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Advances in cassava breeding in Uganda

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Abstract

Cassava breeding work in Uganda started as far back as 1920 and to date attention has been problem oriented focusing mainly on disease and pest resistance, tuber quality and yield. The approach to cassava breeding has evolved from breeder led, through a multidisciplinary approach to a more farmer participatory approach in order to address farmer needs more effectively. Collaboration and networking have featured prominently in cassava breeding activities. Between 1990-2000, 12 cassava varieties were released. Future plans for cassava improvement activities include targeting specific end uses in order to transform cassava into a broad based commercial commodity.

Introduction

Cassava is an important staple food in Uganda. Its hardiness expressed in its ability to withstand marginal conditions together with its low labour requirements make it an appropriate crop for the low resource farmers. Cassava has been widely appreciated because of its relatively stable yields even under marginal conditions like drought, low soil fertility and low intensity management. After maturity, the crop can store long in the soil spreading out food supply over time, hence its role as a food security crop.

In Uganda, cassava was introduced between 1862 and 1875 (Langlands, 1972). Since its introduction, the crop has changed status from a famine reserve crop, to a major food crop and recently has assumed a new status as a major cash crop. Cassava sells for its tuberous roots, processed products and vegetative seed and is a raw material for industry. Owing to the declining soil fertility in the country, the worsening pest damage to many other crops, and the unreliable weather conditions, the role of cassava in Uganda's economy is currently more important than ever.

History of cassava breeding in Uganda

Though records of cassava breeding in Uganda date as far back as 1920, serious breeding efforts were recorded in the 1930's. This research was stimulated by the outbreak of a serious mosaic epidemic in Eastern Uganda to which all local varieties succumbed. Merits of varieties with resistance/tolerance to mosaic were appreciated for the first time around 1930 (Storey, 1930). Around this time, the East African Agricultural Research station at Amani in Tanzania initiated breeding and testing of cassava to viral diseases. A number of resistant clones were selected and issued to the territorial departments of agriculture of which Uganda was one.

In Uganda, critical comparative mosaic resistance evaluation trials were started at Serere in 1941. By mid 1943, yield trials were conducted to compare resistant clones with the local varieties. The clones Binti misi, 37244E, Aipin Valencia, F100, F 279, Mauritius 29, Kru, Kiwuku and Mkezumbe were selected from these trials for distribution to farmers. Some testing was also done at Bukalasa and this yielded the famous Bukalasa series of which B 8 and B 11 became very popular with farmers and were eventually released officially.

The cassava breeding process prior to 1950 was clearly characterised by the lack of involvement of farmers. Breeders tested the cassava clones in isolation and distributed what they felt was good to farmers. Though they released some varieties that became popular among farmers, the degree of success of those breeding programs is not documented but is likely to have been low.

Recent advances in cassava breeding

Between mid-1950s and 1970 there are very scanty records of cassava breeding in Uganda. Cassava breeding work was revitalised at Serere research institute between the late 1970's and early 1980s,. However, due to the political instabilities that erupted in the area, cassava research activities were moved to Namulonge research station around 1987.

Around 1988 another epidemic of cassava mosaic broke out. The National Cassava Programme embarked on afresh search for CMD resistance. This was preceded by assembly and evaluation of available cassava germplasm within the country. Results from the evaluations indicated that most of the locally available germplasm was susceptible to mosaic. The susceptible germplasm also included the earlier bred varieties like B 11 and B 8 whose resistance had 'broken down'.

Introductions of cassava germplasm were made most of which were from the International Institute of Tropical Agriculture (IITA). Such materials were acquired either as clones (tissue culture) or as open

Table 1: Cassava clones received as tissue culture from the International Institute of Tropical Agriculture for ACMD resistance breeding.

