Sub 1	4.0	1.4	2.445	7.845
BUTTER CUP	2.5	1.8	-	4.300
NERICA L-19	6.8	2.5	0.7	10.000
NERICA L-19 Togo (NERICA-TGR)	-	-	1.070	1.070
NERICA L-20	3.8	1.1	0.764	5.664
ROK 35 [GIBOB]	-	-	0.733	0.733
ROK 36 [No. 1 B.P. (148)]	1.2	1.8	0.611	3.611
ROK 37 [WAR 77-3-2-2]			1.008	1.008
ROK 24	3.4	2.0	0.764	6.164
ROK 10	4.3	2.5	1.039	7.839
INDOCHIN BLANC			1.283	1.283

GENETIC STOCK MAINTENANCE

Majority of mangrove farmers that participated in the Field Days, on mangrove associated swamp and tidal mangrove swamp trials (AYTs), preferred high yielding, non-lodging, medium to tall-statured rice varieties with long and heavy panicles (i.e with high percentage of filled clean grains). The Varietal Registration and Release Committee (VRC), after reviewing the DUS and VCU information submitted, recommended the five on-shelf rice varieties nominated for release, comprising three mangrove associated swamp (NERICA L-19, NERICA L-20 and GIBOB) and two tidal mangrove (No. 1 B.P (148) and WAR 77-3-2-2) to the National Seed Board (NSB), which has given approval for their release- bearing released names as follows: NERICA L-19, NERICA L-20, ROK 35, ROK 36 and ROK 37, respectively, but seed rice availability of ROKs 35, 36 and 37 still stands an impediment to their official release.

Promising breeding lines identified in 2014 trials were further evaluated in the advanced yield trial (AYT) and participatory varietal selection (PVS) trial, conducted at Rokupr (long season mangrove), Rokel (medium season mangrove) and Balancera (short season mangrove), respectively, in 2015 cropping season. From the maintenance of segregating populations of recent crosses we made in our hybridization program, we are hopeful, in the medium and long-terms, that multiple-stress tolerant plant types/rice varieties will evolve from our selections made, 70 and 73 on the F_{5-6} (highly homogenous) and F_{2-3} segregating populations, respectively, in 2015 cropping season.

SURVEY ON THE STATUS OF DISSEMINATED AND ADOPTED TECHNOLOGIES FOR MANGROVE SWAMP RICE IN SIERRA LEONE

The objective was to evaluate disseminated mangrove swamp rice technologies and their adoption status in Sierra Leone. A total of three districts including Kambia, Port Loko and Moyamba Districts with characteristic mangrove ecology were purposively selected in 2014 for the study.

Findings revealed that nine RARC mangrove varieties including CP4, ROK4, ROK5, ROK8, ROK9, ROK10, ROK21, ROK22 and ROK23 were identified (Table A22).
Most of the farmers in Kambia District were knowledgeable about all the RARC mangrove varieties but farmers in Port Loko and Moyamba Districts are more knowledgeable about ROK 4, ROK 5 and ROK 10. In total, ROK 5 and ROK 10 were the most known varieties by farmers in all the districts surveyed. About 528 farmers had knowledge about ROK 5 and 321 farmers had knowledge about ROK 10.

Table A22. Knowledge of RARC mangrove varieties

District	Chiefdom	Knowledge of variety									
		CP4		ROK 4		ROK 5		ROK 8		ROK 9	
		Count	%	Count	%	Count	%	Count	%	Count	%
Kambia	Mambolo	81	81.0	66	66.0	97	97.0	36	36.0	34	34.0
	Samu	61	61.0	66	66.0	98	98.0	34	34.0	34	34.0
Port Loko	Kaffu Bullom	26	26.0	61	61.0	92	92.0	15	15.0	14	14.0
	Lokomasama	32	32.0	46	46.0	90	90.0	17	17.0	17	17.0
Moyamba	Bumpeh	22	22.0	21	21.0	89	89.0	6	6.0	9	9.0
	Ribbi	20	20.0	31	31.0	62	62.0	8	8.0	7	7.0
	Total	242		291		528		116		115	
		ROK 10		ROK 21		ROK 22		ROK 23			
Kambia	Mambolo	98	98.0	51	51.0	60	60.0	48	48.0		
	Samu	88	88.0	26	26.0	22	22.0	24	24.0		
Port Loko	Kaffu Bullom	34	34.0	1	1.0	5	5.0	4	4.0		
	Lokomasama	61	61.0	15	15.0	11	11.0	11	11.0		
Moyamba	Bumpeh	24	24.0	5	5.0	4	4.0	4	4.0		
	Ribbi	16	16.0	6	6.0	4	4.0	5	5.0		
	Total	321		104		106		96			

Varieties ROK 5, ROK 10 and ROK 4 are the most cultivated, grown at least once by some farmers in all the districts (Table A23). 380 farmers grow ROK 5, 315 farmers grow ROK 10 and 98 farmers grow ROK 4. For CP 4, more farmers in Kambia Districts 44% in Mambolo Chiefdom and 33% in Samu Chiefdom has grown the variety at least once compared to the other districts. ROK 8, ROK9, ROK 21, ROK 22 and ROK 23 are not widely grown by farmers in all of the districts interviewed, due to poor awareness about them. ROK 9, ROK 21 and ROK 22 have never been grown by farmers in Moyamba District; and ROK 21 and ROK 23 have not been grown by farmers in Port Loko District, due to lack of awareness and accessibility.

Table A23. Mangrove rice varieties grown by farmers at least once

District	Chiefdom	Knowledge of variety									
		CP4		ROK 4		ROK 5		ROK 8		ROK 9	
		Count	%	Count	%	Count	%	Count	%	Count	%
Kambia	Mambolo	44	44.0	22	22.0	88	88.0	6	6.0	5	5.0
	Samu	33	33.0	20	20.0	84	84.0	8	8.0	8	8.0
Port Loko	Kaffu Bullom	6	6.0	28	28.0	57	57.0	4	4.0	2	2.0
	Lokomasama	7	7.0	12	12.0	57	57.0	1	1.0	1	1.0

Moyamba	Bumpeh	7	7.0	4	4.0	61	61.0	0	0.0	0.0	0.0
	Ribbi	2	2.0	12	12.0	33	33.0	2	2.0	0.0	0.0
	Total	99		98		380		21		16	
		ROK 10		**ROK 21**		**ROK 22**		**ROK 23**			
Kambia	Mambolo	94	94.0	11	11.0	29	29.0	12	12.0		
	Samu	68	68.0	7	7.0	5	5.0	6	6.0		
Port Loko	Kaffu Bullom	10	10.0	1	1.0	1	1.0				
	Lokomasama	33	33.0	2	2.0	0	0.0	1	1.0		
Moyamba	Bumpeh	4	4.0			1	1.0	0	0.0		
	Ribbi	6	4.0	1	1.0			1	1.0		
	Total	215		22		36		17			

The perception on the knowledge and use of the varieties indicated that some varieties are specific to some areas while others are grown in several localities. Improved varieties are given local names linked to the source of access, the performance of the variety or physical traits.
Varieties ROK 5 and ROK 10 were the most adopted rice varieties. About 163 farmers adopted ROK 5 and 86 farmers adopt ROK 10. ROK 4 and CP4 were also adopted by farmers in all the districts surveyed by quite a reasonable number of farmers (Table A24).

Table A24. Adopters of RARC mangrove varieties

District	**Chiefdom**	**Adopters - still growing the variety**									
		CP4		**ROK 4**		**ROK 5**		**ROK 8**		**ROK 9**	
		Count	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Kambia	Mambolo	11	17.5	5	7.9	40	63.5	1	1.6		
	Samu	4	21.1	2	10.5	11	57.9	0	0.0		
Port Loko	Kaffu Bullom	1	3.3	14	46.7	23	76.7	1	3.3		
	Lokomasama	0	0.0	1	4.0	19	76.0	0	0.0		
Moyamba	Bumpeh	5	10.6	2	4.3	45	95.7	0	0.0		
	Ribbi	2	7.4	6	22.2	25	92.6	2	7.4		
	Total	23		30		163		4			
		ROK 10		**ROK 21**		**ROK 22**		**ROK 23**			
Kambia	Mambolo	53	84.1	1	1.6	4	6.3	0	0.0		
	Samu	9	47.4	0	0.0	0	0.0	1	5.3		
Port Loko	Kaffu Bullom	3	10.0	0	0.0	0	0.0	0	0.0		
	Lokomasama	15	60.0	0	0.0	0	0.0	0	0.0		
Moyamba	Bumpeh	2	4.3	0	0.0	0	0.0	0	0.0		
	Ribbi	4	14.8	0	0.0	0	0.0	1	3.7		
	Total	86		1		4		2			

The number of non-adopters was high for ROK 5 and ROK 10. About 217 and 127 farmers did not adopt ROK 5 and ROK 10, respectively (Table A25).

Loss of variety was recorded for all the varieties but ROK 5 and ROK 10 recorded the highest of 172 and 112 farmers, respectively (Table A26).

Table A25. Non-adopters of RARC mangrove varieties

District	**Chiefdom**	**Non-adopters**

		CP4		ROK 4		ROK 5		ROK 8		ROK 9	
		Count	%	Count	%	Count	%	Count	%	Count	%
Kambia	Mambolo	33	75.0	17	77.3	48	54.6	5	83.3	5	100.0
	Samu	29	87.9	18	90.0	73	86.9	8	100.0	8	100.0
Port Loko	Kaffu Bullom	5	83.3	14	50.0	34	59.6	3	75.0	2	100.0
	Lokomasama	7	100.0	11	91.7	38	66.7	1	100.0	1	100.0
Moyamba	Bumpeh	2	28.6	2	50.0	16	26.2	0	0.0	0	0.0
	Ribbi	0	0.0	6	50.0	8	24.2	0	0.0	0	0.0
	Total	76		68		217		17		16	
		ROK 10		ROK 21		ROK 22		ROK 23			
Kambia	Mambolo	41	43.6	10	90.9	25	86.2	10	100.0		
	Samu	59	86.8	7	100.0	5	100.0	5	83.3		
Port Loko	Kaffu Bullom	7	70.0	0	0.0	1	100.0	0	0.0		
	Lokomasama	18	54.5	0	0.0	0	0.0	0	0.0		
Moyamba	Bumpeh	2	50.0	0	0.0	0	0.0	0	0.0		
	Ribbi	0	0.0	0	0.0	0	0.0	0	0.0		
	Total	127		17		31		15			

Table A26. RARC mangrove rice varieties lost by farmers

District	Chiefdom	Varieties lost									
		CP4		ROK 4		ROK 5		ROK 8		ROK 9	
		Count	%	Count	%	Count	%	Count	%	Count	%
Kambia	Mambolo	24	54.50	12	54.5	37	42.0	5	83.3	3	60.0
	Samu	26	78.8	12	60.0	69	82.1	6	75.0	8	100.0
Port Loko	Kaffu Bullom	1	16.7	13	46.4	27	47.4	3	75.0	1	50.0
	Lokomasama	3	42.9	5	41.7	22	38.6	0	0.0	0	0.0
Moyamba	Bumpeh	1	14.3	1	25.0	10	16.4	0	0.0	0	
	Ribbi	0	0.0	6	50.0	7	21.2	0	0.0	0	
	Total	55		49		172		14		12	
		ROK 10		ROK 21		ROK 22		ROK 23			
Kambia	Mambolo	35	37.2	6	54.5	22	75.9	11	91.7		
	Samu	59	86.8	7	100.0	5	100.0	5	83.3		
Port Loko	Kaffu Bullom	2	20.0	1	100.0	1	100.0	0	0.0		
	Lokomasama	13	39.4	2	100.0	0	0.0	1	100.0		
Moyamba	Bumpeh	1	25.0	0	0.0	1	100.0	0	0.0		
	Ribbi	2	33.3	1	100.0	0		0	0.0		
	Total	112		17		29		17			

Table A27 shows the number of farmers that cultivated the rice varieties for at least once but abandoned. The abandonment rate was high for ROK 5 (19 farmers), CP 4 (22 farmers), ROK 4 (19 farmers) and ROK 10 (16 farmers). The abandonment is partly attributable to the high bird damage and the lack of access to seeds of RARC rice varieties.

Table A27. RARC mangrove rice varieties abandoned by farmers

District	Chiefdom	Abandonment rate				
		CP4	ROK 4	ROK 5	ROK 8	ROK 9

		Count	%	Count	%	Count	%	Count	%	Count	%
Kambia	Mambolo	9	20.5	5	22.7	9	10.2	0	0.0	2	400.0
	Samu	3	9.1	6	30.0	4	4.8	2	25.0	0	0.0
Port Loko	Kaffu Bullom	4	66.7	1	3.6	7	12.3	0	0.0	1	50.0
	Lokomasama	4	57.1	6	50.0	16	28.1	1	100.0	1	100.0
Moyamba	Bumpeh	2	28.6	1	25.0	6	9.8	0	0.0	0	0.0
	Ribbi	0	0.0	0	0.0	1	3.0	0	0.0	0	0.0
	Total	22		19		43		3		4	
		ROK 10		**ROK 21**		**ROK 22**		**ROK 23**			
Kambia	Mambolo	6	6.4	4	36.4	3	10.3	1	8.3		
	Samu	0	0.0	0	0.0	0	0.0	1	16.7		
Port Loko	Kaffu Bullom	4	40.0	0	0.0	0	0.0	0	0.0		
	Lokomasama	5	15.1	0	0.0	0	0.0	0	0.0		
Moyamba	Bumpeh	1	25.0	0	0.0	0	0.0	0	0.0		
	Ribbi	6	6.4	4	36.4	3	10.3	1	8.3		
	Total	16		4		6		3	16.7		

Findings of the probit regression analysis are presented Table A28. All the variables in the model except farm income have the expected signs and eight are significant in explaining the use of the RARC improved rice technologies. The positively related and significant variables include: farmers' level of education, training, access to credit, farm size, extension contact and farming experience as expected. This means that improvement in these major factors would lead to higher level of technology adoption.

Table A28. Parameter estimates for probit model

	Parameter	Estimate	Std. Error	Z	Sig.
PROBIT[a]	Age	-0.126***	0.187	-0.673	0.005
	Educational level	0.014***	0.047	0.291	0.010
	Farmer's income	-0.166	0.006	-0.183	0.255
	Training	0.055*	0.023	0.247	0.065
	Access to credit	0.202**	0.020	0.920	0.038
	Membership of association	0.010	0.159	0.060	0.352
	Farm size	0.044***	0.022	0.323	0.008
	Sex	-0.167***	0.183	-0.624	0.009
	Extension contact	0.289***	0.325	0.297	0.007
	Farming experience	0.072**	0.096	0.086	0.041
	Intercept	0.369	1.080	0.341	0.733

a. PROBIT model: PROBIT(p) = Intercept + BX
Note: ***, ** and * indicate significance at 1, 5 and 10% probability levels, respectively.

ASSESSING THE SUITABILITY AND PROFITABILITY OF THE SYSTEM OF RICE INTENSIFICATION METHODOLOGY UNDER FARMERS' CIRCUMSTANCES IN SIERRA LEONE (2013 -2014)

The treatments compared were: (i) conventional methods (farmers' cultivation practices of transplanting of at least 30-day old seedlings, three to four seedlings per stand and with random spacing); (ii) basic SRI, transplanting one 12-day old seedling at a spacing of 25 cm × 25 cm, with minimal water control by preventing standing water through draining; and (iii) enriched basic SRI, which supplements (ii) above with the addition of organic matter in the form of 10 t ha^{-1} palm kernel cakes (PKC) and *Calopogonium mucunoides* (CM). The SRI methodology involves systematic weeding of the crop with a mechanical weeder to actively aerate the soil, stimulating plant root growth and the number and vigor of soil organisms. Since none of the trials sites has irrigation facilities, systematic water control or alternate wetting and drying was not achieved.

