BREEDING AND SELECTION PAPERS

Breeding orange-fleshed sweetpotato varieties for East Africa

Mwanga R.O.M[1], S. Tumwegamire[1], W. Grüneberg[2] S. Agili[3] and G. N. Ssemakula[4]

[1]International Potato Center (CIP), Box 22274, Kampala, Uganda [(Address correspondence to: r.mwanga@cgiar.org and rmwanga7@gmail.com; Phone-Off.: +256-312266250/1/2/3/4, Cell: +256-772-825725, Fax: +256-414-287947); s.tumwegamire@cgiar.org)]

[2]CIP, La Molina P.O. Box 1558 Lima 12, Peru (w.gruneberg@cgiar.org)

[3]CIP, Box 25171 Nairobi, Kenya (S.agili@cgiar.org)

[4]G.N. Ssemakula, [1]National Agricultural Research Organization (NARO), National Crops Resources Research Institute (NaCRRI), Box 7084 Kampala, Uganda. E-mail: (nankingag@yahoo.com)

Abstract

The area under sweetpotato is expanding faster than any other major food crop in sub-Saharan Africa (SSA) and yet vitamin A deficiency (VAD) is a chronic threat on the continent. Orange-fleshed sweetpotato (OFSP) varieties with high levels of beta-carotene (vitamin A) in storage roots exist for combating the widespread VAD. Minerals and vitamins in food staples eaten globally by the poor may be increased by conventional plant breeding or by use of transgenic techniques, a process known as biofortification. One of the requirements for biofortification to be successful is that the breeding must be successful, which means that high nutrient density must be combined with high yields and high profitability. The International Potato Center (CIP) and collaborating partners introduced approximately 200 sweepotato genotypes from CIP, Lima, Peru, to East Africa over the last decade. CIP and the partners also conducted a genotype by environment (GxE) OFSP trial including mostly landraces between 2004 and 2006 to standardize sweetpotato breeding protocols by collaborators. Although some OFSP landraces had high dry matter (about 30%) desired by consumers and were released in different countries, they did not have high field sweetpotato virus resistance, very much required in the region. Promising OFSP clones from the field tests were included in crossing blocks at Namulonge in Uganda. The program at Namulonge produced breeding populations, a large proportion, about 40%, of which was sent to 14 collaborating SSA countries. Some of the clonal selections from these populations are about to be released by different countries. Currently, it takes 7-8 years to breed deep OFSP varieties adapted to local conditions because the high beta-carotene must be combined in the same genetic background with high yield and other desirable important traits. To shorten the breeding cycle, CIP proposes to centrally generate by population improvement diverse populations for national programs to use to produce a wide range of varieties that have the preferred trait combinations required by farmers and consumers in their countries. The proposed breeding scheme will use "accelerated breeding", exploit heterosis, and use molecular markers to achieve rapid progress in producing new adapted sweetpotato varieties.

Keywords: Sweetpotato virus disease, SPVD, *Alternaria bataticola* blight, biomass yield.

Introduction

The area under sweetpotato is expanding faster than any other major food crop in sub-Saharan Africa (SSA) and yet vitamin A deficiency (VAD) is a chronic threat on the continent. Orange-fleshed sweetpotato (OFSP) varieties with high levels of beta-carotene (provitamin A) in storage roots exist for combating the widespread VAD. Malnutrition among young children is increasing in SSA. Vitamin A is an essential micronutrient for humans. Globally, 127 million children under six years of age are estimated to be affected (West, 2002). SSA and India have the highest estimated prevalence rates of sub-clinical VAD. VAD limits growth, weakens immunity, causes xeropthalmia leading to blindness, and increases mortality (Sommer and West, 1996). There are two forms of vitamin A available in foods: preformed retinol (vitamin A) found in animal foods such as milk, liver, milk and eggs, and provitamin A carotenoids obtained from plant foods such as yellow and orange vegetables, dark green leafy vegetables, and fruits, and OFSP (McLaren and Frigg, 2001). β-carotene is the major provitamin A carotenoid, and the main carotenoid in OFSP. Poor households normally cannot afford to consume the highly bioavailable animal foods in their normal diet. High rates of deficiency in the major micronutrients (vitamin A, iron, and zinc) are prevalent among poor populations that depend on plant-based diets (Hess

et al., 2005). Most plant sources of vitamin A are seasonal, and after provitamin A carotenoids are absorbed into the body, they must be converted into retinol for use by the body. Rates of conversion vary among carotenoid containing plant foods (up to five fold) and also depend on other foods consumed at the same time (e.g., fat increases absorption) and the health status of the individual. More deficient individuals absorb and/or convert at higher rates than replete individuals. Heat processing may also enhance conversion rates compared to the raw product, depending on the plant matrix (Hess et al., 2005). Current guidelines express provitamin A activity in Retinol Activity Equivalents (RAE). In the RAE definition it is assumed that 16.7% of the ingested beta-carotene is absorbed and 50% is converted to retinol. The result is an average conversion factor of 12 units of betacarotene to form 1 RAE. Most dark green leafy vegetables are possibly less bioavailable than this, while palm oil is far superior (2:1 conversion factor). On the contrary, the conversion factor for preformed retinol from animal sources is 1:1 and for other provitamin A carotenoids 24:1 (Institute of Medicine, 2001). In a recent studies Africa, evidence was presented regarding the potential impact of OFSP on young child vitamin A status. The study demonstrated that OFSP is bioavailable and efficacious in improving vitamin A status in children (Jaarsveld et al, 2005). In another study, significant improvements in vitamin A intake and serum retinol concentrations (a proxy for vitamin A status) were obtained from an action-research project of an OFSP-based integrated agriculture-nutrition-market intervention in a very resource poor setting in Central Mozambique (Low et al., 2007). The study in Mozambique emphasized the importance of having the three important components (agriculture, nutrition and market interventions) to ensure improvement in young child vitamin A intakes and sustained adoption of the new material. In a third study, Haskell et al. (2004) using isotopic tracer deuterated retinol to estimate total vitamin A stores in 14 Bangladeshi men determined a conversion factor of 13:1 for OFSP when it was cooked pureed with a small amount of oil.

OFSP as a staple food has advantage over most vegetables because it can supply significant amounts of vitamin A and energy simultaneously, thereby helping to reduce both VAD and undernutrition. OFSP is an example of a biofortified crop in which the micronutrient status of staple foods is improved by plant breeding to the point where impact on micronutrient status can be achieved (Bouis, 2002). Because the poorest households normally obtained over 60% of their energy needs from food staples, this strategy is especially suited to poor rural households that cannot access purchased fortified food products but could grow OFSP. Due to the urgent need to address widespread VAD in SSA, the development and use of betacarotene-rich OFSP roots deserves special attention. One of the requirements for biofortification to be successful is that the breeding must be successful, which means that high nutrient density must be combined with high yields and high profitability.

Materials and Methods

Sources of OFSP: There were three sources of OFSP:

a) During 1990s, CIP began introducing OFSP clones collaborating with National Agricultural Research Institute (NARI) partners. Most existing varieties in SSA then were white or yellow-fleshed. SSA countries received approximately 200 clones as in vitro sweepotato plantlets directly or indirectly from CIP, Lima, Peru, via CIP, Muguga, Kenya (Mwanga and Ssemakula, 2010).

b) Twenty pathogen tested OFSP clones were sent in November 2002 as in vitro plantlets (2 per clone) from the International Potato Center (CIP), Lima, Peru to CIP, Muguga, Kenya, and Namulonge, Uganda. The 20 OFSP clones had been bred by CIP in Lima for high dry matter content. The clones were micropropagated in 2003 in tissue culture laboratories at Mugaga and Namulonge, and then propagated in aphid proof screenhouses. In 2004 an evaluation of the clones to establish adaptability was conducted in four locations in Uganda, at Namulonge, Kachwekano, Ngetta, and Serere (Table 1).

c) In 2004/2005 15 pathogen tested sweetpotato clones, most of them landraces and from different countries were sent by CIP Muguga, Kenya to different countries in SSA to conduct genotype by environment (GxE) trials. The clones were: Carrot C, (deep orange), Mayai (deep orange), and Ukerewe from Tanzania; 199062.1 (breeding line) from CIP, Lima; K135 (orange), Zambezi (deep orange) from Zambia; K566632, Pipi, K118, and Kakamega (SPK004) (yellow/orange) from Kenya, Ejumula (check for beta-carotene content), and NASPOT 1 (check for root yield) from Uganda, Resisto - originally from USA (check for beta-carotene content), Jonathan originally from USA (check for beta-carotene content). Based on

the results of trials in Uganda and GxE trials in 15 countries, the individual countries went to scale with promising clones, and countries with active sweetpotato breeding programs included the most promising clones in their crossing blocks.

In Uganda the the trials were planted in June/July 2004 following experimental details described below for the regional trial. Based on the performance of the clones in 2004 in Uganda, in 2005 mini vine cuttings of seven promising clones in Uganda were sent from CIP Muguga to collaborators in seven countries, namely, Democratic Republic of Congo, Ethiopia, Kenya, Madagascar, Rwanda, Tanzania, and Uganda. Each country selected at least three trial sites representing low, 0 to 1,000 meters above sea level (m.a.s.l.), mid, 1,000 to 1,500 m.a.s.l., and high, above 1,500 m.a.s.l. altitudes. The site selection was based on altitude or clearly distinct agro-climatic conditions.

OFSP GxE regional trials: In the GxE trials the clones were selected based on the availability of OFSP vines in each country. SPK004 was used as a common check because it had been already introduced in the participating countries before the conduct of the experiment. Mini cuttings were propagated in the field. Planting materials were vine tip cuttings, about 30 cm long. Each clone was planted in 4 rows, 1 m apart, 6 m long, 0.3 m between plants (33,300 plants ha^{-1}) in 3 replications in a randomized complete block. The trials were planted between mid to late 2005, and were harvested 4-6 months after planting depending on elevation. Standard data sheets were provided for collecting data during the growth period on establishment, vigour, sweetpotato virus disease (SPVD), Alternaria blight, and at harvest on stand count, vine weight, and root characteristics, including taste and acceptability. The middle rows of each plot were harvested for data analysis. For the GxE data were analyzed only for countries and sites that had complete data sets. Sites and countries that had missing clones or inconsistent data were excluded from the analysis. Information on status of crossing blocks, number of clones at different stages in the sweetpotato breeding cycle in each country was obtained from reports during an annual sweetpotato breeding meeting in Mukono, Uganda, in June 2010.

Results

Almost 100% of the OFSP clones received and evaluated in different agroecologies in Uganda were not adapted to the growing conditions. The clones were not suitable for local consumption; they had low dry matter content (DMC); were susceptible to *Alternaria bataticola* blight at high altitude, and at lower altitudes under high SPVD pressure, the most devastating disease of the crop in SSA (Table 1). Promising clones were included in crossing blocks at the National Crops Resources Research Institute (NaCRRI) at Namulonge and other countries in East Africa. Promising OFSP clones (Table 2) were released and disseminated in different countries (Table 3). The Uganda National Sweetpotato Program at NaCRRI under the National Agricultural Research Organization (NARO) in collaboration with the PRAPACE Network, was responsible for improving sweetpotato for SPVD resistance. The program focused on combining desirable traits in a genetic background with SPVD resistance; it generated breeding populations (seed) between 2002 and 2009. About 20-40% of the seed was sent to collaborating countries, Burundi, Ethiopia, Rwanda, Kenya, Tanzania, Madagascar, Ghana, Nigeria, Malawi, Mozambique, Zambia, South Africa, and Burkina Faso. For example, about 471,400 seed was sent out from Uganda in 2007/2008 to 14 collaborating countries in SSA. The parents in the crossing blocks were exploited to produce populations that combine important traits such as resistance to SPVD and *A. bataticola* blight, high -carotene concentration; high DMC (30% or more); good root shape; and high biomass. Table 3 shows the current status of OFSP clones in East and Central Africa as a result of screening, evaluation, and selection from introductions, landraces, and breeding materials. Varieties Kakamega, Ejumula, NASPOT 9 O (Namulonge sweetpotato orange-fleshed) and NASPOT 10 O have been introduced into several African countries.

Discussion

Although some OFSP landraces had high dry matter (about 30%)(Table 2) desired by consumers and farmers and were released in different countries (Table 3), they did not have high field sweetpotato virus resistance, very much required in the region. Promising OFSP clones based on field evaluations were included in crossing blocks at Namulonge in Uganda and other African countries. The program at Namulonge produced breeding populations, a large proportion, about 40%, of which was sent to 14 collaborating SSA countries. Some of the clonal selections from these populations are about

to be released by different countries. Currently, in countries with two seasons in a year, it takes 7-8 years to breed deep OFSP varieties adapted to local conditions because the high beta-carotene must be combined in the same genetic background with high yield and other desirable important traits (Andrade et al. 2009; Grüneberg et al. 2009). To shorten the breeding cycle, CIP proposes to centrally generate by population improvement diverse populations for national programs to use to produce a wide range of genotypes that have the preferred trait combinations required by farmers and consumers in their countries. The proposed breeding scheme will use "accelerated breeding" to reduce the sweetpotato breeding cycle from eight to about four years (Grüneberg et al. 2009). The accelerated sweetpotato breeding method which involves rapid multiplication of genotypes from seedlings, and early evaluation of the genotypes and families in multiple environments, is also used by national programs for selecting new varieties. Near infrared spectroscopy (NIRS) will be used for rapid analysis of quality attributes (Andrade et al. 2009). In population improvement, heterosis will be exploited, and development, validation and use of molecular markers will complement the efforts to achieve rapid progress in producing new adapted sweetpotato varieties.

Acknowledgment

We thank the McKnight Foundation, HarvestPlus, NARO, and the NARS in the participating countries for supporting the research.

References

Andrade, M. I. Barker, H. Dapaah, H. Elliot, S. Fuentes, W. *Grüneberg*, R. Kapinga, j. Kroschel, R. Labarta, B. Lemaga, C. Loechl, J. Low, J. Lynam, R. Mwanga, O. Ortiz, A. Oswald and G. Thiele. 2009. Unleashing the potential of sweetpotato in Sub-Saharan Africa: Current challenges and way forward. International Potato Center (CIP), Lima, Peru. Working Paper 2009-1.

Bouis, H. 2002. A new tool for fighting micronutrient malnutrition. Journal of Nutrition 132 (Symposium: Plant breeding): 491S-494S.

Grüneberg, W.J., R.O.M. Mwanga, M. Andrade and J. Espinoza. 2009. Selection methods Part 5: Breeding clonally propagated crops. In: S. Ceccarelli, E.P. Guimarães, E. Weltzien (eds) Plant breeding and Farmer Participation, 275 322. FAO, Rome.

Hess, S.Y., Thurnham, D.I., and Hurrell, R.F. 2005. Influence of provitamin A carotenoids on iron, zinc, and vitamin A status. Washington D.C., International Food Policy Research Institute (IFPRI) and the International Center for Tropical Agriculture (CIAT).

Institute of Medicine. 2001. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington D.C., National Academy Press.

Sommer, A., and West, K.P.1996. Vitamin A deficiency: Health, survival and vision. New York, Oxford University Press.

Low, J.; Arimond, M.; Osman, N.; Cunguara, B. ; Zano, F.; Tschirley, D. 2007. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. Journal of Nutrition 137:1320-1327.

McLaren, D.S., and Frigg, M. 2001. Sight and Life guidebook on vitamin A in health and disease. Basel, Switzerland, Task Force Sight and Life.

Mwanga, R.O.M. and G. Ssemakula. 2010. Orange-fleshed sweetpotatoes for food, health and wealth in Uganda. In J. Pretty and R. Hine (Eds), Sustainability, resilience and increased productivity in African food and agricultural systems. UK Foresight Global Food and Farming Futures Project, Summaries of Cases. University of Essex, UK.

Van Jaarsveld P.J., M. Faber, S.A. Tanumihardjo, P. Nestle, C.J. Lombard, and A.J.S. Benadé. 2005. ß-Carotene-rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test. American Journal of Clinical Nutrition, 81(5): 1080-1087.

West, K.P. 2002. Extent of vitamin A deficiency among preschool children and women of reproductive age. Journal of Nutrition (132): 2857S-2866S.

Table 1. Performance of 2nd batch CIP orange-fleshed sweetpotato clones at Namulonge, Kachwekano, Ngetta, and Serere, October 2003 March 2004.

Serial No.	CIP code	Clone name or pedigree	Site				Mean across sites	SPVD[1] at Namulonge	Flesh color
			Namulonge	Kachwekano	Ngetta	Serere			
			Storage root yield (t/ha)						
1	199004.2	CC89.147. 4 xOP	21.5	41.4	32.1	33.5	38.5	4.5	PO
2	199004.3	CC89.147. 4 x OP	25.0	26.2	26.9	11.5	29.1	4.3	DO
3	199005.1	CHGU 1.002 x OP	24.5	32.2	14.3	0.3	26.2	3.5	PY
4	199015.1	LM92.032 x OP	34.1	31.6	33.8	8.6	27.0	4.3	PY
5	199015.1	LM92.032 x OP	31.2	38.3	46.1	3.3	29.7	4.8	DO
6	199024.1	SR91.109 x OP	32.0	17.9	24.1	40.8	28.7	4.3	DO
7	199024.2	SR91.109 x OP	35.9	27.5	29.7	9.7	25.7	4.3	PO
8	199025.2	SR92.095. 3 x OP	25.0	41.1	57.1	22.2	42.6	4.0	DO
9	199026.1	SR92.095. 8 x OP	33.0	33.6	57.1	21.6	44.7	4.3	Y/O
10	199027.3	SR92.095. 10 x OP	11.2	46.6	49.5	15.7	30.8	4.0	Y/O
11	199034.1	SR95.628 x OP	28.3	27.5	21.4	27.8	26.2	5.0	PY
12	199035.1	SR95.636 x OP	24.5	32.1	22.8	20.6	32.1	4.3	DO
13	199035.5	SR95.636 x OP	36.8	26.6	47.6	5.6	41.6	5.0	DC
14	199035.7	SR95.636 x OP	20.0	41.7	57.1	5.9	37.9	4.0	PO
15	199035.8	SR95.636 x OP	37.8	39.1	25.0	14.6	29.1	5.0	PY
16	199057.4	LM94.422 x OP	35.0	50.0	16.4	11.1	28.1	4.3	PY
17	199062.1	SPV 78.001.3 x OP	35.0	30.4	40.7	5.6	37.1	3.3	PO
18	440203	Unknown	48.2	20.0	27.2	26.0	30.3	3.8	C
19	440443	Nashu 88 (81-88)	40.0	25.0	31.0	10.8	36.7	4.3	Y/O
20	420020	Huarmeyano	23.6	13.8	13.8	10.0	15.3	3.5	DY
21		Tanzania (LC[2])	41.3	23.1	16.8	19.6	26.4	2.8	PY
22		Dimbuka (LC)	40.1	24.4	21.8	50.0	47.2	3.5	C
23		New Kawogo (LC)	38.0	NA	NA	NA	NA	2.0	C
24		Kyabafuruki (LC)	49.3	NA	41.7	21.6	NA	3.8	W
25		Magabali (LC)	NA[3]	52.4	NA	NA	NA	NA	W
26		Otada (LC)	NA	NA	10.9	NA	NA	NA	C
27		Araka (LC)	NA	NA	NA	33.3	NA	NA	W
Mean			32.1	32.3	31.9	17.9	32.3	4.0	NA
LSD(0.05)			10.7	15.1	9.2	9.6	7.7	0.8	NA
CV (%)			23.7	33.1	20.6	38.1	34.3	15.7	NA

[1]SPVD (sweetpotato virus disease) rating scale = 1-5: 1 = no apparent damage/not present, 2 = very little damage/few present, 3 = moderate damage/numbers present, 4 = considerable damage/numbers, 5 = severe damage/very high numbers. Flesh color: W = white, C = cream, PY =pale yellow, DY = dark yellow, Y/O = yellow with orange or vice versa, PO = pale orange, DO = dark orange. NA = not applicable

Table 2. GxE root yield (t/ha) and dry matter (DM%) of orange-fleshed clones, 15 locations, 2006/2007

Clone		Ango oni	Gu rue	Umbe lezi	Zanzi bar	Buko ba	Kaka mega	Nge tta	Namu longe	Sere re	Rubo na	Kibu ngo	Kiba ha	Hom bolo	Man doto	Mim osa	Clone mean	Flesh color	DM
1	Carrot-C	2.8	12.0	13.2	1.1	4.1	23.3	6.4	32.2	27.9	2.5	3.6	3.5	5.5	12.2	3.5	10.3	O	29.8
2	K135	1.5	6.3	5.5	1.6	3.4	17.1	7.6	32.3	17.0	4.3	5.2	2.3	12.6	5.4	5.8	8.5	Y/O	30.9
3	Gweri	3.0	10.2	2.6	2.6	3.0	17.9	4.4	20.4	15.2	2.4	2.7	4.8	4.5	1.8	5.1	6.7	Y/O	33.0
4	Zambezi	2.8	15.7	14.0	2.8	8.1	15.4	1.7	22.9	5.8	3.2	4.1	3.6	4.3	15.7	4.7	8.3	O	33.0
5	Ukerewe	3.0	13.5	14.1	0.7	7.3	26.3	0.5	10.7	10.6	3.5	4.0	5.2	2.8	13.3	4.7	8.0	Y/O	34.0
6	Mayai	2.2	10.2	17.3	0.6	4.9	26.3	3.4	15.6	41.6	2.1	3.2	5.4	0.9	11.3	5.0	10.0	O	29.4
7	K566632	2.0	10.1	10.0	3.5	7.4	28.9	3.9	23.7	47.9	2.1	3.0	4.5	6.6	12.5	4.4	11.4	DO	32.7
8	K118	1.8	17.4	6.4	1.3	4.1	20.5	18.1	36.7	40.0	2.9	2.7	2.6	6.5	10.2	5.9	11.8	O/Y	29.3
9	Ejumula	2.8	19.4	13.6	6.4	5.6	33.1	2.0	12.6	11.0	2.1	2.2	2.6	4.0	16.1	4.3	9.2	O	33.3
10	Pipi	2.0	15.2	10.6	1.4	6.1	20.0	11.5	33.1	20.8	2.3	3.0	4.8	6.7	13.1	6.8	10.5	C	27.5
11	SPK004	0.7	12.1	10.1	1.0	5.0	17.3	11.5	28.1	26.8	3.2	4.1	5.0	2.5	8.9	4.3	9.4	O/Y	30.7
12	199062	3.0	16.0	15.5	1.3	9.7	26.7	2.8	28.1	24.1	3.7	4.7	7.1	3.8	20.3	3.1	11.3	Y/O	30.3
Site mean		2.3	13.2	11.1	2.0	5.7	22.7	6.2	24.7	24.1	2.9	3.5	4.3	5.1	11.7	4.8	9.6	NA	31.2
LSD(0.05)		1.3	8.1	9.0	1.8	2.4	10.2	5.2	13.0	12.7	1.8	1.9	3.5	6.7	3.2	0.9	1.9	NA	NA
CV		39.3	36.4	49.2	56.9	27.4	26.6	49.7	31.1	32.4	40.3	36	47.2	78.7	16.5	11.8	42.3	NA	NA

O = orange, O/Y = yellow with orange, C = cream

Table 3. Orange-fleshed sweetpotato in East and Central Africa (Eth= Ethiopia, Rw=Rwanda, Ke=Kenya, TZ=Tanzania, Ug=Uganda; DM= dry matter, O=orange, Y=yellow, DO=dark orange, SPVD=sweetpotato virus disease, Alt= Alternaria, S= susceptible, M=moderate, R=resistant, NA=not applicable)

Landrace	Country	Yield (t/ha)		DM	Root	B-carotene content/ 100g fresh weight		Resistance
		Root	Foliage	(%)	flesh color	mg	Retinol activity equivalent (RE)	to SPVD
Kakamega	Ug, Ke, Rw, TZ , Eth	14.9	42.0	32.1	O/Y	5.5	457.5	M
Ejumula	Ug, Ke, Rw, TZ , Eth	18.0	30.0	34.2	O	12.4	1032.5	S
Carrot C	Ke, TZ, Ug	10.4	NA	33.2	O	12.4	1032.5	S
K566632	Ke	11.7	25.5	21.3	PO	NA	NA	S
Mayai	Ke, TZ, Ug	17.0	12.7	33.0	O	12.4	1032.5	S
K135	Ke	11.7	33.4	27.7	Y/O	NA	NA	S
Gentute	Eth	17.8	35.4	27.8	DO	NA	NA	S
Kulfo	Eth	29.8	27.0	29.8	O	NA	NA	S
Damato	Eth	30.7	30.7	18.3	DO	NA	NA	S
Bred cultivars								
NASPOT 9 O	Ug,, Ke, TZ	19.9	22.6	30.1	O	11.0	919.2	R
NASPOT 10O	Ug,, Ke, TZ	19.8	25.7	30.5	O	11.0	919.2	R
SPK2001/261	TZ	13.2	8.3	31.0	O	NA	NA	M
SP KBH 03/069	TZ	8.8	6.3	35.0	O	NA	NA	M
Caceaperdo	Rw, DR. Congo	18.2	NA	29.5	DO	NA	NA	M
97/062	Rw	14.4	NA	28.4	O	NA	NA	M
2004/024	Rw	17.2	NA	30.8		NA	NA	M
Introductions								
Resisto (440001)	Ug, Ke, TZ	15.8	NA	27.0	DO	11.0	919.2	M
Tainung 65 (440189)	TZ	15.0	40.0	25.0	O	3.8	313.3	M
Zapallo (420027)	Ke, TZ, Eth	19.3	18.2	26.0	DO	NA	NA	S
199062.1	Ke, Rw, Ug, TZ, Eth	20.9	22.2	28.1	Y/O	NA	NA	M
Salybolo	Ke, TZ	11.0	15.2	27.5	O	NA	NA	S, Alt

Development of mapping populations for genetic analysis in yams (*D. rotundata* and *D. alata*)

Alieu Sartie and Robert Asiedu
International Institute of Tropical Agriculture (IITA), c/o IITA Limited, Carolyn House, 26 Dingwall Rd, Croydon CR9 3EE, UK.
Email: a.sartie@cgiar.org
Tel: +234 2 241 2626 Ext. 2336

Abstract
Progress is being made at the International Institute of Tropical Agriculture to develop molecular tools for marker-assisted selection that would complement and expedite conventional breeding approaches for genetic improvement of yams (*Dioscorea* spp.). F_1 mapping populations were developed from crossing male and female parents of *D. rotundata* Poir. and *D. alata* Lam. that differ in specific traits of interest towards identification of molecular markers linked to those traits. Success in hybridization was validated based on DNA analysis with SSR markers on agarose gel. Traits for which the populations were developed included multiple tuber production, cooking quality and virus disease resistance in *D. rotundata*, and anthracnose disease, cooking quality and tuber oxidation in *D. alata*. Death of plants in the field and rotting of tubers in storage, possibly due to pests, diseases and other environmental factors were encountered that led to the reduction in sizes of the populations. Low seed multiplication ratio necessitates two to three cycles of tuber multiplication of mapping population genotypes to achieve adequate numbers of seed tubers for field experimentation. These mapping populations are valuable tools for genetic analysis and molecular marker development in yam improvement programmes.