Clone	Year	Clone	Year	Clone	Year
TMS 60142	1984/1992	TMS 70775	1992	87/00487(1)	1993
TMS 30572	1984/1992	TMS 85/00576(1)	1992	TMS 41369	1993
TMS 30395	1984/1992	TMS 81/01635(2)	1992	TMS 40160	1993
TMS 30001	1984/1992	TMS 80/00086(1)	1992	M 82/00062	1996
TMS 30337	1990/1992	TMS 60506	1992	M 85/00695	1996
TMS 4(2)1425	1990/1992	TMS 63397	1990/92	085/00120	1996
TMS 82/00249	1992	TMS 90257	1992	I 84/00038	1996
TMS 40764	1992	TMS 90442	1992	I 91/00455	1996
TMS 8010	1992	TMS 4488	1992	084/00271	1996
TMS 83672	1992	TMS 81/00110(1)	1992	I 91/00458	1996
TMS 84776	1992	TMS 82/00661(2)	1992	088/01168	1996
TME 2	1992	TMS 82/00942(2)	1992	I 84/00460	1996
TMS 84/00040	1992	TMS 82/00058(1)	1992	I 92/0042	1996
TMS 1095-D1	1992/93	TMS 80/00661	1992	I 91/02316	1996
TMS 30555	1992/93	TMS 40764	1992	W 4080	1996
TMS 81983	1992/93	TMS 82/0422	1992	088/00039	1996
TMS 30040	1992/93	TMS 84/00040	1992	92/0430	1996
TMS 30786	1984/1992	TMS 82/00576	1992	I 92/0520	1996
TMS 40160	1992/93	TMS 61036	1993	I 89/00660	1996
TMS 50395	1992/93	TMS 84563(2)	1993	I 82/00142	1996
TMS 90059	1992	TMS 85/00066(2)	1993	I 93/0160	1996
TMS 84537	1992	TMS 84/00001	1993	I 82/00959	1996
TMS 4(2)1443	1992/93	88/02346(2)	1993	I 93/0665	1996
TMS 71173	1992/93	84/00524(1)	1993	I 93/0658	1996
TMS 81/00065(2)	1992	84751(1)	1993	I 91/00453	1996
TMS 80/01935	1992	60121(1)	1993	I 88/0367	1996
TMS 81/01610(2)	1992	LCNA 41369(5)	1993	I 93/0571	1996
TME1	1992/93	LCN 30474(1)	1993	M 86/00019	1996
TMS 30211	1992/93	82/0447(2)	1993	TMS 84716	1992
TMS 42025	1992	CB 81/00202(1)	1993	LCN A5	1992
TMS 60444	1992	84/00029(1)	1993	TMS 90233	1992
TMS 91934	1992/93	87/00609(1)	1993	TMS 90953	1992
TMS 83350	1993	84/00045(1)	1993	LCN 8110	1992
TMS 90853	1992	61677	1993	TMS 81/004422	1992
TMS 4(2)0267	1992/93	87/00501(1)	1993	TMS 84776	1992

Table 2: Open pollinated seed batches received from the International Institute of Tropical Agriculture between (IITA) 1989-1997

Year	No.of Families Received /evaluated	Total No. of seeds	No. of seedlings selected for Clonal trial
89/90	36	15,560	470
90/91	32	20,115	358
91/92	91	63,802	560
92/93	40	14,250	400
93/94	132	15,322	448
94/95	113	50,000	958
95/96	40	18,000	405
96/97	343	64,971	562

Table 3: Improved cassava varieties released by the Uganda National Cassava Programme

Variety	Form of introduction*	Year of introduction	Year of Release	Registered name
TMS 60142	Clone	1984	1994	NASE 1
TMS 30337	Clone	1990	1994	NASE 2
TMS 30572	Clone	1984	1994	NASE 3
SS 4	Seed	1985	1998	NASE 4
SS 5	Seed	1985	1998	NASE 5
TMS 4 (2) 1425	Clone	1990	1998	NASE 6
CE 85	Seed	1990	1998	NASE 7
CE 98	Seed	1990	1998	NASE 8
30555-17	Home bred+	-	1998	NASE 9
95/NA-00063	Seed	1992	2000	NASE 10
95/NA-2-TC1	Clone	1993	2000	NASE 11
MH 95/0414	Seed	1994	2000	NASE 12