Findings revealed significant ($p<0.05$) differences in grain yields associated with the various treatments across locations, and treatment × location effects. Transplanting of one 12-day old seedling at a of spacing of 25 cm × 25 cm gave consistently higher yields than the conventional farmers' methods, whether organic matter (PKC or CM) was incorporated into the soil (Enriched basic-SRI) or not (Basic SRI). Compared with farmers' practice, modifications in the age, number and spacing of transplanted seedlings even without adding organic matter raised paddy yields by 60% in 2013 and 70% in 2014 (Tables A29 and A30). When PKC or CM were incorporated into the soil along with using SRI transplanting methods, the average paddy yields were almost doubled compared with using the basic SRI transplanting practices alone. Average yields under the 'enriched SRI transplanting methodology' were three times those obtained under farmer's practices. In 2014, 'enriched basic SRI' gave significantly higher yields than basic SRI and conventional practices, thus confirming the finding sin 2013.

Table A29. Mean yield (t ha^{-1}) under different treatments for 10 farmers across locations - 2013

	Treatments		
Location	**Conventional practice**	**Basic SRI**	**Enriched Basic SRI**
Bo	2.2	3.7	7.5
Kenema	1.5	2.8	5.9
Western Area (Rural)	1.7	3.0	6.8
Port Loko	2.2	3.2	5.3
Kambia	2.3	3.1	5.5
Mean	2.0	3.2	6.2
CV(%)	10.6		
LSD(0.05)			
Treatment	0.15		
Location	0.34		

Table A30. Mean yield (t ha^{-1}) under different treatments for 10 farmers across locations - 2014

	Treatments		
Location	**Conventional practice**	**Basic SRI**	**Enriched Basic SRI**
Bo	2.1	3.9	7.2
Kenema	1.9	3.4	6.4
Western Area (Rural)	2.2	3.6	7.4
Port Loko	2.0	3.1	5.9
Kambia	1.9	3.1	6.1
Mean	2.0	3.4	6.4
CV(%)	3.2		

LSD(0.05)		
Treatment	0.51	
Location	0.65	

Treatments exhibited substantial positive net benefits in all the districts where the experiments were conducted (Tables A31 and A32). The highest net benefits were generated by the enriched basic SRI treatment in all the districts, followed by the SRI basic. In general, SRI net benefits were much better in Port Loko and Kambia districts.

Table A31. Net benefits (Le/ha) per type of SRI – 2013

Practices	Port Loko	Kambia	Bo	Kenema	Western Area
Conventional	5,770,600	6,052,400	3,750,188	2,292,007	3,080,225
Basic SRI	8,522,600	8,240,800	6,533,684	4,584,214	5,697,750
Enriched Basic SRI	9,985,399	10,548,999	9,297,232	5,752,629	9,086,899

Table A32. Net benefits (Le/ha) per type of SRI – 2014

Practices	Port Loko	Kambia	Bo	Kenema	Western Area
Conventional	5,207,000	4,925,200	3,560,225	3,017,609	4,112,350
Basic SRI	8,240,800	8,240,800	6,913,561	5,672,617	6,936,300
Enriched Basic SRI	16,021,199	12,239,799	8,727,342	11,004,631	10,325,449

Marginal Rate of Returns (MRRs) were positive for the basic and enriched basic SRI. However, they were low for the enriched basic SRI when PKC was used (Tables A33 and A34). The low marginal returns for the enriched basic SRI were due to the high cost of the organic manure (PKC). However, in 2014, higher MRRs were obtained with the use of *Calopogonium mucunoides* in Port Loko and Kenema districts (Table A34) as no cost was incurred for purchasing the organic manure. Based on the MRR values, enriched basic SRI seems to be a profitable venture with the use of low-cost source of organic manure such as *Calopogonium mucunoide*s.

Table A33. Marginal Rate of Return (%) for SRI in 2013

Practices	Port Loko	Kambia	Bo	Kenema	Western Area
Conventional					
Basic SRI	4170	3316	4,217	3473	3966
Enriched Basic SRI	33	52	62	26	76

Table A34. Marginal Rate of Return (%) for SRI in 2014

Practices	Port Loko	Kambia	Bo	Kenema	Western Area
Conventional					
Basic SRI	4,597	5,024	5,081	4,023	3,748
Enriched Basic SRI	7,073	90	41	4,847	55

The results of this study confirmed previous studies at Rokupr that incorporation of 10 t ha^{-1} of *Calopogonium mucunoides* into well-puddled Inland Valley Swamps 14 days before transplanting of one 12-day old seedling per stand at a spacing of 25 cm × 25 cm with minimal water control (Enriched basic SRI) could be a profitable methodology worth recommending for increase productivity and income generation for farmers. The average yields of 6.2 in 2013 and 6.4 t ha^{-1} in 2014 are above the estimated national average of 4.0 t ha^{-1} projected for 2016.

Post-harvest Loss Assessment of Boliland Rice Production in Sierra Leone
The objective of this study was to evaluate the post-harvest losses occurring at the various stages of the processing system in the boliland ecology in Sierra Leone.

Findings revealed that postharvest loss varies among individuals and processes (Table A35). This could be attributed to limited knowledge of various rice value chain actors on postharvest loss reduction using appropriate equipment. For instance, the total postharvest loss for farmer D was more than twice the total loss for farmer H. Furthermore, postharvest losses varied with activities in the processing chain. It was observed that more losses were occurred during storage than any other processes. This could be attributed to the fact that most farmers do not take their produce to centre storage systems at village level, instead they prefer storing them in their individual houses which in most cases is heavily infested with rats.

The average quantitative postharvest loss percentage for all ten farmers in the five districts covered at all nine stages in the processing system was 21.09%. This is within the average postharvest loss in Sub Saharan Africa which ranges between 15% and 22% (AfricaRice loss assessment manual 2013). Storage loss is high for all the ten farmers involved in the study this high loss is as a result of the fact that all the farmers that took part in the study store their grains in their houses instead of centre storage systems which were available in some of the communities where we did the loss assessment. Most of the storage systems used by these farmers is not ideal and are prone to storage pest and diseases.

IDENTIFICATION OF GENDER ISSUES IN RICE PRODUCTION ACTIVITIES IN SIERRA LEONE

This study assessed the gender issues in rice cultivation with specific consideration for women's needs and constraints. The summaries on the sample size of participant categories across districts, chiefdoms, villages and related information are presented in Table A36. Findings revealed limited access to formal micro credit scheme geared towards rice farming. This implies that farmers are afraid to collect the very few that are even available because of the terms of payment (i.e. monthly) which does not suit their farming calendar. So, either government steps in with a revolving community loan scheme in a form of providing services at their peak requirement and creating access to markets by farming through which these loans could be readily and easily repaid during harvest, or providing water conservation system so that farmers can do double cropping to reduce the time lapse for loan repayment. In almost all of the districts in this study, respondents in response to questions of access to market mentioned among others farm gate as most times during planting time, which in Sierra Leone is referred to as "the hunger season" business people step in to give them loans, which they pay back at harvest time and at farm gate and most times the prices are determined by these business people.
Inadequate extension services is a huge challenge which needs to be addressed. For those communities with access to extension facilities, they were either from NGOs or because they are closer to the district headquarter towns where these institutions were based. Some of the challenges

mentioned with regards this was either bad road network or because the communities were farther away from the district headquarter towns.

Table A35. Total and average postharvest loss analysis

Farmer	Harvesting	Stacking	Transportation	Farmer threshing	Improve threshing	Drying	Parboiling	Milling	Storage	Total
A	0.28	1.14	0.08	6.7	4.05	1.79	6.5	1.22	7.2	**28.96**
B	2.98	0.83	2.78	1.24	0.51	0.96	0.37	1.65	11	**22.32**
C	2.03	2.29	1.55	1.1	0.45	1.01	0.41	1.82	9.7	**20.36**
D	0.02	0.54	5.9	6.4	4.1	1.18	7.1	1.9	5.6	**32.74**
E	3.04	0.4	0.39	2.32	0.42	0.25	0.41	1.07	6.5	**14.8**
F	1.99	2.29	1.55	1.1	0.45	0.11	0.83	2.31	8.4	**19.03**
G	1.15	0.46	1.98	3.98	0.75	0.25	0.27	1.25	7.1	**17.19**
H	2.91	0.49	0.021	1.6	0.27	0.18	0.16	0.69	8.1	**14.42**
I	1.12	0.43	2.67	2.15	0.65	0.26	0.39	1.16	7.94	**16.77**
J	2.1	1.4	0.82	3.5	1.67	1.5	0.67	2.11	10.5	**24.27**
Mean	**1.76**	**1.03**	**1.77**	**3.01**	**1.33**	**0.75**	**1.71**	**1.52**	**8.2**	**21.09**

Table A36. Sample size and data collection methods

Districts	No. of chiefdoms	No. of villages per chiefdom	No. of Key Informant Interviews	No. of FDGs done in age and gender segregated groups	No. of Household Interviews	No. of Policy Interviews
Kailahun	5	25	25	5	175	3
Kenema	6	30	30	6	210	3
Moyamba	5	25	25	5	175	3
Bonthe	4	20	20	4	140	3
Kambia	3	15	15	3	105	3
Bombali	5	25	25	5	175	3
Total	**28**	**140**	**140**	**28**	**980**	**18**

Inadequate farm machinery and they should be made gender sensitive. From policy interviews it came out that there are few farm machineries at district levels, but these were not filtrating down to at the chiefdom level levels let alone at village level. One of the recommendations from both focus group discussion and at policy makers/service providers is that these machines should be provided at chiefdom level. For instance, in Bonthe, it was stated in the focus group discussion that all of the machines were based in Tormabum and having access to such machines even within and communities outside the Tormabum is a challenge. Most times farmers end up not cultivating because the machines are late and planting beyond April is a waste of resources as the floods will wash the rice fields away.

Fertilizer usage for rice farming is very minimal if not non-existent. Units of measurement for fertilizer usage ranged from packets which were like a third of one kg to 50 kg for those respondents who said they have ever applied fertilizer on their rice fields, and these were Urea and NPK 15-15-15 and their main source was from private business men, that visit the communities, but from policy interviews and some focused group discussions it came up that some NGOs and the Ministry of Agriculture intervened to a minimal level in some communities with the provision of improved seeds, fertilizers and tools. But in most if not in all of such communities, as the project phases out, the farmers revert to their old practices, even when they confirm the positive effects of such interventions. The questionnaire is therefore now hinged on the fact of what could be done to maintain sustainability.

Reasons for non-usage of fertilizer ranged from being expensive to the fact that crops do well in certain areas in Bonthe without fertilizer application. According to the agrochemical service provider, yields in fertilized plots far outweighs those of the non-amended farmers' fields. Thus, ignorance of the standard operating procedures of fertilization in different ecological zones is among critical issues limiting farmers.

Low educational status of farmers generally but specifically of female farmers was recorded. Thus, the need for adult literacy and numeracy for them to be able to at least cost and calculate their expenditure during rice farming, and to ascertain whether their farming was profitable or not. A question on whether they were satisfied with their yields and why? Gave responses like that is what gave me, I was able to have food for the rest of the year; I was able to sell some and attend to other needs. But was their activity really profitable or not, when majority cannot even keep records of their expenditure. A question on whether women can be allowed to head a mixed farmers association resulted in interesting responses. These ranged from tradition of male supremacy, to women being better managers of resources, and women not being educated therefore will not be allowed to lead where there are educated men.

B. NJALA AGRICULTURAL RESEARCH CENTRE (NARC)

The root, tuber and grain legume crops research programme are implemented at the NARC. The programme is aimed at addressing challenges to enhance sustainable productivity, commercialization, and competitiveness of the root, tuber and grain legume crops.

ENHANCING THE CONCURRENT SELECTION AND EVALUATION OF BIOFORTIFIED AND BIO-ENRICHED VARIETIES DERIVED FROM MUTANT RICE, CASSAVA AND OTHER CROPS (IAEA PROJECT FS-SIL5020-1801894)

A 2-month training on "enhancing the concurrent selection and evaluation of biofortified and bio-enriched varieties derived from mutant rice, cassava and other crops" was held in National Crops Resources Research Institute, Namulonge, Kampala –Uganda on 18th June 2018 to 17th August 2018. The purpose was to capacitate participants on plant tissue culture, nutrition and bioanalysis of cassava, double haploid TC systems, disease diagnostics, high throughput phenotyping methodologies and genotyping of cassava.

The experimental materials were stem cuttings, each measuring 20 cm. These materials were planted in perforated plastic pots filled with cocopeat medium soaked to field capacity and placed in the screenhouse. The whiteflies were reared in the laboratory for introduction in the net cages placed in the screenhouse. After sprouting of cassava cuttings, the whiteflies were introduced for infestation of the growing plants that lead to subsequent infection of CMD (Figure B1). The infected and uninfected (control) plants were harvested at four days interval for nutrient analysis. Findings revealed lower leaf length, width and weight of cassava sampled infected with CMD than the noninfected control plots (Figures B2 and B3).

Figure B1. Caged cassava and insect experimental plots

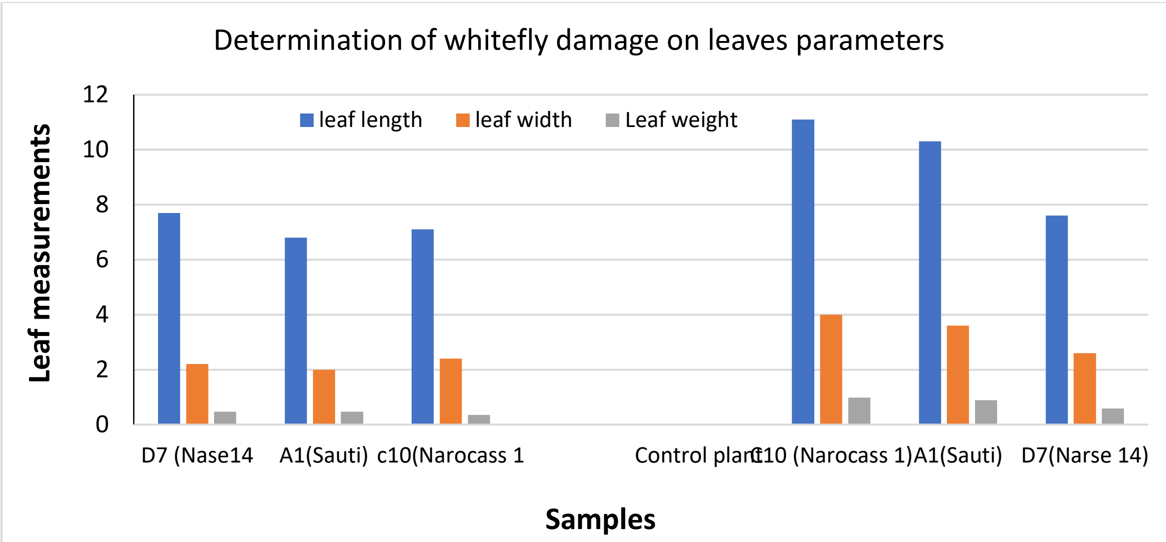


Figure B2. Effect of whitefly infestation and CMD infection on leaf length, width and weight of cassava

Similarly, the control plots had higher chlorophyll a,b and carotenoid than the CMD infected plots (Figure B2). Figure B3 presents the effect of CMD infection on chlorophyll a,b and carotenoid on cassava leaves. Carotenoid was highest in control A1 followed by A1 (Sauti), whereas D7 (Nase14) had the lowest of 0.14. C10 (Narocass1) had the lowest of chla (0.03) and chlb (0.02).