Keywords: *Dioscorea alata. Dioscorea rotundata*. Hybrid identification. Mapping population. SSR markers. Trait mapping. Yam. Seed multiplication and seed losses.

Introduction

Yam (*Dioscorea* species of family Dioscoreaceae) is a multi-species, polyploid and clonally-propagated crop that is cultivated for its starchy tubers. Yam is important for food, income and socio-cultural events. The major edible yam species are *D. rotundata* Poir., *D. cayenensis* Lam., *D. dumetorum* (Kunth), *D. alata* L., *D. bulbifera* L., *D. esculenta* (Lour.) Burk., *D. trifida* L. and *D. nummularia* Lam.

Genetic improvement of yams at the International Institute of Tropical Agriculture (IITA) and its partners in West Africa is focused on *D. rotundata, D. cayenensis* and *D. alata*. *D. rotundata* ($2n$ = 40 chromosomes) and *D. cayenensis* ($2n$ = 60 and 80 chromosomes) (Dansi et al. 2000; Dansi et al. 2001), (together also referred to as *D. cayenensisrotundata* complex) are indigenous to Africa, and represent most of global yam production. They have the highest market value owing to the superior suitability of their tubers to the preferred food uses for the crop in West Africa. *D. alata,* introduced from Asia to Africa during the 16th century, is the most widely distributed *Dioscorea* species throughout the tropics. It includes accessions with $2n$ = 40, 60 and 80 chromosomes (Abraham and Nair 1991; Gamiette et al. 1999; Malapa et al. 2005; Arnau et al. 2009). Its advantages include high yield potential, ease of propagation (through production of bulbils and reliability of sprouting), early growth vigor for weed suppression, and long storability of tubers. These are valuable characteristics for sustainable production but the species has a major limitation in the field- high susceptibility of most varieties to a devastating foliar disease, anthracnose, caused by *Colletotrichum gloeosporioides* Penz.

Genetic improvement of yam through conventional breeding alone is difficult and slow. Molecular markers are being developed in *D. alata* and *D. rotundata* for genetic linkage and QTL analyses to identify markers that are linked to traits of interest, and can be used to aid selection in breeding programs. These analyses require mapping populations.

A mapping population is a population in which recombination of parental alleles can be traced. An appropriate mapping population, together with suitable marker system and the software for analyses of data are the key requirements for a molecular mapping and molecular breeding programme. The type and size of mapping population are very important for quantitative locus (QTL) analysis, but their choice largely depends on the goal of the mapping project, the species concerned, type of marker system, traits to be mapped and the availability of time and other resources. In choosing the crossing parents, it is recommended that they should be different in traits of interest in order to facilitate linkage mapping and segregation analysis (Young 1994).

However, when using mapping populations based on highly heterozygous parents, differences in the trait of interest between the parents is not essential, because many of the genes underpinning the trait still segregate in the population (e.g. Barrett *et al.* 2004). There are several methods of generating a mapping population, but the choice depends on the pollination pattern of the plant species. In open pollinated species, populations suitable for genome mapping can be generated via a cross between two heterozygous genotypes (Grattapaglia and Sederoff 1994) or between one heterozygous parent and a doubled haploid parent (Bert *et al.* 1999; Jones *et al.* 2000). One advantage of the former breeding method is that it minimises the risk of inbreeding depression and segregation distortion in the mapping population, both of which can significantly reduce the power and utility of a genome map (Faville *et al.* 2003). The successful use of a double heterozygous (or double-pseudotestcross) strategy has been reported in linkage mapping for perennial ryegrass (Faville *et al.* 2004), white clover (Barrett *et al.* 2004) *Eucalyptus* (Grattapaglia and Sederoff 1994) and asparagus (Lewis and Sink 1996).

The size of the mapping population is important because it determines the resolution of a map and the precision in marker ordering (Young 1994). The larger the mapping population is, the higher the chance of seeing more recombinants in the study and hence the better the map resolution. However, population size may be limited by several factors including the number of seeds available and the amount of resources available for data collection. Populations less than 50 individuals provide too little mapping resolution to be useful (Young 1994). If the goal is high resolution mapping or QTL mapping, much larger populations will be required (Young 1994; Beavis 1998).

The development of mapping populations for yams is, however, not as easy as is done in other crops. To date, only two mapping populations, one for *D. alata* and the other for *D. rotundata* have been reported for cultivated yams (Mignouna et al 2002a and b). Apart from the challenges of poor to non flowering, lack of synchrony in flowering of male and female genotypes and the variation in flowering intensity with season and location (Hamadina et al 2009), population development in yams is also constrained by pests and diseases, soil nutrient deficiencies and other environmental factors that affect the survival of yams both in the field and in storage (Akoroda and Hahn 1995; Green and Florini 1996; Manyong and Oyewole1997; Manyong et al. 2001). Inspite of these constraints, the need for mapping population to facilitate genetic analysis in yam is urgent.

Materials and Methods

Selection of crossing parents: Accessions of IITA improved lines and landraces of *D. rotundata* and *D. alata* were characterised based on sex, multiple tuber production, oxidation (enzymatic browning), tuber texture and other morpho-phsiological and quality traits at the IITA yam breeding unit, Ibadan, Nigeria. *D. alata* accessions were further screened for reaction to various *C. gloeosporioides* isolates based on growth patterns of mycelia and symptom types using detached leaves and whole plant methods. Accessions of *D. rotundata* were screened in the field and screenhouse for reaction to viruses. Accessions that differ for each trait were selected and used as crossing parents to generate a mapping population for the trait. The ploidy status of selected parents was determined using flow cytometry.

Crossing procedures and seed processing: The male and female parents of the selected accessions were grown in separate crossing blocks (about 500 metres apart). Bi-parental crosses of genotypes with same ploidy status (4X) were performed through controlled pollination in 2006 for *D. rotundata*, and in 2006 and 2008 for *D. alata*. This involved bagging (cotton fabric) of selected female inflorescences before the flowers were opened. When ready for pollination, anthers were excised from male flowers using the fine point of a pin and deposited on a stigma of the female flower. The flowers were enclosed again in the pollination bags for another two weeks to avoid contamination from other pollen through insects. The fruits (capsules), when matured, were harvested and botanic seeds were extracted and processed.

Seedling nursery establishment and seed tuber multiplication: Botanic seeds of the F_1 populations were germinated in Jiffy 7 peat pellets, and four week old seedlings were transplanted in a seedling nursery at a spacing of 0.4 x 0.5 m for *D. rotundata* and 1 m x 1 m for *D. alata*. Tubers were harvested seven to eight months after seedlings were transplanted and stored at ambient temperature in an open-air barn. Tubers harvested from the seedling nursery will go through one, two or three subsequent cycles of multiplication in order to get enough seed tubers for evaluation of traits. Seed tubers of five of the populations (*D.*

alata mapping populations 1 (AM1) and 2 (AM2), and *D. rotundata* mapping populations 1 (RM1), 2 (RM2) and 3 (RM3)) were multiplied in the field in 2009 using tuber sett size of 25-50 g at a spacing of 50 x 1 m for *D. alata* and 25 x 1 m for *D. rotundata*. *D. alata* mapping populations 3 (AM3) and 4 (AM4) were grown in seedling nursery in 2009 and are in the first stage of tuber multiplication cycle during the 2010 cropping season.

Verification of hybridization between crossing parents: For each of the mapping populations, total DNA was isolated from the two parents (P1, the female parent and P2, the male parent) and six randomly selected progenies using a modified protocol of the Asian Maize Biotechnology Network (ABIONET Service Laboratory, 2004). About 100 mg of fresh leaf tissue was ground in liquid nitrogen using a mortar and a pestle. The ground tissue was transferred into an eppendorf tube and 500 ìl of CTAB buffer (2% CTAB, 1.4 m NaCl, 20mMEDTA, 100mm Tris HCl, pH 8, 3% mercaptoethanol) was added. The samples were incubated in 65 °C water bath for 45 min, with the tubes gently mixed 3-4 times. Tubes were then removed from the water bath, uncapped and allowed to cool at room temperature or on ice for 1-2 min. Chloroform-isoamyl alcohol (24:1) 500 ìl was added and the content was mixed for about 1 min by inverting the tube and centrifuged at 13000 rpm for 10 min. The supernatant (about 500 µl) was carefully transferred into 1.5-ml fresh microcentrifuge tubes, and 500 µl of ice-cold isopropanol was added. The content was mixed by gentle inversion until the white, thread-like DNA appeared, and centrifuged at 13000 rpm for 10 min. The liquid was poured off, the DNA pellet was washed with 500 µl of 70% ethanol, centrifuged at 13000 rpm for 10 min and the ethanol was carefully poured off. The DNA was dried by inverting the tube on a clean paper towel for 20-30 min. The DNA was dissolved in 100 µl of 1xTE (high salt) by gently flicking the tube, and centrifuged at 13000 rpm for 10 min to collect the solution at the bottom. One microlitre of 10 mg/ml RNase was added to 100 µl of DNA and incubated at 37 °C for 30 min. DNA was precipitated by adding 1/10 volume (10 µl) of 3.0 M sodium acetate and 2 volumes (200 µl) of absolute ethanol, and the content was mixed by gentle inversion and centrifuged at 13000 rpm for 10 min to collect the DNA. The liquid was carefully taken out using a 200 micropipette without disturbing the DNA pellet. Three hundred microlitres of 70% ethanol was again added to the DNA, centrifuged for 2 min at 13000 rpm and liquid pour off. The DNA was dried by inverting tube on a clean paper towel, resuspended in 100 µl of 1xTE (low salt), centrifuged for 2 min at 13000 rpm and kept at -20 °C. The quantity of DNA was subsequently estimated by visual comparison against Lambda (ë) DNA standards loaded at 200, 100, 75, 50, 35, 25, 20, 15, 10 and 5 ng per lane.

The 60-well agarose gels were prepared using 250 mL of 0.5xTBE buffer (Tris Borate-EDTA, pH 8.0), 0.8% (w/v) agarose. DNA samples were mixed briefly by flicking the tube, and then centrifuged at 13000 rpm for 1 min. Two microlitres of DNA solution plus 2 ìL of 6x loading dye (15% ficoll (w/v); 0.25% bromophenol blue; 0.25% xylene cyanol FF) were loaded onto the gel and run at 80 V for 2-3 hr. The gel was stained in 2 mL ethidium bromide solution (500 ìL /mL) for 30-60 s, and then de-stained by placing in fresh tap water (about 2 mL) for 20-30 min. Quantities were estimated by eye against the ë DNA standards, and based on these estimations, DNA solutions of 5 ng/ìL were made with sterile (autoclaved) water for each genotype.

One hundred and forty five simple sequence repeat (SSR) primers pairs, 45 from genomic origin (Tostain et al 2006; Mignouna et al 2003; Tamiru et al unpublished) and 100 from expressed sequence tags (Satya et al 2007), were screened for amplification and polymorphism in the parents of each of the mapping populations. Primers that were polymorphic between parents of each of the populations were used to genotype the two parents and six randomly selected progenies of the respective populations.

PCR amplifications were conducted in a 20 ìL reaction volume (96-well plate format) containing 20 ng (4 ìL) of genomic DNA, 2.0 mM magnesium chloride, 10x PCR buffer (Invitrogen), 0.2 mM of each dNTP, 2.0 ìM each of forward and reverse SSR primer, and 0.06 U of Platinum Taq DNA polymerase (Invitrogen). PCR was carried out using iCyclers (Bio-Rad, Hercules, Calif., USA) programmed for one cycle at 94 °C for 4 min, followed by 34 cycles of 94 °C for 30s, 51 °C for 1 min and 72 °C for 1 min. After the 34 cycles, the samples were held at 72 °C for 8 min (final extension step) and then stored at 4 °C. The PCR products were electrophoresed in 2% SFR agarose (AMRESCO®, AMRESCO Inc. Solon Industrial Pkwy, USA) gel at 80 V for 2-3 hr. The gels were next stained with ethidium bromide for 30-60 s, de-stained for 20-30 min and then observed under a UV transilluminator.

A problem of amplification and reproducibility of PCR products was encountered with DNA from three parental genotypes - TDa 01/00081, TDa 95/00328 and TDr 97/00917. The DNA extraction protocol was modified and used to re-extract DNA from those genotypes.

Results

The morpho-agronomic characteristics of the parents of the mapping population are listed in Table 1, and their pedigree information is shown in Table 2. Traits for which the mapping populations were developed are shown in Table 3. The results from the crosses are shown in Table 4. Fruit set ranged from 14% in cross TDa 01/00081 x TDa 01/00039 to 56% in TDa 95/00328 x TDa 95 310. Percent seed set was highest (65%) in TDr 97/00793 x TDr 95/01932 and lowest (6%) in TDa 01/00081 x TDa 01/00039, and was generally higher in *D. rotundata* than in *D. alata*. The number of seeds harvested ranged from 266 in TDa 01/00081 x TDa 87/01091 to 1010 in TDr 97/00793 x TDr 95/01932.

Percent loss of progenies was 5 to 57% in the seedling nursery and 7 to 86% in storage (Table 5). The number of tubers produced per progeny was small during the first cycle of tuber multiplication, but was higher in *D. alata* populations than in populations of *D. rotundata* (Table 5). The mean tuber number per genotype was 11 and 12 in populations AM1 and AM2, but less than 10 in RM1, RM2 and Rm3.

The result of SSR primer (or marker) analysis confirming successful hybridization of the mapping population parents is shown in Table 6 and Figure 1. Out of the 145 markers surveyed across the seven mapping populations (AM1, AM2 AM3, AM4, RM1, RM2 and RM3), nine were polymorphic between the parents of each of the populations. The number of markers used to genotype the populations ranged from two (AM3 and RM1) to four (AM1). Populations AM2, AM4, RM2 and RM3 were genotyped by three markers each. All the markers were informative in more than one population except for marker Dab2E07 that was specific to population AM1. Marker Dab2Co5 was informative in all the populations. All the markers amplified in all the six selected progenies from each of the populations, except for markers Dcay 245 and Dab2Co5 that failed to amplify in two genotypes of population AM2 and one genotype of AM4 respectively. The number of bands (alleles) amplified at each marker locus ranged from 2 to 5, and the size of alleles ranged from 100 to 550 base pairs. In the RM2 population, one of the alleles of Parent 1 did not amplify in the progeny. In all the populations, the genotype of each of the six progenies showed a combination of their parental alleles.

Discussions

Seven F_1 mapping populations, three of *D. rotundata* (RM1, RM2 and RM3) and four of *D. alata* (AM1, AM2, AM3 and AM4) were developed. The sizes of the mapping populations ranged from 50 in population AM2 to 283 in population AM4. Losses of 5-57% in the field and 7-86% in storage were encountered that led to the reduction in the size of the populations. These losses, mainly in the form of plant death in the field and tuber rot in storage, may have been caused by pests and diseases or other environmental conditions. Losses of about 30% in storage and also during processing due to pre-harvest invasion or infection by pathogens and insect pests; damage during harvest and transit; and unfavorable physical factors of the environment (especially temperature and humidity) have been reported (Akoroda and Hahn 1995, Green and Florini 1996). The loss of genotypes in the field and in storage warrants an alternative method of conserving yam genotypes, for instance, in tissue culture, especially for those of mapping populations, in order to prevent the population or the individual progenies going into extinction.

Tuber multiplication is another constraint in the development and utilization of mapping populations in yams. Seed multiplication ratio, which is very low in yams (less than 1:10) compared to some cereals (1: 300) prevents the immediate use of a mapping population. For instance, during the first year of seed tuber multiplication, the numbers and sizes of tubers produced per progeny were too small to establish a field trial especially for *D. rotundata* populations. Tuber increase was relatively higher in *D. alata* populations (more than 10 tubers per genotype) than in those of *D. rotundata* (fewer than 10 per genotypes). The relatively large quantity of tubers produced per progeny in populations AM1 and AM2 suggests that enough planting materials may be available to establish field trial in *D. alata* after one or two cycles of multiplication. In the case of *D. rotundata*, two to three cycles of seed tuber multiplication may be required before field experimentation.

Yam is an open-pollinated crop and there is a chance for cross pollination with pollen from unwanted male plant to occur if hybridization is not properly controlled. Contamination by pollen

from an unknown parent will lead to spurious analysis. Genetic analysis using mapping populations requires the determination of the genotype of the parents in order to trace recombination of parental alleles in the population. To confirm that mapping population progenies were the true hybrids of the male and female crossing parents, DNA from six progenies and their two parents (P1 and P2) of each of the seven populations were analysed with SSR markers. Results indicated that the parental alleles recombined in the progenies of each of the populations (Table 6, Figure 1) confirming that the crosses were successful. The male parent (P2) allele, either in the form of heterozygote or homozygote was present in all the six samples of each population indicating that all the six F_1 progeny were hybrids. The failure of markers Dcay 245 and Dab2Co5 to amplify in two progenies of population AM2 and AM4 reveals the difficulty of isolating quality DNA from a population of yam genotypes using the same protocol. This may be due to the high heterozygosity as a result of the out-crossing nature of yams. It has earlier been highlighted that a single DNA isolation protocol for heterozygous species may not allow optimal DNA yield, and that even closely related species may require different DNA extraction protocols (Loomis, 1974; Weishing et al 1995). We used more than one DNA extraction protocol for parental genotypes TDa 01/00081, TDa 95/00328 and TDr 97/00917 before achieving reproducible DNA amplification in these genotypes.

Conclusions

We have developed seven F_1 mapping populations in yams; three in *D. rotundata* for virus disease, multiple tuber production, cooking quality or tuber texture, and four in *D. alata* for anthracnose disease, cooking quality and oxidation. Death of plants in the field and rotting of tubers in storage possibly due to pests, diseases and other environmental factors were encountered that led to the reduction of the size of the populations. SSR markers analysis of DNA from parents and six randomly selected progeny of each of the populations indicated that parental crosses were successful, and the progeny were true hybrids. It is recommended that the populations be maintained in the field and also in tissue culture (in-vitro) for long term conservation.

Acknowledgements

We thank Mrs. Kafilat Odesola for providing the laboratory technical assistance, Messrs. Kabiru Ganiyu, Patrick Ezighi, Sunday Itebojie, Oye Azeez, Sunday Olajide and Kola who are all yam breeding staff for providing field assistance. We are very grateful to Dr. Muluneh Tamiru for providing 20 SSR genomic primers that were screened together with SSRs from other sources.

References

Abraham K, Nair PG (1991). Polyploidy and sterility in relation to sex in *Dioscorea alata* L. (Dioscoreaceae). Genetica 83:93-97.

Akoroda MO, Hahn SK (1995). Yams in Nigeria: status and trends. A Workshop Report in African Journal of Root and Tuber Crops (AJRTC), Vol. 1 No. 1, 38-41.

AMBIONET Services Laboratory (2004). Laboratory hand book. Protocols for maize genotyping using SSR markers and data analysis. CIMMYT.

Arnau G, Nemorin A, Maledon E, Abraham K (2009). Revision of ploidy status of *Dioscorea alata* L (Dioscoreaceae*)* by cytogenetic and microsatellite segregation analysis. Theoretical and Applied Genetics. 118: 1239-1249.

Barrett B, Griffiths A, Schreiber M, Ellison N, Mercer C, Bouton J, Ong B, Forster J, Sawbridge T, Spangenberg G, Bryan G, Woodfield D (2004). A microsatellite map of white clover. Theoretical Applied Science 109: 596-608

Beavis WD (1998). QTL analysis: power, precision, and accuracy. Molecular dissection of complex traits. A.H.Paterson. New York, CRC Press: 145-162.

Bert PF, Charmet G, Sourdille P, Hayward MD, Balfourier F (1999). A highdensity molecular map for ryegrass (*Lolium perenne*) using AFLP markers. Theoretical and Applied Genetics 99: 445-452.

Dansi A, Pillay ., Mignouna HD, Dainou O, Mondeil F, Moutairou K (2000). Ploidy level of the cultivated yams (*Dioscorea cayenensis/D.rotundata* complex) from the Republic of Benin republic as determined by chromosome counting and flow cytometry. African Crop Science Journal 8: 355-364.

Dansi A, Mignouna HD, Pillay M, Zok S (2001). Ploidy variation in the cultivated yams (*Dioscorea cayenensis-Dioscorea rotundata* complex) from Cameroon as

determined by flow cytometry. Euphytica 119:301-307.

Faville M, Barrett B, Griffiths A, Schreiber M, Mercer C, Baird I, Ellison N, Bryan G, Woodfield D, Forster J, Ong B, Sawbridge T, Spangenberg G, Easton HS (2003). Implementing molecular marker technology in forage improvement. Proceedings of the New Zealand Grassland Association 65: 229-238.

Faville M J, Vecchies AC, Schreiber M, Drayton MC, Hughes JL, Jones ES, Guthridge KM, Smith KF, Sawbridge T, Spangenberg GT, Bryan G, Forster JW (2004). Functionally-associated molecular genetic marker map construction in perennial ryegrass (*Lolium perenne* L.). Theoretical and Applied Genetics 110: 12-32.

Gamiette F, Bakry F, Ano G (1999). Ploidy determination of some yam species (*Dioscorea* spp.) by flow cytometry and conventional chromosomes counting. Genet Resour Crop Evol 46:1927.

Grattapaglia D, Sederoff R (1994). Genetic linkage maps of *Eucalyptus grandi*s and *Eucalyptus urophylla* using a pseudo-testcross: mapping strategy and RAPD markers. Genetics 137: 1121-1137.

Green KR, Florini DA (1996). Pest and pathogens of yams in storage. A Workshop Report in African Journal of Root and Tuber Crops (AJRTC), Vol. 1 N. 2, 38-42.

Hamadina EI, Craufurd PQ, Asiedu R (2009). Flowering intensity in White yam (*Dioscorea rotundata*). Journal of Agricultural Science: 469-477.

Jones ES, Mahoney NL, Hayward MD, Armstead I, Gilbert Jones J, Humphreys MO, King IP, Kishida T, Yamada T, Balfourier F, Charmet G, Forster JW (2000). An enhanced molecular marker based genetic map of perennial ryegrass (*Lolium perenne*) reveals comparative relationships with other genomes. Genome 45: 282-295.

Lewis ME, Sink KC (1996). RFLP linkage map of asparagus. Genome 39: 622-627.

Loomis, M.D. 1974. Overcoming problems of phenolics in the isolation of plant enzymes and organelles. Meth. Enzymol. 31:528-545.

Malapa R, Arnau G, Noyer JL, Lebot V (2005). Genetic diversity of the greater yam (*Dioscorea alata* L.) and relatedness to *D. nummularia* Lam. and *D. transversa* Br. as revealed with AFLP markers. Genetic Resources and Crop Evolution 52: 919929.

ManyongVM, Oyewole B. (1997). Spatial patterns of biological constraints to cassava and yam production in West and Central Africa: Implications for technology development and transfer. African Journal of Root and Tuber Crops, 3: 15-21.

Manyong VM, Asiedu R, Olaniyan GO (2001). Farmers' perception of, and actions on, resource management constraints, in the yam based systems of western Nigeria. Pages 156 167 *in* Root Crops in the 21st Century, Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root Crops Africa Branch (ISTRC-AB), Cotonou, Benin, 11-17 October 1998. Compiled by M.O. Akoroda and J.M. Ngeve. ISTRC-AB and Government of Benin.

Mignouna HD, Mank RA, Ellis THN, Van den Bosch N, Asiedu R, Ng SYC, Peleman, J (2002a). A genetic linkage map of Guinea yam (*Dioscorea rotundata* L.) based on AFLP markers. Theor. Appl. Genet. 105: 716-725.

Mignouna HD, Mank, RA, Ellis THN, Van den Bosch N, Asiedu R, Abang MM, Peleman J (2002b). A genetic linkage map of water yam (*Dioscorea alata* L.) based on AFLP markers and QTL analysis for anthracnose resistance. Theor. Appl. Genet. 105:726-735.

