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Successful innovations and lessons learnt in cassava improvement and deployment by IITA in the Eastern African Region

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Abstract

The International Institute of Tropical of Agriculture (IITA) established its East and Southern Africa Regional Research Centre (ESARC) in Uganda at the former Namulonge Agricultural and Animal Research Institute (NAARI), presently Namulonge Animal and Crops Research Institute (NaCRRI), to address issues of cassava, banana, and plantain development; coordinate all related activities, and work closely with the national agricultural research institutes (NARS). IITA-ESARC began extensive cassava germplasm development to counter the pandemic of African cassava mosaic disease (ACMD) in the region in 1995 through the Eastern Africa Root Crops Research Network (EARRNET). More than 100,000 seeds were evaluated through the conventional plant breeding scheme. Selected genotypes were kept in *in-situ* conservation from where the regional cassava national programs selected clones for further evaluation in their own countries. Burundi, Democratic Republic of Congo (DRC), Kenya, Rwanda, Tanzania, and Uganda benefited immensely. Through EARRNET, the region gained significantly from the large germplasm base to mitigate the scourge of ACMD and the production of cassava was restored. A new joint effort that was established between Catholic Relief Services and IITA in collaboration with the NARS and other stakeholders promoted the adoption of improved germplasm through participatory variety selection. The breeding approach used enabled to reduce selection period for NARS to release new varieties to farmers as they received elite materials for evaluation. However, the spread of cassava brown streak disease (CBSD) in mid altitude threatened the achievements already made as the new disease attacked most of the ACMD-resistant and high yielding varieties. Its spread in the region calls for more effective collaborative action than before from IITA and its partners to develop new resistant materials to mitigate the effects of both ACMD and CBSD. The present paper attempts to summarize the breeding work efforts made and demonstrate how the germplasm development at this regional center has been useful to the region through effective partnership.

Keywords: cassava mosaic disease, cassava brown streak disease, germplasm development, exchange, partnership and participatory variety selection

Introduction

Cassava provides the means of livelihood for up to 500 million farmers and countless processors and traders around the world. . It is a source of food security, not only because it can be grown on less productive land, but also because it provides income for producers and is generally a low-cost source of food ([3]). However, from 1988, severe epidemics of a new variant of African Cassava Mosaic Disease (ACMD) traversed Uganda from north to south and caused devastating losses and food shortages ([11])). There was almost total infection of the cassava crop with very severe symptoms in most parts of the country. As a result, farmers became discouraged and in the absence of adequate amounts of healthy planting material, they abandoned the growing of cassava. Annual losses were estimated at over 60,000 ha of cassava, equivalent to over 600,000 tonnes of fresh cassava with an estimated value of US$60 million ([12]). Disease surveys and local reports confirmed that the new variant of ACMD had spread into the Democratic Republic of Congo (DRC), Kenya, Rwanda, and Tanzania, causing yield losses of up to 90%. Many farmers were forced to abandon the crop, causing localized famine and revenue losses of more than US$1 million in Kenya alone ([6]). In 1994, IITA established its regional office [then Eastern and Southern Africa Research Center (ESARC*)] in Uganda at Namulonge Agricultural and Animal Research Institute (NAARI**) to address issues of cassava, banana and plantain in East and Southern Africa, coordinate all related activities, and work closely with the NARS. IITA-ESARC scientists began extensive development of cassava germplasm to counter the pandemic in the region in 1995 ([12]). IITA together with the former Eastern Africa Root Crops Research Network (EARRNET) developed an extensive cassava breeding program. Different projects have taken advantage of the considerable amount of experience gained by IITA and its partners, mainly the NARS, NGOs, and the private sector in the region over a period of more than 15 years in seeking to mitigate the effects of ACMD. Different approaches have been adopted in multiplying and distributing planting materials of improved ACMD-resistant varieties. Important lessons have been leant on the attitude and requirements of farmers regarding their choice of varieties, especially when the crisis in production had been overcome and criteria other than virus-resistance became paramount. This then emphasized the importance of variety selection done to meet changing requirements and with the farmers' full participation.

This paper summarizes the breeding efforts made in the Eastern African region to mitigate the scourge of disease using conventional plant breeding methods and participatory approaches.

Notes: * After the East and Southern Africa Regional Center (ESARC) was transferred to Tanzania in 2006, the Ugandan center became known as IITA-Uganda

** NAARI later became National Crop Resources and Research Institute (NaCRRI)

Materials and Methods:

IITA opened its cassava work in Uganda with the introduction of thousands of seeds from IITA-Nigeria with multiple resistance to pests and diseases (along with other attributes) and conducted evaluations first at Namulonge research station since 1995. Later these were expanded in 1996 to Serere Agricultural and Animal production Institute (SAARI). These two sites differ in that Namulonge is mid-altitude with high rainfall (selections made there were therefore designated “MH”) while Serere is mid-altitude with medium rainfall (MM). More germplasm was introduced to the program in the form of botanical seeds and tissue culture plantlets. Additionally, full-sib and half-sib seeds were collected within the program from introduced germplasm, local varieties, and their crosses.

Germplasm evaluation scheme

A 4-stage methodology was adapted and used in the evaluation of the materials. These were seedling, clonal and performance evaluation, and finally conservation. In each stage strong selection pressure was exerted against susceptibility to ACMD, cassava bacterial blight (CBB) and cassava green mite (CGM); low yielding ability, high cyanogenic potential (CNp), low dry matter content (DM) and poor agronomic characteristics.

Seedling evaluation:

Direct planting of seeds was done in Serere and from time to time at Namulonge. The seed beds were prepared with a spacing of 20 cm between seeds and 1 m between rows. A variety susceptible to ACMD was planted as a spreader. Biotic data for major stresses (ACMD, CGM, CBB, and cassava anthracnose (CAD) were taken. Selection was done by IITA in collaboration with staff from the National Cassava Program of Uganda – National Agricultural Research

Organisation (NARO) for yield potential attributes at 12 months after planting (MAP). Those accessions selected were advanced to clonal evaluation.

Clonal evaluation:
Single row plots of 10 m^2 with 1 m ×1 m spacing were used. A local check common in the location was used, such as Tereka, Bao and Alado. Data were collected on the major biotic stresses as listed below. Selection was done at 12 MAP based on yielding ability, disease resistance, root quality, and other plant characteristics.