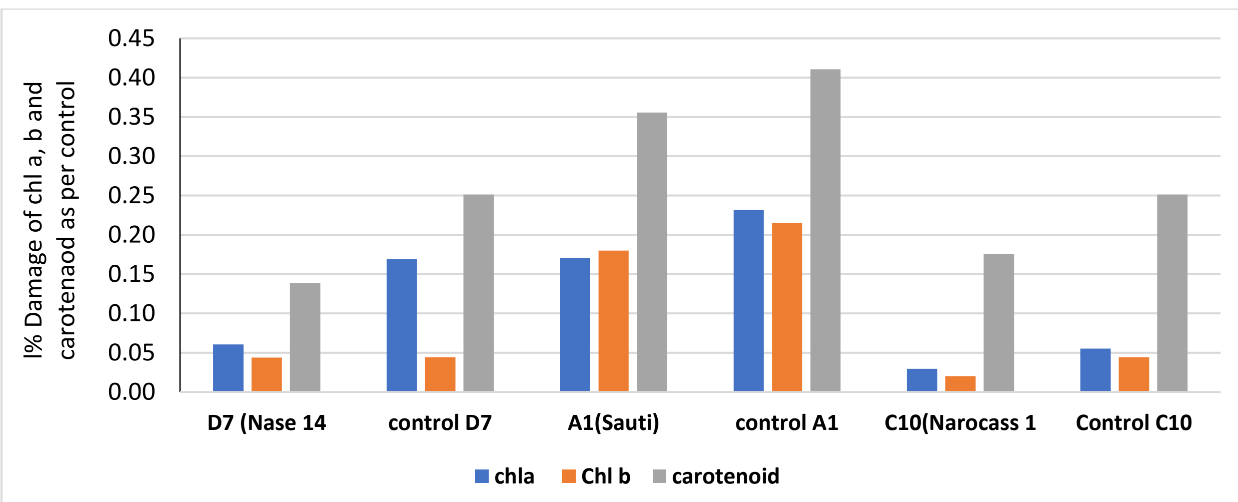
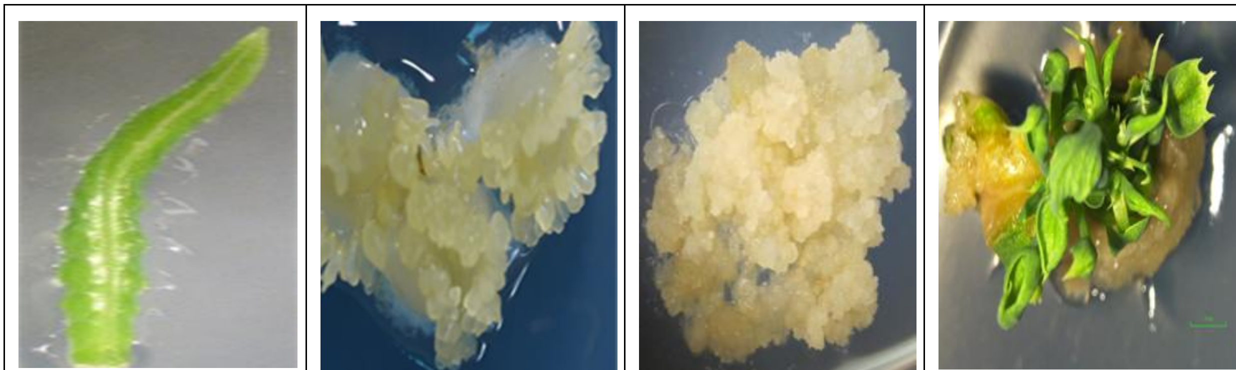


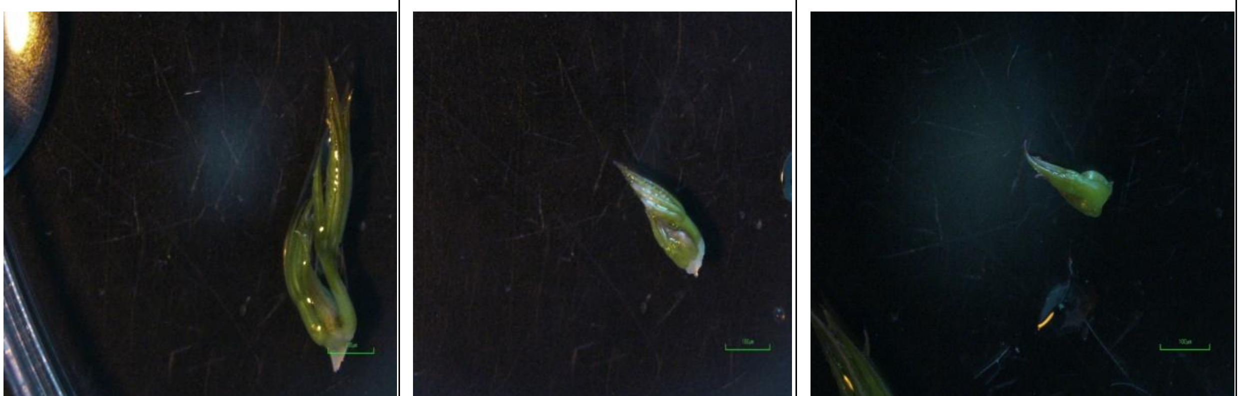
Figure B3. Effect of CMD infection on chlorophyll a,b and carotenoid on cassava leaves

The techniques for production of tissue targeted for transformation including somatic embryos, friable, embryogenic calli and meristematic tissues (Figure B4) and the pathway of meristem culture (Figure B5) were explored.



Leaf lobe	Somatic embryos	Friable callus	Germinated friable

Figure B4. Production of somatic embryos, friable, embryogenic calli and meristematic tissues



Leaf tip or bud	Leaf tip	Leaf tip

Figure B5. Pathways of meristem culture

Genotype NAROCAS 1 had 100% response of explants with emerging leaves in all sampling plates, whereas Nase 19 had three explant plates with 80% emerging leaves, indicating differential genotypic response to explant regeneration with emerging leaves (Table B1) and somatic embryos (Table B2).

Table B1. Regeneration of the apical shoot meristems of two genotypes

Genotype	# of plates	% Response of explant with emerging leaves
Nase 19	1	5/5 (100)
	2	4/5 (80)
	3	5/5 (100)
	4	4/5 (80)
	5	4/5 (80)
	6	5/5 (100)
NAROCAS 1	1	3/3 (100)
	2	3/3 (100)
	3	4/4 (100)
	4	3/3 (100)
	5	3/3 (100)
	6	4/4 (100)

Table B2. Production of somatic embryos in cultivar 60444

# of plates	Frequency response of explants (%)	% Surface area coverage of somatic embryos
1	9/9 (100)	30/9 (33.3)
2	9/9 (100)	21/9 (23.3)
3	7/9 (78)	18/9 (20)
4	3/8 (38)	6/8 (75)
5	2/8 (25)	3/8 (38)

SEMI AUTOTROPHIC HYDROPONICS (SAH)

Slow and low multiplication ratios are among key constraints in cassava seed system. The use of this new technology called Semi-Autotrophic Hydroponics (SAH) is a novel, robust and low-cost method for rapid seed multiplication of true –to- type clean cassava planting materials will help to overcome this challenge. Some of the photographic display of the training are given below (Figure B6).

			
Trainee doing monitoring and lab	Substrate preparation	Measuring for preparation of solution	Labelling of SAH boxes
			
Removal of SAH plantlet from the box	Planting of SAH plantlets in the field	TME 419 from SAH in the field	Cassava green mite disease identification

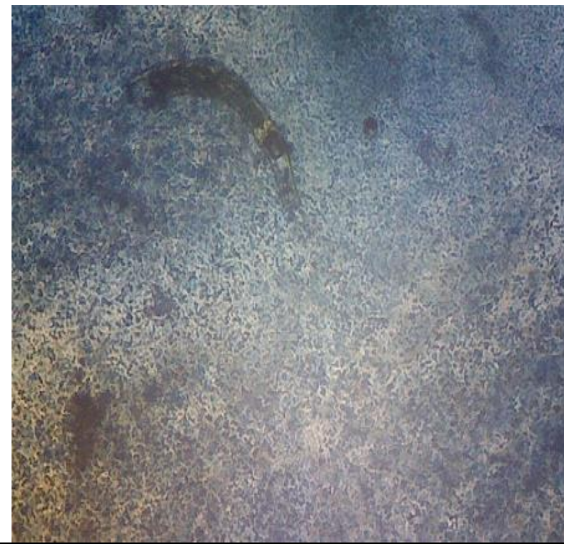
Figure B6. Training in Semi-Autotrophic Hydroponics (SAH) technique

The participants understood the theoretical and practical application of SAH Technology in both the lab and field. However, the implementation of this technology requires provision of a functional lab with materials (consumables) and equipment, electricity and irrigation facilities.

Since SAH requires clean planting materials from TC as starter, there is need for virus-indexing of our released genotypes or IITA can send us Virus-indexed materials.

VALIDATION OF AN INTEGRATED PEST MANAGEMENT OPTION FOR THE CONTROL OF STEM ROT DISEASE AND SWEET POTATO SCAB USING NEEM LEAF EXTRACT AS A BIO PESTICIDE

The objective of this study was to promote an integrated pest management package for the sustainable production of orange flesh sweet potato. Characteristics of fungal isolates from the infected sweet potato cutting such as, colony texture, spore or conidia-producing structures and spore shapes were detected (Figure B7).



(a) Stem rot disease	**(b) Image of pathogen**

Figure B7. Photos of (a) stem rot disease on genotype Chipika collected from Newton; and (b) pathogen isolated from OFSM at Njala Agricultural Research Centre Pathology lab, Njala

FACTORS LIMITING THE EFFICIENT OPERATION OF CASSAVA PROCESSING CENTRES IN SIERRA LEONE

The objectives of this study were to assess the technical and economic performances of cassava processing plants established in Sierra Leone; (ii) identify the major constraints hindering the smooth operations of the enterprise; (iii) provide recommendations for resolving these constraints; (iv) provide recommendations for taking advantage of the existing market opportunities; (v)

The installed capacities of the various processing plants ranged between 0.32 tons/day – 20.25 tons/day. For processing plants of such kind to be effective and efficient, it is expected that:

- ❖ A good management system should be in place;
- ❖ A robust raw material supply management system should be in place;
- ❖ A very good quality management system – hygienic practices, plant sanitation, etc. - should be in place;

- Water sources for processing must be carefully selected to guarantee the quality of the products;
- Production scheduling should be well planned;
- Production records should be well kept, analyzed and monitored;
- Health and other safety measures should be well planned for;
- Equipment maintenance procedures must be strictly followed;
- Equipment maintenance and repair records must be kept, analyzed and monitored;
- A very good marketing strategy should be pursued; and
- The profitability of the operations should be constantly assessed and monitored.

The assessment was undertaken through interviews conducted using a structured questionnaire, and a review of secondary information. The respondents for the structured questionnaire included: (i) managers of processing enterprises; (ii) processors; (iii) farmers; (iv) traders; (v) transporters; (vi) community elders for remote villages; and (vii) team members of each processing enterprise. The secondary data reviewed included: (i) National Cassava production statistics; (ii) Constitutions and Bye-Laws of Cooperative Societies managing the Centres; (iii) Data on the dry matter content of various cassava varieties; and (iv) Production and Financial Records of the Enterprises.

Results reveled that Adamaris Cassava Processing Centre was established by The Roberts family (Christopher and Eva) and SLARI/CFC/IITA joint effort in 2005. The centre has an installed capacity of 2 tons/day gari output. The most critical constraints that affected the effective and efficient operations of this centre included limited supply of roots, poor maintenance culture, inadequate capital and the lack of effective marketing strategies. The recommendations for the effective operations of this centre were: (i) provide support for mechanical cultivation of fresh cassava roots and establish a cassava out-grower scheme; (ii) develop a bankable business plan for acquisition of a loan as well as a guide for its operations; (iii) financial support/credit facilities in the form of loans; (iv) expansion of facility to accommodate a storage room; (v) expand cooperative farms and establish out-grower system for root supply; (vi) purchase of improved planting materials from SLARI; (vii) training of farmers on good agronomic practices and organizing them into production groups to serve as out-growers; (viii) processors on minor machine maintenance in order to improve the efficiency of the machines and reduce maintenance costs; marketing strategies such as business promotion, sales and pricing strategy, marketing and sales forecast and others to enable them increase sales and generate more revenue; and production planning and record keeping.

Binkolo Cassava Processing Centre of the Binkolo Growth Centre was established by the Ministry of Trade and the United Nations Industrial Development Organization (UNIDO) in 2009. The centre has an installed capacity of 4.8 tons/day gari output (Figure B8). The most critical constraints of this centre included: poor equipment maintenance skills; scarcity of fresh cassava roots; lack of effective marketing strategies; lack of capital for operations; and the high labour cost. Recommendations for its effectiveness included: Establish a cassava out-grower scheme for the center; establish own farm; expand cooperative farms; practice mechanical cultivation of fresh cassava roots on all three farms; training of farmers on good agronomic practices; training of processors on minor machine maintenance; marketing strategies; proper operation and maintenance of equipment and the implementation of a regular maintenance regime; and facilitating access to some minimal working capital for operations.

The Dunstan Spencer Cassava Processing Centre was established in 2009 by the Njala Agricultural Research Council (NARC) of Sierra Leone and the IITA through the CFC Project with the objective generating income, and for training purposes (Figure B9). This facility has an installed capacity of 800 kg/day gari output. Dunstan Spencer processing center is presently not in operation due to incomplete installation of equipment and rehabilitation of facility. The most critical constraints of this centre included: disruption due to introduction of flash dryer requiring removal of presses, scarcity of FCR, lack of effective marketing strategies where market fluctuates with student availability, inadequate capital and high cost of production of FCR. Recommendations for its operationalization included: establishment of a cassava out-grower scheme for the center, own farm, and expansion of cooperative farms; financial support/credit facilities to enable acquisition and installation of new presses and graters; working capital needs; linking the centre to on-going donor-funded projects in SLARI with enough funding to support the acquisition of this equipment. Processors should be trained on marketing strategies, production planning and record keeping; proper operation and maintenance of equipment; provision of guidance and mentorship in effective records keeping and production planning; and exploration of additional market outlets; and implementation of market expansion strategies.