Satya Narina, Teklu Andebrhan, Mohamed Ali, Asiedu Robert 2007. Development of Genomic Tools for Improvement of Yam (Dioscorea alata L) International Plant and Animal Genomic Conference Jan 11-17th 2007.

Young ND (1994). Constructing a plant genetic linkage map with DNA markers. DNA-based markers in plants. R.L.Philips and I. K. Vasil. London, Kluwer Academic Publishers: 39-57.

Weishing, K., H. Nybom, K. Wolff, and W. Meyer. 1995. DNA isolation and purification. In: DNA fingerprinting in plants and fungi. CRC Press, Boca Raton, Florida. pp. 44-59.

Table 1: Characteristics of *D. rotundata* and *D. alata* mapping population parents

Parent	Morphological and agronomic characteristics
TDr 02/00076	Produce multiple tubers, susceptible to virus
TDr 95/01932	Produce single or fewer tubers, moderately resistant to virus
TDr 97/00793	Multiple tubering, non-oxidising
TDr 97/00917	Moderately resistant to virus, good cooking quality
TDr 00/00380	Moderately resistant to virus, poor cooking quality
TDa 01/00081	Non-oxidising, produce bulbils, good cooking quality, moderately resistant to anthracnose
TDa 87/01091	Oxidises, resistance to aggressive strain (SGG) of *Colletotrichum gleosporioides*, produce bulbils, high yielding
TDa 92-2	High yielding, poor tuber shape, purplish fleck flesh colour, oxidises, susceptible to anthracnose, bulbils
TDa 01/00039	Oxidising, resistance to anthracnose, cooks well, produce bulbils
TDa 95/00328	High yielding, poor tuber shape, oxidises, resistance to moderately virulent (FGS) of *Colletotrichum gleosporioides*
TDa 95-310	Purplish fleck flesh colour, purplish petiole colour, susceptible to anthracnose, produce bulbils

Table 2: Pedigree of *D. rotundata* and *D. alata* accessions that were used as crossing parents in developing mapping populations

Parents of mapping population	Pedigree
TDr 02/00076	(TDr 93 -1 x TDr 95 -204) x TDr 00 -2-5
TDr 95/01932	TDr 86/00609 (HS)
TDr 97/00793	TDr 93 - 23 (HS)
TDr 97/00917	TDr 89/01892 x IN94R - 2
TDr 00/00380	(TDr 87/00571x TDr 91/00200)x(TDr 95- 235 x IN94R -31) x IN94R
TDa 01/00081	(TDa 95/00328x TDa 98-150) x (TDa 95/00270 x TDa 291)
TDa 87/01091	OP of A19 -165 -445
TDa 92-2	Landrace
TDa 01/00039	(TDa 95/00328 x TDa 98 - 150) x (TDa 95/00270 x TDa 291)
TDa 95/00328	TDa 92 -2 x TDa 85/00257
TDa 95 -310	Landrace

HS = half-sib ; OP = open pollination ; TDr 93-23 =Landrace 'Obiaoturugo' collected from Obinagu in Ohaozara LGA, Ebonyi State Nigeria ; IN94R-2 =Landrace collected from Benin Republic; TDa92-2 =Landrace 'Werededе' collected from Sagbe in Ibadan, Oyo State Nigeria ; Tda 95-310 =Landrace 'Brazo Fuerte' collected from Bouake, Côte d 'Ivoire

Table 3 : Bi-parental crosses and mapping populations for traits analyses in *D. rotundata* and *D. Alata*

Crosses	Mapping population	Trait
TDr 02/00076 (P1) x TDr 95/01932 (P2)	*D. rotundata* mapping population 1 (RM1)	Multiple tubering/virus
TDr 97/00793 (P1) x TDr 95/0193 2 (P2)	*D. rotundata* mapping population 2 (RM2)	Multiple tubering
TDr 97/00917 (P1) x TDr 00/00380 (P2)	*D. rotundata* mapping population 3 (RM3)	Cooking quality
TDa 01/00081 (P1) x TDa 87/01091 (P2)	*D. alata* mapping population 1 (AM1)	Cooking quality
TDa 01/00081 (P1) x TDa 01/00039 (P2)	*D. alata* mapping population 2 (AM2)	Oxidation
TDa 92 - 2 (P1) x TDa 01/00039 (P2)	*D. alata* mapping population 3 (AM3)	Anthracnose
TDa 95/00328 (P1) x TDa 95 310 (P2)	*D. alata* mapping population 4 (AM4)	Anthracnose

Table 4: Data on bi-parental crosses for generating mapping populations in *D. rotundata* and *D. Alata*

Species	Cross	Code name	No. of flowers pollinated	No. of fruits collected	% fruit set	Expected No. of seeds	No. of seeds obtained	% seed set	Crossing year
D. rotundata	TDr 02/00076 (P1) X TDr 95/01932 (P2)	RM1	517	240	46	1440	613	43	2006
	TDr 97/00793 (P1) X TDr 95/01932 (P2)	RM2	597	258	43	1548	1010	65	2006
	TDr 97/00917 (P1) X TDr 00/00380 (P2)	RM3	513	219	43	1214	744	57	2006
D. alata	TDa 01/00081 (P1) X TDa 87/01091 (P2)	AM1	251	100	40	1506	266	18	2006
	TDa 01/00081 (P1) X TDa 01/00039 (P2)	AM2	2016	285	14	12096	707	6	2006
	TDa 92- 2 (P1) X TDa 01/00039 (P2)	AM3	207	118	57	1242	461	37	2008
	TDa 95/00328 (P1) X TDa 95 310 (P2)	AM4	359	202	56	2154	473	22	2008

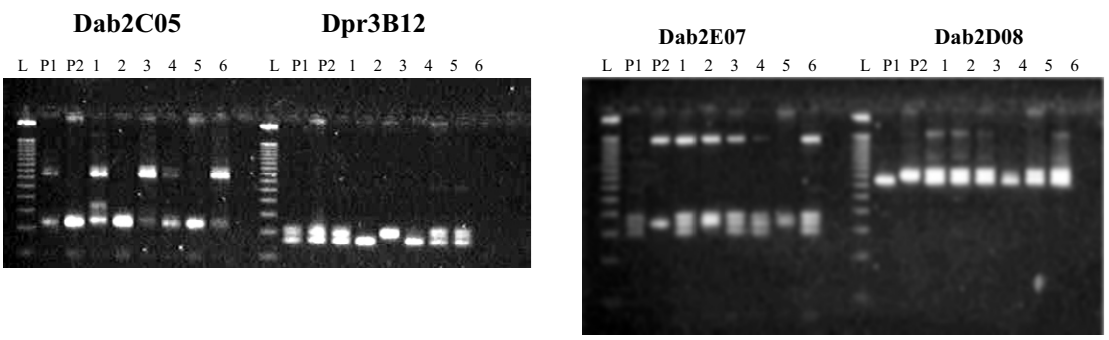
Table 5: Size of mapping population, percent loss of genotype in nursery and during storage, and number of tubers multiplied in the field in 2009. Populations AM3 and AM4 were in seedling nursery in 2009 and are in the multiplication field this year.

Mapping population	Number of plants transplanted in seedling nursery	Number of plants survived in seedling nursery	% genotype loss in seedling nursery	% genotype loss in storage	Population size	Number of tuber setts per geno type planted in multiplication		Number of tuber per genotype harvested in multiplication	
						Range	Mean	Range	Mean
RM1	416	396	5	56	175	2 - 49	12	1 - 47	9
RM2	777	420	46	35	263	1 - 10	2	1 - 8	8
RM3	518	450	13	69	109	1 - 24	5	1 - 18	4
AM1	215	190	12	24	144	1 - 108	12	1 - 119	12
AM2	518	345	33	86	50	2 - 58	9	1 - 74	11
AM3	322	140	57	7	130				
AM4	349	267	23	0	283				

Table 6: Segregation pattern of parental alleles in six selected progenies of seven mapping populations of *D. alata* (AM1, AM2, AM3 and AM4) and *D. rotundata* (RM1, RM2 and RM3) using nine SSR markers (Dab2C05, Dpr3B12, Dab2E07, Dab2D08, DPr3F12, Dcay 223, Dcay 245, Dcay 405 and YM-13).

Mapping population	SSR Marker	No. alleles in parental genotypes	Size of alleles (base)pair				Parent 1 alleles	Parent 2 alleles	No. progeny with alelle 'a'	No. progeny with allele 'b'	No. progeny with allele 'c'	No. progeny with allele 'd'
			Allele 'a'	Allele 'b'	Allele 'c'	Allele 'd'						
	Dab2C05	3	150	170	190		a,b and c	a and b	2	6	4	
RM1	Dcay 223	4	350	370	400	500	a and c	b and d	6	0	2	6
	Dab2C05	4	120	150	170	200	a, b and c	b and c	3	3	3	4
	DPr3B12	2	140	200			a and b	a	6	0		
RM2	Dcay 223	4	370	420	450	550	a, c and d	b and d	2	4	1	6
	Dab2C05	2	190	220			a	a and b	6	6		
	Dcay 405	2	270	300			a	a and b	6	5		
RM3	YM13	4	220	250	290	300	b and c	a,b and d	3	3	1	1
	Dab2C05	2	100	300			a and b	a	2	4		
	Dpr3B12	3	120	150	160		a, b and c	a and b	3	2	1	
	Dab2E07	3	100	120	150		a, b and c	b	4	5	3	
AM1	Dab2D08	2	300	350			a and b	b	5	1		
	Dab2C05	4	150	200	220	400	a,b,c and d	a,b and c	5	6	6	5
	DPr3F12	3	150	170	220		b and c	a,b and c	1	6	5	
AM2	Dcay 245	2	300	350			a	b	1	3		
	Dab2C05	4	170	250	400		a,b and c	a and b	6	2	3	
AM3	Dab2D08	2	320	370			a and b	a	6	4		
	Dab2C05	4	160	180	220	400	a,b,and c	a,b,c and d	3	5	5	2
	DPr3B12	2	170	190			b	a and b	5	6		
AM4	DPr3F12	2	170	190			b	a and b	5	5		

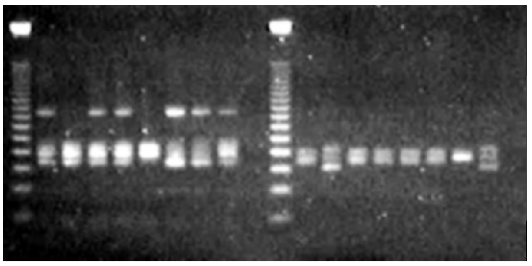
Population AM1



Population AM2

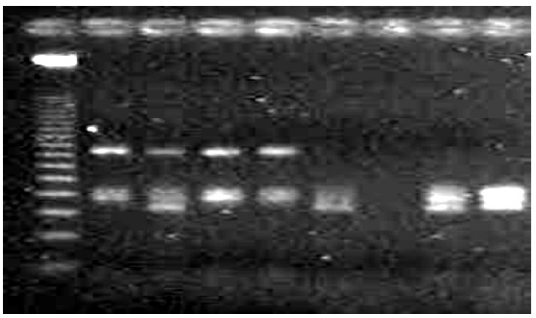
Dab2C05 DPr3F12

L P1 P2 1 2 3 4 5 6 L P1 P2 1 2 3 4 5 6



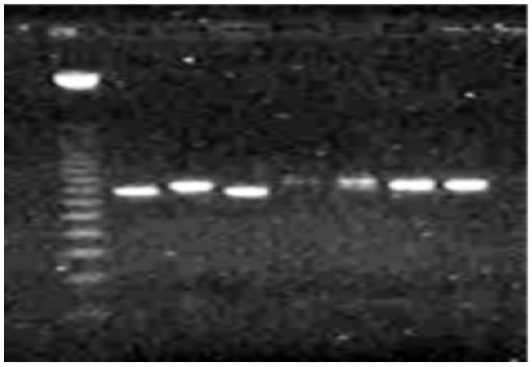
Dab2C05

L P1 P2 1 2 3 4 5 6



Dcay 245

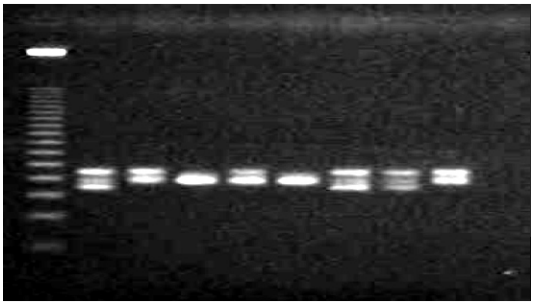
L P1 P2 1 2 3 4 5 6



Population RM1

Dab2C05

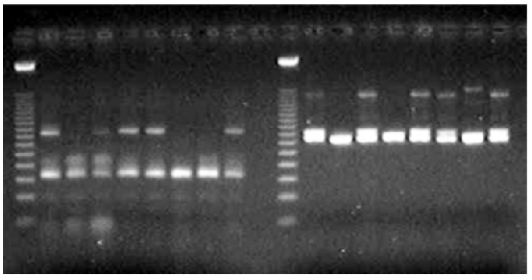
L P1 P2 1 2 3 4 5 6



Population AM3

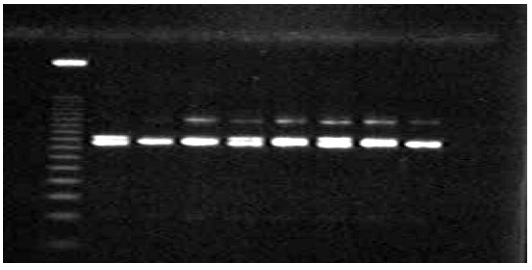
Dab2C05 **Dab2D08**

L P1 P2 1 2 3 4 5 6 L P1 P2 1 2 3 4 5 6



Dcay 223

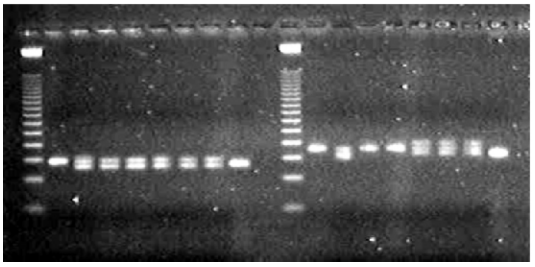
L P1 P2 1 2 3 4 5 6



Population AM4

DPr3B12 **DPr3F12**

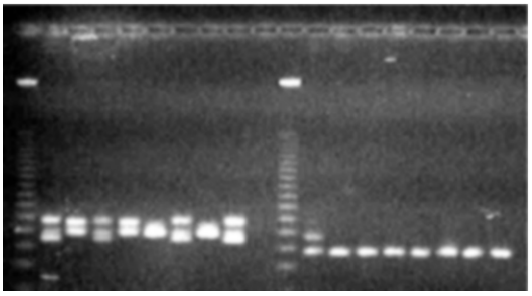
L P1 P2 1 2 3 4 5 6 L P1 P2 1 2 3 4 5 6



Population RM2

Dab2C05 **DPr3B12**

L P1 P2 1 2 3 4 5 6 L P1 P2 1 2 3 4 5 6



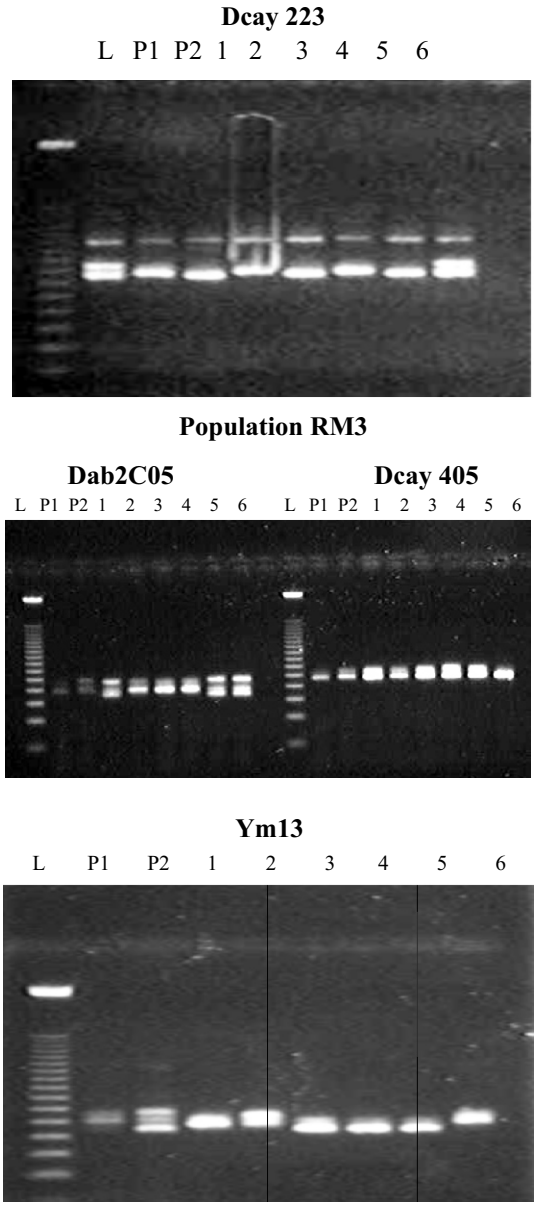


Figure 1: Agarose gel photos indicating banding pattern of DNA from six progenies (1, 2, 3, 4, 5 and 6) and their two parents (P1 and P2) of mapping populations AM1, AM2, AM3, AM4, RM1, RM2 and RM3 using nine SSR markers (Dab2C05, Dpr3B12, Dab2E07, Dab2D08, DPr3F12, Dcay 223, Dcay 245, Dcay 405 and YM-13). L is 50bp ladder.

Morphological diversity and distribution of yam (*Dioscorea* spp.) cultivars in Kenya

Muthamia Z.K[1]., Ngae G1., Ateka E., Njau S., Nyende A.B.[2] and Mamati E.G.[2]
Kenya Agricultural Research Institute, P.O.Box 30148-00100, Nairobi, Kenya[1].
Department of Horticulture,Jomo Kenyatta University of Agriculture and Technology, P.O.Box 62000-00200, Nairobi[2]
Corresponding author email:
zkmuthamia@yahoo.com

Abstract
Morphological characterization was carried out on 163 local yam varieties collected from 18 districts which represent major growing areas in Kenya. The corms were planted in a screen house then transferred to a field genebank. A total of 62 Morphological traits were recorded using IPGRI Descriptors for Yam (*Dioscorea* spp.), Twenty nine (29) variables representing mainly aerial parts of the plant were considered for analysis. To determine variation of multiple categorical characters agro morphological traits, Multiple Coordinate Analysis (MCA) was carried out.

A cumulative contribution of 32 % for the first to sixth principal components was observed with 25% contribution derived from first to fourth components. There were distinct groups comprising yam germplasm from the Coastal region and those from the Central parts of the country which seemed to be more related. There were some isolated distinct groups within the central Kenya germplasm.

The results indicate that farmers have distinct characters to describe their local varieties. There is clear partitioning of yam germplasm from Central and Coastal regions. Even within the central Kenya group there are varieties with distinct traits. Tuber characteristics and inclusion of wild species in addition to genotypic differentiation will provide valuable information.

Keywords: Morphological characterization, Multiple Coordinate Analysis, agro morphological traits, yam germplasm.

Introduction

The genus *Dioscorea* belongs to the botanical family Dioscoreaceae and contains over 600 species distributed throughout the tropics, with

eight being cultivated for food (Ayensu, 1972). Yams are grown principally for their carbohydrate content, but their storage organs (underground and/or aerial tubers) are also sources of proteins, fats and vitamins. In Kenya , yam diversity has evolved over many years as many generations in different parts of the country selected and domesticated different species and types independently to suit local cultivation practices and needs. The slopes of Mount Kenya and Aberdares highlands in the Eastern and Central provinces of the country respectively, form the most important yam growing regions, with a wide genetic variability of the crop. In Kenya literature on yams is scanty but available information indicates that Kenya's yam diversity is represented by a number of species including *D. rotundata, D. minutiflora, D. bulbifera, and D. dumetorum* that are grown for food mainly by elderly farmers in the Eastern, Central, Western and Coastal regions of the country (Maundu et al., 1999). Most production of yams in Kenya is in the Eastern and Central parts of the country. Production increased from 7,238 tons in 2005 to 8,001 tons in 2006, while area under yams decreased from 960 hectares in 2002 to 842 hectares in 2006 (MoA, 2007). Some of production constaints include pests, unavailability of planting materials and access to markets (Mutegi, et l., 2004). This study seeks to assess distribution and diversity of yam cultivars in the country.

Objectives

1. To assess distribution of cultivated yam species in Kenya
2. To assess the morphological diversity among yam populations in Kenya

Objective 1

To determine distribution of cultivated yam species in Kenya

Materials and methods

A purposive sampling was used whereby knowledge of the cropping systems by the agricultural extension staff in the field was used to locate the few farmers growing the crop.

The selected farmers were interviewed to give social economic data and the cultivars known or grown using a structured questionnaire.

Plant samples, mainly the vegetative part, also called the corm, and voucher specimen of the shoot for each of the identified cultivars were then collected for further studies and conservation. The corms were potted temporarily at the field genebank at Muguga.

Results and Discussion

Farmers' descriptor characteristics

Seventeen districts were covered; eight in Eastern Province, three in Central Province and 2 in Coast Province, three in Rift Valley and two in Western Province.(Table. 1)

The four most abundant varieties were M'Ikinyori, Nkandau , Mbeu Mpuria and Mbeu Nkuru (Figure 1).

Table 1. Survey coverage districts and respondents

Province	District	Female	Male	Total
	Kiambu East	8	3	11
	Kirinyaga	1	2	3
Central	Nyeri North	1	2	3
Coast	Taita Taveta	2	2	4
	Embu	2	8	10
	Igembe	3	22	25
	Imenti North	1	7	8
	Imenti South	1	5	6
	Maara	3	18	21
	Meru Central	9	37	46
	Meru South	1	52	53
Eastern	Tigania	5	23	28
	Molo		3	3
	Tranzoia West	1	2	3
Rift Valley	Uasin Gishu		2	2
	Bungoma west		1	1
Western	Teso	2	1	3
Total		40	190	230

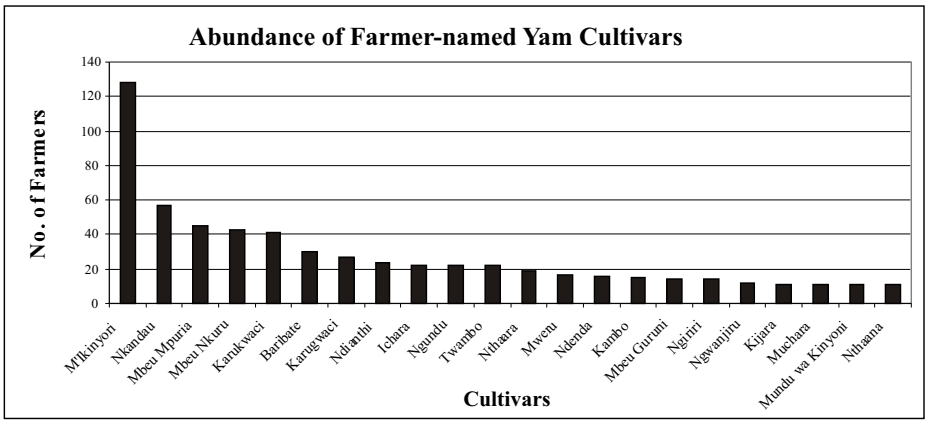


Figure 1. Abundance of various yam varieties

Meru Central District. The district is divided into 4 divisions namely, Abothuguchi Central, East and West and Kibirichia., Yams are, however grown in all but Kibirichia Division.

It emerged that the crop is widely grown but only by the older farmers. It is not a preferred crop by the relatively young farmers who instead go for those that generate fast incomes such as horticultural crops. In addition, yam is a crop almost exclusively cultivated by men. Some people even take it as a taboo for women to involve themselves in its farming activities. Consequently, women have very little or no information about the crop.

Table 3. Some cultivars identified in Meru Central District

Local Name	Language	Characteristics
Baribate	Kimeru	Thick vines
Carungai	Kimeru	Can harvest every 6 months; small tubers with yellow flesh
Ciotu	Kimeru	Moderate yielder; deep toots and tubers; not sweet
Karukwaci	Kimeru	Many small smooth -skinned soft and sweet tubers; thin vines, narrow small leaves; goes bad quickly
Majara	Kimeru	Thick stems; big spikes
Mbeuiguru	Kimeru	Stout vines; takes long to mature
Mbeumpuria	Kimeru	Purple y oung shoot; strong and vigorous growth; two vines; very deep seated tubers; high yielder; tubers can stay underground for up to 6 years
Mbeunkuru	Kimeru	Sweet tubers; small spikes; thin vines
Mtoikinyoni 1	Kimeru	Up to 10 large tubers per plant; bitter if taken immature; thick vines; big forked tubers; 3 years between harvests
Mtoikinyoni 2	Kimeru	Broad leaves; vine has larger spikes; tubers not so sweet; takes 2 years to mature
Ngombe njiru	Kimeru	Poor yielder; tasteless tubers
Unknown		Producing aerial tubers; suspected to be an introduction probably from West Africa; vines are spineless;

Embu District. The district is divided into 4 divisions namely, Manyatta, Runyenjes, Nembule and Central divisions. While yams are grown in all the divisions, they are more in Manyatta and Runyenjes divisions. More weight in coverage was given to these two divisions than the other two.