Disease and pest scoring system
Disease/pest damage incidence (Count of infected plants)

0%:	Resistant
> 0–10%:	Moderately resistant
> 10–25%:	Moderately susceptible
> 25–50%:	Susceptible
> 50%:	Highly susceptible

Disease/pest damage severity (Extent of damage)

1.0–1.3:	Resistant
> 1.3–2.0:	Moderately resistant
> 2.0–2.3:	Moderately susceptible
> 2.3–3.0:	Susceptible
> 3.0:	Highly susceptible

Performance evaluation:
Clones were planted in plots of 3 × 10 m, replicated three times with one check per replication in the preliminary yield trial (PTY). Biotic data were collected as in the above trials but selection at harvest was very strict. Those selected needed to have the desired traits such as resistance to the above mentioned biotic stresses as well as good root qualities and agronomic characteristics. Selected clones were qualified for conservation. However, in some cases, the performance trial was repeated for two more years before conservation. National program breeders of Kenya and Rwanda participated in some years in the evaluation process and selected clones potentially suitable for their countries. DRC and Burundi benefited from the germplasm introduced into Rwanda. These were the first introductions by NARS using the exchange of cuttings through the Open Quarantine facility arrangement as agreed by the network during its Steering Committee meeting.

Between 1995 and 2007, approximately 3 to 3.5 million botanical seeds of cassava were evaluated, representing several hundred families of improved broad-based and special trait populations. Over 28,000 clones were advanced to clonal level and 5,954 clones were advanced to yield performance trials. Out of the performance trials, selected genotypes were cumulatively bulked under improved conservation germplasm characterized with broad-based populations that combined multiple pest/disease resistance and the desired agronomic characters.

Table 1. Materials evaluated at each stage by season 1995– 2007 at Namulonge and Serere Research Stations.

	Stages of evaluation			
Seasons	**Sib-families**	**Clonal**	**Performance**	**Improved cultivars**
1995/1996	1,670	426	-	-
1996/1997	858	10,040	130	-
1997/1998	1,083	5,800	2,005	-
1998/1999	181	4,928	740	626
1999/2000	-	138	695	536
2000/2001	404	1,780	691	295
2001/2002	192	1,846	227	560
2002/2003	-	2,093	269	359
2003/2004	-	-	490 (*)	112
2004/2005	-	-	276 (*)	0
2005/2006	724	-	155 (*)	0
2006/2007	86	736	-	113
2007/2008	59	541	276	0
Total	5,257	28,328	5,954	2,601

* The performance trial of 2003/2004 was evaluated in three consecutive years before conservation

Conservation:

The first conservation of germplasm was established in 1998 and over the years materials were accumulated and added to it. However, the collection was not static, since materials were periodically re-evaluated to eliminate those that broke down to ACMD as well as for other attributes. A total of 2,600 elite materials were developed through the breeding cycles carried out between 1995 and 2007 (Table 1).

Results and Discussions

Among the populations some clones, such as MH05/0414, MH97/2961, and I91/2324, had such high levels of resistance to the Ugandan variant of cassava mosaic (ACMD/UgV) that they could be considered as nearly immune. Available clones now had higher potential performances characterized by multiple resistance to the major biotic stresses, earliness, higher DM contents (40–45%) and better yields (> 50 t/ha) with low CNp.

However, following the outbreak of cassava brown streak disease (CBSD) in the mid-altitude in Uganda around 2005, the number of improved genotypes dropped from 2,600 to 300 because most of the varieties resistant to ACMD were very susceptible to the new disease.

Germplasm introduction through the Open Quarantine Facility system

According to quarantine regulations, the standard procedure for introducing new germplasm between countries requires that it should be introduced via tissue culture. Thereafter, the new materials require screening for local adaptability. This process can take several years, and the lack of local capacity in handling tissue culture means that failure rates can be high. The restrictions on the movement of germplasm have been a major drawback to the expansion of production and utilization of improved cassava varieties.

After approval by the Steering Committee, EARRNET worked then with plant quarantine officials in Kenya, Tanzania, and Uganda to establish Open Quarantine Facilities (OQF) at Alupe (Kenya), and Karama (Rwanda) in 1997 and at Bukoba (Tanzania) in 1999. These facilities made possible the fast-track introduction of improved germplasm from the regional improvement program in Serere, Uganda, to the quarantine sites. There it was observed for one year instead of the usual 3–4 years, before release to the national cassava programs (NCP) for further evaluation and release to farmers ([2]).

After sprouting, the plants were closely inspected (weekly) for any disease symptoms. After every 2 months, inspectors from the post-entry quarantine in each country inspected the plants to make sure that only the apparently disease-free plants would be multiplied after the one-year compulsory confinement in the OQF.

The first introductions of improved clones were made in 1997 by Rwanda (506) and Kenya (503). Two released varieties, Nase 3 and 4 from Uganda were also introduced into Kenya. After release, the clones from quarantine supervision in 1998 formed the basis of multilocational participatory evaluation by farmers in these countries. In Rwanda, these formed the base from which DRC and Burundi obtained their first introduction of improved clones. In 1999, Tanzania introduced 497 clones followed by Southern Sudan with 10 clones. The OQF significantly reduced the cost of establishing cassava using tissue culture material, shortened the time required for evaluation to release of a variety by approximately 3 years and greatly enriched the cassava genetic base of the national germplasm collection. In the situation of the ACMD epidemic, it provided a highly efficient and quick regional solution for the problems of the cassava farming community.

The OQF system was also adopted by IITA to enable the exchange of tolerant/resistant materials in Tanzania. To increase the number of cultivars resistant/tolerant to CBSD available to farmers in Tanzania, about 555 clones were introduced into the OQF established at Kibaha, Tanzania, between March 2003 and November 2004, from what was then the EARRNET breeding program at KARI Mtwapa, near Mombasa, Kenya. Mtwapa was considered the CBSD hot spot.

Disease and yield trends in IITA/EARRNET cassava germplasm over a period of more 10 years

Due to the OQF system, the number of clones increased in all EARRNET countries and even beyond, in Mozambique and South Africa. The highest number of clones was exchanged between 1997 and 2000 with Kenya taking the lead with 1,572 including two varieties officially released in Uganda (Nase 3 and Nase 4). Rwanda followed with 1,546 and Tanzania with 1,441 (Table 2).

Table 2: Advanced cassava clones distributed under OQF and tissue culture facilities to EARRNET member countries 1997–2007.