*The genetic source of all the varieties is the International Institute of Tropical Agriculture, Nigeria
+ 30555-17 was derived from open pollinated seed TMS 30555

pollinated seed (see Tables 1&2). The introductions were evaluated for CMD resistance and some resistant/ tolerant clones were identified. This led to a series of activities among which were evaluation for adaptability, stability and root quality in on-station trials. After on station trials, the clones were evaluated under farmer managed conditions and this was aimed at capturing farmers' perceptions. The on-farm trials were followed by multiplication and distribution of the varieties that were found acceptable to farmers. It is evident that the shortcomings of not involving farmers in variety evaluation had been realised. By 1980's farmers were being involved during the last stages of variety evaluation in order to capture farmers' perception of the varieties and their performance under farmers' conditions. Through this kind of process, the UNCP was able to release officially 3 varieties by 1994; TMS 60142, TMS 30337 and TMS 30572 which were registered as NASE 1, NASE 2 and NASE 3 respectively (Table 3). Because the breeding and selection process was done in both Namulonge and Serere, the released varieties were registered as the Namulonge Serere (NA = Namulonge, SE = Serere) series. In 1998, another 6 cassava varieties; SS4, SS5, TMS 4(2) 1425, CE 85, CE 98 and 3055-17 were released and registered as NASE 4 to NASE 9 respectively (Table 3)

Following the introduction of CMD resistant varieties into the farming system, there was an accompanying reduction in disease pressure. Farmers started reverting to their local varieties that they had abandoned. The few local varieties that survived the CMD epidemic apparently have some degree of tolerance to CMD. It was evident that farmers had taken up the new varieties out of crisis but preferred their local ones. Interactions

Table 4: Farmers assessment of cassava varieties in advanced trials during pre-harvest stage, June 2000

Variety	Positive attributes	Negative attributes	Selected (S) Not selected (NS)	
			Male	Female
MH 96/0245	Variety is tall with big stems. Good branching habit, can easily be inter-cropped, resistant to CMD, looks short term, good for multiplication.	Poor leaf retention Does not fruit	S (3) NS (1)	S (4)
TME 5	Medium height, good canopy, close nodes, good for multiplying, CND resistant to CMD, good for inter-cropping, not very many shoots, looks high yielding, looks attractive.	Die back Poor leaf retention	S (4)	S (4)
97/NA-0024	Resistant to CMD, poor establishment, fruiting.	Dire back, long inter-nodes, fairly susceptible to CMD low branching	NS (4)	S (1)
MH 96/561	Good branching habit, erect stems, CMD resistant, good leaves, plenty of good planting material.	Succumbs to anthracnose Some nodes are not dormant	S (4)	S (4)
MH 96/0264	Good branching habit, good for inter-cropping, resistant to mosaic, high branching, looks high yielding.	Poor leaf retention, does not look tolerant to drought, long inter-nodesthat waste planting materials,does not fruit.	S (4)	S (4)
97/NA-0010	Tolerant to CMD, a lot of planting materia l, thick canopy for weed smothering and moisture conservation during dry season, close nodes, looks high yielding, free of most diseases.	Looks long term, has too many small branches, does not fruit.	S (4)	S (4)
MH 96/0775	Tolerant to CMD, has thick canopy for weed smothering, good for multiplication, close. nodes indicate high yields, good, good stem	Low branching, non-fruiting, colour, resistant to leaf leaves spots.	S (3) NS (1)	S (3)
I 92/0427	Tall, resistant to CMD, close nodes good for inter-cropping, plenty of good planting material, good dormant nodes.	Non-fruiting, does not smother weeds	S (4)	S (4)
97/NA-004	Medium branching, good for multiplication, good noding.	Shoot tips dry up, side sprouting,some modes not dormant	S (2) NS (2)	S (2) NS (2)

Table 5: Farmers assessment of cassava varieties in advanced trials after harvest, June 2000