Table 4. Some cultivars identified in Embu District

Local Name	Language	Characteristics
Icara 1	Kiembu	Harvest every 12 months
Icara 2	Kiembu	Harvest every 8 months
Itarekia	Kiembu	Harvest every 12 months
Maribate	Kiembu	Highly susceptible to black ants; Harvest every 9 -12 months
Mundu wa Kinyoni	Kiembu	Very large forked tubers; relatively thin and many vines; harv est every 8 to 12 months
Ndendera	Kiembu	Vines are spineless
Ndianthe 1	Kiembu	Relatively few vines; broad leaves; deep seated straight tubers; harvest every 18-24 months
Ndianthe 2	Kiembu	Creamish shoots but slender vines; forked tubers can form up to 3 feet deep; Harvest every 2 -3 years
Ngwanjiru	Kiembu	Broad leaves; vine has many sharp thorns; very sweet tubers that form about 1 foot from corm

Meru North District. The district has recently been subdivided into Igembe and Tigania Districts with headquarters in Maua and Kangeta towns respectively. Each of the districts is subdivided into 5 divisions and yams are grown mainly in Igembe Central and Tigania Central divisions where it is grown especially by the older farmers. It is not a preferred crop by the relatively young farmers who instead go for *Miraa*, an intoxicant, which generates fast income.

Of these, the survey team visited farmers in Igembe Central and South, Laare, Mutwati and Tigania East divisions 9 farmers were interviewed and 31 cultivars identified and collected as shown in Table4.

Table 5. Some cultivars identified in Meru North District

Local Name	Language	Characteristics
Acumbi	Kimeru	Few thick vines; high yielder
Baibate	Kimeru	Shallow placed many tubers;
Baicuru	Kimeru	Harvest after 12 months; high yielder
Gaaka (Kaaka, Aaka)	Kimeru	Many very hard but sweet tubers; tubers deep seated not forked; dark green shoots; produces flowers and powdery seeds; harvest after 4 months

Kingotha	Kimeru	Produces pods with seeds- sign that tubers are ready for harvest; large leaves; Harvest every 4 months
MIkinyoni	Kimeru	Large dark leaves; light green young twig; high yielder up to 2 bags from a single plant; shallow seated branched tubers
Mbeuguru	Kimeru	Thin vines and forked tubers; harvest after 4 months;
Mbeumwera	Kimeru	Forked tubers; high yielder up to 1 bag per plant; purple young twig sign of ready tubers; tubers can stay flesh undergr ound even if detached from corm
Mujochia	Kimeru	Large straight tubers
Mwakakianda	Kimeru	Very large tubers; Harvest after 3 years
Mweru	Kimeru	Sweet soft tubers; up to 4 tubers per plant; whitish corm and tubers; black young vines
Ncubi	Kimeru	Slender vines; small leaves
Nereri	Kimeru	Can propagate easily from tubers, tubers can last 10 years if left unharvested; not preferred because tubers take too long to form

Samples for the following varieties were not collected since the yams were too young but can be collected after one year: *Nkwaruiru, Mweru, Ngundu, Kirigi* while the following cultivars were said to have disappeared: *Nkwamikui, Nkwamu-thira, Rwere, Mbithi, Nduru, Ndwere, Ndenda*

Meru South District. In addition to the cultivars identified by farmers in other districts, 5 additional ones were mentioned and described as listed in Table 5.

Table 6. Some cultivars identified in Meru South District

Local Name	Language	Characteristics
Icara	Kimeru	Drought resistant
Kamwere	Kimeru	Slender tubers; takes 1 year to mature; vines turn yellow at base when tubers are ready; brown reddish tubers
Kirandi	Kimeru	Sweet hairy skinned tubers;
Mbeuku	Kimeru	Single vine; very wide corm; harvest after 1 year
Nakirima	Kimeru	Short but large tuber; many vines; harvest after 6 months
Ngondu	Kimeru	Shallow seated short fingered tubers; cross section of tuber shows stripes or dots; takes 3 years to mature from planting; harvest every 12-18 months
Ngochi	Kimeru	Harvest every 3 m onths when vines change colour to black;
Njoka	Kimeru	Relatively smooth vines;
Nkandau A	Kimeru	Takes 2 years to mature; high yielder up to 2 bags per plant; young shoots indicate tuber formation;
Nkandau B	Kimeru	Small slender tubers; good for ma rket; takes 2 years to mature;

Nyeri District: The district has recently been divided into two namely Nyeri North and South The survey covered Mathira and Kieni West divisions.

Table 7. Some cultivars identified in Nyeri District

Local Name	Language	Characteristics
Ichara	Kikuyu	Takes 1 year to mature;
Ichoho	Kikuyu	Takes 6 months to mature;
Karema -ageni	Kikuyu	Takes 6 months to mature;
Muchara	Kikuyu	Sweet forked tubers harvested after 2-3 years; many spikes on vines;
Ndiathi	Kikuyu	Thick vines; green young twigs; high yielder; large straight deep rooted tubers; corm highly spreading; harvest every 3-4 years;
Ngwanjiru	Kikuyu	Harvest every 6 -12 months; few spikes on vine; maximum 2 fingers on tuber;
Njuhi	Kikuyu	Reddish skin; small vines and tubers; dark young vines not too spiky; straight sweet tubers with purplish flesh; up to 2 fingers; harvested every 6 months;

Three cultivars, namely *Karema-ageni, Ichara* and *Icoho* were said to have been grown in the past but have disappeared over the years. However one farmer claimed to have them but could only distinguish them from the tubers. Since he had recently harvested, we arranged to visit him in future and collect their samples.

Kirinyaga District: The district is sub-divided into 4 divisions. However, yams would only be found in the tea/coffee transitional zone with main cultivars identified.

Table 8. Some cultivars identified in Kirinyaga District

Local Name	Language	Characteristics
Mundu wa kinyoni	Kikuyu	Very spiky vines; Harvest every 2 years;
Muraru	Kikuyu	Smooth spineless vines; harvest every 2 years;
Ndiandi (Ndurandi)	Kikuyu	Highly productive up to 2 bags per plant every 3 -5 years; sweet but hard deep seated tubers; very spiky thick vines; straight but fingered tubers;
Ndiru	Kikuyu	Many relatively small shallow seated tubers; soft and sweet tubers; harvest after 1 year;
Ngwanjiru	Kikuyu	Spiky vines; soft easy -to-cook tubers; harvest every 2 years; dark green colour of shoot;
Njubi	Kikuyu	Slender vines; s traight tubers with just 1-2 fingers; brighter colour of shoot than the rest; harvest every 6 months;

Taita District: Yam is a very rare crop in the coast province. In fact it is virtually unknown to most farmers and agricultural extension officers. It is only in Taita and Taveta districts that some but very few farmers will have a few plants in their farms.

Taita district comprises all divisions of the former Taita-Taveta district except Taveta division which has been elevated into a district.

The survey covered Wundanyi and Mwambirwa divisions and interviewed 3 farmers. They pointed out that yam used to be grown in the past mainly as a food security crop. Tubers that are ready for harvest would be left underground to be uprooted for food in times of famine. The crop is now almost extinct and only very few farmers have a few plants in their farms.

Table 9 below shows the characteristics of the 4 yam varieties identified in this district.

Table 9. Cultivars identified in Taita District

Local Name	Langua ge	Characteristics
Iko	Kitaita	vines have no spikes
Kiechangao	Kitaita	produces very large forked tubers and has spiked vines
Nduu	Kitaita	produces aerial tubers which are medicinal as well as being for food
unknown (nicknamed *Kesse* -village name)	Kitaita	relatively many slender vines with spikes

Taveta District: The survey team visited and interviewed farmers in Kimorigo and Bomeni locations (being elevated into divisions). The farmers in Kimorigo who speak Kipare language identified 2 but very similar yam varieties namely, *Kilukwa and Kiiye* while those in Bomeni identified 3 yam types which in their Kitaveta language are *Mafore (2 types) and Kilikwa* as shown in Table 10

Table 10. Cultivars identified in Taveta District

Local Name	Language	Characteristics
Kiiye	Kipare	has soft tubers and relatively smaller leaves than those of *Kilukwa*
Kilikwa	Kitaveta	round spiked vines and produces small tubers with yellow flesh
Kilukwa	Kipare	has very hard but floury tubers which are also very sweet
Mafo re 1	Kitaveta	spineless vines and whitish tubers more productive
Mafore 2	Kitaveta	spineless 4-faced vines and reddish tubers sweet to eat and hence marketable

Objective 2

To determine the morphological diversity among yam populations in Kenya

Materials and Methods

One hundred sixty farmer named yam varieties collected from earlier survey were planted in the screenhouse in Muguga and later transferred to the field genebank. Sixty two aerial agro morphological characters were recorded based on Descriptors for Yam (*Dioscorea* spp.) IPGRI 1997. Some of the variables recorded included; time to emergence, plant vigour, stems colour, leaf colour, presence or absence of vines, twining direction among others.

Tuber characteristics recorded after harvest included tuber shape, flesh tuber colour, absence or presence of thorny skin among other characters. This study reports only the aerial morphological characters. 29 variables representing mainly aerial parts of the plant were considered for analysis (Table 11).

Table 11. Some morphological characters recorded

Emergence days, stem l ength, number of stems per plant, Spine position, leaf margin colour, petiole colour, vein c olour
Stem cross section shape at base, stem colour
Internode length, absence/presence of waxiness
Absence/presence of hairs, absence/presence of spines, absence/presence of wings
Number of stems per plant, undulation of l eaf Absence/presence of coalescence spines
Spines on stem base , leaf shape, plant type
Leaf tip c olour, leaf apex s hape , twinning direction, l Eatheriness, spine shape absence/presence of ridges, first leaf emergence, plant vigour, spines on stem above base

Data Analysis

To determine variation of multiple categorical characters agro morphological traits, Multiple Coordinate Analysis (MCA) was carried out to generate scatter diagrams.A hierarchical cluster analysis was also carried out using 25 environmentally stable variables.

Results and Discussion

Results indicate morphological variability of among cultivated yams in Kenya (Mwirigi, P. N, *et al.* (2009).

A cumulative contribution of 32 % for the first to sixth principal components was observed with 25% contribution derived from first to fourth components. There were distinct groups comprising yam germplasm from the coastal region and those from the central parts of the country which seemed to be more related (Fig 2.).There were some isolated distinct groups within the central germplasm. Farmers use specific morphological to distinguish characters to identify their yam varieties (Muthamia, et al., 2008). Central Kenya presented the highest diversity of cultivated yam cultivars and this represents the single major yam cultivation region in the country. This region also represents closely related yam varieties. Whereas coastal varieties were found growing in the central parts of the country the opposite was not the case. Tuber characteristics data will be included in future analysis.

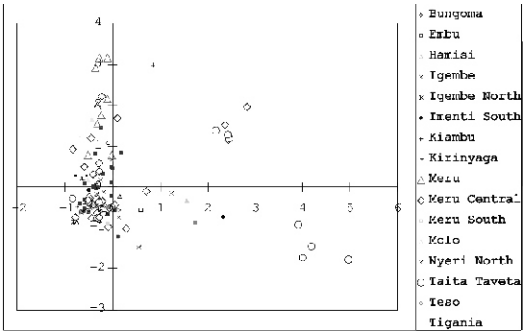


Figure 2. Scatter diagram A(PC1 &PC2)Districts

Conclusion and Recommendation

There are clear yam varietal and morphological differences from the coastal regional through the central and western parts of the country.

It is recommended that tuber characteristics and inclusion of wild species in addition to genotypic differentiation be further investigated. Molecular genotyping will provide further information that will help understand yam diversity in Kenya. Further research on the crop is essential imperative for full exploitation of the crop's potential. Such strategies should include conservation for yam need to be put in place to stem the loss of this crop.

Acknowledgement

We wish to thank Director KARI for the provision of the study leave, the extension staff for their valuable time and Sida through EAPGREN for the financial support, the farmers for their invaluable time, the KARI Biometricians and technical staff for data collection and analysis.

References

Ayensu, E.S. and D.G. Coursey. 1972. Guinea yams: The botany, ethno botany, use and possible future of yams in West Africa. Economic Botany 26: 301-318.

IPGRI/ IITA, 1997. Descriptors for Yam (*Dioscorea* spp.).

Maundu, P.M., G.W. Ngugi and C.H. Kabugi 1999. Traditional Food Plants of Kenya. National Museums of Kenya, Nairobi.

Ministry of Agriculture. Republic of Kenya: Economic Review of Agriculture, 2007.

Mutegi E.,Nyamongo.D.O, C.Githunguri, G.Ngae and G.Muthee. Challenges and Opportunities in the Underutilized and Neglected Yam (*Dioscorea* spp.) Genetic Resources of Kenya: Outcome of a Baseline Survey in Eastern Province. Paper presented at the 9th Triennial

Symposium of the International Society for Tropical Root Crops-African Branch. November, 2004, Mombasa, Kenya.

Muthamia.Z.K., G.N.Ngae., E.Ateka., A.B.Nyende.,and E.Mamati. Paper Presented at the 10th Biennial KARI Scientific Conference in Nairobi, 10th-14th November 2008.

Mwirigi,P.N.,Kahangi,E.M.,Nyende,A.B and Mamati,E.G. Morphological Variablity within the Kenyan yam (Dioscorea spp.) Journal of Applied Biosciences (2009) 16:894-901. ISSN 1997-5902.

Heritability of root peel thickness and its influence in extractable starch from cassava (*Manihot esculenta* Crantz) roots

Pérez J.C., Lenis J.I., Calle F., Morante N., Sánchez T., Debouck D. and Ceballos H.
International Center for Tropical Agriculture (CIAT), Apartado Aéreo 6713, Cali, Colombia
Corresponding Author: h.ceballos@cgiar.org

Abstract
Cassava roots are the most important commercial product from this crop. Roots have two major components: the starchy parenchyma and the peel with higher amount of fiber and cyanogenic glucosides. A uniform trial involving 64 clones was grown in five locations and peel thickness (PT) measured along other traits. Roots 33 of these clones were further analyzed for the amount of extractable starch. Broad sense heritability for PT was high (0.93) compared with that for yield (0.63). The values obtained demonstrate that there is a very strong genetic component in the expression of peel thickness. Extractable starch depended heavily on dry matter content but also on PT. In an additional evaluation, 1448 accessions from the germplasm collection were evaluated for PT and showed a wide range of variation (from 0.79 to 5.14 mm).

Keywords: Easy to peel; fiber; root quality.

Introduction

Cassava (*Manihot esculenta* Crantz), along with maize, sugarcane and rice, constitute the most important sources of energy in the diet of people from most tropical countries of the world. A new era for cassava research began for cassava with the implementation of successful breeding projects, modernization of cultural practices and development of new processing methods (Cock, 1985; Jennings and Iglesias, 2002, Ceballos et al, 2007a).

Except at crop establishment, cassava has no specific water stress sensitive growth stage. It can also produce well in dry air conditions during a great part of the growth cycle, high air temperatures, high potential evapotranspiration, low fertility soils (with particular capacity to withstand low-P conditions) and intense pest and disease pressures (El-Sharkawy, 2006).

The most important commercial product of cassava is the storage root, full of starch . Cassava

roots have a very short shelf life due to a process known as post-harvest physiological deterioration (PPD). Tolerance to PPD has also been recently reported (Morante et al, 2010). Other important characteristics of the root are starch quality traits (Carvalho et al. 2004; Cebal los et al, 2007b, 2008; Moorthy, 2004; Sanchez et al, 2009; Sriroth et al., 1999); cyanogenic glucosides (Andersen et al., 2000; Bokanga, 1994; Mkumbira et al., 2003); dry matter content (Cach et al., 2006; Jannings and iglesias, 2002; kawano 1998) and nutritional quality (Chavez et al. 2005; Thakkar et al., 2007).

About 74 to 85% of dry root weight of cassava is starch (Rickard et al. 1991). Dry matter content strongly influences the amount of extractable starch from cassava roots. Therefore, starch factories usually pay differential price for the fresh roots depending on their dry matter content. Variation in root cortex or peel thickness (PT) was recently reported by Kawiki (2009) in a large sample (> 800) of African genotypes including elite germplasm and landraces from Democratic Republic of Congo, Kenya, Tanzania, Madagascar and Uganda. PT ranged from 0.34 to 4.89 mm. The starch in the peel is much more difficult to extract, therefore the peel is frequently considered a byproduct that is nonetheless used for animal feed.

The objectives of this study were to estimate broad sense heritability for root peel thickness and to establish the relationship of extracted starch with dry matter content of the roots and the thickness of the peel.

Materials and Methods

A set of 64 genotypes were evaluated in five locations in the northern coast of Colombia. Trials had three replications. Each experimental plot had 25 plants at a density of 1 x 1m. Only the nine central plants were harvested for analysis. Trials were hand planted and standard fertilizations and weed-control measurements were made. No irrigation was provided. Harvest took place when plants were about 11 months of age (the typical harvesting age in this region of Colombia).

Trials were harvested following the standard procedure (Ceballos et al., 2007a). Several variables were measured: fresh root yield (**FRY**); dry matter content (**DMC**) by the gravimetric method (Kawano et al., 1978); plant height (**PHT**); a score for plant type (**PTY**) combining plant architecture, stay green at harvest and overall plant health was taken using a 1-5 score (1=excellent; 5=very poor); and harvest index (**HIX**) were measured. In addition a sample of three commercial-sized roots from three random plants from each experimental plot was taken to quantify PT. Roots were cut in the mid-section and a disc was taken. A digital caliper was used to measure PT at three different points in these root slices from the middle section of the root.

Because of limitations on the number of roots that could be transported and processed at a given time, a set of 33 genotypes (from the total of 64 genotypes included in this study) was used for more detailed analysis on extractable starch.

From each experimental plot a sample of about one kg of roots was packed and shipped. Processing of the roots took place the day after harvest. Roots from each genotype were identified with plastic pearls of different color inserted at their proximal extreme of (neck of the root). All roots from a given entry were weighted before washing and then washed in a rotating cylinder common in many small-sized (fermented) starch factories of Colombia. This process typically rasps some of the peel and therefore the weight of the roots after washing is lower than before washing. All entries from a given location were processed simultaneously in the same day.

Three PT measurements in the mid section of the roots were taken on each root as it was done in the *in situ* evaluations. Roots were then peeled and the weight of the peel (**PW**) and parenchyma recorded. Peel and parenchyma from the roots of a given genotype were then pooled together for starch extraction following the protocol described in Sánchez et al., 2009. The extracted starch (**EXS**) was expressed as Kg of dry starch per Kg of fresh root.

A sample of 1448 accessions from the collection was harvested as part of ongoing efforts to characterize the entire collection (unreplicated evaluation based on four plants per genotype). Three measurements of PT were made per genotype to assess the range of variation for this variable.

Broad sense heritability was estimated using the expectations of the mean squares in the analysis of variance to obtain estimates of genetic and phenotypic variances (Nyquist, 1991). Broad sense heritability was estimated using plot averages, which in the case of PT included as many as 27 observations (three quantifications per root, three roots per plant and three plants per plot). Heritability was estimated as follows (Nyquist, 1991):

$$h^2_{(\text{Broad Sense})} = \sigma^2_{\text{Genetic}} / \sigma^2_{\text{Phenotypic}}$$

Results and Discussion

General conditions of the experiments were satisfactory with adequate plant densities and normal plant growth. Results for the data collected *in situ* (PT, FRY, DMC, HIX, PTY, and PHT) on the 64 entries of this study are presented in Table 1. Broad sense heritability ranged from 0.63 (FRY) to 0.93 (PT). Broad sense heritability has limited value in predicting actual genetic progress as a considerable fraction of the genetic variance it is based on cannot be fully exploited by the phenotypic recurrent selection used in cassava. These h^2 values, however, are useful for understanding the relative influence of the non-genetic sources of variation in the phenotypic expression of traits.

Average FRY (30 t ha^{-1}) was outstanding and combined with an average DMC of 32.2% resulted in an average dry matter production of about 10 t ha^{-1}. The range of variation for average FRY across locations was 25.60 (Location 3) to 37.46 t ha^{-1} in Location 2. DMC was generally uniform across locations (around 31.5%) except for Location 4 which had a much higher value (34.52%). Average plant height ranged from 1.75 m in Location 3 up to 2.72m in Location 1.

Table 2 presents the results of the 33 entries analyzed at CIAT's Experimental Station in Palmira. Heritability values for DMC and PT were similar to those measured *in situ* in the five different locations were trials grew. Table 2 presents three additional parameters that could not be estimated *in situ*: amount of extractable starch (**EXS**), peel weight (**PW**) after washing the roots, and DMC estimated by drying a 100 g sample per genotype/replication. Since the weight of roots from each plot ranged around 1 kg (1092 g) but was not exactly uniform (ranging from 536 to 2544 g) **EXS** and **PW** were standardized on a per kg of fresh root basis.

Location effects were highly significant ($P < 0.01$) for all variables, except for EXS (significant at 5% probability level). Genetic effects (variation among 33 clones), was highly significant ($P < 0.01$) for all traits. Genotype-by-environment interaction was also highly significant for PT and DMC (estimated by the gravimetric method), significant ($P < 0.05$) for EXS and non-significant for DMC (oven method) and PW. Heritability values were (as it is frequently the case for broad sense heritability) high, ranging from 0.70 for EXS to 0.95 for PT. Interestingly, heritability was higher for DMC estimated by the indirect gravimetric method than by drying samples in the oven (0.87 and 0.83, respectively). Although the oven method is a direct measure of DMC, results from this study suggest that it is not as precise as the indirect gravimetric method. This is likely to be the result of sample size (100 grams for oven versus around 1000 grams in this evaluation of DMC by the gravimetric method).

The average of EXS per kg of fresh root varied widely among clones (146 to 206 g of dry starch per kg of fresh root) as presented in Table 2. Stepwise regression analysis was conducted to explain as much as possible the factors influencing the variation in EXS. The adjusted R^2 value was only 0.36 indicating that many other factors influence the amount of EXS in addition to those included in the model. The most important factor, as expected, was DMC whose sequential sum of squares was 239558, followed by PT with a sum of squares clearly smaller (10476). Both factors were significantly ($P < 0.01$) different from zero and, as expected, the coefficient for DMC was positive, whereas that for PT was negative. Therefore higher DMC and thinner peels tended to increase the amount of EXS.

The the variation was considerably wider for the germplasm collection than in the replicated trials which only had 64 genotypes. PT ranged from 0.79 to 5.14 mm, with an average higher (2.55 mm) than that observed in the replicated trials (1.92 mm).

As reported by Kawiki (2009) there is a clear genetic variability for PT in cassava. This trait seems to be highly heritable in spite of the variations reported within clones, among roots from the same plant and even within the same root (data not presented but available). The range of variation for PT observed in the replicated trial (1.48-2.55 mm), however, is considerably smaller than that reported by Kawiki (0.35mm to more than 4.5 mm) and the range of variation in the 1448 accessions from the germplasm collection (0.79 to 5.14 mm). This should be taken into consideration because the impact of PT on EXS may be larger in other populations with wider range of variation for PT.

Heritability for HIX was considerably higher than for FRY (0.85 vs. 0.63, Table 1). This has been and remains an important distinction that justifies the inclusion of HIX as a selection criterion, particularly in early phases of selection (Kawano 1990; 2003). The two variables showed very high genetic correlations (data not presented but available). However, the association between HIX and FRY vanishes for HIX values typical for improved and adapted germplasm (>0.50). The widest range of variation for FRY (17 to 58 t ha^{-1})

was observed among genotypes with HIX around 0.70. As expected HIX above a threshold (around 0.75) tends to be undesirable as they are correlated with a reduction in productivity. They are also rather infrequent. Results of this study supports the prevailing criteria that most productive clones usually have a HIX ranging from 0.55 to 0.75.

Finally the most relevant aspect of this research focuses on the relationship between PT (or PW) and EXS. As expected, DMC played a very important role in defining EXS. This article also provides evidence of the statistically significant role played by PT on EXS, although it was considerably less important than DMC. It has to be emphasized that the impact of PT on EXS should be much larger whenever a wider variation for PT is considered (such as the variation presented in Table 6). It should also be mentioned that thicker peels are not necessarily undesirable. Thicker peels are easier to separate from the parenchyma facilitating the labor for those processing pathways that require peeling the roots. This is an activity that is typically carried out by women in many areas of the world and is labor intensive, time consuming and unsuitable for large scale processing (Adetan et al., 2003). In these cases, the peel is frequently used for animal feeding with the caution that the levels of cyanogenic glucosides in higher in the peel than in the parenchyma (Bokanga, 1994). Finally, thick peel has been linked to tolerance/resistance to certain types of insects feeding on the roots (Riis, 1997).

References

Adetan, D. A., L. O. Adekoya, and O. B. Aluko, 2003: Characterisation of some properties of cassava root tubers. Journal of Food Engineering 59, 349-353.

Andersen, M.D., P.K. Busk, I. Svendsen, and B.L. Møller, 2000: Cytochromes P-450 from cassava (*Manihot esculenta* Crantz) catalyzing the first steps in the biosynthesis of the cyanogenic glucosides linamarin and lotaustralin. The Journal of Biological Chemistry 275, 1966-1975.

Bokanga, M. 1994: Distribution of cyanogenic potential in cassava germplasm. International Workshop on Cassava Safety. IITA, Ibadan, Nigeria. Acta Horticulturae 375, 117-123.

Cach T. N., J. I. Lenis, J. C. Pérez, N. Morante, F. Calle and H. Ceballos, 2006: Inheritance of relevant traits in cassava (*Manihot esculenta* Crantz) for sub-humid conditions. Plant Breeding 125, 177-182.