Countries	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Ethiopia	-	-	-	-	-	-	28	39	117	-	-	184
Rwanda	506	473	187	5	-	308	-	-	51		16	1,546
Kenya	503	219	600	245	-	-	-	-	5	-	-	1,572
Tanzania	-	-	497	500	-	25	419	-	-	-	-	1,441
Burundi	-	-	81	-	-	-	-	200	-		28	309
DRC	-	-	84	-	350	-	-	-	-	-	-	434
S. Sudan	-	-	-	10	-	-	-	5	-	-	-	15
Mozambique	-	-	-	-	-	25	110	0	20	-	-	155
Madagascar	-	-	-	-	-	-	-	-	20	-	-	20
Total	**1,009**	**692**	**1,449**	**760**	**350**	**358**	**557**	**244**	**213**	**0**	**44**	**5,676**

Other direct introductions of IITA-Uganda/ EARRNET germplasm were also made to Burundi and Southern Sudan. Following the rapid success that was registered, the demand for the elite germplasm from IITA-Uganda/EARRNET increased and arrangements were made with Kenya Plant Health and Inspectorate Services (KEPHIS) to put some materials in tissue culture for conservation and distribution to other distant countries such as Madagascar and Ethiopia. However, in 2006, IITA-Uganda/EARRNET banned the supply of materials in the form of cuttings and adopted the tissue culture form due to the CBSD outbreak reported in the country ([9]).

All member countries released a number of varieties ranging from two (Burundi), three (Rwanda) five (DRC) to 24 (Uganda). All these varieties were being promoted among end users ([2]). Preliminary Yield Trials (PYT) indicated 150- 200% increase in yield compared with local checks.

On-farm trials showed that over 40% of the clones showed no CMD symptoms, indicating their potential to halt the spread of the disease in the affected countries (Fig. 1).

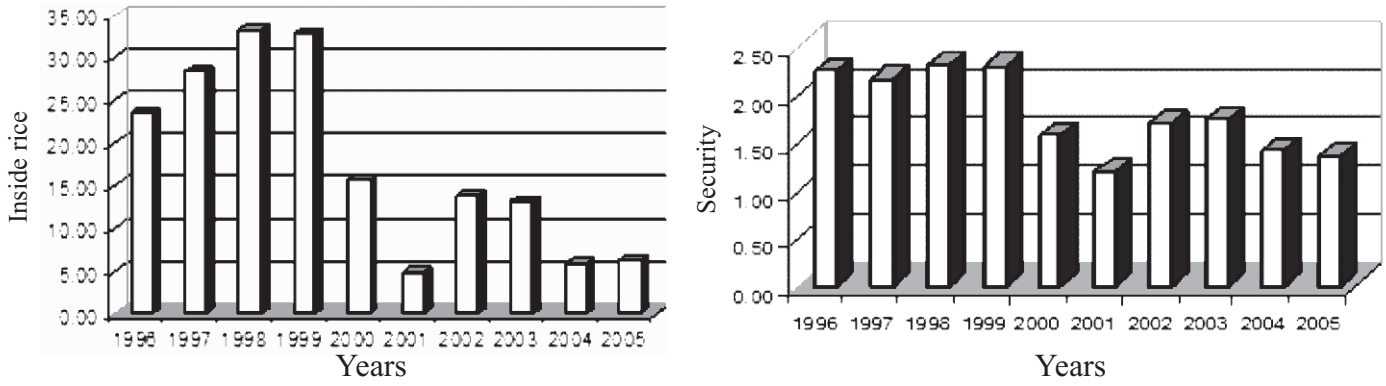

Figure 1. Trend of improvement of resistance to CMD (expressed by incidence and severity) of the germplasm developed over years in Uganda

In Uganda where the regional program was based, the mean on-station yields shifted from about 8 t/ha in local cultivars to about 35–40 t/ha in the improved genotypes over a decade, while the selected genotypes had a DM content above 35% (Fig. 2).

In the epidemic situation, the OQF has provided a highly efficient regional solution to the problems of the cassava farming community.

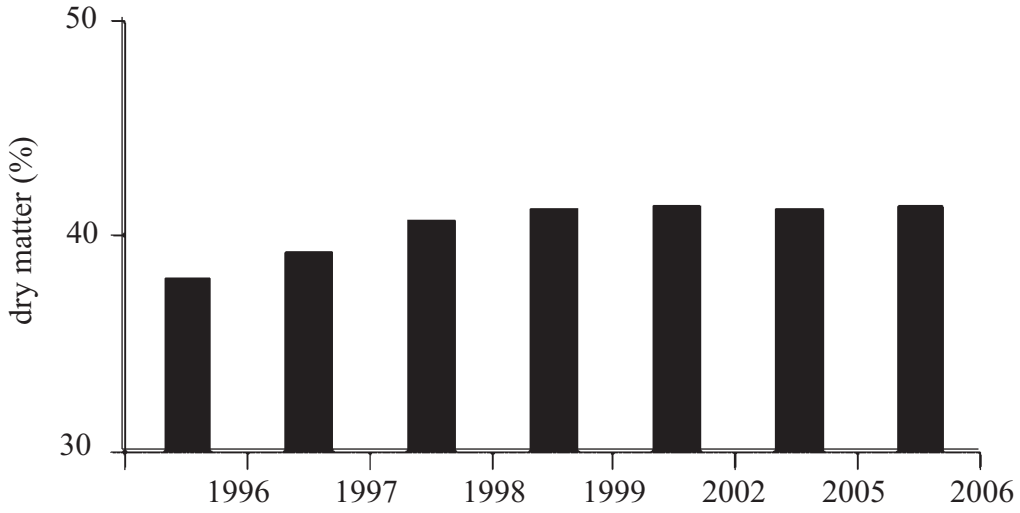

Figure 2. Improvement of DM content in the advanced germplasm over years in the regional breeding program in Uganda