	
**Grater powered with *HP Lister engine. (In very good condition but idle*)*	**Two Manual roaster of 4 ft X 4 ft. (in very good condition but idle)**
	

Hammer mill. (In very good condition but not in use)	**The two available screw type presses need replacement. (Not in use)**

Figure B8. Status of some equipment at Binkolo Processing Centre

		
Dunstan Spencer Processing Centre	Frame of damaged grater	Damaged prime mover - a small petrol engine

Figure B9. Status of selected equipment at the Dunstan Spencer Processing Centre

Gbaiima Cassava Processing Centre was established by IITA in 2016 with the objective of reducing drudgery in processing (Figure B10). The facility is technically owned by The Community Chief. The Centre has an installed capacity of 250 kg/day gari output, but has however never operated since its establishment. Key challenges of this centre included: lack of funds; needs a managing partner; no management team in place; vandalization of equipment; and lack of technical manpower. The operationalization of this facility requires: (i) revision of existing business plan to access funds from donors such as the AfDB; (ii) formation of a management team; Explore of opportunities to obtain a managing partner; training of processors on marketing strategies; production planning and record keeping; Processing techniques; and proper operation and maintenance of equipment and the implementation of a regular maintenance regime.

		
Modern Automated facilities with higher installed capacity waiting for funding	Vandalized grater. The electric motor was not in place with the belts.	Twin basket hydraulic press. (Abandoned for years)

Figure B10. Selected Equipment at Hamdalaye Cassava Processing Centre

The Makonkori Processing Centre was established by IITA in 2014 with the objective of improving income generation and food availability through cassava processing (Figure B11). The facility is owned by the Sorbeh Farmers Association. It has an installed capacity of 500 kg/day gari output. Key constraints included: poor leadership; improper installation of equipment; high cost of cassava root production; lack of technical skills and experience in processing; equipment operation and maintenance; and poor skills and knowledge in marketing. Formation of taskforce to resolve deep rooted conflict among stakeholders; create an effective management team and structure; establish a management board/team of respected community elders to monitor and direct the management team; train members on group dynamics and cohesion, basic management skills and conflict resolution; processing techniques to minimize processing losses; and equipment operation and maintenance.

		
Makonkori Processing Centre	Exhaust rigidly fixed to the wall	Unconnected drainage

Figure B11. Faulty exhaust and drainage pipe connection

Mandu Cassava Processing Centre was established by IITA through the UPoCA project in 1998 with the objective generating income, reducing poverty and providing food security for the rural poor (Figure B12). Key challenges of this centre included: limited FCR supplies; inadequate capital; lack of effective marketing strategies; labour scarcity; and poor water source. These constraints could be mitigated through development and submission of a bankable business plan; establishment of a cassava out-grower scheme, own farm, expansion of cooperative farms; support with improved planting materials from SLARI; sinking a borehole; and working capital needs. purchase of FCR and operating supplies for processing; training on good agronomic practices; marketing strategies, proper operation and maintenance of equipment.

Ngainderma Cassava Processing Centre (also known as Manenko Cassava Processing Centre) was established by IITA with the objective to reduce poverty by providing income generating opportunities and food security for the rural poor. The Centre has an installed capacity of 320 kg/day gari output (Figure B13).

The 4ft × 8ft roasting tray (No longer in use)	**The grinder is no longer working**
	
The grater had a bad Petrol Engine	**All the jacks are down**

Figure B12. Selected equipment at Mandu Cassava Processing Centre

	
Grater. (Made of low-quality material, broken into parts; needs a replacement, training on how to operate it)	Pressers. (Of good quality with Jacks; Currently not in use)
	
Hammer Mill. (Poorly installed; Reported faulty, never used and taught how to repair or operate it).	Grinder. (Poorly installed. The mill was reported not fit and not effective and not in use either. They need training on how to operate)

Figure B13. Status of selected equipment at Ngainderma Cassava Processing Centre

Pujehun Cassava Processing Centre was established by The Ministry of Trade, Sierra Leone, UNIDO, IITA and PaRD (Partners in Relief and Development), an NGO with the objective of generating income, providing food security, meeting an observed demand for processed cassava products as well as capacity building for the rural poor (Figure B14). The Ministry of Trade undertook the necessary facilitation that led to UNIDO financing the construction of the building and 60% of the equipment installed. IITA and PaRD financed 30% and 10% respectively of the installed equipment. The Centre has an installed capacity of 100 kg/day gari output. Key challenges of this centre included: lack of processing skills, water, competitive, effective marketing strategies, and sustainable supply of cassava roots for processing, inadequate capital; poor processing building, poor record keeping on sales, equipment maintenance, production, etc. These constraints could be mitigated through establishment of a cassava out-grower scheme, sinking a borehole; own farm, expansion of cooperative farms; purchase of FCR and operating supplies for processing; training on good agronomic practices; marketing strategies, proper operation and maintenance of equipment.

	
Hammer mill with very bad petrol engine	Poorly maintained grinder with faulty petrol engine
	
Manageable stitching machine	Screw press rusting away without use

Figure B14. Selected equipment at the Pujehun Processing Centre

Village Hope Enterprise is a cassava processing centre established by Dr. John Bart and the Rotary Club of Sierra Leone in 2015 with the objective reducing poverty by providing job opportunities for the rural poor (Figure B15). Dr. Bart financed the construction of the building whilst the Rotary Club supplied all the equipment for the processing of cassava. The Centre has an installed capacity of 2 tons/day gari output. Key challenges of this centre included: lack of effective storage facility, funds to cultivate cassava, skilled personnel in maintenance, process management skills and proper drainage; and low recovery rate. These constraints could be mitigated through capacity development in proper operation, maintenance of equipment, implementation of a regular maintenance regime, basic operations management, and record keeping; preparation of a business plan, construction of drainage, process audit, and sinking of a borehole.

	
Good Grater	Cassava peeler & Hammer Mill. Good working condition
	
Grinder mill. In good working condition	Gari toasting trays [Circular and 4ft × 8ft types]. In good working condition

Figure B15. Selected equipment at Massory

GEO-SPATIAL FACTORS AFFECTING CASSAVA PROCESSING CENTRES IN SIERRA LEONE

This study involved managers/chairmen of processing enterprises, processors, farmers, traders, transporters, engineering workshops and equipment fabricators, agro-input dealers, consumers and buyers of cassava products, community elders for remote villages, and executive members for each processing enterprise. Findings revealed that mean distance from cassava roots' sources to factories were less than 10 km in all the processing centers surveyed except at Njala and Binkolo, implying that most processing centers source their raw materials close to their factories. Maximum distance reported for sourcing cassava roots varied greatly and it could be as far as 40 km reported for Binkolo. Percentage of roads for supplying cassava roots to the factories that are paved were very low and mostly non-existent in most processing centers. Over 97% of road from cassava sources were in poor conditions suggesting that, in terms of raw material accessibility, all the factories surveyed were operating in sub-optimal conditions. Mean transportation cost of cassava roots to the factories during the rainy season was generally higher than during the dry season mainly due to deteriorating road conditions. Seasonal increases of transportation cost were highest at Village Hope and Binkolo by over 50%, while average seasonal increase for all factories was around 19%. Transport cost was highest at Ngainderma and Pujehun at about 2.7 $/ton/km during dry season and 3.3 $/ton/km for the wet season. Roads around Pujehun factory were in very poor condition which may be responsible for this high cost. From the business analysis data, cassava transport cost during dry and wet seasons were compared to cost of cassava roots for some of the centers where data was available. This ratio was highest at Village Hope processing center (35%) during dry season while it was lowest at Mandu (20%). At Mandu, this ratio was also lowest during the wet season (23.3%). This is probably due to the fact that Mandu has its own truck. During rainy seasons, the ratio of transport cost to that of cassava root ranged from 30 to 41 % except at Mandu where it was 23%. Transport costs were high at all processing centers in comparison to the cost of cassava roots, which might be one of the reasons why most of these factories were not making profits.

Mean distance from factories to markets of products varied widely among the processing centers as it ranged from about 15 km at Adamaris to 128 km at Njala. Some of these centers travel as far as Freetown for marketing their products. Hence the distance varied widely. Compared to distance from sourcing cassava roots, distance to markets of products were far larger with a maximum of over 300 km observed at Pujehun processing center. Proportion of road type that were paved from factories to markets were above 60% in most of the centers except at Mandu and Pujehun which were low at 25 and 38%, respectively. This is probably due to the fact some of these centers are located close to paved roads. Conversely, percentage of road type that were unpaved to markets were low in most cases except at Mandu and Pujehun which were far from all-weather road. As a result of this, mean transport cost, to market, of finished cassava products were much lower compared to the cost of transporting cassava roots. Seasonal variations in transport costs to markets were also lower in most of the centers. Highest transport cost of 0.62 $/ton/km was obtained at Adamaris while the lowest was at Njala with a value of about 0.1 $/ton/km. Njala processing center is located at the campus of Njala University and directly connected to paved road either to Bo or Freetown. Hence its transport cost of finished cassava products was reported to be lowest among all the processing centers surveyed.

To improve profitability of cassava value chain business, the government of Sierra Leone must increase the density of paved road network as it was done in some countries of the world.

To transform the agricultural sector in Sierra Leone policy priority must be given to maintenance of rural roads and construction of new roads following the examples of some emerging economies of the world.

New cassava factories must be sited where the negative influence of road infrastructure and cost of delivery of cassava output products is kept minimum.

AGRONOMIC EVALUATION OF OFSP DEMO PLOTS DURING FIRST AND SECOND CROPPING SEASON

The specific objectives of this study were: (i) increase production, availability, accessibility and affordability of OFSP and pumpkin; (ii) increase consumption of OFSP and pumpkins among children 6-23 months of age; and (iii) develop innovative and efficient small-scale, decentralized food processing with processors based on locally available materials to produce innovative and diverse nutrient-rich processed food products.

The average percentage of plants harvested was slightly higher in the plots where NPK 15:15:15 fertilizer was applied in each district except Bombali. When the cropping seasons were compared, the average percentage of planted harvested in the second cropping season was considerably lower when compared to the first cropping season. The average percent of plants harvested was decreased by 49.4% in Bo, 46.2% in Bombali, 59.5% in Kenema, 52.3% in Koinadugu, 46.5% in Moyamba, 51.9% in Tonkolili and 19.6% in Western Area (Table B3). The decrease in the average percentage of plants harvested could adversely affect the root yield of the OFSP genotypes. Yield is a component of weight and numbers, therefore a decrease in the number of plants harvested is directly proportional to the yield, therefore any factor that affect the number of plants harvested could affect the root yield.

Table B3. Average percent of OFSP plants harvested as affected by cropping season and NPK 15:15:15 application in the seven districts

		Phases (Cropping season)			Rate of fertilizer application		
		Phase 1	Phase 2		F0	F1	
District	**Variety**	**1st CS (%)**	**2nd CS (%)**	**Mean (%)**	**0 kgha^{-1} (%)**	**270 kgha^{-1} (%)**	**Mean (%)**
Bo	Chipka	91	47	69	69	69	69
	Kaphulira	87	44	66	64	67	66
	Mathuthu	95	47	71	70	72	71
	Mean	91	46		68	69	
Bombali	Chipka	78	48	63	66	60	63
	Kaphulira	77	39	58	60	56	58
	Mathuthu	78	38	58	57	59	58
	Mean	77	42		61	58	
Kenema	Chipka	71	35	53	50	56	53
	Kaphulira	68	19	43	40	47	43

	Mathuthu	85	37	61	56	66	61
	Mean	75	30		49	56	
Koinadugu	Chipka	91	44	67	68	67	67
	Kaphulira	89	43	66	66	67	66
	Mathuthu	87	41	64	63	66	64
	Mean	89	43		65	66	
Moyamba	Chipka	86	45	66	65	67	66
	Kaphulira	76	42	59	57	61	59
	Mathuthu	85	45	65	65	65	65
	Mean	83	44		62	64	
Tonkolili	Chipka	87	44	65	63	68	65
	Kaphulira	85	43	64	60	69	64
	Mathuthu	90	39	65	62	67	65
	Mean	87	42		61	68	
Western Area	Chipka	36	34	35	32	39	35
	Kaphulira	23	23	23	22	24	23
	Mathuthu	57	36	47	44	49	47
	Mean	39	31		32	37	

The average fresh root yield of OFSP genotypes as affected by cropping season and NPK 15:15:15 application in the seven districts is illustrated in Table B4. The total fresh root weight of Chipka, Kaphulira and Mathuthu decreased considerably when planting was done in the second cropping season in each district. The average fresh root yield across the district decreased by 74.4% in Bo, 72.2% in Bombali, 89.3% in Kenema, 78.9% in Koinadugu, 76.2% in Moyamba, 76.1% in Tonkolili and 63.0% in Western Area. As a result of the decrease in the fresh root yield in the second cropping, the full yield potential of the OFSP genotypes was not fully realized by the Phase 2 groups, this may affect the adoption of the OFSP

Table B4. Average fresh root yield (t ha^{-1}) of OFSP genotypes as affected by cropping season and NPK 15:15:15 application in the seven districts.

		Phases (Cropping season)			**Rate of fertilizer application**		
District	**Genotype**	**Phase 1: 1st CS (t ha^{-1})**	**Phase 2: 2nd CS (t ha^{-1})**	**Mean (t ha^{-1})**	**F0: 0 kg ha^{-1} (t ha^{-1})**	**F1: 270 kg ha^{-1} (t ha^{-1})**	**Mean (t ha^{-1})**
Bo	Chipka	7.0	1.8	4.4	3.4	5.5	4.4
	Kaphulira	8.5	2.3	5.4	4.6	6.2	5.4
	Mathuthu	8.0	1.9	4.9	4.1	5.7	4.9
	Mean	7.8	2.0		4.0	5.8	
Bombalili	Chipka	5.6	1.9	3.8	2.9	4.7	3.8
	Kaphulira	6.4	2.0	4.2	3.1	5.3	4.2
	Mathuthu	5.8	1.1	3.5	2.9	4.0	3.5
	Mean	6.0	1.7		2.9	4.7	
Kenema	Chipka	6.0	0.8	3.4	2.6	4.2	3.4
	Kaphulira	7.2	0.6	3.9	2.9	4.9	3.9

	Mathuthu	7.9	0.8	4.3	3.4	5.3	4.3
	Mean	7.0	0.8		3.0	4.8	
Koinadugu	Chipka	10.9	1.9	6.5	6.0	6.9	6.5
	Kaphulira	9.3	2.4	5.8	4.9	6.8	5.8
	Mathuthu	9.7	2.0	5.9	4.8	6.9	5.9
	Mean	10.0	2.1		5.2	6.9	
Moyamba	Chipka	10.6	2.4	6.5	5.6	7.5	6.5
	Kaphulira	10.7	2.6	6.7	5.3	8.2	6.7
	Mathuthu	10.2	2.4	6.2	5.6	6.9	6.2
	Mean	10.5	2.5		5.5	7.5	
Tonkolili	Chipka	5.6	1.4	3.5	2.6	4.4	3.5
	Kaphulira	6.4	1.8	4.1	3.5	4.7	4.1
	Mathuthu	5.8	1.1	3.4	2.7	4.2	3.4
	Mean	5.9	1.4		2.9	4.4	
Western area	Chipka	3.9	1.4	2.6	1.8	3.5	2.6
	Kaphulira	2.7	1.4	2.0	1.7	2.4	2.0
	Mathuthu	5.6	1.8	3.7	2.7	4.7	3.7
	Mean	4.1	1.5		2.1	3.5	

genotypes. Therefore, a review of the strategy in 2019 project beneficiaries is necessary. A new strategy of targeting all the project beneficiaries in the first cropping season and subsequent follow up of project activities in the second cropping is hereby proposed for the 2019 project.