Variety	Positive attributes	Negative attributes	Selected (S) Not selected (NS)	
			Male	Female
MH 96/0245	Good taste (not bitter), easy to peel, marketable tubers, white skin colour Indicates sweet taste), high yielding.	Watery, tubers hollow inthe centre	S (4)	S (4)
TME 5	Good tuber size, sweet not watery		S (4)	S (4)
97/NA-0024	Easy to peel, sweet, not watery	Unmarketable tubers, low yielding, good skin colour, short tubers	NS (4)	S (1) NS (3)
MH 96/561	High yield, good outer skin colour, marketable tubers, easy to peel, good tuber shape, not woody	A bit watery	S (4)	S (4)
MH 96/0264	High yielding, marketable tubers, easy to peel, has good dry matter content, marketable skin colour, good for processing, easy to dry, good tuber shape.	Has a woody end, slightly bitter	S (4)	S(4)
97/NA-0010	Easy to peel, marketable skin colour, high yielder, big tubers, sweet taste, no woody end	Watery tubers	S (4)	S(4)
MH 96/0775	High yielding, marketable, easy to peel, high dry matter	Small tubers, long neck length, branching tubers, long-term, woody tubers	S (2) NS (2)	NS (2) S (2)
I 92/0427	Easy to peel, sweet taste, marketable, good outer skin colour, high yielding, good tuber size, good flesh colour	Slightly water	S (4)	S (4)
97/NA-004	Easy to peel, good outer skin colour, good tuber size	Low yielding, bitter, watery	NS (2) S (2)	NS (2) S (2)
SS4 (Check)	Easy to peel, big tubers, would	Water, slightly bitter,	S (2)	NS (2)
	yield better but stolen marketable tubers	low yielding	S (2)	S (2)
Ogwok (local check)	Good taste, not marketable, not very watery, pink skin colour	Difficult to peel, low yield	NS (4)	NS (4)
97/NA-0021	Easy to peel, may be good for flour, high dry matter, medium yield, sweet taste	Woody neck, small tubers, not marketable	S (2) NS (2)	NS (2) S(2)

Table 5.co..

Variety	Positive attributes	Negative attributes	Selected (S) Not selected (NS)	
			Male	Female
97/NA-0027	Good tuber size, good outer skin colour, high dry matter content	Not marketable, has small tubers, difficult to peel, sugary taste	NS (2) NS (2)	S (4)
97/NA-0015	Not a high yielding, easy to peel, marketable, high dry matter, good tuber size, good skin colour, sweet	Not a high yielder	S (4)	S (4)
MH 96/1276	High yielding, easy to peel, good tuber size, sweet, good tuber colour	Slightly watery, good for home consumption only	NS (4)	S (4)
97/NA-0005	High yielder, marketable, sweet, pink skin colour, good tubers	Hard to peel	S (4)	S (4)
MH 96/1319	Pink skin colour, marketable tubers, high yield, big tubers, high dry matter sweet	A bit watery	S (2)	NS (2) S (4)
I 91/2324	Sweet, easy to peel, marketable tubers	Low yield, watery	S (2) SN (2)	S (4) S (1)
MH 96/106	Marketable tubers, peels easily, not watery	Low yield (theft), may be late maturing, tuber size not appealing	NS (2) S (2)	NS (4)

Numerals in brackets are selection frequencies

Table 6: Promising cassava varieties tested/selected from in on-farm trials between 1997 and 2000

Year	District Tested	No. of varieties selected	No. of varieties selected	Identities of varieties	Remarks
1995/96	Mpigi	8	2	CE 85, CE 98	CE 85 and CE 98 released as Nase 7 and
	Luwero	8	2	CE 85, CE. 98	8 respectively
	Kibaale	8	1	CE. 85	Nase 8 respectively
19996/97	Mpigi	11	0		
	Soroti	2	0		
	Kamuli	11	1	80/00080-1	Eventually succumbed to
	Masindi	12	1	80/00080-1	CMD. In Germplasm
1997/98	Kamuli	3	1	92/MG 11	
	Luweero	5	1	30555-17	30555-17 released and
	Masindi	6	1	30555-17	registered as Nase 9.
	Pallisa	3	1	30555-17	
1998/99a	Mpigi	4	2	94/SE-00036, MH95/0414	MH95/0414 released and
	Masindi	4	2	94/SE-00036, MH95/0414, MH96/0161	registered as Nase 12.
	Luweero	4	2	94/SE-00036, MH95/0414	
1998/99b	Luweero	2	2	95/NA-2-TC1, 95/NA-00063	95/NA-00063 and
	Mpigi	2	2	95/NA-2-TC1, 95/NA-00063	95/NA-2-TC1 released
	Mukono	2	2	95/NA-2-TC1, 95/NA-00063	as Nase 10 & 11 respect.
1999/2000	Luweero	4	3	94/SE-00036, TME 14, 95/SE-00087	All three varieties await
	Mukono & Busia	4@	3	-do-	release
2000/2001	Nakasongola	20	-		
	Lira & Kumi	20@	-		
	Katakwi&Gulu		20@	-	