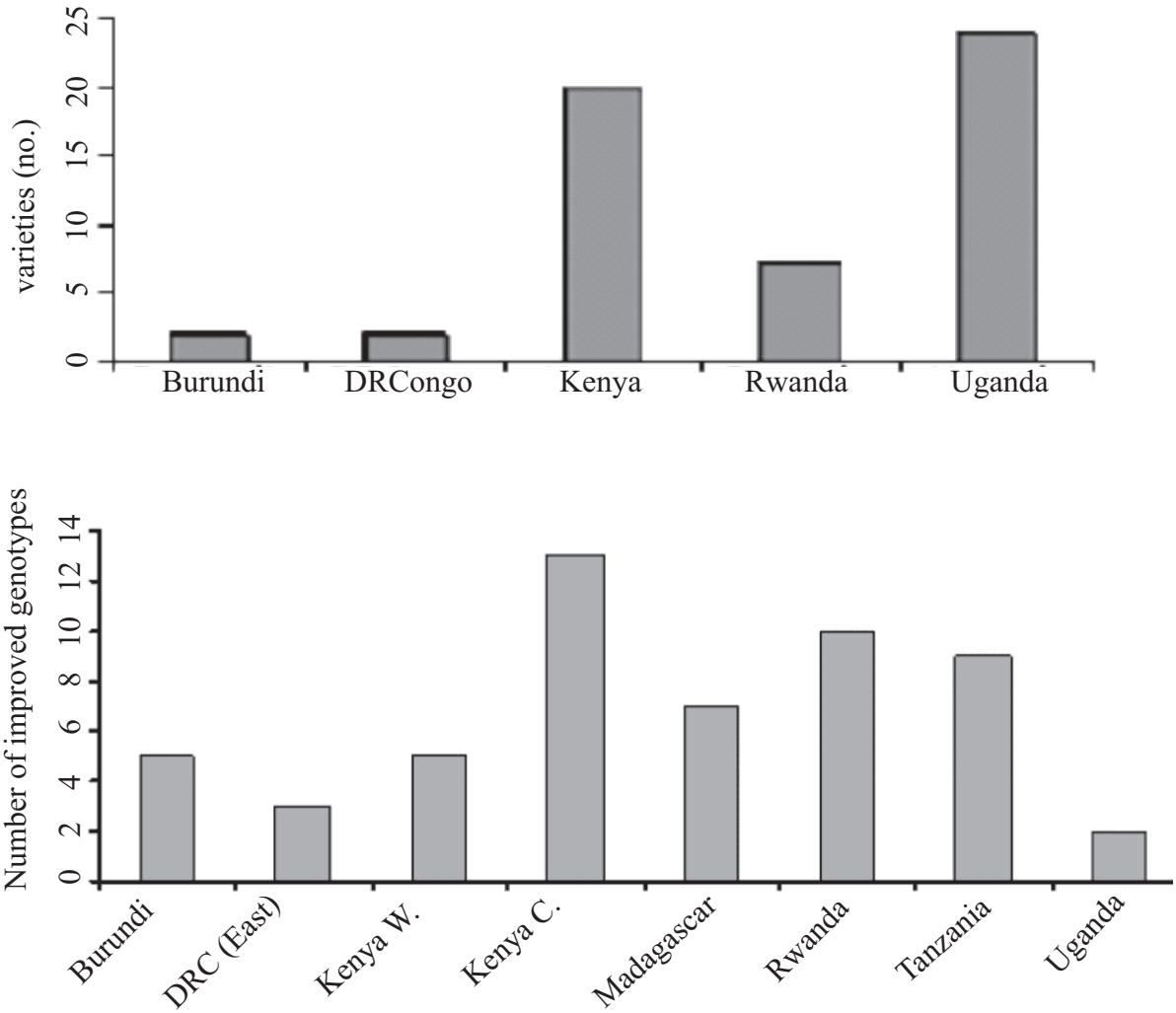

Figure3. Cassava varieties released in 2004 (a) and promoted through on-farm trials (b) in 2007 in EARRNET member countries.

Collaboration with NARS in germplasm evaluation and enhancement

All member countries in EARRNET had access to improved populations and continued to introduce large numbers of improved clones from the mid-altitude ecology at Serere, Uganda, or the lowland ecology at Mtwapa, Kenya . Between 1999 and 2003, a total of 39,000 seedlings were derived from several half-sib families out of which 5,573 and 1724 clones were advanced to Clonal level and to subsequent yield performance trials respectively, in different countries.

The time taken for the NARS to release varieties was considerably made shorter through the elimination of the early stages of evaluation. All clones evaluated in Kenya, Rwanda, and Burundi were introductions, making possible faster progress in releasing or moving towards the release of improved varieties, as evidenced by the proposed number ready for release.

In Burundi, seven varieties that were showing resistance to ACMD with good agronomic performance were tested on-farm and multiplied at a large scale using rapid multiplication techniques by the Ministry of Agriculture in collaboration with the Institut des Sciences Agronomiques du Burundi (ISABU) and different NGOs. The materials which were previously acquired from IITA-Uganda/EARRNET were MM96/5280, MM96/0619, MM96/7688, MM96/2266, ABBEY-IFE, MM96/2352, and MM 96/5533. More genotypes were introduced in 2004 and evaluated in the different agro-ecologies.

In DRC, the germplasm materials initially introduced came from the first batch that was introduced in Rwanda. Later, in 2001, a second introduction was made directly from Uganda to Eastern DRC at Mulungu research station. Extensive evaluation was made and the five most popular genotypes which were preferred and selected by farmers were MM 96/0287 (Liyayi), MM 96/7762 (Mayombe), MM 96/7204 (Namale), MM 96/3920 (Sawa Sawa), Sukisa MM 96/1661 (Sukisa). These genotypes were extensively multiplied and distributed to farmers by FAO and C3P project in both the south and north of Kivu Province and in the Northern part of Katanga Province.

In Kenya, the collaboration on germplasm development was intensified around 1997 when ACMD devastated the crop in the western part of the country. Many advanced yield trials (AYTs) of more than 30 clones each were then evaluated at Kenya Agricultural Research Institute (KARI-Alupe) from 2003, to 2005. In 2005, 18 out of 60 clones were selected for advancement to on-farm trials and 10 best are presented in Table 3. The basis for selection included the following: no CMD symptoms, high yields, low CNp level, high %DM, and low disease incidence of CBB and CAD.

Table 3. Yield performance of 10 best clones selected for on-farm trials in Kenya.

Clone	Mean yield (t/ha)	%DM	CNp
MM98/3567	23.7	45.3	2.5
MH97/0284	20.9	31.7	2.0
I96/1642	20.7	41.1	3.0
MM97/2634	19.5	40.2	2.0
MM98/1596	17.9	35.6	2.5
MH96/0398	16.9	42.7	2.0
MM98/1669	16.8	37.8	2.5
MM98/4105	16.2	42.6	2.0
MM98/2636	15.7	41.2	3.0
MM98/3572	15.6	41.5	3.0
Mean	16.7	40.8	2.6

Source: ([4])

IITA/EARRNET initiated on-farm trial activities using augmented design in Uganda and Kenya to hasten the evaluation of the larger number of genotypes coming out of the AYT. In Kenya, 14 clones were evaluated in seven sites representing six agroecological zones of the major cassava growing areas of Western Kenya. Two improved varieties, SS4 and Migyera (TMS 30572), were used as checks, and where possible the inclusion in the trial of the farmers' best local landrace was encouraged. Cultivars were planted in an unreplicated augmented design where four farmers at a site were assigned five cultivars in such a way that only the two checks appeared on all farms and this arrangement constituted a cluster with a total of 20 farmers used. The farmers provided land and labor and ensured the security of the trials in collaboration with the community and managed the trial plot as they managed their own plots. The researchers provided new planting materials and made regular visits to the trials with farmers. Diseases were scored using a 1–5 scale where 1 = clean and 5 = severely infected. Stakeholders evaluated the clones before and after harvesting based on health status, branching habit, and height, tuber size, and shape, skin color, ease of peeling, texture of boiled tubers, and taste when cooked. Table 4 summarizes the yield results.