The application of NPK 15:15:15 fertilizer at the rate of 270 kg ha^{-1} increased the fresh root yield in Chipka, Kaphulira and Mathuthu. The average fresh root yield across the district increased by 45.4% in Bo, 58.3% in Bombali, 61.8% in Kenema, 30.9% in Koinadugu, 36.6% in Moyamba, 51.2% in Tonkolili and 71.1% in Western Area. The increase in yield indicates that, it is a prerequisite to apply NPK 15:15:15 at the rate of 270 kg ha^{-1} for increasing the fresh root yield of the OFSP genotypes.

The average fresh root yield of the OFSP genotypes differ across the districts. The fresh root yield was obtained in the Moyamba district (6.5 t ha^{-1}) followed by Koinadugu (6.0 t ha^{-1}), Bo (4.9 t ha^{-1}), Kenema (3.9 t ha^{-1}), Bombali (3.8 t ha^{-1}), Tonkolili (3.7 t ha^{-1}) and Western Area (2.8 t ha^{-1}). The low fresh root yield in the Western Area and Tonkolili could be attributed to the low soil fertility in this district.

The average fresh root yield differs among the OFSP genotypes. The highest fresh root yield was obtained from (4.6 t ha^{-1}) Kaphulira followed by Mathuthu (4.56 t ha^{-1}) and Chipka (4.34 t ha^{-1}). Even though the rate of survival of Kaphulira was relatively low, it however produced the highest root yield. This could be attributed to the larger root size when compared to the other OFSP genotypes (Figure B16).

Figure B16. Photographs of root size of Kaphulira (A), Chipka (B) and Mathuthu (C)

AGRONOMIC AND ECONOMIC EFFICIENCY OF FERTILIZER USE IN OFSP CULTIVATION

The agronomic efficiency of NPK 15:15:15 use for OFSP cultivation is illustrated in Table B5. In the first cropping season, the change in yield increase due to NPK 15:15:15 fertilization was positive and the agronomic efficiency greater than 1 for each OFSP genotype in all the districts. This shows the OFSP genotypes positively responded to NPK 15:15:15 fertilizer application. The same trend occurred for the second cropping season except Chipka in Koinadugu and Moyamba districts.

The gross margin analysis and benefit cost ratio (BCR) showed that, the application of NPK 15:15:15 fertilizer at the rate of 270 kg ha^{-1} is profitable for OFSP production, except for Mathuthu in Bombali and Moyamba districts, Chipka in the Koinadugu district and Kaphulira in the Western Area (Table B6). The increase in marketable root yield could be attributed to the increase gross margin due to fertilizer application. However, the gross margin and BCR varied among the OFSP genotypes across each district. This showed that, the blanket rate of 270 kg ha^{-1} of NKP 15:15:15 was not adequate to supply the required nutrients for the growth and development of OFSP genotypes in some districts where the that initial fertility was very low. Therefore, site specific rates for NPK 15:15:15 should be determined for OFSP cultivation across the varying soil types and fertility level. Averaged across districts, the fertilized plots of Kaphulira had the highest gross margin and BCR, followed by Chipka and Mathuthu. The averaged BCR across the seven districts showed that, for every Leone spent on applying NPK fertilizer at 270 kg ha^{-1} for OFSP cultivation, there is an increase in the gross margin by 44% for Kaphulira, 26% for Chipka and 25% for Mathuthu. This shows that is more profitable cultivate Kaphulira under fertilized conditions when compared to the other OFSP genotypes.

Table B5. Agronomic efficiency (AE) of NPK 15:15:15 fertilizer for OFSP cultivation during the first and second cropping season in the seven districts.

		Phase 1 (Main cropping season)					Phase 2 (Second cropping season)				
		Fresh root yield ($kg\ ha^{-1}$)					Fresh root yield ($kg\ ha^{-1}$)				
District	Genotype	F0	F1	Δ Yield	Quantity of fertilizer ($kg\ ha^{-1}$)	AE	F0	F1	Δ Yield	Quantity of fertilizer ($kg\ ha^{-1}$)	AE
Bo	Chipka	5466.7	8594.9	3128.2	270	11.6	1236.1	2444.4	1208.3	270	4.5
	Kaphulira	7299.1	9648.7	2349.6	270	8.7	1819.4	2819.4	1000.0	270	3.7
	Mathuthu	6620.5	9340.2	2719.7	270	10.1	1597.2	2111.1	513.9	270	1.9
Bombali	Chipka	4410.3	6820.5	2410.2	270	8.9	1333.3	2555.6	1222.3	270	4.5
	Kaphulira	5102.6	7717.9	2615.3	270	9.7	1083.3	2833.3	1750.0	270	6.5
	Mathuthu	5102.6	6564.1	1461.5	270	5.4	652.8	1500.0	847.2	270	3.1
Kenema	Chipka	4743.6	7230.8	2487.2	270	9.2	472.2	1208.3	736.1	270	2.7
	Kaphulira	5474.4	8961.5	3487.1	270	12.9	430.6	861.1	430.5	270	1.6
	Mathuthu	6205.1	9576.9	3371.8	270	12.5	519.4	1027.8	508.4	270	1.9
Koinadugu	Chipka	9776.9	12112.8	2335.9	270	8.7	2305.6	1619.4	-686.2	270	-2.5
	Kaphulira	8028.2	10502.6	2474.4	270	9.2	1694.4	3027.8	1333.4	270	4.9
	Mathuthu	7789.7	11661.5	3871.8	270	14.3	1805.6	2180.6	375.0	270	1.4
Moyamba	Chipka	8641.0	12641.0	4000.0	270	14.8	2472.2	2277.8	-194.4	270	-0.7
	Kaphulira	8115.4	13256.4	5141.0	270	19.0	2527.8	3055.6	527.8	270	2.0
	Mathuthu	9000.0	11128.2	2128.2	270	7.9	2138.9	2583.3	444.4	270	1.6
Tonkolili	Chipka	4051.3	7128.2	3076.9	270	11.4	1166.7	1611.1	444.4	270	1.6
	Kaphulira	5461.5	7269.2	1807.7	270	6.7	1472.2	2138.9	666.7	270	2.5
	Mathuthu	4692.3	6961.5	2269.2	270	8.4	694.4	1416.7	722.3	270	2.7
Western Area	Chipka	2307.7	5474.4	3166.7	270	11.7	1222.2	1500.0	277.8	270	1.0
	Kaphulira	2128.2	3307.7	1179.5	270	4.4	1227.8	1488.9	261.1	270	1.0
	Mathuthu	4064.1	7192.3	3128.2	270	11.6	1416.7	2194.4	777.7	270	2.9

Table B6. Gross margin analysis and benefit cost ratio (BCR) of OFSP fresh root production for Chipka, Kaphulira and Mathuthu under fertilized and unfertilized conditions in the seven districts

		Chipka		Kaphulira		Mathuthu	
District	**Items**	**F0**	**F1**	**F0**	**F1**	**F0**	**F1**
Bo	**Revenue generated**						
	Marketable root yield (kg ha^{-1})	2,765	4,852	3,908	5,682	3,286	4,936
	Unit price per kg (SLL)	1,600	1,600	1,600	1,600	1,600	1,600
	Total Revenue (SLL ha^{-1})	4,423,200	7,763,040	6,252,800	9,090,560	5,256,960	7,897,120
	Variable cost						
	Fertilizer (SLL ha^{-1})	0	1,350,000	0	1,350,000	0	1,350,000
	Labour (SLL ha^{-1})	0	600,000	0	600,000	0	600,000
	Total (SLL ha^{-1})	0	1,950,000	0	1,950,000	0	1,950,000
	Gross margin (SLL ha^{-1})	**4,423,200**	**5,813,040**	**6,252,800**	**7,140,560**	**5,256,960**	**5,947,120**
	BCR due to fertilizer application		**1.71**		**1.46**		**1.35**
Bombali	**Revenue generated**						
	Marketable root yield (kg ha^{-1})	2,294	3,723	2,713	4,830	2,289	3,381
	Unit price per kg (SLL)	1,600	1,600	1,600	1,600	1,600	1,600
	Total Revenue (SLL ha^{-1})	3,670,080	5,957,280	4,340,160	7,728,160	3,661,600	5,410,240
	Variable cost						
	Fertilizer (SLL ha^{-1})	0	1,350,000	0	1,350,000	0	1,350,000
	Labour (SLL ha^{-1})	0	600,000	0	600,000	0	600,000
	Total (SLL ha^{-1})	0	1,950,000	0	1,950,000	0	1,950,000
	Gross margin (SLL ha^{-1})	**3,670,080**	**4,007,280**	**4,340,160**	**5,778,160**	**3,661,600**	**3,460,240**
	BCR due to fertilizer application		**1.17**		**1.74**		**0.90**
Kenema	**Revenue generated**						
	Marketable root yield (kg ha^{-1})	2,263	3,778	2,674	4,514	2,915	4,739
	Unit price per kg (SLL)	1,600	1,600	1,600	1,600	1,600	1,600
	Total Revenue (SLL ha^{-1})	3,620,480	6,044,480	4,277,760	7,222,240	4,664,320	7,582,880
	Variable cost						
	Fertilizer (SLL ha^{-1})	0	1,350,000	0	1,350,000	0	1,350,000
	Labour (SLL ha^{-1})	0	600,000	0	600,000	0	600,000

	Total (SLL ha^{-1})	0	1,950,000	0	1,950,000	0	1,950,000
	Gross margin (SLL ha^{-1})	**3,620,480**	**4,094,480**	**4,277,760**	**5,272,240**	**4,664,320**	**5,632,880**
	BCR due to fertilizer application		**1.24**		**1.51**		**1.50**
Koinadugu	**Revenue generated**						
	Marketable root yield (kg ha^{-1})	5,143	6,020	4,312	6,145	3,949	5,893
	Unit price per kg (SLL)	1,600	1,600	1,600	1,600	1,600	1,600
	Total Revenue (SLL ha^{-1})	8,228,800	9,631,360	6,898,400	9,831,840	6,317,760	9,428,320
	Variable cost						
	Fertilizer (SLL ha^{-1})	0	1,350,000	0	1,350,000	0	1,350,000
	Labour (SLL ha^{-1})	0	600,000	0	600,000	0	600,000
	Total (SLL ha^{-1})	0	1,950,000	0	1,950,000	0	1,950,000
	Gross margin (SLL ha^{-1})	**8,228,800**	**7,681,360**	**6,898,400**	**7,881,840**	**6,317,760**	**7,478,320**
	BCR due to fertilizer application		**0.72**		**1.50**		**1.60**
Moyamba	**Revenue generated**						
	Marketable root yield (kg ha^{-1})	4,782	6,439	4,848	7,603	4,813	5864.3
	Unit price per kg (SLL)	1,600	1,600	1,600	1,600	1,600	1,600
	Total Revenue (SLL ha^{-1})	7,651,360	10,302,560	7,757,280	12,164,160	7,700,800	9,382,880
	Variable cost						
	Fertilizer (SLL ha^{-1})	0	1,350,000	0	1,350,000	0	1,350,000
	Labour (SLL ha^{-1})	0	600,000	0	600,000	0	600,000
	Total (SLL ha^{-1})	0	1,950,000	0	1,950,000	0	1,950,000
	Gross margin (SLL ha^{-1})	**7,651,360**	**8,352,560**	**7,757,280**	**10,214,160**	**7,700,800**	**7,432,880**
	BCR due to fertilizer application		**1.36**		**2.26**		**0.86**
Tonkolili	**Revenue generated**						
	Marketable root yield (kg ha^{-1})	2197.6	3842.9	3,084	4,416	2,261	3,615
	Unit price per kg (SLL)	1,600	1,600	1,600	1,600	1,600	1,600
	Total Revenue (SLL ha^{-1})	3,516,160	6,148,640	4,935,040	7,064,960	3,617,120	5,784,640
	Variable cost						
	Fertilizer (SLL ha^{-1})	0	1,350,000	0	1,350,000	0	1,350,000
	Labour (SLL ha^{-1})	0	600,000	0	600,000	0	600,000
	Total (SLL ha^{-1})	0	1,950,000	0	1,950,000	0	1,950,000

	Gross margin (SLL ha^{-1})	**3,516,160**	**4,198,640**	**4,935,040**	**5,114,960**	**3,617,120**	**3,834,640**
	BCR due to fertilizer application		**1.35**		**1.09**		**1.11**
Western Area	**Revenue generated**						
	Marketable root yield (kg ha^{-1})	1,171	2,676	1,319	1,981	1,908	3,639
	Unit price per kg (SLL)	1,600	1,600	1,600	1,600	1,600	1,600
	Total Revenue (SLL ha^{-1})	1,873,440	4,281,120	2,110,080	3,169,280	3,052,800	5,823,040
	Variable cost						
	Fertilizer (SLL ha^{-1})	0	1,350,000	0	1,350,000	0	1,350,000
	Labour (SLL ha^{-1})	0	600,000	0	600,000	0	600,000
	Total (SLL ha^{-1})	0	1,950,000	0	1,950,000	0	1,950,000
	Gross margin (SLL ha^{-1})	**1,873,440**	**2,331,120**	**2,110,080**	**1,219,280**	**3,052,800**	**3,873,040**
	BCR due to fertilizer application		**1.23**		**0.54**		**1.42**

ASSESSMENT OF ORANGE-FLESHED SWEETPOTATO PESTS AND DISEASES IN SIERRA LEONE

The objective of this study was to identify adaptable varieties with resistance to major pests and diseases that form the basis for recommendation of selected varieties for release by the Sierra Leone Seed Certification Agency (SLeSCA). Grasshopper damage was moderate and location sensitive. Kenema recorded the highest incidence suggesting that the rain forest zones harbour more grasshoppers compared to drier regions in Makeni. Generally proper sanitation and monitoring is required to avoid grasshopper damage. Variety Chipka had significantly (P>0.0001) the highest mean incidence of stem rot (17.58%) than all other varieties. Kapulira had an incidence of 0.67% while no incidence was recorded on Mathuthu and the local farmers' check variety (Figure B17). Western Area had the highest incidence of stem rot (8.75%) followed by Njala (6.56%). Bo and Kenema had an incidence of 3.9% and 3.5%, respectively. Mean severity of stem rot was low with no significant difference among varieties. Variety Chipka had the highest mean severity score of 1.23 followed by Kapulira (1.01), whereas no disease symptom was observed on Mathuthu and the local variety.