Carvalho, L.J.C.B., C.R.B. de Souza, J.C.M. Cascardo, C.B. Junior, and L. Campos, 2004: Identification and characterization of a novel cassava (*Manihot esculenta* Crantz) clone with high free sugar content and novel starch. Plant Molecular biology 56, 643-659.

Ceballos, H., M. Fregene, J.C. Pérez, N. Morante, and F. Calle, 2007a: Cassava Genetic Improvement. In: M.S. Kang and P.M. Priyadarshan (eds), Breeding Major Food Staples, 365-391. Blackwell Publishing, Ames, IA.

Ceballos H., T. Sánchez, N. Morante, M. Fregene, D. Dufour, A.M. Smith, K. Denyer, J.C. Pérez, F. Calle, and C. Mestres, 2007b: Discovery of an Amylose-free Starch mutant in cassava (*Manihot esculenta* Crantz). Journal of Agricultural and Food Chemistry 55, 7469-7476.

Ceballos, H., T. Sánchez, K. Denyer, A.P. Tofiño, E.A. Rosero, D. Dufour, M.A. Smith, N. Morante, J.C. Pérez, and B. Fahy, 2008: Induction and identification of a small-granule, high-amylose mutant in cassava (*Manihot esculenta* Crantz). Journal of Agricultural and Food Chemistry 56, 7215-7222.

Chávez, A.L., T. Sánchez, G. Jaramillo, J.M. Bedoya, J. Echeverry, E.A. Bolaños, H. Ceballos, C.A. Iglesias, 2005: Variation of quality traits in cassava roots evaluated in landraces and improved clones. Euphytica 143:125-133

Cock, J, 1985: Cassava. New potential for a neglected crop. Westview Press. Boulder, CO., USA, 240 pp

El-Sharkawy, M.A., 2006: International research on cassava photosynthesis, productivity, eco-physiology, and responses to environmental stress in the tropics. Photosynthetica 44, 481-512.

Jennings, D.L., and C.A. Iglesias 2002: Breeding for crop improvement. In: R.J. Hillocks, J.M. Tresh and A.C. Bellotti (eds), Cassava: biology, production and utilization, 149-166. CABI Publishing, Wallingford.

Kawano, K., 1990: Harvest index and evolution of major food crops cultivars in the tropics. Euphytica 46, 195-202.

Kawano, K. 2003: Thirty years of cassava breeding for productivity-biological and social factors for success. Crop Sci. 43, 1325-1335.

Kawano, K., P. Daza, A. Amaya, M. Ríos, and M.F. Gonçalvez, 1978: Evaluation of cassava

germplasm for productivity. Crop Sci. 18, 377-380.

Kawano, K., K. Narintaraporn, P. Narintaraporn, S. Sarakarn, A. Limsila, J. Limsila, D. Suparhan, V. Sarawat, W. Watananonta, 1998: Yield improvement in a multistage breeding program for cassava. Crop Sci 38, 325-332.

Kawiki, R.S., 2009: Variation in cassava (*Manihot esculenta* Crantz) based on single nucleotide polymorphisms, simple sequence repeats and phenotypic traits. Ph.D. Disertation, Department of Plant Sciences, Faculty of Natural and Agricultural Sciences, University of Free State. Bloemfontein, South Africa. pp. 56-89

Mkumbira, J., L. Chiwona-Karltun, U. Lagercrantz, N. Meso Mahungu, J. Saka, A. Mhone, M. Bokanga, L. Brimer, U. Gullberg, and H. Rosling, 2003: Classification of cassava into 'bitter' and 'cool' in Malawi: From farmers' perception to characterisation by molecular markers. Euphytica 132, 7-22

Moorthy, S.N., 2004: Tropical sources of starch. In: A.C. Eliasson (ed), Starch in food, 321-359. CRC Press, Boca Ratón.

Morante, N., T. Sánchez, H. Ceballos, F. Calle, J.C. Pérez, C. Egesi, C.E. Cuambe, A.F. Escobar, D. Ortiz, A.L. Chávez, 2010: Tolerance to post-harvest physiological deterioration in cassava roots. Crop Sci. 50, 1333-1338.

Nyquist, W.E., 1991: Estimation of heritability and prediction of selection response in plant populations. Critical Reviews in Plant Sciences 10, 235-322.

Rickard, J.E., M. Asaoke, and J.M.V. Blanshard, 1991: The physico-chemical properties of cassava starch. Trop. Sci. 31, 189-207.

Riis, L., 1997: Behaviour and population growth of the burrower bug *Cyrtomenus bergi* Froeschner: effects of host plants and abiotic factors. Ph.D. thesis, Royal Veterinary Agricultural University, Copenhagen.

Sánchez, T., G. Mafla, N. Morante, H. Ceballos, D. Dufour, F. Calle, X. Moreno, J.C. Pérez, D. Debouck, 2009: Screening of starch quality traits in cassava (*Manihot esculenta* Crantz). Starch/Stärke 61, 12-19.

Sriroth, K., V. Santisopasri, C. Petchalanuwat, K. Kurotjanawong, K. Piyachomkwan, and C.G. Oates, 1999: Cassava starch granule structure-function properties: influence of time and conditions at harvest on four cultivars of cassava starch. Carbohydrate Polymers 38, 161-170.

Thakkar, S.K., B. Maziya-Dixon, A.G.O. Dixon, M.L. Failla, 2007: â-carotene micellarization during *in vitro* digestion and uptake by Caco-2 cells is directly proportional to â-carotene content in different genotypes of cassava. Journal of Nutrition 137, 2229-2233.

Table 1. Mean squares from the combined analysis of for relevant agronomic traits estimated from 64 genotypes (cassava clones) evaluated across five locations. In the last row of the table the estimated h^2 values for each variable (based on plot averages or totals) are presented.

Parameter	df	PT mm	FRY t ha^{-1}	DMC %	HIX 0-1	PTY 1-5	PHT m
Loc.1		1.92	28.36	31.32	0.49	2.79	2.72
Loc.2		2.05	37.46	31.97	0.65	2.65	2.06
Loc.3		1.83	25.60	31.54	0.64	2.94	1.75
Loc.4		1.93	29.30	34.52	0.68	2.66	2.11
Loc.5		1.89	29.11	31.62	0.56	2.27	2.21
Average		1.923	30.0	32.2	0.60	2.66	2.17
h^2		0.93	0.63	0.87	0.85	0.83	0.91

Table 2. ANOVA for variables measured at CIAT based on roots from 33 clones.

Parameters	Peel Thickness mm	DMC (%) Weight g	Extracted Oven %	Peel Field %	DMC (%) starch kg (kg root)$^{-1}$
Average	1.7 91	168.15	32.36	31.78	0.177
Max. clone average	2.469	220.44	36.07	34.24	0.206
Min. clone average	1.345	139.96	28.16	28.09	0.146
h^2	0.95	0.90	0.83	0.87	0.70

Progress in screening cassava genotypes for resistance to cassava brown streak Uganda virus

Kanju E.*[1], Ntawuruhunga P.[2] and Otim-Okello F.[3]

[1]IITA, P.O Box 34441 Dar es Salaam, Tanzania,
[2]IITA, P.O Box Lilongwe, Malawi,
[3]IITA, P.O Box 7878 Kampala, Uganda,
* Corresponding author

Abstract

Cassava is a key food security crop in sub-Saharan Africa, and is increasingly offering opportunities for income generation from the sale of fresh roots, cuttings and diverse processed products. The total fresh root production is increasingly constrained, by the two principal biotic constraints; cassava mosaic disease (CMD) and cassava brown streak disease (CBSD). Considerable successes have been achieved in mitigating the effects of the CMD pandemic through the multiplication and dissemination of CMD-resistant varieties, but severe CMD continues to spread. In more recent years, there has been a rapid and devastating outbreak of CBSD, especially in the Great Lakes region where it was not prevalent. Outbreaks have been reported in parts of Uganda, Kenya, Rwanda and Tanzania near Lake Victoria, and reports were also received of CBSD-like symptoms in the western part of the Democratic Republic of Congo. Recent reports have confirmed that CBSD is comprised of two distinct species of viruses, *Cassava brown streak virus* (CBSV) and *Cassava brown streak Uganda virus* (CBSUV).

The most effective and realistic approach to reducing losses to CMD and CBSD is the use of host-plant resistance or the deployment of less-susceptible cultivars. Cassava trials were therefore, established in Uganda to screen cassava germplasm for resistance to CBSD from 2005/2006 to date. In 2009 fourteen clones that combined dual resistance to CMD and CBSD with good cooking qualities were selected in collaboration with farmers. The fourteen clones were: MM 06/0013, MM 06/0090, MM 06/0130, MM 06/0143, MM 06/0139, MM 06/0082, MM 06/0128, MM 06/0123, MM 06/0083, MM 06/0046, MM 06/0112, MM 06/0074, MM 06/0005 and MM 06/0138. They significantly differed in fresh root yielding ability, which ranged from 3.8 to 25.2 T/ha with a mean 12.3 t/ha. In contrast, the improved check (TME 204) yielded 4.8 t/ha. Their dry matter content ranged from 29.4 to 47.7%. The 14 clones were sent to the Kenya Plant Health Inspectorate Services (KEPHIS), Muguga, Kenya for cleaning and virus indexing ready for regional distribution.

However, when the clones were evaluated across three sites during the 2009/2010 season, only three (MM 06/0082, MM 06/ 0123 and MM 06/0128) showed tolerance to CBSD. The three new clones would be the major arsenal against CBSD and specifically CBSUV, in all the mid-altitude regions of the Great Lakes region. Most importantly, farmers will need to evaluate these new clones under actual field conditions for dual resistance to CMD and CBSD, as well as for utilization characteristics. The best of them will be used in further disease-resistance breeding among national programs in other countries in the Great Lakes region such as Burundi, Rwanda, Kenya, Tanzania and DR Congo.

Keywords: Cassava, breeding, CBSD, host resistance

Introduction

Cassava is a key food security crop in sub-Saharan Africa, and is increasingly offering opportunities for income generation from the sale of fresh roots, cuttings and diverse processed products. The total fresh root production of > 180 million tonnes is increasingly constrained, by the two principal biotic constraints, cassava mosaic disease (CMD) and cassava brown streak disease (CBSD). Considerable successes have been achieved in mitigating the effects of the CMD pandemic through the multiplication and dissemination of CMD-resistant varieties, but severe CMD continues to spread. CBSD had for many years been recognized as an important disease of cassava in coastal East Africa as well as the shores of Lake Malawi, but was rarely observed in parts of East Africa at altitudes > 1000m above sea level. In recent years, there has been a rapid and devastating outbreak of CBSD, especially in the Great Lakes region. Outbreaks have recently been reported in parts of Uganda, Kenya, Rwanda and Tanzania near Lake Victoria, and reports were also received of CBSD-like symptoms in the western part of the Democratic Republic of Congo (DRC) (Hillocks and Jennings, 2003; Mahungu et al., 2003; Alicai et al., 2007). These changes precipitated a significant increase in the degree of research attention directed towards CBSD and the virus(es) causing it. Some of the most significant recent

research findings include: Isolation, sequencing and identification of two distinct species of viruses, *Cassava brown streak virus* (CBSV) and *Cassava brown streak Uganda virus* (CBSUV) which cause CBSD (Winter, 2010; Fauquet, 2010).

The most effective and realistic approach to reducing losses to CMD and CBSD is the use of host-plant resistance or the deployment of less-susceptible cultivars. This activity was therefore, initiated to screen cassava germplasm for resistance to CBSD in Uganda. The output from this initiative would then be shared with NARS in the region.

Materials and Methods

In 2005/06 season about 5,000 cassava seeds were sown in the field at Serere Agricultural Research Institute, near Soroti, Uganda. The seeds were from ten half-sib families (Kibaha-OP, Kigoma Red-OP, Nachinyaya-OP, SS4-OP, Kitumbua-OP, Namikonga-OP, NDL 90/34-OP, UKG 93/41-OP, Kiroba-OP and TMS 4(2) 1425-OP) derived from CBSD and CMD tolerant parents planted in a polycross block at ARI Naliendele, Mtwara, Tanzania. At harvest 12 Months after planting (MAP) 124 seedlings that did not show any disease symptoms were selected and cloned for further evaluation under Clonal Evaluation Trial (CET) planted at Mukono, near Kampala, (one of the CBSD hot spots) during the 2006/07 season. After every 10 rows a susceptible spreader / check (TME 204) was planted. Sixty-six clones that showed promising resistance to CBSD and CMD as well as good yield potential were selected for further evaluation under Preliminary Yield Trial (PYT) during the 2007/08 season. The PYT consisted of two replications with plot size of 3m x 5m.TME 204 was again planted after every two plots to increase CBSD inoculum pressure. Forty promising clones were selected and were evaluated in an Advanced Yield Trial (AYT) at Mukono during the 2008/09 season. The AYT had three replications. At harvest 14 clones were selected and were planted in a Uniform Yield Trial (UYT) with replications across three sites namely, Mukono, Namulonge and Serere. The plants in all the trials were spaced at 1m x 1m. Plots were weeded by hand whenever it was necessary. At harvest, roots were counted and weighed to estimate fresh root yield and other yield components. Root samples were taken for the determination of the cyanogenic potential (CNp) using the picric acid method. Dry matter content (DMC) was determined using the oven dry method. Dry root yield (DRY) was obtained by multiplication of FRY with DMC/100). CBSD symptoms were scored on foliar parts and on roots using a scale of 1:5 where 1 indicated no symptoms and 5 very severe symptoms. Farmers were invited to participate in the selection of clones they preferred. The selected clones were cooked and the farmers evaluated them for their cooked qualities. The fresh yield data was subjected to analysis of variance using the SPSS (AYT) and Systat software (UYT).

Results

Some of the characteristics of the 14 clones selected among the 40 evaluated in the AYT are presented in Table 1. Significant differences in root yield were observed among the clones. The yield of the selected clones ranged from 3.8 t/ha (MM 06/0083) to 25.2 t/ha (MM 06/0112) with a mean of 12.3 t/ha (Table 1). The yield of the check (TME 204) was 4.8 t/ha and five of the selected clones significantly out-performed it. The dry matter ranged from 29.4 (MM 06/0005) to 47.7% (MM 06/0013). All the selected clones had low mean cyanogenic potentials (ranging from 2.5 to 4.5), cooked well and were liked by the farmers that tested them.

The performance of the 14 clones across the three sites is shown in Table 2. Highly significant differences were detected among the clones and sites. The variety x site interaction was also highly significant. The best performing clone in terms of fresh root yield was MM 06/0090 which gave an average yield of 23.13 t/ha. Yields at Mukono and Namulonge were unusually very low (5.37 and 4.49 t/ha respectively) due to dry spells experienced during the early growth of the plants. However, as far as CBSD disease pressure was concerned, all the three sites could be classified as high pressure sites, but Mukono had the highest CBSD pressure because it had the highest incidence of severe root necrosis. For example, at Serere clone MM 06/0090 had very few roots that scored class 3 for root necrosis but at Mukono many roots were affected and more than 70% of the affected roots scored class 3.

Table 1: Some characteristics of the 14 CBSD tolerant clones selected from the AYT at Mukono, Uganda, 2008/09 season

Clone	FRY (t/ha)	DMC %	DRY (t/ha)	CBSD-FS	CBSD-RS	Pedigree
MM06/0013	11.2	47.7	5.3	1	1	Kitumbua -OP
MM06/0090	18.0	47.4	8.5	2	2	Kibaha-OP
MM06/0130	8.3	46.0	3.8	1	2	Kitumbua -OP
MM06/0143	5.7	43.2	2.4	1	1	Kibaha-OP
MM06/0139	20.1	43.1	8.6	1	1	Kibaha-OP
MM06/0082	9.8	43.1	4.2	1	1	Kibaha-OP
MM06/0128	6.9	41.5	2.9	1	2	Kigoma Mafia-OP
MM06/ 0123	13.8	37.9	5.2	1	2	Kibaha-OP
MM06/0083	3.8	37.9	1.4	1	1	Kibaha-OP
MM06/0046	5.0	37.6	1.9	1	1	Kigoma Mafia-OP
MM06/0112	25.2	34.7	8.7	1	2	Kibaha-OP
MM06/0074	5.2	34.5	1.8	1	1	Kigoma Mafia-OP
MM06/0005	17.3	29.4	5.1	2	2	SS4-OP
MM06/0138	22.5	40.7	9.2	1	1	Kibaha-OP
Mean	12.3	39.0				
TME 204 (Check)	4.8	38.4		4	4	
Trial Mean	10.2					
LSD (0.05)	10.7					
C.V %	37.4					

FRY = Fresh Root Yield; DMC = Dry Matter Content; DRY = Dry Root Yield;
CBSD-FS = CBSD Foliar Symptoms; CBSD-RS = CBSD Root Symptoms;
OP = Open Pollination

Table 2: Fresh root yield (t/ha) of 14 clones evaluated in the UYT across three sites in Uganda, 2009/2010

	Mukono	Namulonge	Serere	Mean
MM 2006/0013	2.73	1.81	15.67	6.74±1.18
MM 2006/0090*	17.47	18.47	33.47	23.13±1.18
MM 2006/0130*	4.95	3.84	24.40	11.06±1.18
MM 2006/0143	3.17	0.31	6.20	3.23±1.18
MM 2006/0139	3.96	2.56	8.07	4.86±1.18
MM 2006/0082*	6.29	3.64	4.67	4.87±1.18
MM 2006/0128*	3.61	2.57	23.80	10.00±1.18
MM 2006/0123*	11.53	8.47	18.47	12.82±1.18
MM 2006/0083	1.88	1.89	7.93	3.90±1.18
MM 2006/0046*	1.48	3.01	21.00	8.49±1.18
MM 2006/0112*	10.51	10.51	34.60	18.54±1.18
MM 2006/0074	0.95	0.59	13.89	5.14±1.18
MM 2006/0005	4.51	5.17	7.27	5.65±1.18
MM 2006/0138	1.32	1.37	12.67	5.12±1.18
TME 204 (Check)	2.32	2.39	13.27	5.99±1.18
TME 14 (Check)	9.97	5.32	17.47	10.92±1.18
Mean	5.37±0.52	4.49±0.52	16.42±0.52	8.78±1.18
LSD (0.05)	5.73	5.73	5.73	3.31

*These seven clones will be used in establishing a crossing program to develop a new improved population

Discussion

The recent CBSD pandemic in the cassava growing regions in Uganda and around Lake Victoria in Tanzania is unfortunately devastating the CMD resistant varieties that were deployed with much effort to mitigate the CMD pandemic that emerged in the 1990s. These clones were not selected for resistance to CBSD because the disease was not prevalent in that agro-ecology. Very few of the CMD resistant varieties have reasonable tolerance to CBSD i.e. MM 96/4684, officially released in Tanzania as Mkombozi (Swahili for Saviour) for the Lake Zone regions and MM 96/4271 which is in the pipeline for official release in Uganda.

The three new clones mentioned above, have so far shown promising field resistance to both CMD and CBSD. They stand to be the major arsenal against CBSD and specifically CBSUV, in all the mid-altitude areas of the Great Lakes region. Most importantly, farmers will need to evaluate these new clones under actual field conditions for dual resistance to CMD and CBSD, as well as for utilization characteristics. The best of these varieties will be used in further disease-resistance breeding programs in other countries in the Great Lakes region such as Burundi, Rwanda, Kenya, Tanzania and DR Congo. The 14 clones were sent to the Kenya Plant Health Inspectorate Services (KEPHIS), Muguga, Kenya for cleaning and virus indexing ready for regional distribution. The pedigrees of these three clones indicate that two of them (MM 06/0082 and MM 06/0123) are half-sibs of a local cultivar called Kibaha (Table 1). However, this cultivar is susceptible to CBSD in coastal lowlands of Tanzania. This might indicate that Kibaha has tolerance genes against CBSUV and not CBSV. Therefore this cultivar can be used in breeding for CBSUV resistance in the Great Lakes region. The third clone (MM 06/0128) was derived from Kigoma Mafia which is tolerant to CBSV in the coastal lowlands. This implies that this cultivar could have tolerance to both of the viruses. The three tolerant clones together with four others that had very good other attributes will be used in a crossing program to develop a new improved population with resistance to CMD and CBSD.

Acknowledgements
We are very grateful to our Field Assistants, Messrs. Omongole, A. and Akena, C. for their job well done in managing the trials. IITA core donors are acknowledged for funding. Dr. Legg, J. is acknowledged for his assistance in data analysis for the UYT.

References

Alicai, T., C.A. Omongo, M.N. Maruthi, R.J. Hillocks, Y. Baguma, R. Kawuki, A. Bua, G.W. Otim-Nape and J. Colvin. 2007. Re-emergence of cassava brown streak disease in Uganda. Plant Disease 91:2429.

Fauquet, C. 2010. Molecular Diversity of cassava Brown Streak Viruses in East Africa. In: Cassava Brown Streak Disease: Research achievements, challenges and potential for control. Abstracts of the International Cassava Brown Streak Disease Workshop, 5th-7th May 2010, Entebbe, Uganda. National Crops Resources Research Institute, Namulonge, Uganda.

Hillocks, R.J. and D.L. Jennings. 2003. Cassava brown streak disease: a review of present knowledge and research needs. International Journal of Pest Management 49:225234.

Mahungu, N.M., M. Bidiaka, H. Tata, S. Lukombo and S. N'luta. 2003. Cassava brown streak disease-like symptoms in Democratic Republic of Congo. Roots 8:89.

Winter, S. 2010. A diversity analysis of viruses causing Brown Streak Disease of cassava in East Africa. In: Cassava Brown Streak Disease: Research achievements, challenges and potential for control. Abstracts of the International Cassava Brown Streak Disease Workshop, 5th 7th May 2010, Entebbe, Uganda. National Crops Resources Research Institute, Namulonge, Uganda.

Current status of Irish Potato (*Solanum tuberosum* L.) Production and constraint in Sierra Leone

A.E. Samura,[1] F.B. Massaquoi,[1] D. Quee.,[1] L. C. Marrah,[2] G. Samba, S.N. Fomba[1] and A.G.O. Dixon

[1] Sierra Leone Agricultural Research Institute (SLARI), Tower Hill, Freetown, Sierra Leone
[2] Daindenden Federation Koinadugu District
Email: aesamura@yahoo.com

Abstract
Potato is one of the emerging crops of high economic value cultivated in the highlands of Kabala, Koinadugu district in the northern region of Sierra Leone. The highland stretches on to the futajallon highland in Guinea which grows and export potato into Sierra Leone. The market demand for the crop and the high price it commands in the local market makes it a highly favored crop. There is limited knowledge about the production and constrain to production under Sierra Leone condition. On the spot check in farmer's field was conducted to validate and assess constrains to production. Questionnaires and interview were conducted compliment data observed in the field. The active age group interested in production of irish potato production were the youth accounted for 94% of the sample population. Area under cultivation was small with majority of the farmers having less than 2 acres of the crop. The most common potato varieties used at the time of the survey were Nicolas, Resy and Ostra. Cultivation of potato was done during the coolest period in Sierra Leone which falls between December and January referred to as the harmattan season. The lowland ecology was mostly preferred by due to easy access to water. Diseases of economic importance included the Late blight and the potato virus. Incidence and severity of late blight was high and increased with time while symptom expression of potato virus was fairly constant throughout the growing season. Among the two varieties evaluated Nicolas expressed higher degree of resistance to late blight as well as potato virus. Yield estimate were extremely low ranging from 2.6 t/ha to 4 t/ha. Varietal difference was also observed in yield indicating variation in the level of adaptability among varieties.

Introduction
The potato (*Solanum tuberosum* L.) is the world's fourth most important food crop (Fehr, 1987), but

with increasing production in most of the developing countries. Over the past decade, both the area planted and the production of potato has increased faster than the human population in sub-saharan Africa (Abalo et al., 2001). Potato is one of the emerging crops of high economic value cultivated in the highlands of Kabala, Koinadugu district in the northern region of Sierra Leone. Yield per unit area at farm level are disappointedly low. In some cases total loss has been reported in farmers field (Samura, 2008). However, there is still high potential for growth, as indicated by the big yield gap. For example, in the case of Uganda, FAO, (1999) gives average yield estimates of 7.0 Mt per hectare, as compared to 25 Mt per ha under good management (Haxiza et al., 1997), 15Mt per ha under improved management and 5 Mt per ha under poor management (PRAPACE, 1998). In most part of the east Africa highlands, efforts to obtain high potato yield are being curtailed by limited availability of good quality seeds at affordable prices and severe epidemics of late blight caused by *Phytophthora infestans* (Mont L.) DeBary (Hakiza et al., 1997)

Irish Potato has become one of the emerging crops in Sierra Leone. It is similarly a major cash crop more expensive than sweet potato which is of the same duration and more adapted to farmers. However its potential as a food security crop has not being exploited. In collaboration with CARE INTERNATIONAL through funds provided by USAID, farmers in the Koinadugu district have been most recently actively engaged in the production of potato this effort has created a felt feed which require high research input to compliment local initiative. Attempts to popularize cultivation had been met with serious constrains with total crop failure reported by the Koinadugu women vegetable farmer's cooperative (Samura, 2008). This study was conducted with the following objectives in mind:

(i) To assess the major pest and diseases
(ii) To assess the level of production and constraint

Materials and Methods

Location, size and population:

Koinadugu accounts for 12,121 sq km. or 16.8 percent and happens to be the largest district in the country. According to the 1985 census report, Koinadugu had a population of 183,286 people, corresponding to 15 persons per sq km, the least populated district in the country.

Koinadugu lies in the interior plateau at Lat $9^0$05N and long $11^0$06W. It is part of the Guinea highlands, a major West African watershed.