Table 4. Root yields (kg/36 m^2) and rankings (in bracket) of genotypes evaluated across six districts in Kenya, 2005 /2006

	Locations					
Clones	**Kuria**	**Migori**	**Rucuonyo**	**Mumias**	**Siaya**	**Teso**
SS4	5.5(14)	5.6(11)	7.2(15)	8.5(18)	12.3(13)	13.9(10)
Migyera(TMS 30572)	4.7(17)	4.3(13)	8.3(13)	12.3(8)	20.6(8)*	13.5(11)
MM96/1871	7.8(5)	-	-	8.7(16)	-	15.6(7)
MM96/3868	6.7(8)	6.3(10)	22.3(1)	26.3(1)**	26.5(4)*	19.7(3)
MM96/4052	5.6(13)	10.0(5)	9.2(12)	13.8(4)	17.0(11)	12.2(12)
MM96/4466	15.0(2)*	8.4(6)	9.9(11)	18.0(3)	21.0(7)	4.5(15)
MM9 6/4684	4.9(16)	-	12.3(7)	9.0(14)	24.6(5)*	
MM96/4884	6.6(9)	13.3(1)	10.0(10)	11.1(10)	11.0(14)	14.3(9)
MM96/5280	8.9(4)	10.1(4)	12.0(8)	13.0(6)	22.8(6)*	19.0(4)
MM96/7151	6.6(10)	-	11.6(9)	11.2(9)	18.1(9)	15.2(8)
MM96/7688	19.8(1)**	-	14.9(3)	13.5(5)	2 6.7(3)*	17.3(6)
MM96/9308	5.9(11)	6.6(8)	14.9(3)	7.5(19)	6.6(15)	21.2(2)
MM96/9362	10.9(3)	6.49()	12.9(5)	8.7(17)	31.6(2)**	9.1(14)
TME14	5.0(15)	11.0(3)	13.8(4)	12.4(7)	17.6(10)	18.9(5)
MH95/0183	6.7(7)	7.1(7)	12.7(6)	10.2(12)	40.2(1)**	9.5(13)
CK2	7 .3(6)	11.0(2)	6.9(16)	10.0(13)	16.7(12)	24.8(1)
Unknown 2	5.8(12)	5.212()	7.7(14)	19.2(2)	-	-
55329	-	-	-	8.9(15)	-	-
Unknown 3	-	-	-	10.9(11)	-	-

* Significantly different at $P \leq 0.05$, *Source*: (4)
** Significantly different at $P \leq 0.01$

Farmers' acceptance of a clone was strongly influenced by root yield, resistance to ACMD, and end use, as had been earlier observed in coastal Kenya. Genotypes MM96/5280, MM96/1871, MM96/4466, and MH95/0183 had high frequency of acceptance across locations while MM96/7151, MM96/7688, TME14, MM96/4684, MM96/3868, Unknown 2, and MM96/4884 were selected at specific locations. The clone MM96/7688 also performed well in DRC, Rwanda, and Burundi ([10]).

Uganda was the base for the IITA germplasm development program for the eastern and southern African region**.** Multi-locational trials were conducted in collaboration with the National Agricultural Research Organization (NARO) and some results (Table 5) show the performance of the advanced materials. Significant differences ($P < 0.01$) were observed among clones for tuber yields with a range from 9.93 t/ha in MH95/0024 to 30.1 t/ha in MH95/0414 while %DM ranged from 32 (TME 14) to 39.7 (95/SE-00088). All clones had CNp levels lower

than the upper limit of 300 µg cyanide equivalent/kg dry weight and the sweet taste was also identified by tasters. Though incidences of ACMD were high, severity ranged from moderate to low with eight clones having mean scores of less than 2.5, indicating good levels of tolerance in the material evaluated. Clones MH95/0414 and 95/SE-00087 showed no ACMD/UgV symptoms. MH95/0414 was released as the best resistant variety however, unfortunately it succumbed to CBSD.

Table 5. Mean performance of selected cassava clones planted in multi-locational trials in Uganda, 2002/2003.

Clone	Yield (t/ha)	%Dry matter	Taste [a]	No. of roots/plant	CNp [b]	CMDI [c]	CMDS [d]
MH95/0414	30.71	36.7	1.26	8.64	90.0	0.0	1.0
95/SE - 00094	29.22	37.6	1.00	6.76	204.0	27.6	2.2
95/SE - 00050	28.08	38.4	1.42	7.64	109.0	25.5	2.7
MH95/0420	24.71	35.7	1 .47	7.77	154.9	15.6	2.1
MH95/0134	23.70	38.3	1.70	6.66	110.0	40.2	3.0
MH95/0161	22.93	36.8	1.26	5.77	133.0	41.7	3.0
95/SE - 00087	21.91	37.4	1.19	8.00	110.0	0.00	1.0
MH95/0349	21.53	34.5	1.21	8.88	272.6	53.5	3.0
MH95/0311	20.28	37.8	1.16	6.88	134.4	28.5	3.0
SS4 (check)	19.15	37.4	1.40	6.65	110.8	10.6	3.0
MH95/0080	19.06	36.5	1.56	6.77	122.1	61.2	3.0
TME 14	18.29	32.0	1.17	5.82	144.5	33.0	1.3
95/SE - 00044	17.97	39.3	1.35	10.3	179.0	33.3	1.3
95/SE - 00088	17.37	39.7	1.26	6.44	144.5	0.00	1.0
MH95/0204	2.16	37.6	1.37	6.94	264.3	17.3	2.2
N a s e (Check)	12.41	39.7	1.04	5.16	179.0	93.0	3.3
MH95/0192	12.20	36.7	1.21	5.38	193.0	65.5	3.0
MH95/0024	9.93	34.5	1.50	7.12	166.0	41.0	2.9

[a]Taste scored on a 1–3 scale (1 = sweet, 2 = slightly bitter, 3 = bitter)
[b]CNp: Cyanogenic potential determined as mg HCN/kg dry weight
[c]CMDI = Cassava mosaic incidence
[d]CMDS = Cassava mosaic severity = scored on a 1–5 scale, 1 = no symptoms, 5 = very severe symptoms
Source: ([4]).