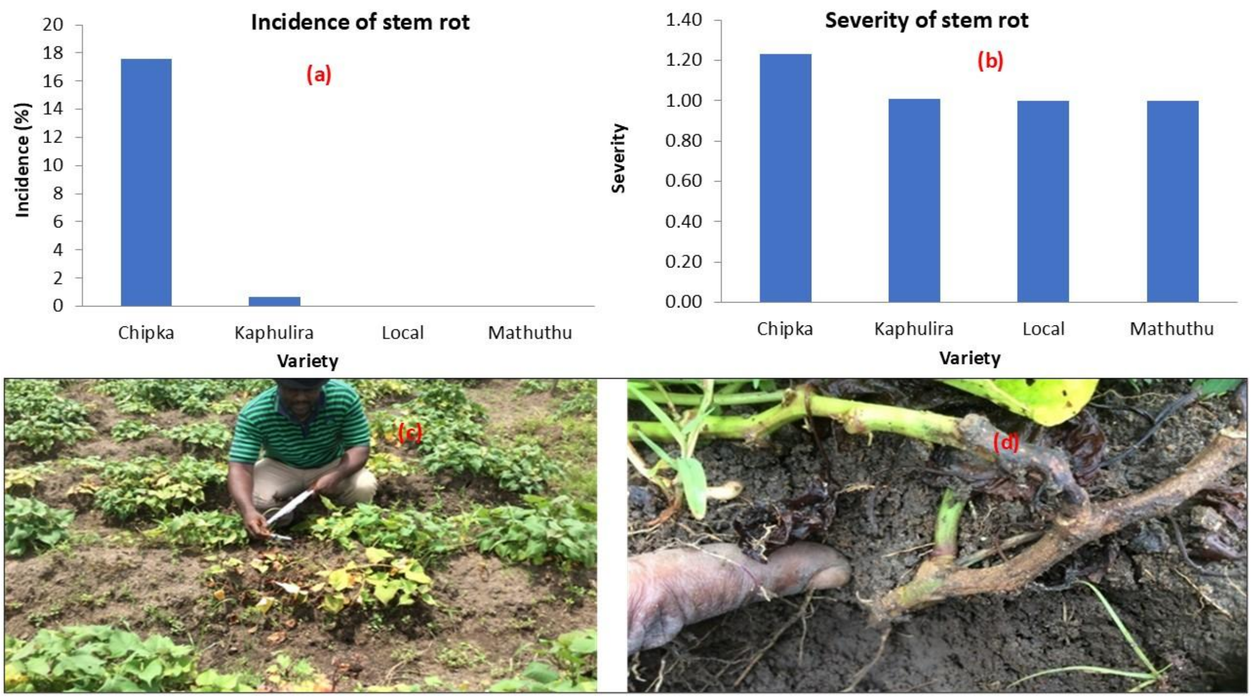
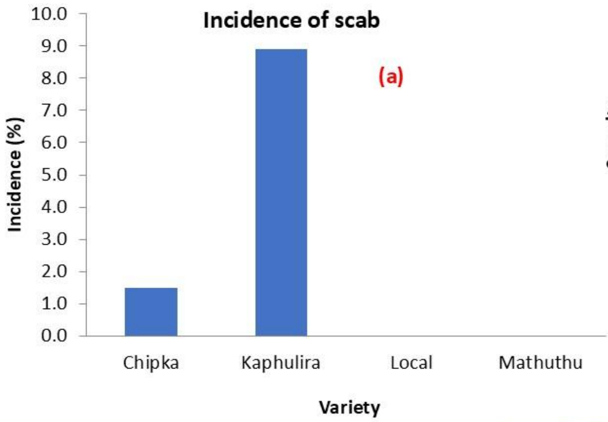


Figure B17. Mean (a) incidence, (b) severity, (c-d) and (c) symptom expression of stem rot among sweet potato varieties

Variety Kaphulira had significantly (P>0.0001) the highest mean incidence of scab (8.9%), Chipka had 1.5%, while Mathuthu and the local check showed no symptom of the disease. Kenema and the Western Area had the highest incidence of stem rot with 5.3% and 4.0%, respectively followed by Bo with 2.3%. No significant difference was observed between the fertilized and unfertilized plots. Mean disease severity score was low with Kapulira highest severity score of 1.1, followed by Chipka (1.02), whereas Mathuthu and the local variety check had nonvisible symptom of the disease (Figure B18). Results indicate that Kapulira is susceptible to scab and under high inoculum pressure, Chipka could also express susceptibility to scab.



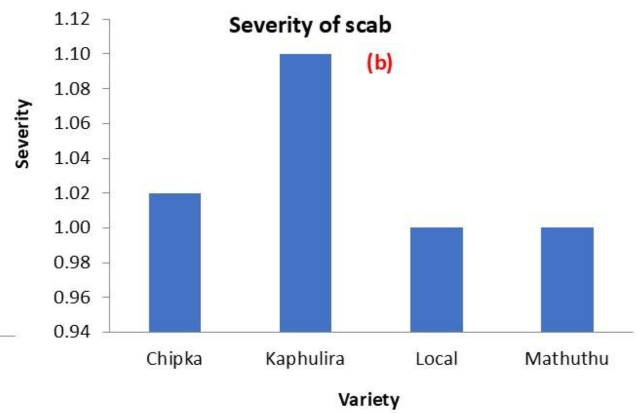


Figure B18. Mean (a) incidence, and (b) severity and (c) symptom expression of stem rot among sweet potato varieties

Mathuthu and Chipka had the highest incidence of 99% followed by Kaphulira with 98%, while the local variety had the lowest incidence of 93% (Figure B19). Makeni had a 100% incidence of leaf spot followed by Njala Kenema Bo and The Western Area with 98.4%, 96.9%, 95.8%, 95.3% respectively. No significant difference was observed between the fertilized and unfertilized plot. Similarly, there was no significant difference among varieties in terms of leaf spot severity. Severity scores ranged from 2.01 for Chipka and Mathuthu to 1.99 for Kapulira and the local variety. Makeni had the highest severity score of 2.09 significantly higher than all other varieties. Kenema had a severity score of 2.0 not significantly different from Njala (1.98), Western Area (1.96) and Bo (1.95). The unfertilized plot had significantly higher severity score of 2.1 compared to the fertilized plot with 1.96.

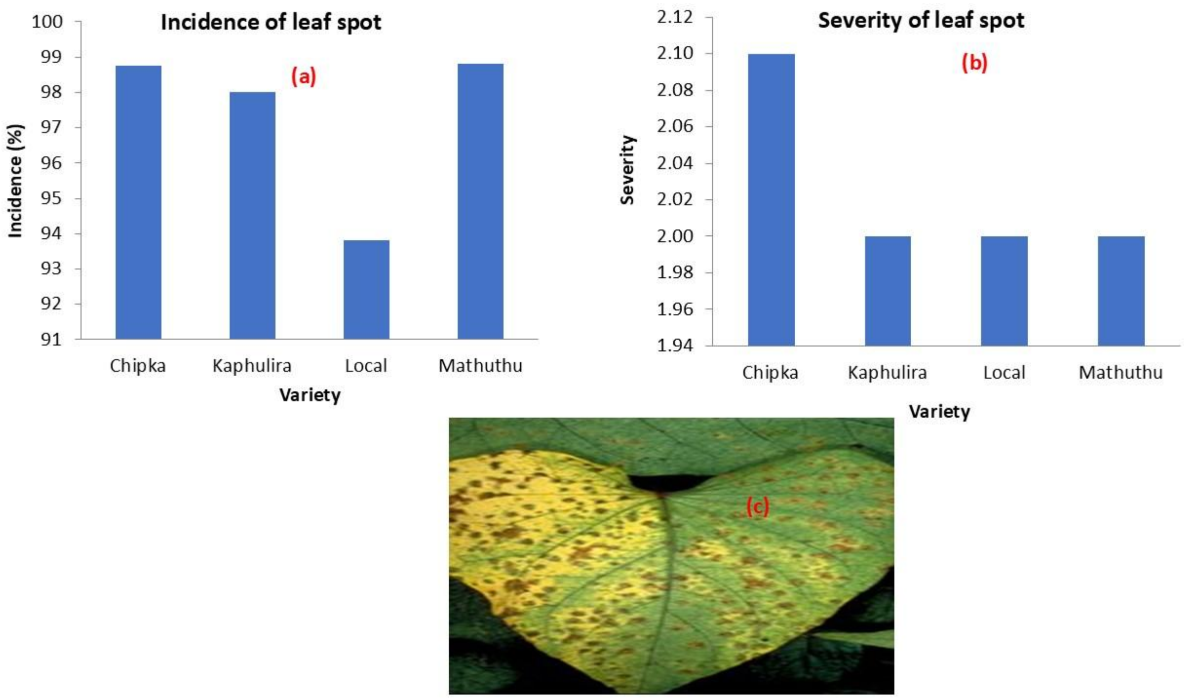


Figure B19. Mean (a) incidence, and (b) severity and (c) symptom expression of leaf spot among sweet potato varieties

DISSEMINATION OF OFSP VINES TO OTHER BENEFICIARIES AND RELEASE OF OFSP GENOTYPE

Table 6 illustrates the estimated number of beneficiaries of the OFSP genotypes. During harvest of the Phase 1 and 2 demo plots, vines were distributed to group members and other farmers in the community and nearby villages. About 2,645 indirect beneficiaries received OFSP vines from the Phase 1 and 2 demo plots and SLARI/NARC on station research sites. Of which, 688 beneficiaries are from Phase 1, 518 from Phase 2 and 1439 from SLARI on station research sites.

Table B7. Dissemination of OFSP vines in the seven districts

District	Phase 1	Phase 2	SLARI	Total
Bo	140	78	5	223
Bombali	77	76	1300	1453
Kenema	99	100	111	310
Koinadugu	114	85	0	199
Moyamba	110	83	23	216
Tonkolili	94	32	0	126
Western Area	54	64	0	118
Total	**688**	**518**	**1439**	**2645**

National performance trials were conducted by the Varietal Releases Committee (VRC) for OFSP genotypes recommended for release by the Sierra Leone Seed certification agency (SLeSCA). Genotypes Chipika, Kapulira, Mathuth and the local check were evaluated by a multi-disciplinary team of personnel from SleSCA, SLARI and Njala University. Based on the VRC, Mathuthu met the criteria for release by the SLeSCA. The average storage root yield Mathuthu ranges from 3.4 – 6.2 t ha^{-1}. The variety is resistant to major pests and diseases of sweet potato. The key agronomic traits of Mathuthu are illustrated in Figure B20.

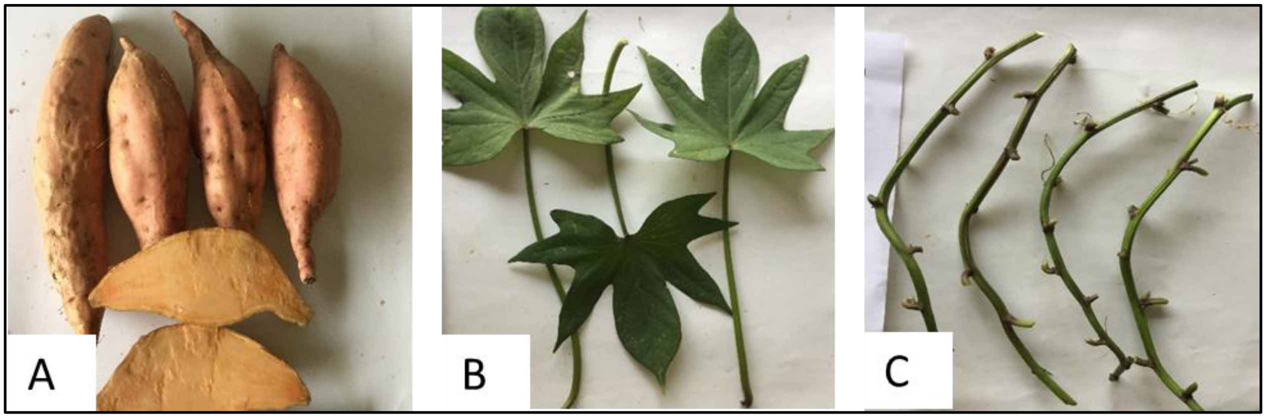


Figure B20. Photos of (a) root, (b) leaf, and (c) vine traits of the Mathuthu recommended to the VRC and officially released by SLeSCA

MOLECULAR AND PHENOTYPIC PROFILING OF WHITE GUINEA YAM (*DIOSCOREA ROTUNDATA*) BREEDING LINES

Phenotypic and genotypic profiling helps identify genotypes with suitable and complementary traits to progress genetic improvement in crops. A total of 32 traits were assessed in 36 genotypes of white Guinea yam established in a 6 × 6 triple lattice design. The objective was to evaluate an array of plant traits that define the genetic merits of breeding lines for yam improvement. Different analytical tools were used to identify and prioritize relevant traits defining the genetic merits of breeding lines in the yam improvement program. Out of the 32 traits measured, the linear combination of 31 traits (Table B8), and 14 traits (Table B9) that minimize within-group variance and maximize between-group variance for discriminating the genetic values of yam breeding lines were identified. When best linear unbiased prediction with genomic relationship matrix (GBLUP) was used, the accuracies of genomic breeding values were higher (r=0.87 to 0.97) for the seven traits (dry matter content, intensity of flesh oxidization of shredded tuber, pasting temperature, pasting time, tuber flesh colour, yam mosaic virus and fresh tuber yield) with high broad-sense heritability values (H^2_m>0.6) (Table B10). While, for the remaining seven traits with low (H^2_m<0.3) to medium (H^2_m=0.3 to 0.54) broad-sense heritability values, the accuracies of genomic estimated breeding values (GEBV) were low (r<0.4) to medium (r=0.4-0.8). Breeding lines with higher breeding values for fresh storage tuber yields that could be utilized for yam population improvement or recommendation for release include TDr08-21-2, TDr8902475, TDr9501932, TDr9518544, TDrNndu, TDrFakesta, TDr9700793 and TDr9519158. Genotypes with high dry matter content include TDr04-219, TDr8902157, TDr8902475, TDr8902665, TDr9518544, TDr9518988, TDrAlumaco, TDrNndu, TDrUfenyi and TDrYangbedu. Those with lowest AUDPC value for yam mosaic virus include TDr89/02475, TDr95/18988, TDrLeusi, TDrMeccakusa, TDrNndu and TDrPampars. Genotypes with high peak viscosity breeding values are TDr00/00362, TDr04-219, TDr89/02157, TDr89/02475, TDr08-21-2, TDr89/02665, TDr95/18544, TDr95/18988, TDrFakesta, TDrMeccakusa, TDrPampars, TDrPouna, TDrUfenyi, and

TDrYangbedu. Complementation of estimated breeding values with genomic estimated breeding values revealed higher prediction accuracy and genetic values of the profiled white yam traits of progenitors. The genotype–trait (GT) biplot display revealed superior clones with desirable genetic values for the key traits. These results are relevant for parental selection aimed at improving key agronomic traits in white Guinea yam.