Vegetation soils and climate

The predominant vegetation consists of forest savannah. It consists of typical fire tolerant tree species and the dominant grasses are usually Andropogon spp. Altitude of Kabala 1s 464.2m above sea level and provide the cool temperature needed for the production of seed potato. Generally, the upland soils have a good drainage quality with clay consisting of Kaolinite together with iron and aluminium oxide which increases gradually with depth. They have low organic matter content, low cation exchange capacity (CEC) and are acidic. In addition to the upland ferallitic soils, there are quiet extensive and economically important hydromorphic soils occurring in valley bottoms and river plains that form lowlands which are usually farmed under arable crops. These soils are relatively fertile.

Like any other part of the country, the climate in the region is tropical. There are two distinct seasons; a rainy season from mid- April to mid-November when up to 95% of the rain falls; and a dry season from mid- November to mid April. Total precipitation is suitable high and estimated to be 2216mm. Average sunshine hours per day are 4.2 with variation of 0.4 to 3.2 hours between June and October. The mean temperature varies from 20°C to 32 $^{\circ}$C. Questionnaires were administered to 50 farmers. Selection of farmers will be base on a randomized sampling. Fifty farmers actively engaged in irish potato production were randomly selected two major producing area, Ssenekedugu, yogomaya and Sulimania and mamodia. Group discussion and interviews was also conducted to compliment data generated from questionnaire. On the spot assessment was conducted to determine incidence and severity of blight, yield estimate and area under cultivation. Late blight was assessed using the 1- 9 CIP scale and percent leaf area affected was used for assessing severity while percent incidence was calculated by expressing in percent the total number of infected plant over the total number of plants sampled. Information on variety, site selection, time of planting, land preparation, cultural practices pest and disease management production, post harvest constrains associated with marketing and indigenous knowledge in overcoming these constraints was addressed by the questionnaires.

Data analysis

Data was analyzed using simple statistics. Analysis of variance (Anova) was used to compare

means through the Genstat discovery edition 3 statistical software.

Results

Irish potato production attracted the economically active population. Analysis from questionnaires and interviews indicated that the active age group of the population involved in irish potato production is between 26 to 50 years. This group accounted for 94% of the sample population while age group of 0 to 25 years accounted for only 6%. Area under cultivation was small with 68% of farmers having less than 2 acres of the crop and 32 % having between 3 to 5 acres. The most common potato varieties used at the time of the survey were Nicolas, Resy and Ostra. The introduction of potato in the koinadugu district has a long history starting with the private sector and most recently the non governmental organizations such as CARE International.v Sensitization on the production of potato has being conducted thus increasing the awareness of the potential of the crop among farmers. This survey indicated that 100% of farmers had at some point being engaged in training and participatory project in irish potato production. 96 % of the farmers reported that cultivation of potato was done during the coolest month of the year in Sierra Leone. This falls between the months of December and January and is generally referred to as the harmattan season. All farmers were aware of the importance of cool temperature and its implication on yield and growth of the crop. 89% of farmers indicated that their source of planting was generally from seed tubers collected from previous planting. A small percentage of farmers 10% claimed that they sourced their material as seed obtained from non governmental organization (NGO) and private business sector. Seventy four percent of farmers preferred the lowland ecology due to easy access to water. These farmers practice hand watering or in the case of a sponsored project, water pumps are applied. Those cultivating in the upland and hill accounted for 26% with very small area under cultivation and dependence on rainfall as a source of irrigation.

Major constrains to production

General constrains were highlighted and were ranked in order of importance. The most important constraint highlighted was labour with 85.7% consensus among farmers. This was followed by diseases and pest with 71% and fertilizer with 67.8%. With respect to gender, Men and Women expressed similar constrains with labour, diseases and fertilizer ranking first second and third respectively. Table 1 about here

Mean severity of late blight over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

Disease symptom expression for late Blight caused by **(***Phytophthora infestans)* was low at 1 month after planting (MAP) but increased with time. Significant difference was observed among varieties to late blight. Nicolas had significantly lower leaf area with symptoms (LAWS) compared to Ostira and was highest at 3 MAP with 57.5% and 76.7% respectively. Table 2 about here

Mean severity of potato virus over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

Disease symptom of potato virus was as early as 1 MAP for both varieties. No significant increase was observed with time. However the variety Nicolas had significantly lower symptom expression compared to Ostira. The highest percent leaf area affected of 50% was observed at 2 MAP for Ostira while Nicolas had the lowest 26.7 percent LAWS within the same period. Table 3 about here.

Mean incidence of late blight over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

Incidence of late blight increases significantly from 1 MAP to harvest. In all locations percent incidence was 93.3% for all varieties at 3 MAP. Significant difference was observed among varieties and month after planting. Ostira had significantly higher disease incidence at 1 and 2 MAP (30% and 90% respectively) compared to Nicolas with 13.3 % and 56.7% respectively. Table 4 about here

Mean incidence of potato virus over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

All varieties were susceptible to potato virus. Disease incidence was however higher for Nicolas with a mean incidence of 42.2% compared to Ostira with 54.4%. Nicolas had the highest incidence of 46% at 3 MAP not significantly different from 1 and 2 MAP. Ostira however had the highest incidence of 53.3 % at 3 MAP. Table 5 about here

Estimated number, weight of tubers and yield from a sample size of 1m2

Yield of potato was low in the sampled area for both varieties. Based on a 1 m by 1m sample plot size the total number of tuber obtained for Nicolas was 13.5 significantly higher than Ostira with 9.2 tubers. Weight of tuber was significantly higher for Nicolas (0.4kg) compared to Ostira (0.26kg). Yield for Nicolas was estimate at 4t/ha significantly higher than Ostira with 2.56 t/ha. Table 6 about here

Discussion

Shortage of good quality seed remains a major production constraint in many developing countries where potato is grown (Demo et al., 2001). The common practice adopted by farmers in koinadugu district is to sell large seed tubers and store smaller seed tuber for the next planting. This practice has lead to the loss previously introduced genotypes as a result of high pest and disease infestation and total crop failure. The timely availability of large quantities of certified seed tubers remains a major problem for farmers since degenerated seed obtained from previous harvest remains infected. In some cases 100% yield losses have being reported (Samura, 2008). There is currently a dearth of knowledge of the varieties being cultivated as imports from Guinea and other non Government organization in terms of passport information and spread.

The high prevalence of late blight disease observed indicates that the disease or source of inoculum is present wherever the crop is grown. Factor such as temperature, rainfall, potato cultivar and cropping systems could account for the spread and manifestation of the disease (Ajanga, 1993). The most effective and environmentally friendly way to prevent widespread devastation by late blight is to incorporate natural resistance into potato cultivars. Since the middle 19th century, there has been extensive selection and breeding especially for late blight resistance Lara et al., 2006). The existences of late blight tolerant varieties have enabled many of the poorest to produce a potato crop without the use of fungicides in Uganda (Low, 1997). Varieties highly susceptible to late blight will not survive under the prevailing climatic and cropping system in Koinadudu district where the growth of vegetables such as tomatoes, garden eggs is dorninat and act as alternate host of related pathogens

The lack of knowledge among farmers regarding proper agronomic practices, high demand for labour and disease management is the most serious constraint to sustained potato yield in Koinadugu district.

Another serious constraint is the lack of a system of sustainable production of clean seed for farmers. There is a strong political will on the part of the Government of Sierra Leone (GoSL) to enhance potato production and advancement through the application of biotechnology. Initial investments amounting to thousands of dollars have being directed to the construction of a biotechnology laboratory, tissue culture laboratory and a molecular biology laboratory at the Njala Agricultural Research Centre (NARC) for the production of micro propagation of low-cost, disease-free tuber "seed" for increase potato yields. New molecular biology and plant cell culture tools have enabled scientists to understand better how potato plants reproduce, grow and yield their tubers, how they interact with pests and diseases, and how they cope with environmental stresses. These advances have unlocked new opportunities for the potato industry by boosting potato yields, improving the tuber's nutritional value, and opening the way to a variety of non-food uses of potato starch, such as the production of plastic polymers.

Despite the low yield observed from farmers fiels and the high incidence of disease, farmer continue to grow the crop because of its high value.

Conclusion

The potential for increase potato production from adaptable varieties and improved agronomic practice is high. Prelininary evaluation trials and cultural practice such as using clean hoes, minimun disturbance during cultivation, rouging diseased plant when they first appear, should be conducted to gain knowledge of the crop and assess the effect of such practice on growth and yoield of the crop.

Result from this studies indicates variation in the reaction of varieties to prevaling diseases. This implies that the search for adaptable varieties that are high yielding and tolerant to pest and disease remain a requirement for mass propagation of seed tuber to farmers. High level technical cooperation needs to sought from the International potato centre (CIP) for the acquisition of tropical genotypes for adaptability.

The Njala Agricultural Research Center with the mandate of conducting research on root and tubers such adopt a policy of mass producing

clean seed tuber for sale to farmers. This would ensure a constant supply of clean planting materials which is critical for expandaed area under cultivation for enviroment similar to the koinadugu district as well as increases in yield

.

Acknowledgement

I wish to thank Dr. A. Jalloh, CORAF/WECARD, Dakar, Senegal for his initiating this study, Stella Attie, CARE INTERNATIONAL, Kabala for mobilizing farmers within the period of this study. Grateful to Dr. A.G.O Dixon, Director General of the Sierra Leone Agricultural Research Institute (SLARI) and the Government for providing fund for this project.

Reference

Abalo, G., Hakiza, J.J., Kakuhenzire, R.M., EL Bedewy, R. and Adipala, E. 2001. Agronomic Performance of twelve elite potato genotypes in southwestern Unganda. *African Crop Science Journal*, Vol, 9. No. 1, pp.17 23.

Ajanga, S. 1993. Status of bacterial wilt in Kenya. In: Bacterial Wilt. Hartman, G.L. and Hayward, A.C. (Eds.), pp. 338 340. ACIAR. Proceedings No.45, Canderra, Australia.

Demo,P., Akoroda.,M.O. and Njualem, D.K. 2001. A model for rational determination of prices of seed potato (*Solanum tuberosum* L.) tubes of different size grades using agronomic data. Proceeding of the Eighth Triennial Symposium of the International Society for Tropical Root Crops Africa Branch. Ibadan, Nigeria.

Fehr, W.R.1987. Principles of cultivar development. Vol.2. Crop Species. Macmillan Publishing Company, New York. 672pp

Food and Agriculture Organization (FAO). 1999. FAO Quarterly bulletin of statistics 12:38. FAO, Rome, Italy.

Hakiza,J.J., Kakuhenzire, R.M., Alacho, F.O., and Mukalazi,J. 1997. The international blight and coordinated regional yield evaluation of potato genotypes in Uganda. African Crop Science Conference Proceedings. 3:981-987.

Lara M. Colton, Horia I. Groza, Susan M. Wielgus and Jiming Jiang 2006. Marker-Assisted Selection for the Broad-Spectrum Potato Late Blight Resistance Conferred by Gene RB Derived from a Wild Potato Species . Crop Sci 46:589-594 .Crop Science Society of America.

PRAPACE, 1998. Evaluation of potato germplasm of field resistance to late blight in East and Central Africa. Recommendations and summaries from regional workshop. Presentation. PRAPACE and CIP. 21pp

Samura , A.E. 2008. Preliminary survey report on Irish Potato (*Solanum tuberosum*) disease in Kabala. Sierra Leone Agricultural Research Institute report. Unpublished.

PRAPACE, 1998. Evaluation of potato germplasm of field resistance to late blight in East and Central Africa. Recommendations and summaries from regional workshop. Presentation. PRAPACE and CIP. 21pp

Table 1.Constraints to Irish Potato production based on gender and level of importance

Constraints	Ranking and percent consensus among sample population					
	General Ranking	%	Women	%	Men	%
Labour	1	85.7	1	85.7	1	85.7
Disease	2	71.4	2	66.6	1	85.7
Fertilizer	3	67.8	2	66.6	2	71.4
Water	4	57.1	3	61	3	42.8
Tuber rot	4	57.1	2	66.61	4	28.5
Storage fa cilities	5	50	4	57.1	4	28.5
Rat	6	46.4	5	38.1	2	71.4
Tools	7	32	6	33.3	4	28.5
Weed	8	10.7	7	14.2	-	
Limited knowledge	9	7	8	7	-	
Land	9	7	8	7	-	
Poor yield	10	3	9	3	-	
Finance	10	3	9	3	-	

Table 2. Percent leaf area with symptoms with late blight for three locations

Variety	1 map	2map	3map	Mean
Nicolas	3.7	24.7	57.7	28.7
Ostira	6.3	43.3	76.7	42.1
Mean	5.0	34.0	57.2	
Cv	38.2			
Lds (var)*	14.2			

Table 3. Percent leaf area with symptoms of potato virus for three locations

Variety	1 map	2map	3map	mean
Nicolas	36.7	26.7	30.0	31.1
Ostira	43.3	50.0	46.7	46.7
mean	40	38.3	38.2	
cv	13			
Lds (var)	5.65			
Lsd (map)	6.91			
Lsd (var x map)	9.78			

Table 4. % Incidence of late blight disease across three locations

Variety	1 map	2map	3map	Mean
Nicolas	13.3	56.7	93.3	54.4
Ostira	30.0	90.0	93.3	71.1
Mean	21.7	73.3	93.3	
Cv	18.3			
Lds (var)*	12.1			
Lsd (map)**	14.8			
Lsd (var x map)	20.1			

Table 5. % Incidence of Potato virus disease across three locations

	Months after Planting (MAP)			
Variety	1 map	2map	3map	Mean
Nicolas	40	40	46	42.2
Ostira	53.3	50	50	54.4
Mean	46.7	45.0	53.3	
Cv	16.5			
Lds (var)*	8.35			
Lsd (map)	10.24			
Lsd (var x map)	14.48			

Table 6. Estimated number, weight of tubers and yield from a sample size of 1m2

Variety	No of tuber	Weight of tubers (kg)	Yield t/ha
Nicolas	13.56	0.4	4
Ostira	9.22	0.26	2.56
Mean	11.39	0.33	3.28
Cv	19.9	0.06	0.06
Lds (var)*	2.2	20	20.2

Current status of root and tuber crops improvement, production and utilization in Sierra Leone

S. N. Fomba[2*], F. B. Massaquoi[2], P. E. Norman[2], A. E. Samura[2], A. Mansaray[2], A. Jalloh[2], A. G. O. Dixon[3], N. A. Anthony[2], M. T. Benya[2], D. S. Fornah[2], M. K. Sawi[4], A. Sartie[5], O. Onadipe[5], and L. O. Sanni[5]**

[2] Njala Agricultural Research Centre (NARC)/ Sierra Leone Agricultural Research Institute (SLARI), PMB 540, Freetown, Sierra Leone;
[3]SLARI, PMB 1313, Freetown, Sierra Leone;
[4] Njala University (NU), Makonde Campus, Njala, Sierra Leone;
[5] IITA, Ibadan, Nigeria.
* Contact author; ** now at CORAF/WECARD, Dakar, Senegal.

Abstract
Cassava (*Manihot esculenta* Crantz) is the second most important food crop after rice, the staple in Sierra Leone; it is also the most important root and tuber crop. It is followed by sweet potato (*Ipomoea batatas* L.), yam (*Dioscorea* spp.), which forms part of the traditional farming system and has only recently been included in the research agenda of NARC/SLARI and potato (*Solanum tuberosum* L) aka "Irish" potato in Sierra Leone, an introduced crop from neighbouring Republic of Guinea. Genetic improvement of the above crops is mainly through introduction of exotic germplasm from the International Institute of Tropical Agriculture (IITA) at Ibadan, Nigeria; and screening, selection and advancement of promising lines in a participatory manner with farmers and other stakeholders in the crop development process. Breeding objectives of the above crops are aimed at addressing the devastating problem of pests and diseases prevalent in Sierra Leone, cassava mosaic disease (CMD), cassava bacterial blight (CBB), green mite, mealy bug and grasshoppers; sweet potato virus x and scab, and late blight of potato), yield and quality for the various desirable traits of eating, processing and potential industrial uses. Several genotypes of cassava have been released in the recent past (SLICASS 1-6) with yield range of 25-35 mt/ha whilst new and more nutrient-rich genotypes including yellow rooted ones with yield range of 40-50 mt/ha are in the pipeline for release. The yield ranges of sweet potato, yam and potato are 6-10 mt/ha, 10-27 mt/ha and 2-4 mt/ha, respectively. Four potato varieties (SLIPOT 1-4) were recently released to the farming population of

Sierra Leone. The current status of cassava, sweet potato (including recent and more nutritious, â-carotene genotypes), yam and potato breeding activities at NARC/SLARI, Sierra Leone is summarized and presented. Yam and potato improvement is new but significant strides have already been made in identifying promising lines of the former with the desirable traits or qualities that are acceptable to both farmers and consumers alike in the country.

Production of cassava has increased more than three folds since the end of the civil war in 2002, during which period it served as the most easily cultivated, accessible and affordable food crop, along with sweet potato to the majority of the then internally displaced population (IDP). Recent trends in production of these two crops are also given.

Cassava transformation into many useful food products, especially *gari*, *fufu* and high quality cassava flour (HQCF) is receiving tremendous boost in many parts of the country by both regional and national projects (CFC/IITA/SLARI) Cassava Value Addition, USAID/IITA-Sierra Leone Unleashing the Power of Cassava in Africa (UpoCA), AfDB/FARA/CORAF/WECARD/ SLARI Promotion of Science and Technology for Agricultural Development (PSTAD) in Africa Project (Dissemination of New Agricultural Technologies in Africa (DONATA) and Regional Agricultural Information Learning Systems (RAILS), Non-Governmental Organizations (NGOs) and the private sector. Strides made in that direction are also summarized and presented.

On a lesser scale, processing of sweet potato into more durable and useful by-products such as flour is beginning to receive the necessary attention by scientists at NARC/SLARI, and Njala University (NU), Sierra Leone and the Federal University of Agriculture at Abeokuta (UNAAB) and Association of African Universities (AAU) Regional Food Developers Initiative (FDI) Project, Nigeria. This will hopefully prevent market glut and improve the livelihood of root and tuber crops farmers with a consequent reduction in poverty.

Keywords: *Manihot esculenta Crantz, Ipomoea battatas L, Dioscorea spp, Solanum tuberosum L.*

Introduction

The tropical root crops are a group of plants which includes cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* Lam.), yams (*Dioscorea* spp.) and the edible aroids (*Colocasia esculenta* L.) Schott. and *Xanthosoma* spp. L.) Schott. They provides stable carbohydrate source for an estimated population of over 500 million people (Coursey,1983; O'Hair, 1990). Roots and tubers belong to the class of foods that basically provide energy in the human diet in the form of carbohydrates. The terms refer to any growing plant that stores edible material in subterranean root, corm or tuber. Tropical root crops such as cassava, yam, sweet potato, and cocoyam are important staple foods throughout Africa. Estimates suggest that over 90% of the world's yam production and more than half of its cassava is produced in Africa (Dipeolu, *et al.,* 2002). The increased use of major roots and tubers for food and livestock feed in developing countries will have wide-ranging effects on global public-and private-sector policies and investments (IFPRI, 2000). Root and tubers will continue to play a significant role in Sierra Leone's food systems because they contribute to the energy and nutrition requirements of people; produced and consumed by many of the households; important source of employment and income in rural, and often marginal areas, especially for women and are adaptable to a wide range of uses, from food-security crops to cash crops and from fresh to processed products.

Importance and Use of Root and Tuber Crops in Sierra Leone

Sierra Leone has a population of about 5 million people and lies on the West coast of Africa covering an area of 72,300 km^2. A total of 5.4 million ha (74%of the total land area) is potentially cultivable. It has a largely favourable environment for agriculture with abundant rainfall (2000-4500 mm per annum) and sunshine, higher temperatures (24.6^{0C} to 28.3^{0C}) and relative humidity (95-100%), diverse agroecologies, and biodiversity. Root and tubers constitute a very important component in the farming system in Sierra Leone.

Cassava. In Sierra Leone, Cassava *(Manihot esculenta* Crantz) is the most important root crop and the second most important food crop after rice, the country's staple. The tuberous roots of cassava are eaten in a variety of ways ranging from the boiled form to processed products like gari and foofoo. A considerable amount of cassava is also processed into starch. The leaves are used to prepare the very popular cassava leaf sauce.

One of the major factors responsible for the low production of cassava in the country is the widespread cultivation of inherently low-yielding local varieties that are also highly susceptible to

the yield-depressing African cassava mosaic disease (ACMD). Low soil fertility in most parts of the country and high pest incidence also contribute towards the low root yields obtained by farmers.

Sweet potato: Sweet potato (*Ipomoea batatas* L. (Lam)) is grown throughout the country for food and cash. It ranks third after rice and cassava as a major food crop in Sierra Leone. Both the young leaves and vine tips serve as vegetables and are consumed by most households. Due to its wide adaptation to different environments and relatively short duration, it serves as a major source of food in alleviating hunger during the hunger season.

However, despite the growing importance of sweet potato in Sierra Leone, total production of the crop is still low. The major production constraints include pests and diseases, especially the sweet potato weevil (*Cylas punticolis*), scab (*Elsinoe batatas*), virus complex, weeds, low soil fertility, poor production practices and the limited use of improved varieties. There is increasing awareness of sweet potato as a cheap and valuable source of pro-vitamin A which plays an important role in preventing blindness in children. The Njala Agricultural Research Centre (NARC), formerly theInstitute of Agricultural Research (IAR) is currently collecting nationwide germplasm of orange-flesh sweet potato genotypes, which are generally high in beta carotene to broaden the genetic base and provide opportunities for further improvement.

Yam: Yam is a tuber crop that is highly cherished by Sierra Leoneans but not widely cultivated in the country. Its cultivation is labour-intensive, often requiring high mounds, staking and weeding. Moreover, planting materials or 'seed yams' (small whole yam tubers weighing 100 to 1000 g produced from minisetts weighing about 25 g) to produce ware yams (over 1000 g) are not readily available, are expensive and often of poor quality. With the traditional big setts used in Sierra Leone, a significant number of the yam tubers harvested need to be retained for use as planting material for the production of yam during the following year. The fresh tubers are eaten boiled, fried or used in the preparation of porridge. It could also be dried and pounded into flour which can be used in various ways including pounded yam, foofoo and gari for human consumption. In addition, yam could be a valuable raw material in the starch industry.

Irish Potato

Root and Tuber Improvement Research in Sierra Leone

Root and Tuber improvement research programme in Sierra Leone seeks to develop and adapt appropriate crop varieties in terms of adaptability to the physical and socioeconomic environments as well as ensuring the possession of desirable consumer qualities and market attributes that will ensure widespread adoption and cultivation by farmers in the country.

Significant progress has been made in developing varieties with reasonably high yields for most of the major crops under the mandate of Njala Agricultural Research Centre (NARC) of the Sierra Leone Agricultural Research Institute (SLARI).

Cassava: Following the post war period of 2002 and beyond, the Institute of Agricultural Research (IAR), now NARC relocated to Njala in 2005. In May 2007 a cassava seedling nursery was established at Njala crop site. A total of over 10,000 seeds obtained from 91 different families were planted. Desirable genotypes were selected at the end of the May 2009 cropping season and cloned in 2009/10 cropping season.

There is also a clonal evaluation and an advanced clonal plots comprising 86 and 20 genotypes, respectively. Desirable genotypes selected at the advanced clonal stage were advanced to the participatory varietal selection (PVS) trials with the involvement of farmers. Presently there is PVS trial comprising 36 genotypes established in farmers fields in Njala and Moyamba in the south of the country; Kenema in the east, and Kambia and Makeni, in the north, respectively.

Also in October, 2008, a total of 2,179 genotypes were received from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria for evaluation in Sierra Leone. These were initially evaluated in an inland valley swamp (IVS). These were transferred to an upland crop site at Foya, near Njala. Evaluation and selection process is ongoing.

SLICASS 1-6 with fresh root yield in excess of 25mt/ha have been released and adopted by farmers (NARC, 2008; 2009).Cassava varieties and their characteristics recently released in Sierra Leone are summarized in Table 2 below.

Table 2: Cassava varieties selected, improved and released and their attributes in Sierra Leone

No.	Characteristics	Slicass 1	Slicass 2	Slicass 3	Slicass 4	Slicass 5	Slicass 6
1	Leaf colour:						
	- unexpanded apical leaves	Light purple	Purple	Green to purple	Purple	Green to purple	Green to purple
	- Fully expanded leaves	Green to purple	Green to purple	green	Green to purple	Green to purple	Green
2.	Leaf lobe						
	- Shape of centre lobe	Lanceolate	**Lanceolate**	**Lanceolate**	**Lanceolate**	**Lanceolate**	**Lanceolate**
	- Number of leaf lobe	7	**5**	**9**	**7**	**7**	**7**
3.	Leaf vein colour						
	- Adaxial side	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green
	- Abaxial side	Light Red (l-g at tip)	Light Purple	Light Pink	Light Pink	Red	Red
4.	Petiole						
	- Angle of insertion	90^0- 105^0	75^0 90^0	75^0 90^0	90^0 105^0	90^0-95^0	90^0-1.05^0
	- Colour	Red	Red	Red	Light Green	Red	Red
	- Colour at point of branching	Green	Deep Green	Red	Light Green	Red	Reg
5.	Stem						
	- Growth habit of young stem	Straight	Straight	Straight	Straight	Zig zag	Straight
	- Height of first apical branching	20 40 cm	70 100 cm	100 120 cm	50 100 cm	80 100 cm	90 100 cm
	- Number of levels of branching	3 Levels	2 Levels	1 Level	2 Levels	1 Level	2 levels
	- Stem colour	Silver Green	Light Brown	Silver Green	Silver Green	Silver Green	Silver Green
6.	Storage roots						
	- Length of paduncle	Intermediate	Long	Short	Absent	Short	Short
	- Storage root form	Conical to cylindrical	Fusiform	Fusiform	Conical	Cone Cylind	Cone. Cylind.
	- Position of root in ground	Tending towards horizontal	Tending towards horizontal	Tends horizontal	Tends vertical	Tends vertical	Tends vertical
	- Skin colour	Cream	Pink	Cream	Cream	Cream	Cream
	- Fresh colour	Cream	White	Cream	Cream	Cream	Cream
	- Storage root d ry matter content (%)	35 40	-		25 30	25-30	35-40
	- Sweetness of boiled roots	Sweet	Sweet	Sweet	Slightly bitter	Sweet	Sweet
7.	Resistance						
	- African cassava mosaic disease	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant
	- Bacterial blight	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant
	- Cassava mealy bug	Fairly tolerant	Fairly tolerant	Fairly tolerant	Fairly tolerant	Fairly tolerant	Fairly tolerant
	- Cassava green mite	Fairly tolerant	Fairly tolerant	Fairly tolerant	Fairly tolerant	Fairly tolerant	Fairly tolerant

Unfortunately, some of these released materials already are beginning to go down with ACMD, viz. SLICASS 2 and SLICASS 3.