On-farm trials were also carried out in Uganda in collaboration with the national cassava program team: 20 clones were evaluated in three districts of Kumi, Lira, and Nakasongora with 80 farmers using the augmented design. Each farmer received five improved clones plus SS4 as a standard check and a local cultivar of their choice. At harvest, more than 30% of clones, including MM96/4614, MM96/0425, I92/0427, and TME 14, withstood CGM with good leaf retention despite extremely high temperatures in northern Uganda. The results indicated genotypes MM 96/1419 and Alice Local were the best yield performers and most stable across districts. They were widely adapted and considered for promotion. Also specific adaptations were identified with clone MM 96/4614 in Lira and MM 96/0561 in Nakasongola. In terms of farmers' preferences, genotypes MH92/2961, MM96/4614, and Alice Local were preferred in Kumi district and Oko Iyawo (2) and MM96/5312 in Lira district. . Genotypes TME 5, MM96/5312, and Abbey Ife were preferred in Nakasongola district ([7])

In Rwanda, 202 clones planted as a multi-locational performance trial at Rubona (1,800 masl) and at Karama research stations were evaluated in a 3 ×8 m plot with three replications. Mean tuberous root yield in Karama was 7.09 t/ha for the improved variety and

14.4 t/ha for the check whereas in Rubona, it was 18 t/ha and 27.5 t/ha respectively. The improved check (Gakiza) out-yielded almost all the entries at both locations, thus emphasizing the need for the deployment of a broader genetic resource base. Because of the poor yield performance, selections were based on a comparison of the yields of the clones with that of Gakiza ([5]) . The following clones, 94/0263HS/1, MM97/1068, MM97/2480, MM96/7688, and I94/0263HS/1, were selected at Rubona and Karama research stations and taken on-farm for adaptability and acceptability evaluation.

A survey conducted in Burundi and Rwanda by IITA/EARRNET scientists and NARS collaborators in 2001 and 2003 confirmed the severe form of mosaic associated with ACMD-UgV strain) in the two countries. The widely grown local varieties Creolina, Gitamisi, and Gakiza in Rwanda had succumbed to the disease and it was no longer possible for farmers to select clean planting material as everything in farmers' fields was infected. Root yields had declined from between 15 and 20 t/ha to almost zero. Improved clones distributed by IITA/EARRNET and tested in collaboration with scientists from Institut des Sciences Agronomiques du Rwanda (ISAR) showed a remarkable performance (Table 6).

Table 6. Clones evaluated on-farm at Bugesera and Gitarama, Rwanda in 2002/2003.

Clones	Comments
MM96/9488	Very good stand, no ACMD
MM96/7212	Poor stand mild, ACMD
MM96/1961	Good stand, under multiplication
MM96/5280	Good stand, under multiplication
MM96/8299	Poor establishment, high CGM
MM96/7459	CBB, CGM
MM96/7688	Fair and no ACMD
MM96/4266	Less vigorous, but no ACMD
MM96/4935	Clean, poor planting material
MM96/7204	Performing well on - station
MM96/5391	Has mild ACMD
MM96/3920	Very good, under multiplication
MM96/4266	Cle an but non - uniform
MM96/7214	Performing well
MM96/4722	Has ACMD and is non - uniform
MM96/2354	Has die back
MM96/0287	Low level of ACMD, yellow root
MM96/4618	Poor planting material

Source: ([4]).

To summarize:, in 2007 EARRNET countries were multiplying and growing farmers' preferred genotypes which were promoted in special projects through the collaborative efforts of different partners. Burundi had five genotypes (MM96/0287, MM96/7204, MM96/5280, MM96/7688, and ABBEY-IFE), DRC East had five {MM96/0287 (Liyayi), MM96/7762 (Mayombe), MM96/7204 (Namale), MM 96/3920 (Sawa Sawa, MM 96/1661 (Sukisa)}, Kenya had 13 in the Western region MM96/4466, MM96.9308, MM96/3868, MH95/0183, MM97/1403, I92/0427, SS4, Migyera (TMS 30772), MM96/5280, MM96/1871, MM96/7688, MM97/0881, and MM96/7151). Madagascar had seven that were selected from the introduction (A 147/99, A 050/02, 81/00110, TMS 82/00249, TMS 82/011610, 85/00066, TMS 8010), Rwanda had ten best clones (TME 14, 95/NA/00063, I92/0057, MH95/0414, MM96/5280, MM96/3920, MM96/1961, MM96/0287, MM96/7204, MM96/4618). Tanzania had nine in the Lake Region (MM96/4619, MM96/4684, MM96/8450, MM96/8233, MM96/5725, MM96/3075B, I91/0057, I91/0067, I91/00063). Uganda had only two genotypes (MH97/2961 and I92/0067) that were being used for multiplication due to the spread of

CBSD that had attacked most of the ACMD-resistant improved varieties.

Initiation of screening for cassava brown streak disease (CBSD) in the mid-altitude

For quite some time, cassava breeding activities of IITA-Uganda were mainly focused on developing genotypes resistant to ACMD, which had been the major biotic production constraint since the early 1990s. Although CBSD had been reported as long ago as the 1940s, it was dormant in Uganda ([1]). Following the outbreak in 2004, it was realized that the best ACMD-resistant varieties were succumbing to the new disease. A meeting was held of scientists from IITA/EARRNET and NARO to draw up strategies to combat the new threat. A joint exercise was initiated to evaluate and characterize the locally conserved germplasm. Screening began in 2005 with a total of 963 improved genotypes initially conserved in-situ at Serere research station. The trial was established in two sets of genotypes (one with 528 and the second with 435) at Namulonge, Central Uganda, a CBSD hotspot, using a check-plot design with single row plots. The highly susceptible cultivar, TME 204, was used as a spreader and a check. Biotic data were taken at 2, 4, 6, 7, 8, and 9 MAP for ACMD, CBSD, CBB, CAD, and CGM).

The preliminary results indicated that 566 genotypes were resistant to CMD; 410 did not show any foliar and storage root symptoms of CBSD (though they could have been susceptible to ACMD). Six hundred and twenty four showed no foliar signs of CBSD but may have shown root symptoms, while 605 showed no storage root symptoms of CBSD. Two hundred and sixty showed resistance to CBSD (both foliar and storage roots) as well as to ACMD. According to this study, the severity of CBSD increased over time and negatively affected fresh storage root yield. These preliminary results showed some hope of the possibility of identifying sources of field resistance to CBSD ([8]).

Intervention of the crop crisis control project in spreading improved germplasm

IITA/EARRNET in collaboration with Catholic Relief Services (CRS) jointly implemented the crop crisis control project (C3P) which aimed at mitigating the catastrophic effects of ACMD and banana bacterial wilt (BBW) in the East and Central Africa in six countries; Uganda, Kenya, Tanzania, Rwanda, Burundi, and DRC. Activities in the cassava component included building the capacity of CRS partner staff on the production and health issues, identifying sources of clean planting material for multiplication, developing training materials, and monitoring ACMD in the region through surveys.

The project conducted inventory surveys of improved varieties in all six project countries to identify the locations of improved materials to serve as potential sources of planting material, quantify varieties available, and evaluate their quality. The study found enough improved materials that were used by the project (Table 7).