Table B8. Eigen vectors, eigen values, percent variation and accumulated variation accounted by the first ten principal components

Traits	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
ASHC	0.13	0.26	0.22	**0.72**	-0.09	0.15	0.10	-0.12	-0.17	0.17
BV	**0.71**	-0.08	0.40	-0.33	0.05	-0.05	0.22	-0.12	-0.03	0.21
CTBRS	-0.15	0.40	0.19	**-0.74**	-0.07	0.05	0.10	0.03	0.15	-0.27
DMC	**0.63**	0.25	-0.11	-0.15	0.28	0.01	0.11	**0.50**	-0.24	0.14
FPV	-0.22	**0.59**	**-0.56**	0.11	0.33	0.05	0.00	0.18	0.09	-0.08
FYLD	**0.62**	-0.29	**-0.48**	-0.04	0.15	0.03	-0.10	0.11	0.28	0.19
ITTS	-0.09	0.21	**0.72**	-0.07	0.36	-0.02	-0.29	-0.09	0.21	0.14
HS	**-0.59**	0.44	**-0.48**	0.25	0.20	0.04	0.00	0.10	0.08	0.04
PLOSS	-0.27	0.16	**0.74**	0.11	-0.01	-0.04	0.14	0.18	-0.30	-0.31
PTB	0.05	-0.30	0.15	0.15	-0.26	**0.63**	-0.35	0.32	0.26	0.03
PTIME	**-0.50**	0.26	**-0.55**	0.29	0.06	0.05	-0.22	-0.18	0.07	-0.16
PTEMP	**-0.76**	-0.25	-0.07	0.03	-0.20	0.06	-0.10	0.07	0.01	0.28
PV	**0.77**	0.19	0.00	-0.31	0.21	0.03	0.14	0.04	0.04	-0.06
SBN	-0.35	0.36	0.04	**-0.62**	0.19	0.13	0.12	0.06	0.41	0.06
RTBS	-0.31	**0.48**	**0.47**	0.11	0.37	-0.27	-0.32	0.05	0.04	0.07
SCMR	0.16	-0.15	-0.08	-0.05	**0.49**	**0.50**	0.02	-0.11	0.03	-0.45
SPNSB	**-0.50**	0.32	-0.02	-0.07	0.29	**0.47**	0.37	-0.15	0.02	0.06
SPNAB	-0.28	0.07	0.26	-0.03	0.30	**0.59**	0.39	0.07	-0.26	0.19
STNP	**0.57**	**0.66**	0.04	0.14	-0.23	0.10	0.20	-0.19	0.03	0.07
TBRFLC	**-0.47**	-0.23	0.11	-0.25	-0.04	0.32	0.08	0.11	-0.27	0.31
SYLD	**0.70**	0.04	-0.43	-0.30	0.15	0.05	-0.12	0.22	-0.04	0.27
TBRS	0.20	-0.06	0.33	0.41	-0.19	**0.48**	-0.22	**0.46**	0.19	-0.10
TTBRYLD	0.38	-0.35	0.11	**0.55**	0.37	0.11	0.12	-0.09	0.05	-0.19
YMVAUDPC	**-0.53**	0.32	0.12	-0.27	-0.44	0.26	-0.16	-0.01	-0.10	0.04
STDP	-0.19	**-0.73**	0.00	-0.21	0.30	-0.03	0.05	-0.09	-0.09	0.07
PLNV	**0.54**	-0.24	0.19	0.35	0.41	0.16	0.06	-0.17	0.14	0.09
TTB	**0.54**	**0.63**	-0.08	0.08	-0.21	0.24	-0.19	0.00	-0.04	0.08
PRTBS	-0.20	0.37	**0.47**	0.07	**0.54**	-0.25	-0.38	0.05	0.06	0.14
RKN	0.32	0.19	0.32	0.25	-0.24	-0.43	0.26	0.34	0.12	0.02
INTOXDS30	**-0.50**	0.10	-0.24	0.39	0.25	-0.14	0.20	0.01	0.00	0.33
TBRNP	**0.50**	**0.68**	-0.14	0.13	-0.22	0.16	0.09	-0.25	-0.12	-0.02
PROTEINC	-0.12	-0.07	0.29	0.12	-0.29	0.06	0.42	-0.23	**0.62**	0.18
Eigenvalue	6.76	4.10	3.60	3.08	2.42	2.19	1.76	1.38	1.25	1.12
Percentage of variance	20.49	12.43	10.92	9.33	7.34	6.64	5.32	4.18	3.80	3.38
Cumulative percentage of variance	20.49	32.92	43.84	53.17	60.51	67.14	72.47	76.65	80.45	83.84

PC=Principal component; values in bolds represent traits that contributed most to variability in the various PCs

Table B9. Variance inflation factor (VIF) values of 31 traits and 14 traits determined based on multicollinearity and path coefficient analysis, respectively, in 36 genotypes of white yam

Trait	First VIF (multicollinearity)	Trait	Second VIF (Path coefficient)
Ash content (ASHC)	**9.5**	ASHC	1.95
Breakdown value (BV)	130.5	DMC	2.56
Cracks on the tuber surface (CTBRS)	20.2	PTIME	1.94
Dry matter content (DMC)	**7.7**	PTEMP	3.11
Final paste viscosity (FPV)	405.8	SBN	2.23
Flour yield (FYLD)	42.8	SCMR	1.99
Intensity of thorns or spines on tuber surface (ITTS)	11.4	SPNAB	1.64
Holding strength (HS)	273.6	TBRFLC	1.78
Peel loss (PLOSS)	48.2	TBRS	1.55
Position of tuber branching (PTB)	12.8	YMVAUDPC	2.21
Peak time (PTIME)	**9.9**	STDP	1.78
Peak temperature (PTEMP)	**9.4**	INTOXDS30	1.52
Peak viscosity (PV)	240.7	PROTEINC	2.11
Scutellonema bradys nematode (SBN)	**9.7**		
Roots on the surface of the tubers (RTBS)	15.7		
Leaf chlorophyll content (SCMR)	**5.0**		
Spines on stem base (SPNSB)	25.2		
Spines on stem above base (SPNAB)	**6.3**		
Stem number per plant (STNP)	64.5		
Tuber flesh colour (TBRFLC)	**5.3**		
Starch yield (SYLD)	81.3		
Tuber shape (TBRS)	**8.3**		
Total tuber yield (TTBRYLD)	**9.6**		
Yam mosaic virus (YMVAUDPC)	**8.7**		
Stem diameter per plant (STDP)	**8.8**		
Plant vigour (PLNV)	26.4		
Tendency of tuber to branch (TTB)	28.7		
Place of roots on tuber surface (PRTBS)	22.5		
Intensity of flesh oxidization of shredded tuber (INTOXDS30)	**6.0**		
Tuber number per plant (TBRNP)	28.8		
Protein content (PROTEINC)	**9.6**		

VIF=variance inflation factor; values in bolds represent traits with low VIF < 10 based on Amos et al. (2019); the second VIF based on path coefficient analysis revealed low VIF < 5 values for 14 traits

Table B10. Trait heritability, standard error, prediction accuracy and reliability estimates of breeding values (BV) under best linear unbiased prediction (BLUP) and genomic estimated breeding value (GEBV) under the genomic best linear unbiased prediction (GBLUP)

	Model 0: BV under BLUP				Model 1: GEBV under GBLUP			
Trait	H^2_m	SE	r^2	r	h^2	SE	r^2	r
ASHC	$2.40e^{-06}$	0.00	0.000	0.001	0.002	0.13	0.26	0.50
DMC	0.83	1.30	0.81	0.90	0.48	1.10	0.89	0.94
INTOXDS30	0.80	0.48	0.77	0.88	0.07	0.45	0.76	0.87
PROTEINC	$1.51e^{-06}$	0.00	-14.81	NA	0.00	0.16	0.18	0.43
PTEMP	0.76	0.54	0.74	0.86	0.11	0.47	0.85	0.92
PTIME	0.88	0.11	0.86	0.92	0.01	0.10	0.93	0.96
SBN	0.32	0.19	0.31	0.56	0.001	0.10	0.20	0.45
SCMR	0.54	1.63	0.53	0.73	0.25	1.32	0.56	0.74
STDP	0.47	0.39	0.46	0.68	0.02	0.33	0.62	0.78
SPNAB	-	-	-	-	-	-	-	-
TBRFLC	0.84	0.24	0.82	0.90	0.03	0.22	0.87	0.93
TBRS	0.47	0.39	0.45	0.67	0.01	0.29	0.46	0.67
YMVAUDPC	0.90	97.70	0.87	0.93	0.999	86.13	0.94	0.97
TTBRYLD	0.75	2.13	0.74	0.86	0.70	1.83	0.87	0.93

r=prediction accuracy (<0.4=low, 0.4-0.8=medium, and >0.8=high accuracies); r^2=reliability; SE=standard error; ASHC=ash content; DMC=tuber dry matter content; INTOXDS30=intensity of flesh oxidization of shredded tuber; PROTEINC=protein content; PTEMP=pasting temperature; PTIME=pasting time; SBN=*Scutellonema bradys* nematode; SCMR=leaf chlorophyll content; STDP=stem diameter per plant; SPNAB=spines on stem above base; TBRFLC=tuber flesh colour; TBRS=tuber shape; YMVAUDPC=yam mosaic virus; TBRYLD=total fresh tuber yield

PATERNITY ASSIGNMENT IN WHITE GUINEA YAM (*DIOSCOREA ROTUNDATA*) HALF-SIB PROGENIES FROM POLYCROSS MATING DESIGN USING SNP MARKERS

White Guinea yam is mostly a dioecious outcrossing crop with male and female flowers produced on distinct plants. Fertile parents produce high fruit set in an open pollination polycross block, which is a cost-effective and convenient way of generating variability in yam breeding. However, the pollen parent of progeny from polycross mating is usually unknown. This study aimed to determine paternity in white Guinea yam half-sib progenies from polycross mating design. A total of 394 half-sib progenies from random open pollination involving nine female and three male parents was genotyped with 6602 SNP markers from DArTSeq platform to recover full pedigree. A higher proportion of expected heterozygosity, allelic richness, and evenness were observed in the half-sib progenies. A complete pedigree was established for all progenies from two families (TDr1685 and TDr1688) with 100% accuracy, while in the remaining families, paternity was assigned successfully only for 56 to 98% of the progenies (Tables B11 and B12). Our results indicated unequal paternal contribution under natural open pollination in yam, suggesting unequal pollen migrations or gene flow among the crossing parents. A total of 3.8% of progenies lacking paternal identity due to foreign pollen contamination outside the polycross block was observed. This study established the efficient determination of parental reconstruction and allelic contributions in the white Guinea yam half-sib progenies generated from open pollination polycross using SNP markers. Findings are useful for parental reconstruction, accurate dissection of the genetic effects, and selection in white Guinea yam breeding program utilizing polycross mating design.

Table B11. Summary statistics: minor allele frequency, major allele frequency, proportion of heterozygosity, and QC = quality check of genetic (6602 SNPs, 394 individuals) of segregating progenies of white yam.

Family	Sample	Sample after QC	Hybrid	Proportion of Heterozygous Mean	Min	Max	σ^2	σ	Minor Allele Frequency	Major Allele Frequency
TDr1685	50	50	50	0.28	0.19	0.49	0.002	0.04	0.205	0.794
TDr1686	50	50	37	0.28	0.12	0.53	0.004	0.07	0.211	0.788
TDr1687	50	46	46	0.29	0.23	0.40	0.001	0.03	0.209	0.791
TDr1688	50	50	50	0.33	0.29	0.41	0.000	0.02	0.233	0.766
TDr1689	50	28	28	0.33	0.16	0.52	0.002	0.05	0.238	0.762
TDr1690	45	44	44	0.27	0.26	0.44	0.001	0.03	0.186	0.813
TDr1691	49	48	48	0.28	0.22	0.36	0.001	0.03	0.204	0.795
TDr1692	50	50	49	0.29	0.25	0.46	0.001	0.04	0.209	0.791

σ^2 = variance, and σ = standard deviation

Table B12. The number and proportions of progenies with recovered paternal identity.

Female	Family	Male TDr9501932	TDr9902789	TDr9902607	Progeny with Fully Recovered Pedigree	Percent of Progenies with Fully Recovered Pedigree
TDr9700793	TDr1685	26 (52%)	1 (2.0%)	23 (46%)	50	100
TDr8902157	TDr1686	12 (24%)	0 (0%)	25 (50%)	37	74
TDr8902475	TDr1687	46 (92%)	0 (0%)	0 (0%)	46	92
TDr9700632	TDr1688	23 (46%)	1 (2%)	26 (52%)	50	100
TDr9700205	TDr1689	18 (36%)	6 (12%)	4 (8%)	28	56
TDr9519158	TDr1690	39 (86.7%)	0 (0%)	5 (11.1%)	44	97.8
TDr9518988	TDr1691	45 (91.8%)	0 (0%)	3 (6.1%)	48	97.9
Ojuiyawo	TDr1692	22 (44.0%)	27 (54%)	0 (0%)	49	98
Total progenies		231	35	86	352	
% contribution		65.63	9.94	24.43	100	96.2

IDENTIFICATION OF QUANTITATIVE TRAIT NUCLEOTIDES AND CANDIDATE GENE FOR TUBER YIELD AND MOSAIC VIRUS TOLERANCE IN AN ELITE POPULATION OF WHITE GUINEA YAM (*DIOSCOREA ROTUNDATA*) USING GENOME-WIDE ASSOCIATION SCAN

Improvement of tuber yield and tolerance to viruses are priority objectives in white Guinea yam breeding programs. However, phenotypic selection for these traits is quite challenging due to phenotypic plasticity and cumbersome screening of phenotypic-induced variations. Agre et al. (2021) assessed quantitative trait nucleotides (QTNs) and the underlying candidate genes related to tuber yield per plant (TYP) and yam mosaic virus (YMV) tolerance in a panel of 406 white Guinea yam (*Dioscorea rotundata*) breeding lines using a genome-wide association study (GWAS).

The phenotypic value for the tuber yield ranged from 0.93 to 1.47 kg plant^{-1} with an average of 1.19 kg (Table B13). Broad-sense heritability estimates were high for tuber yield per plant (0.708) and yam mosaic virus (0.903). The high broad-sense heritability values demonstrated substantial genetic variation in traits among the different genotypes. Therefore, the studied traits are amenable to genetic improvement through selection. Furthermore, the observed natural genetic variation in the study materials signifies their relevance for genetic studies.

Table B13. Descriptive statistics of tuber yield per plant (TYP) and yam mosaic virus (YMV)

Traits	Minimum	Maximum	Mean	Standard Deviation	Broad sense heritability (H^2)
TYP	0.93	1.47	1.19	0.11	0.708
YMV	100.56	2900.45	936.16	481.19	0.903

TYP: Tuber yield per plant; YMV: yam mosaic virus (AUDPC value)

Population structure analysis using 5,581 SNPs differentiated the 406 genotypes into seven distinct sub-groups-based delta K (Figure B21). The high genetic variability indicates the potentials of the studied clones for genetic improvement aimed at tuber yield per plant and yam mosaic virus. The phylogeny analysis reveals similar results as the population structure analysis, indicating their relevance in preventing sham associations in GWAS in this study. Thus, the marker density, diversity, and sample size demonstrated that the yam breeding panel used for this study is sufficiently powered to capture allelic variations for the studied traits.