Sweet potato: A seedling nursery comprising over 100 seeds collected from different families of the existing genetic base in the Centre was established during the first cropping season in June of 2008 at Njala. At the second season of September 2008, a total number of 295 clones including those cloned in 2007 were moved to the clonal evaluation stage and were evaluated in the PVS trials in 2009 cropping season.

SLIPOT 1-4 with fresh root yield in excess of ---mt/ha have been released and adopted by farmers (NARC, 2008; 2009). Sweet potato varieties and their characteristics recently released in Sierra Leone are summarized in Table 3 below.

Table 3: Characteristics of sweet potato varieties recently released in Sierra Leone.

Characteristics		Varieties			
		SLIPOT 1 (Clone 82/123R)	SLIPOT 2 (Clone 82/123W)	SLIPOT 3 (Clone 82/144)	SLIPOT 4 (Clone 84/16)
Plant type	Length of main vine	Spreading (1.5-2.5m)	Spreading (1.5-2.5m)	Semi-erect (.75-1.5m)	Semi-erect (.75-1.5m)
Leaf	Leaf outline	Triangular	Triangular	Triangular	Lobed
Vine	Pigmentation	Green	Green	Mostly purple	Green
Storage root	Shape	Round elliptic	Round elliptic	Round elliptic	Round
	Skin colour	Purple red	White	Purple red	Off-white
	Flesh colour	White	White	Dark cream	White
	Dry matter %	High (28)	High (28)	High (29)	High (29)
	Texture-boiled root	Soft & creamy	Soft & creamy	Soft & creamy	Soft & creamy
	Taste boiled root	Sweet	Sweet	Very sweet	Sweet
Reaction to diseases	Scab	Resistant	Resistant	Resistant	Resistant
	Virus complex	Resistant	Resistant	Moderately susceptible	Resistant
Reaction to pests	Weevil	Susceptible	Susceptible	Escape	Susceptible
Maturity		3.5-4 months	3.5	4 months	3.5 months
Tuber Yield potential		12 t/ha	15 t/ha	10 t/ha	10 t/ha

Yam: Four improved genotypes (TDr 95/01969, TDr 95/00826,TDr 95/18544 and TDr 95/00005), developed at IITA and tested on station at Njala , including a local check, Pulli, were established in a mother trial on the farmers' field in 2008 cropping season to increase available plant genetic resources for farmers' evaluation and selection. The specific objective of the trial was to provide farmers with different genotypes for their joint evaluation and selection and to facilitate farmers' access to yam diversity. Genotypes selected by farmers were established in baby trials in 2009 cropping season and then monitored for recommendation.

Acquisition of farmers' traditional knowledge of yam production

A survey was conducted in the main yam growing regions of Moyamba, Southern Sierra Leone, with 15 villages, representing two chiefdoms: Kaiyamba and Fakunya. A total of 30 farmers, including 16 men and 14 women who were recognized as having experience in yam production were randomly interviewed for their independent judgement on varietal selection.

Participatory assessment of the varieties

Initially, the farmers spontaneously assessed each of the varieties at Foya junction, and Moyamba Crop site. Secondly, they were asked to carryout paired comparison of these varieties, by indicating the one they preferred and the reason for their choice.

These two series of assessments are summarized in Table 3 and made it possible to organize the criteria used by the farmers in their varietal choices. The criteria of appreciation were almost the same in both series (open ended and paired comparison).

Yield was the most important criterion, followed by market value and organoleptic quality. The first criterion was evaluated by output per plant and has direct link with desirable food quality traits for commerce. Tubers with oblong-round shape, possessing few hairs, bland sweet, etc are in high demand in the market.

Storage quality and wide adaptability are vital selection criteria. Varieties which do not deteriorate badly in storage may attract better market price after the glut season; and also utilized as planting material during the planting season. Adaptability concerns both tolerance to different soils and good seed efficiency, i.e. the success rate of field establishment of seed tubers when planted. Vernier and Dansi (2006) reported that this latter criterion is particularly important with early varieties, which explains why they are more demanding in terms of cultivation environment and have sprout and establish before the rainy season becomes stable. The plants rot more easily in less favourable conditions.

Table 4: Frequencies of Varietal Assessment Criteria

Assessment Criterion	Open ended questions before harvest						Paired comparison after harvest		
	Kaiyamba* (N = 18)		Fakunya* (N = 12)		Mean	Rank**	Group I	Group II	Group III
Organole ptic quality	4.4	(4)	3.5	(2)	3.95	(3)	1	4	1
Yield	1.7	(1)	1.4	(1)	1.55	(1)	2	1	2
Chip quality	9.0	(9)	9.0	(9)	9.00	(9)	9	9	9
Wide adaptability	5.2	(6)	3.7	(3)	4.45	(4)	5	5	5
Storage quality	4.4	(4)	5.5	(5)	4.55	(5)	4	3	3
Earliness	6.1	(7)	7.1	(8)	6. 60	(8)	7	6	7
Market value	3.3	(2)	4.1	(4)	3.70	(2)	3	2	4
Disease resistance	6.3	(8)	5.8	(6)	6.05	(7)	6	8	8
Storage ability	4.3	(3)	5.9	(7)	5.10	(6)	8	7	6

Chiefdoms where study was conducted, **numbers in parenthesis denote rank of each variety (based on mean scores) using a 1 9 scale; where 1 = most important and 9 = least considered.

Disease resistance, sprouting ability and earliness were seldom mentioned. This reflects the fact that diseases have generally little visible impact in traditional yam crops, where varieties susceptible to a disease (s) would be eliminated. Sprouting ability and earliness may be a variety dependent and worth considering where the aforementioned are met.

Sierra Leoneans consume boiled yam and in porridge. The preparation of dry chips and other recipes of yam have not yet been popularized. Thus chip quality criterion was considered least. Unlike in Benin and other countries in the yam belt of West Africa, a significant part of the yam is processed in this manner (Bricas et al, 1997).

Farmers' preferred characteristics

The study showed differences between farmers perception when evaluating varieties (Figure…). About 82% of the farmers in both chiefdoms grow late maturing (harvested>6 months period) yam where as 18% grow early types. Most of the growers (63.9) reserve marketable tubers, 12.4% use unmarketable tubers where poor yields and scarcity of planting material exists and 23.7% of them obtain planting material through milking? method, especially for the *D. dumetorum* types and from donors.

About 63.4% of the farmers grow <1 acre of yam, i.e. 0.4 ha compared to 37.6% which can barely grow > 1acre land area or 0.4 ha. The small farm size according to them is due to partly to lack of sufficient planting material during planting season and diversity of improved adaptable varieties. Over one-half (54.2%) of the farmers interviewed grew setts each weighing >500g, while 45.8% used setts of weight ranging from 250-500g. The use of larger sett provides longer duration of food supply for the young sprout and may consequently affect the establishment and yield of the crop. A greater percentage of the farmers (73.5%) preferred round shaped tubers; 26.5% oblong-oval tubers but none of them liked slim and cylindrical tubers because of their high level of damage during harvesting.

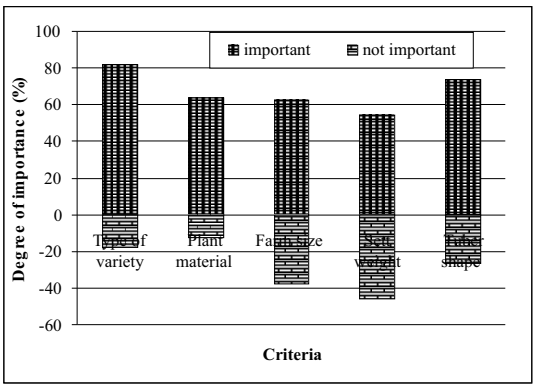


Figure1: Comparison of farmers' perception based on the degree of importance of criteria set.

Yield and yield components

Generally, both yield and yield components differed significantly among genotypes assessed (Table5). Genotypes TDr 95/00826 0ut yielded in weight per tuber, number and yield of marketable and total yield of all the genotypes. TD95/18544 exhibited the highest number of unmarketable tubers and tubers produced per plant compared to the local check, Pulli. It however, had the lowest yield because of its smallest size and weight. The low yields observed in all varieties were due to their late establishment as they were planted in June instead of early April. This tremendously affected late maturing types like TDr 95/18544 and TDr 95//01969.

Table 5: Yield and Yield Components of Five Genotypes in Moyamba District

Genotype	Number of marketable tubers***	Number of non marketable tubers***	Number of tubers per plant***	Weight per tuber (kg)**	Marketable yield (kg) ***	Non marketable yield (kg) ***	Yield (t/ha)***
TDr 95/00005	18.7	43.3	1.70	0.39	16.67	6.67	5.17b
TDr 95/00826	25.0	28.3	1.49	0.56	24.33	7.00a	7.83a
TDr 95/01969	16.7	49.0	2.17	0.19	6.67	5.67	3.08c
TDr 95/18544	12.7	91.0	2.85	0.13	5.67	6.50	3.04c
Pulli	17.7	22.3	1.19	0.43	14.00	3.47	4.37bc
Mean	18.1	46.8	1.88	0.34	13.47	5.86	4.70
LSD	3.24	10.34	0.19	0.21	4.15	1.11	1.46
CV (%)	9.5	11.7	5.4	6.3	16.4	10.1	16.4

*** and ** = significant at $p<0.01$ and $p<0.001$ respectively

Table 6: Assessment of Farmers' Preference for Varietal Choice

Genotype	Group scores [1]			Total scores [2]	Rank[3]	Reasons for choice or rejection
	Group I	Group II	Group III			
TDr 95/00005	3	2	1	6	2	High yield and market value
TDr 95/00826	5	5	4	14	5	Hairy, irregular shape, poor storage quality
TDr 95/01969	2	3	3	8	3	Good organoleptic quality, market value and appreciable yield
TDr 95/18544	4	4	5	13	4	Small and cylindrical tuber size
Pulli (Check)	1	1	2	4	1	High yield and market value

[1]Score given by each farmer group on the variety
[2]Sum of group scores
[3]Rank of each variety (based on total scores)

Results indicate that farmers prefer varieties that are high yielding, possessing appealing market traits such as round-oval oblong tubers, desired culinary traits, good storage or post-harvest quality and wide adaptability. The development of early maturing, disease resistant, better sprouting ability varieties; and diversification of food use (chip quality) may serve as vital secondary back ups. In this study therefore, farmers prefer Pulli, TDr 95/00005, followed by TDr 95/01969 because of their good organoleptic and appealing market values.

Irish potato (*Solanum tuberosum* L)

Irish potato was recently added to the list of crops under the mandate of NARC to conduct research. Since potato is a relatively new crop grown by farmers in Sierra Leone, little is known about the crop. Time of planting remains very critical and is mostly targeted during December to January coinciding with the Harmattan season (dry season) which is the coldest in Sierra Leone.

The search for adaptable genotypes resistance to late blight remains the most viable option with considerable economic advantages to the resource poor farmers. Effort is currently been made to collect germplasm from the Futa Jallon highlands in North-western Guinea where Irish potato is extensively grown. Constraint to production includes late Blight caused by **(***Phytophthora*

infestans) and **potato virus x** Total yield loss has been reported as a result of diseases and pest. Current potato varieties under cultivation includes Resy, Ostira and Nicolas. Nicolsa perhaps is the most tolerant variety to blight and potato virus x3

Table 3. Percent leaf area with symptoms of potato virus for three locations

Variety	1 map	2map	3map	mean
Nicolas	36.7	26.7	30.0	31.1
Ostira	43.3	50.0	46.7	46.7
mean	40	38.3	38.2	
Cv	13			
Lds (var)	5.65			
Lsd (map)	6.91			
Lsd (var x map)	9.78			

Mean incidence of late blight over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

Table 4. % Incidence of late blight disease across three locations

Variety	1 map	2map	3map	Mean
Nicolas	13.3	56.7	93.3	54.4
Ostira	30.0	90.0	93.3	71.1
Mean	21.7	73.3	93.3	
Cv	18.3			
Lds (var)*	12.1			
Lsd (map) **	14.8			
Lsd (var x map)	20.1			

Mean incidence of potato virus over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

Table 5 % Incidence of Potato virus disease across three locations

	Months after Planting (MAP)			
Variety	1 map	2map	3map	Mean
Nicolas	40	40	46	42.2
Ostira	53.3	50	50	54.4
Mean	46.7	45.0	53.3	
Cv	16.5			
Lds (var)*	8.35			
Lsd (map)	10.24			
Lsd (var x map)	14.48			

Estimated number, weight of tubers and yield from a sample size of 1m2

In the case of Uganda, FAO, (1999) gives average yield estimates of 7.0 Mt per hectare, as compared to 25 Mt per ha under good management (Haxiza et al., 1997), 15Mt per ha under improved management and 5 Mt per ha under poor management (PRAPACE, 1998). Estimated yield of potato in Sierra Leone was low in the sampled area for both varieties. Based on a 1 m by 1m sample plot size the total number of tuber obtained for Nicolas was 13.5 significantly higher than Ostira with 9.2 tubers. Weight of tuber was significantly higher for Nicolas (0.4kg) compared to Ostira (0.26kg). Yield for Nicolas was estimate at 4t/ha significantly higher than Ostira with 2.56 t/ha.

Table 6. % Estimated number, weight of tubers and yield from a sample size of $1m^2$

Variety	No of tuber	Weight of tubers (kg)	Yield t/ha
Nicolas	13.56	0.4	4
Ostira	9.22	0.26	2.56
Mean	11.39	0.33	3.28
Cv	19.9	0.06	0.06
Lsd (var)*	2.2	20	20.2

Production, Yield and Associated Constraints

Cassava: Some of the major constraints to cassava production in Sierra Leone include the use of low yielding varieties, untimely and inadequate weeding, low soil fertility, untimely planting and the improper handling and storage of planting materials (Jalloh and Dahniya, 1989). The incidence of diseases, among which the African Cassava Mosaic Disease (ACMD), Cassava Bacteria Blight (*Xanthosoma manihoti*), Cassava Brown leaf spot (*Cercospora henningsii*), Cassava Arthracnose (*Collectotrichum* spp.) is also affecting cassava production. The pests which affect cassava included the Green Spider mite (*Mononychellus tanajoa*) the cassava mealy bug (*Phenacoccus manihoti*), Monkeys, rodents Grasshoppers (*Zonocerus variegates*) and Termites. Weeds are also important constraint. The effect of these constraints on crop yield is summarized in Table 7 below.

Table 7. Production constraints and effect on cassava yield in Sierra Leone

No.	Production Constraint	Details
1.	Soils	Soil disturbance is a problem common to all root and tuber production (TAC 1997). Regular working of the soil can d egrade soils by decreasing soil carbon levels and fostering water and wind erosion. The effects can become accentuated as fallow periods decline and cropping intensity increases. Declining soil fertility is closely related to the shortening of fallow periods as farmers adapt their production systems to demographic and market pressures
2.	Major diseases and pests	
a)	Disases	i) Major diseases of root and tubers of economic importance in Africa do exist. Studies have shown that these diseases cause reduction o f storage root yield by 20% to 69% depending on the affected cultivar and environmental factors.
b)	Pests	Tuber losses resulting form this pests has been estimated to be about 75% while leaf and planting materials (stem cuttings) are also affected. It als o causes strong disturbances of the terminal shoot, which becomes deformed and stunted. Internode length is reduced and the stem appears twisted.
c)	Weeds	Although root and tubers has fewer pests and diseases than other field crops, it shares with these crops a common susceptibility to weed infestation. Slow initial development makes root and tubers very susceptible to weed competition during the first 10 -12 weeks of growth. Delaying first weeding by more than 2 months has been reported to cause over 20% reduction in tuber yield, even if the crop is subsequently weeded three times. Depending on previous land history, soil fertility status and cultivar, yield losses caused by uncontrolled weed growth of root and tubers can be as high as 100%

Sweet Potato: Sweet potato cultivation is constrained by several pests and diseases. These are summarized in the following tables below (Tables 8 and 9).

Table 8: Major Pests of Sweet potato, Symptoms and Control Measures.

Insect Pest	Damage Symptom	Control
Sweet potato weevils (***Cylas puncticolis***)	- damage is done by attack on the tuber and to a lesser extent on the vines. Tunnels are made by small white, legless larvae. The tunnels may be partially filled with frass. Ant like weevils may be found on the leaves or in the tunnels. Yield, storage life and plant vigour are reduced. - the excrements the larvae produce in the tunnels made in tubers cause a disagreeable taste.	- Use resistant varieties - under humid conditions, biological control by the fungus *Beauveria sp* has been found to be efficient in controlling weevils - additional re-ridging - plant clean cuttings normally selected from the end of the vines - weevil population has been found to increase during storage but Actellic and synthetic pyrethroids give satisfactory control when applied at the beginning of storage
Root knot nematodes (*Meloidoyne incognita*)	- secondary fungal and bacterial infections may take place and further destroy the tuber	- Use tip of vines for planting - Carbofuran applied as granules 1 4 days before planting at a rate of 6.7 kg a.i/ha.
Sweet potato horn worm (*Agrius convolvuli*)	Swelling of the entire root, and heavy infection can inhibit apical growth. Longitudinal cracking and general rough appearance of the skin. Both the roots and tops of infected plants are reduced. Leaves are eaten up by horn worms	- Ploughing the land between crops to expose the pupae reduces infestation - Hand picking of the larvae - 0.2% solution of carbaryl, - 0.05% endosulfan or trichlorphon (7 days waiting period before harvest) 100g a.i. in 100 litres of water should be applied when the larvae are first seen.
Rats, squirrels, monkeys, birds	These damage the young sprouted plants as well as dig up the tubers thus drastically reduce the yield and quality of the tubers	Damage is prevented by fencing, trapping, re-ridging to cover up exposed roots and cracks, brushing round the farm and the use of poison baits have been found to effectively control these pests.

Diseases: Major diseases are stem rot, scab (*Elsinoe batatas*), and virus complex as shown in the following table 9:

Table 9: Major Diseases, Symptoms and Control Measures.

Disease	Symptoms	Control
Stem rot (*Fusarium oxysporum)*	- young leaves at the tip of vines turn yellow -older leaves wilt and drop - Infested slips may die soon after setting or become stunted and yellow - Stems at the soil line may turn slightly blue (blue-stem). - The inner stem portion at or below the soil line becomes discolored with brown streaks in the vascular system.	- plant resistant varieties - plant disease free planting materials - practice crop rotation
Scab (*Elsinoe battatas*)	- Scabby lesions or small spots appear on the main veins and midrib on under surfaces of the leaves which may be severely distorted and reduced in size. Lesions which are grey to dark brown also occur on petioles and stems causing distortion and twisting. The growing points of the vines may be killed.	- plant sweet potato in rotation with other crops - plant healthy and uninfested planting materials - use resistant varieties - early planting and harvesting - Benomyl at 1.04g a.i./l - water or copper oxychloride at 2.08g a.i./l - menab at 2.08g a,I,/l apply all every 10-14 days
Virus complex	- various combinations of vein-clearing, leaf strapping, feathery mottling, stunting, puckering and distortion	- plant varieties known to have resistance to the disease - crop rotation - completely remove all crop refuse after harvest - in case of severe disease infestation, any crop refuse should be burnt
Cercospora leaf spot (*Pseudocercospora timorensis*)	Spots are small (about 6mm in diameter) and angular with brownish coloration. Leaves may drop from the lower parts of the stem in severe attacks. Damage to the leaves is most severe during wet conditions.	Control of these spots is not usually necessary. Spraying every 15 days with zineb has given good results.

Yam:

Disease Incidence and Severity

The mean severity rating of genotypes assessed for yam mosaic virus 2.4. Severity was generally low and ranged between 2 and 3. TDr 95/00005 and TDr 95/00826 had the highest incidence of 76.7 and 70%, respectively, which was significantly higher than that of TDr 95/01969 and the local check, Pulli with values of 43.3 and 46.7%, respectively.

Severity of Yam anthracnose disease was low with a mean value of 1.33 among genotypes. TDr 95/00826 and TDr 95/18544 had no visible symptom of anthracnose and were significantly lower than TDr 95/00005 with the highest severity rating of 2. Severity score ranged between 1.0 and 2.0.

Incidence of Yam anthracnose was similarly low with a mean value of 6.0%. TDr 95/00005 had the highest disease incidence of 8.3%, followed by the local check, Pulli with 6.7%.

Table10: Incidence and Severity of Yam Mosaic Virus and Yam Anthracnose in Moyamba District, Southern Sierra Leone.

Genotype	Incidence of yam mosaic virus	Severity of yam mosaic virus	Incidence of yam anthracnose	Severity of yam anthracnose
TDr 95/00005	76.7	3	8.33	2.0
TDr 95/00826	70.0	3	5.0	1.0
TDr 95/01969	30.0	2	5.0	1.3
TDr 95/18544	43.3	2	5.0	1.0
Pulli	46.7	2	6.7	1.3
Mean	53.3	2.4	6.0	1.3
CV (%)	27.1	-	38.8	23.7
LSD (0.05)	27.1	-	4.38	0.59

Irish Potato: Constraints to Production

Constraint to production includes late Blight caused by **(***Phytophthora infestans) and* **potato virus x** Total yield loss has been reported as a result of diseases and pest. Current potato varieties under cultivation includes Resy, Ostira and Nicolas. Nicolsa perhaps is the most tolerant variety to blight and potato virus x

Table 3. Percent leaf area with symptoms of potato virus for three locations

Variety	1 map	2map	3map	mean
Nicolas	36.7	26.7	30.0	31.1
Ostira	43.3	50.0	46.7	46.7
mean	40	38.3	38.2	
Cv	13			
Lsd (var)	5.65			
Lsd (map)	6.91			
Lsd (var x map)	9.78			

Mean incidence of late blight over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

Table 4. % Incidence of late blight disease across three locations

Variety	1 map	2map	3map	Mean
Nicolas	13.3	56.7	93.3	54.4
Ostira	30.0	90.0	93.3	71.1
Mean	21.7	73.3	93.3	
CV(%)	18.3			
LSD0.05 (var)*	12.1			
LSD0.05 (map)**	14.8			
LSD (var x map)	20.1			

Mean incidence of potato virus over time across three locations (Katawuya, Mamudia Koro and Madina) in Koinadugu district

Table % Incidence of Potato virus disease across three locations

	Months after Planting (MAP)			
Variety	1 map	2map	3map	Mean
Nicolas	40	40	46	42.2
Ostira	53.3	50	50	54.4
Mean	46.7	45.0	53.3	
Cv	16.5			
Lds (var)*	8.35			
Lsd (map)	10.24			
Lsd (var x map)	14.48			

Status of Food Processing Activities for Root and Tuber Crops

Cassava: Popular cassava products in Sierra Leone includeare Gari, Foofoo, Kondogbala, Starch, Flour, Cassava bread (served with stew), Boiled cassava served with beans/stew, Atheke, Fried cassava chips, Gbodor, Cassava and potato leaves sauce are the major foods in Sierra Leone. Their status in terms of food processing activities ranges from small to large depending on the consumption pattern of consumers. These are summarized in the table below.