with the farmers both formally and informally gave some indications of the need to restore or improve their local varieties without changing their tuber qualities. It was therefore obvious that the new varieties lacked some of the unique characteristics for which farmers liked their varieties. A process of introgression of genes for mosaic resistance into local varieties was initiated at Namulonge. The objectives of this process were: (i) improve farmers' varieties for CMD resistance (ii) to improve CMD resistant varieties for acceptable tuber qualities. The breeding scheme used is as described by Ssemakula et al, 2000. The CMD resistant varieties used were of the tropical Manihot Series (TMS) from IITA. The TMS series have featured prominently in many African cassava breeding programmes (Ssemakula et al 1997). The TMS series have a lineage with Manihot glaziovii and can be traced back to Amani (Tanzania) where breeding for CMD was initiated.

Combining good tuber qualities especially low cyanogenic potential and high CMD resistance was a problem (Ssemakula *et al* 1997) given the limited germplasm pool at the disposal of the UNCP. Even when the UNCP gained access to a larger germplasm pool from the East African Root Crops Research Network (EARRNET), handling this was difficult because of the financial implications. By 1996/97, the UNCP together with EARRNET agreed that EARRNET takes the lead in the lower stages of germplasm development while the UNCP takes the lead in evaluating clones at the advanced stages. That meant that EARRNET was to handle the lower stages that are normally associated with very large numbers of germplasm, and was therefore shouldering the accompanying costs. The UNCP would then access the cassava germplasm at a more advanced stage of evaluation when they are fewer and less costly to handle. The breeder of the UNCP, however worked hand in hand with the EARRNET team even at the lower stages of evaluation. Even though the UNCP was able to release 9 cassava varieties by 1998, the process of variety development and selection lacked proper integration of farmers.

During the year 1998/99, the approach to cassava variety evaluation and selection was modified to farmer participatory. This was aimed at targeting and integrating farmer needs in the variety development process by empowering their participation in the process. Farmer participatory variety evaluation and selection has led to the development of a new and more effective selection criteria which is a blend of both farmers and researchers independent criteria. An example of farmer selection criteria is shown in Tables 4 and 5. These two tables show that farmers' criteria is more rich and impressive as exemplified by their ability to predict performance from the look at the clones.

The on-farm trials conducted thereafter, use farmer choice varieties other than breeder's selections. The subsequent acceptance of the cassava varieties has been higher than before (Table 6). The table shows that prior to the initiation of farmer participatory variety evaluation, (before 1998), 8 varieties were introduced on-farm during 1995/96 and only 2 were accepted while during 1996/97 up to 12 varieties were introduced on-farm but none was accepted. However, during 1998/99b the 2 varieties that were introduced on-farm in Mukono, Luwero and Mpigi were both accepted. During the year 2000, 3 more cassava varieties were released (Table 3). The latest releases combine both resistance to major biotic stresses and good tuber qualities and therefore, have been adopted much faster than previous varieties. The 3 varieties; 95/NA-00063, 95/NA-2-TC1, MH 95/0414 were released as NASE 10, NASE 11 and NASE 12 bringing the total number of varieties released by the UNCP to 12 (Table 3). The latest releases combine both resistance to major biotic stresses and good tuber qualities and therefore, have been adopted much faster than previous varieties.