Table 7: Improved varieties found available in C3P countries

Country	Improved varieties identified	Estimat ed quantity of planting cuttings	Estimated area to be covered (ha)
Uganda	TMS I92/0067, MH97/2961	3,258,400	326
DRC	MM96/0287, MM96/3920, MM96/7752	4,563,297	456
Burundi	MM96/0287, MM96/7204, MM96/5280, MM96/7688, Abbey Ife	4,694,685	469
Rwanda	TMS I92/0067, 95/NA/00063, TME 14	5,445,853	544
Kenya	Migyera(TMS 30572), SS 4, MH95/0183	928,800	92
Tanzania	TMS 4(2) 1425, SS 4, MM96/4684, MM96/8450, MM96/4619, 95/NA/00063, TME 14, M96/3075B, Kachaga (Local), MM96/8233, MM96/5725, I92/0067, I92/0057	4,986,308	499

Source: www://c3project.iita.org/

To ensure the materials used in C3P multiplication sites were of good quality, IITA-Uganda developed a Quality Management Protocol (QMP) for cassava multiplication which was applied in all participating countries.

Great Lake Cassava Initiative intervention

Another project, the Great Lake Cassava Initiative (GLCI), a multinational and multi-partnered project, is being implemented jointly by CRS and IITA in East and Central Africa and funded by the Bill and Melinda Gates Foundation. Among its activities, it took the participatory variety selection (PVS) as an approach to provide farmers with choices of varieties from NARS breeding programs with the objective of improving production. Its main objectives are to (a) increase farmers' awareness and their access to improved varieties; (b) give farmers an opportunity to select their preferred cassava varieties for wider dissemination; (c) accelerate seed dissemination of farmers' chosen varieties through farmer-to-farmer exchange mechanisms and as an extension methodology; and (d) to scale up the dissemination and adoption of desirable varieties.

Rwanda established 20 on- farm trials in 2008 season A with a total of seven genotypes: MM96/0287, MM96/3920, MM96/4618, MM96/1961, MH95/0414B, MM96/7204, and MM96/5280. In the second season (B), 31 on -farm trials were planted.
From this one year evaluation three varieties preferred by farmers were selected and the Government and the research institute decided to release them (Table 8)

Table 8: Local names given to the three released improved varieties evaluated under PVS in Rwanda Season A

Variety	Local name given	Characteristics served as a reference to choose local name
MM96/3920	Rwizihiza	Variety with big tubers, so the yield is higher. This allegation should be omitted. Yield at on farm > 18.7 t/ha
*MM96/0287	Mavoka	Yellow variety, similar to an avocado. Tastes good. Yield on -farm > 24.6 t/ha
MM96/7204	Garukunsubire	This variety is addictive -eating it is alleged to ca use people to want to eat more and more. Yield on-farm > 19.9 t/ha

In Kenya, 150 trials were established in May and June 2008 in 10 sites. Each site had 15 PVS trials hosted by farmers' groups. Fifteen improved genotypes from Kenya Agricultural Research Institute (KARI) Kakamega were used: MH95/0198, MIGYERA (TMS 30572); MM96/0814; MM96/1872; MM96/4605; MM96/6966; MM96/7688; MM97/0022; MM97/0293; MM97/0442 MM97/0807; MM97/0881; MM97/1403; MM97/1735, and MM98/0602.
Among these materials farmers appreciated well the performance of some good genotypes such as MH95/0198 and MM97/0022 which out-yielded the local clones.

In Burundi, 32 trials were established in April 2008 in eight sites with six improved genotypes developed on-station by ISABU: MM96/3920, MH97/2961, MH97/1744, MM96/1961, MM96/1666 and MM96/4463. The yields were, however, generally low as a result of poor management.

In Tanzania, PVS was implemented in two regions of the country i.e., Mtwara Region (Coastal mainland) and the Lake Region. Twelve trials were established in Mtwara Region using ten improved genotypes (KBH 2002/1056, KBH 2002/477, KBH 2002/482, KBH 2002/494, KBH 2002/517, KBH 2002/554, NDL 2003/031, NDL 2003/067, NDL 2003/111, and NDL 90/034), plus Cv. Kiroba as the common check for all sites. In the Lake Region, 30 trials were established using eight improved genotypes: XUG15, MM 96/0876, MM 96/4570, MM96/5725, MM 96/7487, TMS 4 (2)1425, UKG 2001/150, and UKG 98/343. The pair wise ranking by farmers for Ukiriguru area showed the most liked genotype was UKG 98/343 followed by MM 96/7487. In Maruku area, the preferred genotype was MM 96/5725 (improved check) followed by UKG 98/343. It was found that farmers ranked the varieties based on following qualities: high yield (many tubers), taste (sweetness), high DM percentage, tuber size (medium), resistance to CMD and CBSD, and growth or vigor. The attributes farmers used in rejecting varieties included poor sprouting ability, low yield, taste (bitterness), susceptibility to CMD and mole rat attack.

In DRC, trials were conducted in North Kivu and South Kivu. Planting materials of suggested

genotypes were limited and so only 15 trials were established with six varieties (MM96/4653, MM96/2023, MM96/4463, MM97/2015, TME419, and MM96/5529) and checks. Though the trials' performance was poor because of poor management and a lack of clear communication, the clone MM tter 96/4653 out- yielded the rest. It was recommended that the trials should be repeated using the same genetic materials with better understanding established between partners on their roles and responsibilities.