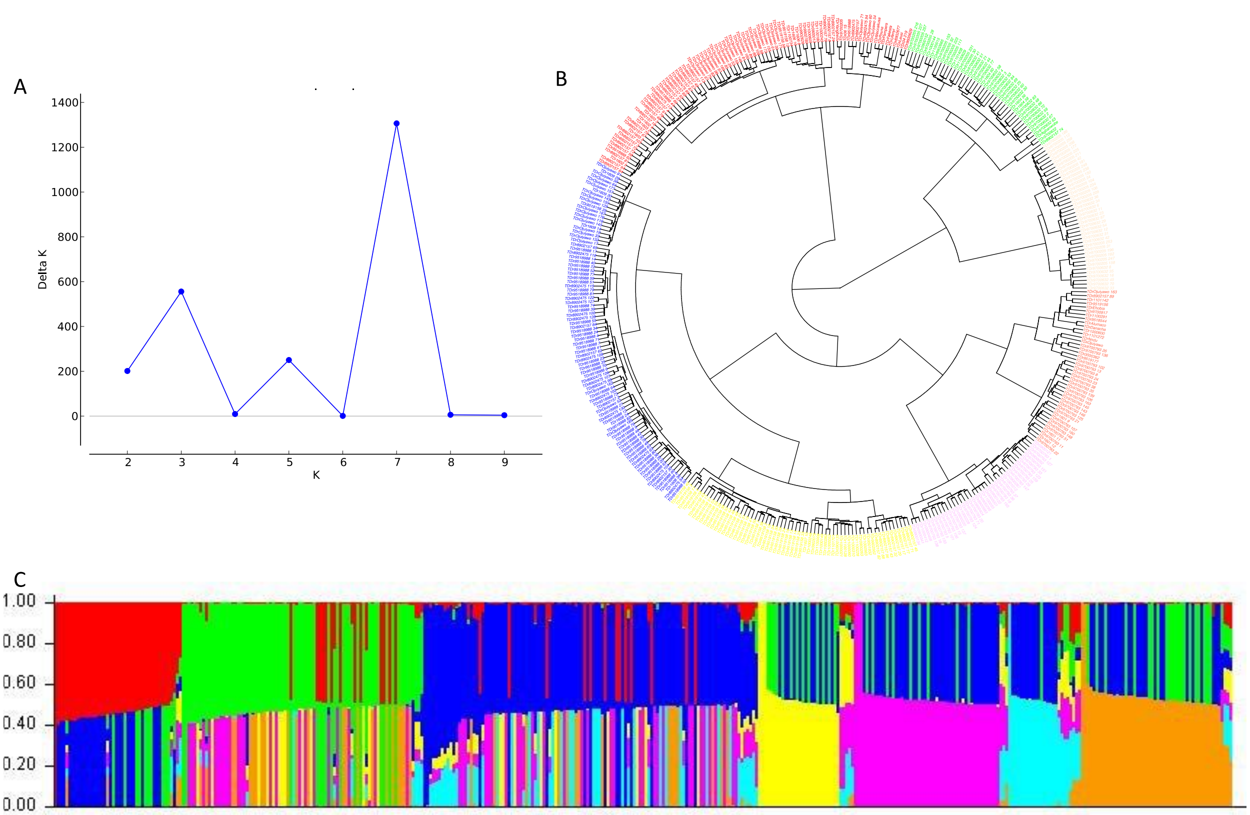


Figure B21. Graphical representation of the population structure of the 406 yam diversity panel. (A) Plot of mean likelihood of delta K against the number of K groups. The highest peak observed at K=7 signifies the grouping of accessions into seven groups. (B) Phylogeny tree showing the 7 Sub-populations. The colours represent each sub-population. (C) Population structure originated from the STRUCTURE based K=7. Each vertical barplot represents a single yam clone

C. KENEMA FORESTRY AND TREE CROPS RESEARCH CENTRE (KFTCRC)

The forestry and tree crops research programme are implemented at the KFTCRC. The Programme is aimed at addressing challenges to enhance sustainable productivity, commercialization, and competitiveness of the forestry and tree crops.

DEVELOPMENT AND PROMOTION OF COFFEE PRODUCT VALUE CHAIN

A coffee rooting chamber with a capacity of 5,000 cuttings was established at the Pendembu nursery by the BAFS Project under the 11th European Development Funds. Some of the seedlings of the rooted coffee cuttings were transplanted into polythene bags, cared for right through to planting on permanent fields.

Cuttings of the ‘high land’ coffee (*Coffea stenophylla*) were also obtained from the Kambui and Kasewe hills for propagation. They were planted in the rooting chamber but survival rate was extremely poor. In the same way also, cuttings of *C. liberica* were also harvested and established in the rooting chamber. These were transplanted in polythene bags and later at permanent site. There shall be continuous search for these coffee as they could provide a niche market for the country if farmers could have established plots purely for *C. stenophylla* and *C. liberica*.

DEVELOPMENT AND PROMOTION OF COCOA PRODUCT VALUE CHAINS

The International Fund for Agricultural Development (IFAD) supported the KFTCRC from 2013 to 2015 in the rehabilitation of the Pendembu and Kpuwabu cocoa clonal gardens. Moreover, 1 ha cocoa clonal garden was established for the production of planting materials to support stakeholders such as the Sustainable Tree Crop Project (STCP) in Liberia. The Smallholder Commercialization and Agribusiness Development Project (SCADeP) from 2017 to 2023. The key deliverables included: Rehabilitation of water supply system at Kpuwabu; Solar electrification of the Kpuwabu senior staff quarters; Installation of a greenhouse at Kpuwabu; Construction of multipurpose farm building at Pendembu; Construction of drying floor at Pendembu; Rehabilitation of conference hall and laboratory at Pendembu; Procurement of assorted laboratory tools and implements at Pendembu; Training of a one staff in the use of laboratory tools and implements at the IITA; Support to 150 cocoa farmers in Kenema and Kailahun districts for the establishment of 150 ha of cocoa (1 ha per farmer); Support to 30 oil palm farmers in Bombali and Kambia districts for the establishment of 30 ha of improved oil palm planting materials that were imported from the Oil Palm Research Institute (OPRI) of Ghana; and Administrative support to the KFTCRC for the procurement of office consumables.
Support from the Boosting Agriculture and Food Security (BAFS) Project started in 2018 and the following results:
About 10,000 seedlings of C67 and C77 were nursed as root stocks at Pendembu and Kpuwabu so that they can be budded/grafted for gap filling of missing cocoa trees at Pendembu. These

buddings/grafts were used for gap filling so that pure genetic lines of the existing materials in the clonal gardens can be maintained.
A borehole was dug at the staff quarters to provide water for staff and an irrigation system (EMAS Pump) was installed at the Pendembu nursery site. Of the 30 clones introduced from the Reading University in 2015 by the Agriculture for Development (A4D) Project, five survived and four were budded and transplanted at Kpuwabu (111 budded plants of CCN51, 180 budded plants of MO20, 4 budded plants of PA 88 and 10 budded plants of MAN15/60). Additionally, thirty-nine (39) clones were imported from the reading university quarantine centre under the BAFS project. These have been budded and 27 of them survived and planted.

Under the Agricultural Value Chain Development Project (AVDP), an International Consultant (cocoa breeder) was hired to rebrand the cocoa clonal seed gardens at Pendembu and Kpuwabu. A total of 15 ha comprising 10 ha in Pendembu and 5 ha in Kpuwabu was rebranded. To facilitate this, an MoU between SLARI and the Kew Garden of the Reading University Quarantine (RUQ) Centre was signed for the transfer of Standard Material Transfer (SMT). This MoU has over the years helped the SLARI/KFTCRC to import elite clones of cocoa from the UK.

DEVELOPMENT AND PROMOTION OF COFFEE PRODUCT VALUE CHAIN

A coffee rooting chamber with a capacity of 5,000 cuttings was established at the Pendembu nursery by the BAFS Project under the 11th European Development Funds. Cuttings of the 'high land' coffee (*Coffea stenophylla*) obtained from the Kambui and Kasewe hills were planted in the rooting chamber. The survival rate was extremely poor. Similarly, cuttings of *C. liberica* harvested were established in the rooting chamber. These were transplanted in polythene bags and later at permanent site. The *C. stenophylla* and *C. liberica* coffee could provide a niche market due to their availability in the country and high global demand.

The BAFS Project supported the importation of 10 varieties (MGSCATIGUA' 3, CATUCAI AMARELO (2SL), IAC 125 RN, CATUCAI AMARELO (IAC 62), PAQAISO 2, PAQAISO (H 419-1), TOPAZIO MG 1190, MUNDO NOVO (IAC 379-19), CATUAI VEQMELHO (IAC 144), and OEIRAS MG 6851) of Arabica coffee from Embrapa in Brazil.

DEVELOPMENT AND PROMOTION OF CASHEW PRODUCT VALUE CHAIN

KFTCRC was supplied with 10 varieties (TAN 393, SG 185, SG 278, SG 261, SG 265, SG 273, SG 276, and SG 266) of improved cashew (3.05 ha) at the Kpuwabu clonal garden by the Competitive Cashew Initiative (ComCashew) Programme through the Solidaridad West Africa (SWA SL) project for establishment of cashew clonal garden. Additionally, another 8 varieties of improved cashew seedlings (2 ha) were supplied to KFTCRC by ComCashew and transplanted in the field at the Pendembu clonal seed garden. The KFTCRC has acquired 2 ha of land at Bombali Shebureh for the establishment of cashew clonal garden under the BAFS Project.

DEVELOPMENT AND PROMOTION OF OIL PALM CROP PRODUCT VALUE CHAIN

Oil palm germplasm was established for oil palm breeding programme during 2018 at Pendembu. The oil palm breeding plots and NAIFOR varieties at Pendembu are regularly maintained in Pendembu and Kpuwabu.

DEVELOPMENT AND PROMOTION OF FRUIT CROP PRODUCT VALUE CHAIN

Grafted fruit trees obtained from Guinea have been fully established at the Pendembu clonal seed garden using the randomized complete block (RCB) design. The following have been established at Pendembu: Five varieties of mango viz-a-viz Keith (73 seedlings i.e. 0.72 ha), Kent (70 seedlings i.e. 0.7 ha), Palmer (75 seedlings i.e. 0.76 ha), Eldon (65 seedlings i.e. 0.64 ha) and Irwin (67 seedlings representing 0.68 ha) at a planting distance of 10 m × 10m; four varieties of citrus viz-aviz Pemplemousse (102 seedlings i.e. 0.67 ha), Nandarine (101 seedlings i.e. 0.65 ha), Sokotoro (41 seedlings i.e. 0.28 ha) and Timbo (35 seedlings occupying 0.24 ha) at a planting distance of 8 m × 8 m; one variety of lime i.e. *Lime tapriti* (11 seedlings occupying 0.012 ha) at a planting distance of 4 m × 4m; three varieties of avocado viz-a-viz Polock (20 seedlings i.e. 0.13 ha), Lula (20 seedlings i.e. 0.13 ha) and Avocado seedlings (77 seedlings i.e. 0.49 ha) at a planting distance of 8 m × 8 m and three varieties of banana viz-a-viz Grande naime (102 seedlings i.e. 0.16 ha), FHIA -23 (85 seedlings i.e. 0.14 ha) and SH –L45 (90 seedlings i.e. 0.14 ha) planted at 4 m × 4 m. Hence, a total of 6.7 ha (83.75%) of grafted fruit trees have been established. It is hoped that when local germplasms must have been collected, the improved fruit trees will be grafted onto the remaining 1.3 ha (16.25%) prior to the end of the project.

AGROFORESTRY

Approximately 2 ha of agroforestry plots have been established at the Bambawo research station. Two experimental plots were established with Tectona grandis being intercropped with Theobroma cacao L. and so also is *Terminalia ivorensis*. Seedlings of certain economic trees and cocoa/cashew will be nursed this year so that several mini-experimental plots with different variables will be compared to achieve maximum and reliable results that may be recommended to smallholder farmers. The first experimental plot contains *T. ivorensis* with cocoa which has a spacing of 3 m x 3 m in between rows was established on the 13th September, 2019. The second plot contains Tectona grandis intercropped with cocoa and was planted on the 16th of October 2019 with the same spacing of 3 m × 3 m in between rows.

D. KABALA HORTICULTURAL CROPS RESEARCH CENTRE (KHCRC)

The horticultural crops research programme is implemented at the KHCRC. The Programme is aimed at addressing challenges to enhance sustainable productivity, commercialization, and competitiveness of the horticultural crops.

E. TEKO LIVESTOCK RESEARCH CENTER (TLRC)

The livestock research programme is implemented at the TLRC. The programme is aimed at addressing challenges to enhance sustainable productivity, commercialization, and competitiveness of the livestock farming system. TLRC has two stations: Teko in Makeni, Bombali district and Musaia in Falaba district. TLRC has been implementing two main projects: Smallholder Commercialization and Agribusiness Development Project (SCADeP) and Boosting Agriculture and Food Security (BAFS) Projects.

F. MAGBOSI LAND, WATER AND ENVIRONMENT RESEARCH CENTER (MLWERC)

The land, water and environment research programme is implemented at the MLWERC. The programme is aimed at addressing challenges to enhance sustainable productivity, commercialization, and competitiveness of the agricultural product value chains. This is achieved through: (i) improvement on the contribution of integrated soil fertility management on agricultural product value chains; (ii) improvement on the contribution of soil and water management on agricultural product value chains; (iii) improvement on the contribution of irrigation and drainage on agricultural product value chains; (iv) improvement on the contribution of soil survey, land evaluation and land use planning on agricultural product value chains; and (v) improvement on the contribution of sustainable environmental management and climate change mitigation on agricultural product value chains.

WORKSHOP/ TRAINING

1. Janatu V. Sesay attended capacity building training on Enhancing the concurrent selection and evaluation of biofortified and bio-enriched varieties derived from mutant rice, cassava and other crops (IAEA Project FS-SIL5020-1801894) in National Crops Resources Research Institute, Namulonge, Kampala –Uganda on 18th June 2018 to 17th August 2018.
2. Ernest G. Kamara and Kadiatu N. Serry were trained on the Semi-Autotrophic Hydroponics (SAH) technique at IITA, Ibadan, Nigeria from the 13th September to the 24th September, 2018.

PROPOSALS SUBMITTED FOR FUNDING OPPORTUNITY

The oil palm project by Islamic Development Bank (IsDB). Under this project it was hoped that the IsDB will sponsor research on farmers' fields, establish tissue culture laboratory at Pendembu and train 2 staff to PhD in Breeding and entomology at the University of Malaysia (the two PhD staff were trained although the other staff have not been able to complete his programme). It was also hoped that the IsDB train 2 laboratory technicians to run the tissue culture laboratory. The project budget is one million dollars (US$ 1,000,000). However, SLARI has not been able to access the funds probably due to reasons beyond the understanding of the KFTCRC management. There is the need to make a follow-up on this at the NAO.

The Food and Agriculture Organisation (FAO) of the United Nations approached KFTCRC for the development of a proposal leading to the development of an 'oil palm mode farms' across the country. This proposal has been developed to the tune of $368,025 and await funding or further negotiations.

The KFTCRC also has collaboratively worked with the Solidaridad West Africa to develop a concept note on the 'REDDA' grant call. The acronym stands for Reversing Environmental Degradation in Africa and Asia. The proposal if approved will be dubbed 'Community-led Ecosystem Restoration and Climate-resilience (CERC) Project'. The proposal developed is to the tune of £1,500,000.

Proposal was also written and submitted to the Agricultural Value Chain Development Project (AVDP – approved and implementation is in progress) to the tune of $250,000 for the development of the clonal gardens at Pendembu and Kpuwabu. This has been submitted to the donor for a 'no objection'. The proposal has been approved and the first tranche of 40% of the funds is yet to be disbursed for commencement of operation.

One of the other scientists (Edward Amara) that was attached to ICRAF has completed his PhD at Helsinki University in Finland. Also, Mohamed M. Luseni is pursuing his PhD through a sandwich programme i.e. collected data in Sierra Leone and is currently at the Swedish University of Agricultural Sciences. Sidique Kutubu has recently submitted his PhD thesis but has not been awarded the doctorate degree yet on the grounds that he needs to address comments from external examiners in Pakistan. Paul Musa Lahai is on his PhD at the Njala University under the sponsorship of the AVDP. He has completed in-country data collection and analysis and is awaiting the molecular analysis results from the United States Department of Agriculture (USDA).

SLARI PUBLICATIONS 2013-2018

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3. BOOK CHAPTERS AND ABSTRACTS

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Land, Water and Environment Research Programme at the Magbosi Land, Water and Environment Research Center (MLWERC), Mile 91.

APPENDICES

PHOTO SHOP