Despite the large number of genotypes accessible by the UNCP from the EARRNET gene pool, only few have been selected at any one given time for evaluation in multi-locational and on-farm trials. This was done in fear of congesting farmers' fields given the limited resources available to them. Of recent however, the augmented design was adopted to enable the testing many genotypes on-farm without necessarily congesting farmers' fields. During the current cropping year, 2000/2001, 20 varieties have been planted on- farm in 5 clusters, involving 100 farmers. Preliminary results indicate that the variability in farmer perception of the varieties may lead to subsequent enhanced cassava genetic diversity within the farming community in the country. This in turn will buffer the system against major biotic stresses and will meet the different food systems needs of the country. Diversification of varieties at farm level, if coupled with appropriate response of post-harvest research on post-harvest issues raised by UNCP would go a long way in meeting needs at farm level.

Given the magnitude of the work involved in evaluating and monitoring 100 farmers' fields, the UNCP together with EARRNET co-ordination felt there was need for collaborators who operate at grass root level. These include NGOs, farmer groups and government extension. The work is currently being conducted in the following areas:

- Nakasongola- collaborating with district extension
- Gulu- collaborating with Catholic Relief Service (NGO)
- Kumi- collaborating with Vision Terudo (NGO)
- Soroti- collaborating with Church of Uganda (NGO)
- Lira- collaborating with Africa –Sana (farmer group)

UNCP is anticipating release of more than 15 varieties at the end of these on-farm trials.

Breeding for resistance to other pests and diseases
CMD resistance is only one aspect of cassava improvement that the UNCP is handling. Other pests that attack cassava are being handled appropriately. Within EARRNET activities, populations for cassava green mite (CGM), Cassava Bacterial Blight (CBB) and cassava anthracnose (CA) are being developed at Serere Research Institute. However, resistance to all other pests is being looked at in conjunction with CMD resistance.

It has been observed that most of the very highly resistant clones to CMD are susceptible to CGM e.g. Nase 3, Nase 4, Nase 10 and Nase 12. Good CGM resistance has been found mostly in moderate CMD resistant varieties like Nase 1, Nase 2, Nase 9 and Nase11. CBB and CA are diseases that have been observed to occur only after heavy rains/ hailstorms. The TME (Tropical Manihot esculenta) lines that have been sourced from EARRNET germplasm pool are susceptible to CBB and resistant to CGM while the TMS lines and their progenies seem to have better resistance to CBB but tend to be more susceptible to CGM..

Attempts to combine superior tuber qualities of the TME lines with multiple resistance to pests through gene introgression have been initiated at Namulonge using TME and TMS lines. The TME lines are local collections from Nigeria and this could explain their good tuber qualities. Some of the TME lines that are at the advanced stages of evaluation are TME 14, TME5 and TME 12. These have gained popularity comparable to that of Bukalasa 11 among farmers.

Lessons and issues arising from past experience in cassava breeding

- Farmers and breeders plus other scientists should work in a participatory team. This gives faster and more accurate results while at the same time offers cheap technology transfer
- Breeding for any cassava disease and pest resistance should not compromise tuber quality if resources are to be used efficiently and effectively. This is drawn from a case where farmers' reverted to their local varieties after the CMD epidemic.
- Collaboration/Networking is paramount. Boarders are porous and therefore countries inevitably share problems. Solving such problems also calls for pooling resources, since the national programs have limited resources. It is evident from available records that Uganda's recurrent cassava development problems have been solved through networking/ collaboration e.g. the early case of Amani and the recent case of EARRNET/IITA.
- How high should be the selection pressure imposed to the virus so that it doesn't undergo genetic changes that are detrimental to the farming community especially the survival of local varieties?

Future of cassava breeding in Uganda
While the current breeding programme is concentrating on improvement of tuber quality characteristics, there is a plan to look seriously into other diseases and pests like CBB CGM and CA. The cassava varieties that are being promoted for tuber quality and CMD resistance especially the TME series are CBB susceptible though they have resistance to CGM. There is a need to incorporate multiple pest and disease resistance in new cassava varieties. Breeding for industrial uses is also another area worth exploiting. There is a need to breed cassava varieties with target end uses like starch and confectionery. Targeting end uses will lead to enhanced diversity of cassava varieties at farm level because farmers will need to grow many varieties to meet the different end uses. Eventually, cassava will transform from a 'poor man's crop' into a broad-based commercial commodity for sustained food security, poverty alleviation and income generation.

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