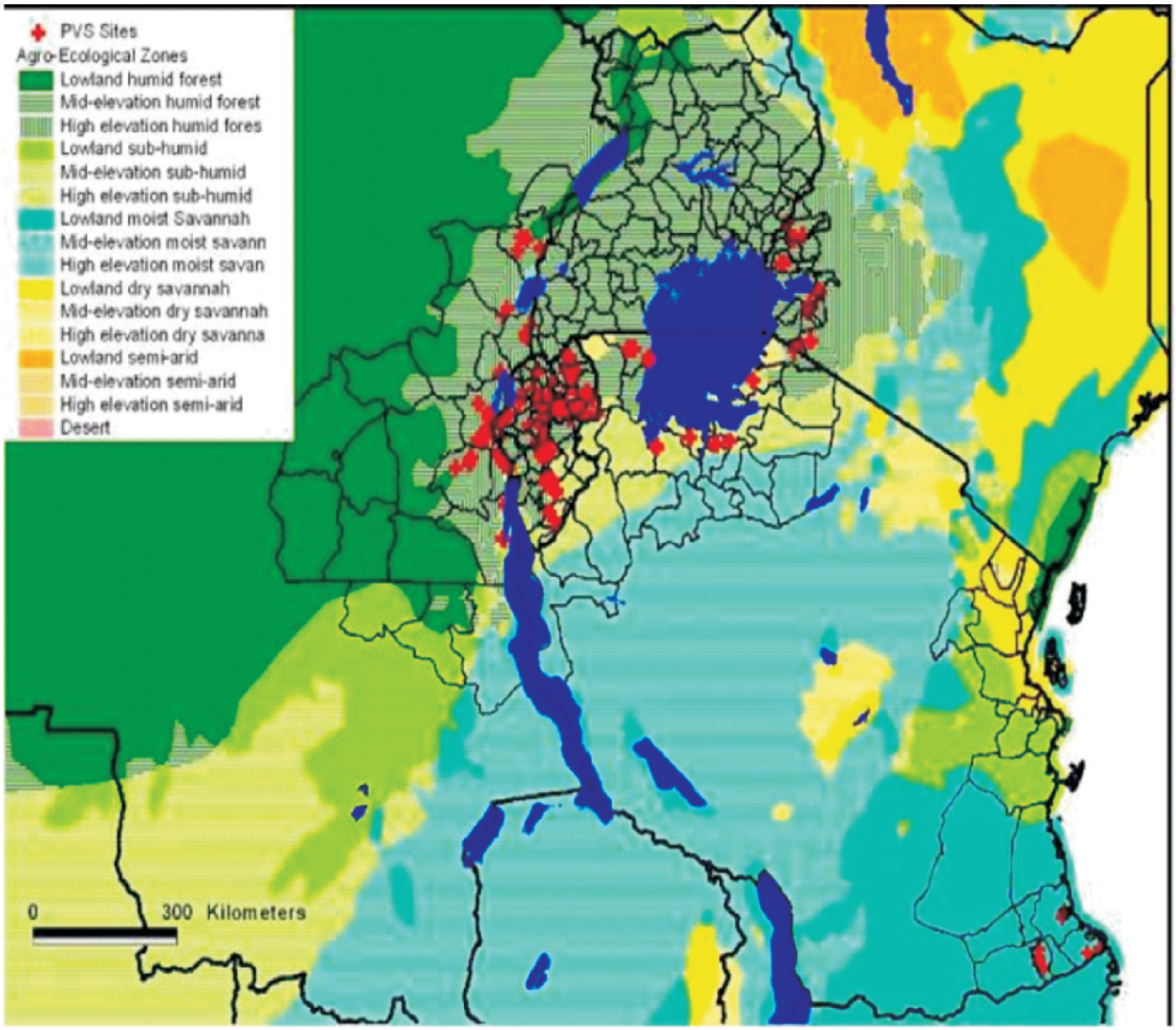

Figure 4. GPS of PVS sites established in the six countries in the Great Lake Region

Conclusions and recommendations

The deployment of IITA germplasm in the Eastern African Region through the former network EARRNET was effective in combating the ACMD pandemic. Significant improvement in yields was recorded in a number of countries. The breeding approach used enabled the selection period to be reduced so NARS released new varieties to farmers as they received elite materials for evaluation. As a result of this success, the application of the approach was proposed in both Western and Southern Africa to speed the access route via germplasm to the improvement of food security. However, the spread of CBSD in Uganda threatened the achievements already made as the new disease attacked most of the ACMD-resistant and high yielding varieties. Its spread through the entire region calls therefore for more effort from IITA and its partners through more effective collaborative action than before to develop new resistant materials to mitigate the effects of both

ACMD and CBSD. Services like those of KEPHIS in cleaning germplasm for CMD and CBSD should be strengthened to facilitate the exchange of the identified potentially resistant materials for urgent further evaluation by NARS in the different agro-ecological conditions of their countries.

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.References

[1]Alicai, T., Omongo, C.A., Maruthi, M.N., Hillocks, R.J., Baguma, Y., Kawuki, R., Bua, A. and Otim-Nape, G.W. 2007. Re-emergence of cassava brown streak disease in Uganda. American Psychopathological Society. Plant Disease 91:1

[2]ASARECA. 2004. Regional commodity research networks in ASARECA: An evaluation of EARRNET, ECABREN, and PRAPACE 1998–2003. ASARECA, Evaluation Report. Entebbe, Uganda.

[3]FAO, 2001. The global cassava development strategy and implementation plan. Vol 1, Rome, Italy. 70 pp.

[4]EARRNET. 2007. Annual performance report of ASARECA Networks and Programs. East African Root Crops Research Network Entebbe, Uganda.

[5]EARRNET, 2004. End of phase II technical report. East African Root Crops Research Network. Entebbe. Uganda.EARRNET. 2006. Annual performance report of ASARECA Networks and Programs. East African Root Crops Research Network Entebbe, Uganda.

[6]Legg, J.P. and Fauquet, C.M. 2004. Cassava mosaic geminiviruses in Africa. Plant Molecular Biology 56: 585–599.

[7]Ntawuruhunga, P., Kiryowa, M., Otim-Okello, F., Okechukwu, R., and Kanju, E. 2007. Preliminary results of screening IITA improved germplasm for resistance to Cassava Brown Streak Disease (CBSD) in Uganda. Presented at ISTRC-AB meeting, Maputo, Mozambique.

[8]Ntawuruhunga, P., Kanobe, C., Ssemakula, G., Ojulong, P., Ragama, J. Whyte, A. Bua. 2006. Evaluation of advanced cassava genotypes in Uganda. African Crops Science Journal 14 (1): 17–25.

[9]Ntawuruhunga, P. and Legg, J. 2007. New spread of cassava brown streak virus disease and its implications for the movement of cassava germplasm in the East and Central African region. http://c3project.iita.org/Doc/A25-CBSDbriefMay6.pdf

[10]Ntawuruhunga, P. and Okidi J. 2010. Eastern Africa Root Crops Research Network (EARRNET) Legacy. 56 pp

[11]Otim-Nape, G.W., Bua, A., Thresh, J.M., Baguma, Y., Ogwal,S., Ssemakula, G.N., Acola, G., Byabakama, B.A., Colvin, J., Cooter, R.J. and Martin, A. 1997. Cassava Mosaic Virus Disease in East Africa and its Control. Natural Resources Institute, Chatham, UK, 100 pp.

[12] Otim-Nape, G.W. 1993. Epidemiology of the African Cassava Mosaic Geminivirus disease in Uganda. PhDthesis, University of Reading, UK. 152 pp.

[13]Otim-Nape, G.W., Bua, A., Ssemakula, G., Acola, G., Baguma, Y., Ogwal, S., and Van der Grift, R. 1995. Cassava development in Uganda: A country case study towards a global cassava development strategy. Proceedings of the validation forum on the global cassava development strategy. Vol 2. A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda, and Bénin, 2005 http://www.fao.org/docrep/009/a0154e/A0154E10.HTM