Table 11.Products/ Recipes Developed at NARC / SLARI, Sierra Leone

No.	Product	Product definition
1.	Cassava bread	" Grated, fermented and pressed ca ssava " Sifted cassava cake into flour
2.	Cassava rich cake	" Grated, fermented and pressed fresh cassava tubers " Break cake and sift into flour " Baked using varying ingredients
3.	Cassava croquette	" Grated, fermented and pressed fresh cassava tubers " Break cake and sift into flour " Baked using varying ingredients
4.	Gari	" Fried, milled, sifted and packaged product of cassava
5.	Foofoo	" Soaked, pulped and sieved cassava tubers " Dewatered (Pressed), dry and grind " Packaged
6.	Kondogbala	" Chopped, partially cooke d/boiled fresh cassava " Completely sun dried " Packaged in sacks and stored for consumption during shortage by re - boiling to softness and served with sauce / soup / beans
7.	Cassava bread (with stew)	" Grated, fermented and pressed fresh cassava tubers " Break cake and sift " Fried in small ringed metallic plates " Served / sold with stew and fried fish
8.	Atheke	" Grated, fermented and pressed cassava tubers " Break cake, sift and fried " Pour hot water on product for few minutes and dewatered " Mixed with salt and ser ve with fish/meat, egg, tomato paste, mayonnaise, lettuce etc.
9.	Fried cassava chips	" Grated, fermented and pressed cassava tubers " Break cake and sift " Addition of salt, pepper, maggi, sometimes pounded fish " Made into smaller balls and fried
9.	Fried cassava chips	" Grated, fermented and pressed cassava tubers " Break cake and sift " Addition of salt, pepper, maggi, sometimes pounded fish " Made into smaller balls and fried " Packaged and served/sold
10.	Gbodor	" Grated, fermented and pressed cassava tubers " Break cake and sift " Addition of salt, pepper, maggi, sometimes pounded fish " Made into smaller balls and fried " Packaged and served/sold

Dissemination of improved cassava varieties, best practices and processing infrastructure

An ongoing project which is actively involved in the dissemination of improved cassava varieties is the AfDB/FARA/CORAF/WECARD and SLARI PSTAD which is promoting improved cassava varieties and best practice of early planting at the beginning of the rains in May/June in an Innovation Platform for Technology Adoption (IPTA) mode. The improved varieties, SLICASS1,4, 5,6 TME 419 and early planting are being promoted in two different agro-ecological zones in the country, namely, the Savannah woodlands in the Bombali Shebora Chiefdom, Bombali District, Northern Sierra Leone and the forest agro-ecology in Njaluahun Chiefdom, Kailahun District in Eastern Sierra Leone. The two platforms were established in 2008 in ten village communities where one 1 ha of cassava farms were established in 2008 cropping season. Each community have expanded the area under cultivation, and have also served as foci of further dissemination of these materials to other farmers, NGOs and the Ministry of Agriculture, Forestry and Food Security (MAFFS) in their respective regions.

The USAID/IITA Unleashing the Power of Cassava in Africa (UpoCA) Project is also involved in the dissemination of improved cassava varieties and transformation activities in several districts across the country.

Whereas the growth of cassava requires a low input of man hours in comparison with other crops, the preparation of cassava root for consumption as a staple food requires labour intensive and prolonged processing (Essers, 1986 and Rosaling, 1988).Primary processing by producers gives added value to a traditionally low-earning crop and helps stabilize fresh root prices (Obrien and Jones,1994). Koch et al (1994) noted that the prime purpose of the processing procedure is to reduce the content of poisonous cyanogenic glucosides or their degradation products (cyanohydrins and free cyanide) in the final products. Secondly, the harvested root rots if they are not processed shortly after harvest. Thirdly, the processing considerably reduces the water content (about 70% in the freshly harvested tuber) and thus facilitates transportation. Fourthly, the processing serves to make the starch of the cassava root suitable for consumption as a major food component in the form of boiled paste, flour or granules in the many different dishes prepared according to cultural preferences.

Thus, the ultimate income generated from the cassava enterprises depends on how fast the fresh tuber is sold or processed into gari, foofoo, or starch in Sierra Leone. The extent to which the potential market for cassava may be expanded depends largely on the degree to which the quality of various processed products can be improved to make them attractive to various markets without significant increase in processing cost and with little delay.

Though cassava processing in the country is largely traditional, yet with the increase in marketed surplus resulting from the use of improved cassava cultivars and response to growing domestic market, mechanized innovations are gradually being adopted. The hand and pedal operated grater fabricated locally by the former Tikonko Agricultural Extension Centre in the early 1980's (TABC- destroyed during the rebel war) are among the early innovations widely distributed and used by cassava processors. Most of these are gradually being replaced by electrically powered mechanical graters.

A gari plant was built at Robinke in the Tonkolili District for large scale production of gari but because of technical problems and unavailability of reliable cassava suppliers, the plant has still not been commissioned. The growth centre in Bo now produces both gari, flour and foofoo under medium scale mechanized conditions. The use of graters is yet limited. Efforts needed to be directed towards rapid use of the equipment if the increased production of the crop should be met with faster conversion into forms acceptable for consumption.

Since 2008, two new cassava processing centres were constructed at Makeni, in the Bombali District and at Hamdalai/Lunsar in the Port Loko District both in the North of the country and/or equipped with modern processing machines and equipment acquired through the CFC/IITA/SLARI **Cassava Value Addition Project**. Similarly, two such centres were also constructed and equipped in Bo City and Walihun village, respectively in the Bo District in Southern Sierra Leone; the Walihun processing centre was constructed between June and July 2010 and commissioned at the end of August, 2010. A similar but larger centre constructed by SLARI at the Njala Agricultural Research Centre at Makeni, in the Bombali District and at Hamdalai/Lunsar in the Port Loko District both in the North of the country (NARC) but equipped by the same project above is now functioning and producing gari and foofoo, albeit on a small scale. Finally a small

cassava bread processing centre was also constructed at Waterloo in the Western Rural District of Sierra Leone, in 2009 by CFC project. Cassava bread is a popular traditional cassava product in Sierra Leone and is served with fried fish and stew.

Marketing of cassava

Due to the short shelf life of cassava roots, nearly 79% of cassava produced is consumed almost immediately in the fresh cooked form. Similarly, cassava leaves a preferred vegetable dish in Sierra Leone is plucked fresh and prepared as source which is eaten usually with rice.

Cassava passes through two main channels to reach the consumer. In the first channel, traders may purchase within a day or two, already harvested cassava ready for market from farmers in villages. Alternatively, traders may purchase the standing crop and spend few days, depending on the acreage, harvesting the roots. The cassava purchased is usually assembled in sufficient quantities in sacs and immediately shipped to urban market using land or sea transportation on the place of assembly and case of shipment.

The second channel is one in which petty traders purchase cassava from either farmers or other traders that have moved (normally by headload in small quantities) their produce to periodic markets. The constraint associated with marketing is that there are inadequate markets for the product in the rural areas where the crop is produced. In the urban areas too, the market is yet to expand since cassava is only recently being considered as an important crop.

There are no special locations for marketing cassava. At the wholesale level in the urban areas, marketing normally takes place in lorry parks or any large open space. Traders sell their produce to retailers in sacs, avoiding retiling it themselves to customers. This is to prevent the risk of spoilage and take advantage of the time and possibility of making another cassava purchase trip back to the village. Retailers then sell to customers by laying the tubers on tables at market centers or on the ground in piles outside the market building. The size of each pile varies with the negotiable price charged.

Transportation of cassava

In Sierra Leone a good percentage of farmers (over 60%), headload their produce from the farm site to their villages and may require walking distances varying from 3 to 7 miles to periodic markets distances to sell their produce or to access a motorable road for onward transportation to urban markets. The rural transport system in Sierra Leone is grossly inadequate (Spencer, 1996). The level of coverage of feeder roads in Sierra Leone is constraining marketing of both farm production inputs and outputs, which will continue to serve as a disincentive to producers of cassava as well as other crops. Due to this difficulty, over 80% of farmers producing cassava sell their produce in their villages to traders coming from bigger towns to the village mainly at harvest time. Due to lack of market information, these traders usually have the advantage to determine the farm gate price of such produce. Cassava being perishable if not processed, puts the farmers at the disadvantaged end of bargaining, thus accepting the price dictates of the traders which in most situations act as a disincentive to increase production.

Sweet potato

Common sweet Products Boiled potato roots served with stew / soup and Fried potato chips are the major foods of sweet potato. Their status in terms of food processing activities is both medium scale.

Boiled potato served with stew / soup

- Fresh sweet potato roots peeled, chopped into smaller sizes and boiled with salt
- Served or sold with stew / beans

Fried sweet potato chips

- Fresh sweet potato roots sliced into smaller chips
- Add salt on sliced chips
- Fried with vegetable oil
- Packaged and served or sold

Sweet potato leaves sauce

- Fresh sliced sweet potato leaves boiled with fish/meat, salt, pepper, ogrie, palm / vegetable oil and water
- Served with cooked rice (country's staple food), boiled cassava, sweet potato or yam.

Yam

Popular yam product is boiled yam served with stew/soup and is the only way yam is consumed in Sierra Leone. This form is medium scale because of the cost of yam because of low production.

a) Boiled yam served with stew / soup

- Fresh yam tubers peeled, chopped into smaller sizes and boiled with salt
- Served or sold with stew / beans

Gender Issues in Food Processing. In Sierra Leone, women and children exclusively participate in food processing activities such as harvesting, washing, peeling, grating and frying. Men are only involved in manual pressing of grated mash of especially cassava.

Conclusions

For research findings to relevant, root and tuber crops should be developed in line with processing and product innovations, substitution levels, root storage stability, pre and post harvest processing, novelty products, food safety, bio-preservatives and enterprise development.

Future Prospects

1. Research will be needed to develop newer uses for root and tuber crops in Sierra Leone. For example the use of composite flour in baking will enhance the financial value of the product.
2. Some of the fermented root and tuber products are yet to be subjected to comprehensive scientific investigations. The micro organisms involved in the fermentation of some of the crops are yet to be studied.
3. There is paucity in the processing standardization and optimization conditions.
4. Capacity and institutions for identifying opportunities and meeting market requirements in terms of quality, traceability, standards, volumes and continuity of supplies need to be strengthened.

References

Adipala, E., Namanda,S., Mukalazi, J., Abala, G., Kimoone,G. and Hakiza, J.J. 2000. Farmer potato varietal selection criteria in Unganda. *African Potato Association Conference Proceedings.*

Coursey, D.G. (1983). Post harvest losses in perishable foods of the developing world. In: "Post harvest physiology and crop preservation", Ed. M.Lieberman, Plenum Publ. Corpn, 485-514.

Dipeolu O. A, Adebayo K, and Ogundokun A.K., (1988). The storage of tropical root and tuber crops cassava, yam and edible aroids. Expl. Agric. 24: 437-470.

Fehr, W.R.1987. Principles of cultivar development. Vol.2. Crop Species. Macmillan Publishing Company, New York. 672pp

Hakiza, J.J., Kakuhenzire, R.M., Alacho, F.O. and Mukalazi, J. 1997. The international blight and coordinated regional yield evaluation of potato genotypes in Uganda. African Crop Science Conference Proceedings. 3:981-987.

IFPRI (2000). Underground solutions; Experts Say Cassava, Potato, Sweet Potato And Yam Can Help The Poor In Developing Countries. News Release, June 15, 2000.

O'Hair, S.K.(1990). Tropical root and tuber crops. Horticultural Rweviews., 12, 157-196.

Orkwor, G.C Asiedu R and Ekanayake, I.J. (editors). 1998. Food yams. Advances in research. IITA and NRCRI Nigeria. 249 p.

Samura 2008. Preliminary survey report on Irish Potato (*Solanum tuberosum*) disease in Kabala. Sierra Leone Agricultural Research Institute report. Unpublished.

Scott, G., Rosegrant, M and Ringer C. 2000. Roots and tubers for the 21st century. Trends,Projections and policy options. IFPRI-CIP Discussion paper No. 31. 64 p.

Advances in seed yam propagation methods in Nigeria

John G. Ikeorgu[1], Mary-Ann Mazza[1], Chris Okonkwo[2] and Hidehiko Kikuno[2]

[1]National Root Crops Research Institute Umudike, PMB 7006 Umuahia Abia State, and International Institute of Tropical Agriculture (IITA) Ibadan Nigeria

Corresponding Author:

E-mail jikeorgu@yahoo.com

Abstract

Scarcity and/or high cost of healthy seed yams are the greatest constraints in yam production in Nigeria and probably across the West African Yam belt. Scientists at the National Root Crops Research Umudike developed the yam minisett technique of seed yam production in 1982 but nearly three decades after, the adoption rate of this technology is still below 40%. Concerned about this development, the World Bank mission to Nigeria supervising the National Agricultural Research Projects (NARP) in 1997 wondered why Nigeria could not develop effective systems that would ensure rapid adoption of this proven technology or develop complementary seed yam propagation technologies that would enable farmers to gain access to newly released, high yielding yam varieties soon after release. This paper, therefore, discusses the progress made so far in promoting the yam minisett technique and three other technologies (minituber, vine-cuttings and peelsett) developed to complement the yam minisett technique.

Keywords: Yam minisett, seed yams, minituber, peelsett, vine-cuttings

Introduction

The West African yam belt currently produces about 93% of global yam output of 51.4 million tones and Nigeria alone produces over 75% of this output. However, most of the yams produced in Nigeria are also consumed within the country with little or nothing to export. Yam production in the sub-region is being threatened by scarcity/high cost of planting material, which is also the source of food (Okigbo and Ibe 1973; FAO,2008). The cost of planting material accounts for between 33% and 63% of the total cost of yam production (Okoli and Akoroda, 1998, Manyong, 2000). Many farmers have taken cassava as a better alternative to yam production because of the relatively lower production cost of cassava. Yam appears to be an African crop and therefore would need Africans to ensure its sustained production in the face of impending global food crisis. Farmers' feedback shows that most of the improved yam varieties released nearly ten years ago are yet to reach the farmers due to the relatively low multiplication ratio of tuber crops such as yams and poor extension services.

Considerable progress has been made in the development of rapid methods of seed yam production (Okoki *et al*, 1982; Ikeorgu and Igbokwe, 2002; Igwilo, 1999, Aighewi *et al.*2003). Recent work done by Kikuno *et al* (2007) suggests that the vine cuttings method of minituber and seed yam production could be a more cost effective complementary method to the yam minisett technique. Kikuno *et al* (2002) have developed the use of carbonized rice husk in inducing sprouting in freshly cut yam vines with considerable success. This paper discusses the advances made so far in the development of rapid multiplication techniques of seed yams in Nigeria and also makes suggestions for the future.

The yam minisett technique

The yam minisett technique was developed by NRCRI Umudike in the early '80s and later modified by IITA (Okoli et al, 1982 Otoo et al. 1987). This technique has been proven to be a quick and efficient way to produce seed yams. To produce seed yams with this technique, selected clean mother seed yams are cut into small setts of approximately 25g called "minisetts". The minisetts are spread on a platform or floor to cure overnight and are dusted with minisett dust or appropriate fungicide/insecticides at recommended rates. The minisetts are often planted on ridges (although some farmers plant on mounds) and spaced approximately 25cm apart on !m ridges to give a plant population of 40,000 plants/ha. This implies that in this technique, 1 tonne of planting material is used to plant 1ha. Seed yams yields of between 4 and 8 (and sometimes 13) tonnes/ha have been achieved in both on farm and on station trials (NRCRI, 2007, 2008). However, feedback from farmers showed, among other things, that the small size (25g) of the minisetts was the major reason for the low adoption rate of this technology. (Ogbodu,1995). Farmers use seed yams of between 500g and 1000g to produce large/ceremonial ware yams but the minisett technique that uses 25g produces seed yam sizes in the 200-500 gram range. (Ikeorgu et al 2000) In 1998 we modified this technique such that farmers who

wish to produce seed yams of sizes that range from 200-500g could use 25g to 30g setts but those who need seed yams 500g and above could use setts of 35g-45g (Ikeorgu et al. 2000). A survey carried out by Anuebunwa *et al,* (1998), showed that adoption rate was below 40% and that farmers were selective in selecting what component of the technology to adopt. It is strongly believed however that lack of commitment on the part of the extension agents, was a major reason in the slow rate of adoption of the yam minisett technique. A project is being currently carried out in this institute to promote the yam minisett by establishing demonstration plots and also by training farmers on this technology.

The yam minituber technique

The yam minituber technique of seed yam production was developed by the Yam Research Program of this institute (Ikeorgu and Nwokocha, 2001) to complement the yam minisett technology developed over two decades ago. This technique aims at producing minitubers (whole but small tubers 30g 150g) from 6g-10g minisetts that could be distributed to farmers to be sown directly into prepared seed beds for seed and ware yam production. Clean seed yams of desired varieties are cut into 6g to 10 g setts and dipped in a mixture of Basudin 600EC (70 ml) and Mancozeb 80% WP in 10 liters of water for 5 to 10 minutes and spread out to cure overnight. These microsetts are planted at a close spacing of 20cm x 10cm to give apopulation of 500,000 plants /ha. Our experience shows that you do not need a special medium to raise the seedings but the use of shed nets capable of 40 -50% sheeding) improves the sprouting percentage and therefore the minituber yield relative to the un-covered plots (Table 1)

Table 1. Percent sprouting achieved at 6 WAP from 7 released hybrid yams covered with 46% shed net in 2007

VARIETY	PERCENT SPROUTS	
	Covered	Un-covered
TDr 89/2565	77	48
TDr 89/2665	81	35
TDr 89/2677	82	34
TDr 89/2461	83	29
TDr 89/1213	53	26
TDr 89/1438	34	18
TDr 95/1924	40	22
LSD(0.05)	2.0	1.2

This technology requires a seed agency to produce the minitubers of desires varieties and supply to the farmers. Thus it eliminates the inherent drudgery for the farmer in cutting setts, treating with chemicals and curing which the farmer often complains as setback to the adoption of the yam minisett technique. The farmer is merely given the minitubers for planting according to his desired variety. The minituber yields so far achieved from our trials range from 1.5 t/ha to 5.0 t/ha depending on the yam variety (Table 2).

Table 2. Fresh minituber yield from microsetts of 7 improved yam varieties evaluated for minituber production In 2006 and 2007.

Yam variety	FRESH TUBER YIELD (t/ha)		
	2006	2007	Mean
TDr 89/02565	3.8	5.9	4.85
TDr 89/02665	4.7	3.8	4.25
TDr 89/02677	2.5	7.7	5.10
TDr 89/02461	6.2	4.4	5.30
TDr 89/01213	3.5	3.8	3.65
TDr 879/01438	3.0	1.2	1.45
TDr 95/01924	0.56	1.5	2.25
LSD (0.05)		0.95	

The vine cuttings technique

The major advantage of this technology over the others is that it uses yam vines and thus makes the yam tubers available for consumption. As in the other techniques, once the vines can be made to develop roots, they will establish and produce tubers.

Healthy 3-node vines of about 20cm long were excised from vines of yams grown in buckets in a screenhouse from 70 days after planting (DAP) up to 90 DAP and planted in 270ml plastic cups filled with carbonized rice husk. The two lower leaves of the vines are removed to reduce moisture loss. The cups were watered sparingly every two days and examined for rooting from 21DAP. They were transplanted to the field and were harvested after 8 months. Our choice of carbonized rice husk is because it was the best of three options: carbonized sawdust, charcoal and carbonized rice husk (Table 3)

Table 3. Effect of rooting media on root and tuber formation in white yam (TDr 89.02665)

Media	% Root formation	% Root and Tuber formation	% Dead vine
Rice Husk	4	68	28
Sawdust	16	8	76
Charcoal	12	20	68

The carbonized rice husk gave highest (68%) roots and tuber formation and least dead vines than the other two media evaluated. With this method we have generated minitubers that range from 50g to 600g. Work is in progress to develop better techniques to improve the rooting percentage. This includes use of Indolebutric Acid (IBA) and manipulations of the micro-environment including using shed nets.

The trial conducted in 2007 and 2008 showed significant differences in the mean yield of tubers of all the hybrid yams (Table 4). TDr 89/02665 and TDr 89/02565 gave significantly higher seed yams and minitubers yields than the other varieties. It is noteworthy that TDr 89/02665 (called miracle yam by some farmers) responds favourably to minituber production through vine cuttings. This will enhance its rapid multiplication above the other released yam varieties.

Table 4. Mean tuber yield g/plot at 8 months after planting

	Mean tuber yield (g/plot)		
Treatment	2007	2008	Two years mean
TDr89/01213	400	850	625
TDr89/02665	1230	2693	1961.5
TDr89/02565	670	1600	1135
TDr89/02677	282	651	467
TDr438	170	503	337
TDr89/01924	513	923	718
TDr89/02461	378	863	621
LSD(0.05)	381.8	341.9	362.2

The peelsett technique

The peelsett technique of seed yam production was developed a few years ago to complement the yam minisett technique for rapid multiplication of seed yams (Igwilo 1999). The added advantage of the peelsett technique is that the farmer cuts out only about 1 cm thickness of the peels of the seed yam and has the rest of the inner food reserve for family consumption. Much of the yam peels that are discarded during food processing, could be used to generate planting material, especially where such varieties are preferred landraces or improved. Presently we aim to popularize the peelset technique of seed yam production among farmers and seed yam producers and thereby increase the number of seed yam multiplication techniques developed so that seed yam producers could choose the method most convenient and most economical to them.

We conducted adaptive trials in Umudike in 2008 with two yam varieties: *D. Rotundata (cv.Obioturugo)* and *D alata (cv.Um 680*). Peelsets were generated from each variety by slicing 5mm *(D.alata)* or 10mm *(D.rotundata)* thick setts from the selected clean seed yam tubers. .The setts were deeped into a fungicide/insecticide mixture at recommended rate in 10 liters of water cured overnight and planted on the crest of 1m ridges in 5m x 5m plots replicated 3 times. Plots were weeded at 3 + 8 +12 weeks after planting. Compound fertilizer NPK (15-15-15) at 300 kg/ha was applied to each plot 8 WAP. The vines were staked with split bamboos at 4 stands/stake when the vines had fully emerged. Data collected were analyzed using standard procedures and means were compared using LSD at 5% level. The yield and yield attributes from peelsett and minisett (control) are presented in Table 5.

Table 5. Seed yam yields from peelsett and minisett technologies in 2008

Treatments	Days to 50% emergence (DAP)	No. of tubers/ha (x1000)	Tuber yield (t/ha)
D.rotundata Peelsett	61.00	16	2.25
D.alata Peelsett	49.25	14.1	2.90
D.rotundata Minisett	55.50	37	12.81
D.alata Minisett	50.00	29.3	11.82
LSD (0.05)			2.48

Results showed that the minisett technique (12.32 t/ha) is still superior to the peelsett technique (2.58 t/ha) unlike Igwilo's (1999) report. The reason for the poorer performance of the peelsetts could be due to the poor sprouting percentage achieved; but

this work is still being confirmed. However, this complementary technology capable of generating over 2 t/ha minitubers is a welcome development, especially since kitchen peels become a resource in raising planting material.

Conclusion and Recommendation

The yam minisett technique of seed yam production was developed to remove the constraint of scarcity and/or high cost of seed yams for food yam production. Over twenty years after this breakthrough, adoption rate is still below 40%. This formed the objective of developing complementary seed production techniques such that farmers could use the methods most economical and convenient for them. We recommend the formation of seed agencies that would produce minitubers using any or all the complementary techniques discussed above, and sell to the farmers at affordable prices. Use of yam slips should also be developed for minitubers production.

References

Aighewi, B.A., Akoroda, M.O. and Asiedu, R. (2003) Seed yam production from pre-sprouted minisetts and varied thichnesses of storage parenchyma. African Jour. of Root and Tuber Crops. 5(1): 20-23.

Anuebunwa, F.O., Ugwu,B.O.Iloka, A.W., Ikeorgu, J.E.G. and Udealor, A.(1998) Extent of adoption of yam minisett technology by farmers in the major yam growing areas of Nigeria. A research report submitted to NARP Abuja by NRCRI Umudike. August 1998. 29pp.

FAO (2006) Statistical data on crop, area, yield for 2006. FAOSTAT. www.fao.org. Food and Agriculture of the United Nations. Rome.

Igwilo, H.N. (1999) Effect of progressive removal of ground tissue with increasing plant population on the growth and yield of yam grown from minisetts. Niger. Agric. J. 30:19-31

Ikeorgu, J.E.G. and Nwokocha, H.N. (2001) Development of the yam minituber technique for seed yam production. Niger. Agric. J. 32:97-108.

Ikeorgu J.E.G. and M.C. Igbokwe (2003) Seed yam production with minitubers. *Niger* Agric, J, 34:63-67.

Ikeorgu, J.E.G; H.N. Nwokocha and M.C. Ikwelle (2000). Seed yam production through the minisett technique: recent modifications to enhance farmer adoption. Proc. 12th International Symposium of ISTRC held in Tsukuba Japan. 10-16 September 2000.pp 372-375.

Kikuno H, R. Matsumoto, H. Shiwachi, H. Youohara and R. Asiedu (2007). Comparative effects of explants sources and age of plant on rooting, shooting and tuber formation of Vine cutting of yams. Japanese Journal of Tropical Agriculture Vol. 51 Extra issue 2: 71-72.

Manyong, V.M. 2000. Farmers' perceptions of the resource management constraints in yam-based systems. Pages 3-4 in Project 13: Improvement of yam-based systems. Annual Report 1999. International Institute of Tropical Agriculture, Ibadan, Nigeria.

NRCRI (2007) Annual Report for 2006. National Root Crops research Institute Umudike. 366pp.

NRCRI (2008) Tuber Crops Division Annual Report for 2007. National Root Crops Research Institute Umudike. 186pp.

Ogbodu, B.C. (1995) Report on extension activities in Enugu State of Nigeria. Proc. 10th Annual Farming Systems Research and Extension Workshop, Umudike. Dec. 4-8, 1995.(in press)

Okigbo, B. N. and Ibe, D.G. (1973). New method of yam propagation. Paper prepared for the Third Symposium of the International Society for Tropical Root Crops, IITA, Ibadan, Nigeria. 2-9 December.

Okoli, O.O. and M. O. Akoroda (1998). Providing seed tubers for the production of food yams. African journal of Root and Tuber crops 1: 1-6.

Okoli, O.O., M.C. Igbokwe, L.S.O. Ene and J.U. Nwokoye. 1982. Rapid multiplication of yam by 'minisett technique'. NRCRI Research Bulletin # 2, 12pp.

Otoo, J.A., D.S.O. Osiru, S.Y.C. Ng and S.K. Hahn. 1987. Improved technology for seed yam production. Second edition. IITA, Ibadan, Nigeria. 56p