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SWEETPOTATO SELECTION RELEASES: LESSONS LEARNT FROM UGANDA

R.O.M. MWANGA, B. ODONGO, C. NIRINGIYE, R. KAPINGA[1], S. TUMWEGAMIRE[1], P.E. ABIDIN[2], E.E. CAREY[3], B. LEMAGA[4], J. NSUMBA[4] and D. ZHANG[5]
National Crops Resources Research Institute (NaCRRI), Namulonge, P.O. Box 7084, Kampala, Uganda
[1]International Potato Centre (CIP), P.O Box 22274, Kampala, Uganda
[2]Department of Plant Sciences, Laboratory for Plant Breeding Wageningen University, P.O. Box 386, 6700 AJ Wageningen, The Netherlands
[3]Department of Horticulture, Forestry and Recreation Resources, Kansas State University, K-State Research and Extension Center at Olathe, 35125W. 135th St., Olathe, KS 66061, USA
[4]Regional Network for the Improvement of Potato and Sweetpotato in East and Central Africa (PRAPACE), P.O Box 22274, Kampala, Uganda
[5]International Potato Center (CIP), P.O. Box 1558, Lima, Peru

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ABSTRACT

The National Sweetpotato Programme of the National Agricultural Research Organisation (NARO) in Uganda released 14 sweetpotato cultivars between 1994 and 2005. Of the released cultivars, six have gained importance in local Ugandan markets and in export trade to Europe and two are being used as parental sources for high dry matter (>30%), sweetpotato virus disease (SPVD) and nematode resistance in hybridization schemes, and in the genetic mapping work in joint international collaborative research. Two orange-fleshed sweetpotato (OFSP) cultivars, namely, Ejumula, and SPK004 (Kakamega), high in beta-carotene (the precursor for vitamin A) are spreading rapidly for combating widespread vitamin A deficiency in Uganda. The major steps leading to the release of Kakemega and Ejumula are used to illustrate the experience of the Ugandan sweetpotato breeding programme sustained activities for a decade, and lessons learnt are highlighted. The sustained breeding activities have led to a vibrant and robust program, increased international and south to south collaboration, increased partnership and alliances; shifted research focus from production to production per se and quality (nutrition), resulting into significant and relevant agricultural research. The lesson here is that it takes a long time to develop technologies, disseminate and commercialize them. It also requires commitment by the donor, government, scientists, farmers and other stakeholders for effective commercialization of the developed technologies.

Key Words: Variety release, food systems, partnerships, stability analysis

RÉSUMÉ

Le Programme National de la patate douce au sein de l'Organisation Nationale de la Recherche Agronomique en Ouganda (NARO) avait lancé 14 variétés entre 1994 et 2005. De ces variétés, six avaient été trouvées importantes dans les marchés locales de l'Ouganda ainsi qu'au niveau du commerce extérieur en Europe pendant que deux avaient été considérées comme substances indispensables au service des ressources familiales (> 30%), pour le virus de la maladie de la patate douce (VMPD) et la résistance de la nématode dans les plantes, au plan de l'hybridation et au travail de la cartographie génétique pour une recherche internationale collaborative. Les deux variétés de Patates Douce en Chair d'Orange (Ejumula) et SPK004 (Kakamega) sont riches en carotène bêta (précurseur de la vitamine A); celle-ci se répand rapidement pour combattre la propagation rapide de la déficience de la vitamine A en Ouganda. Les étapes principales conduisant au lancement de Kakamega et Ejumula sont utilisées pour illustrer l'expérience du programme ougandais pour la culture de la patate douce. Existant depuis une décennie de soutien, on recommande que des leçons soient apprises à partir de ses activités. Les activités du lancement de l'élevage avaient conduit à un programme vibrant et robuste, rehaussé la collaboration internationale et Sud- Sud; il avait aussi rehaussé le partenariat et les alliances; changé le centre de recherche de produit à produit par le « se » et la qualité (nutrition) qui résulte d'une recherche agricole significative et importante. Il faut cependant du temps et apprendre une leçon pour développer leurs technologies, les répandre et les commercialiser. Pour ce faire, l'engagement de la part du donateur, du Gouvernement, des scientistes, des agriculteurs et des partenaires pour la commercialisation effective des technologies avancées s'avère nécessaire.

Mots Clés: Lancement de la variété, système alimentaire, partenaire, analyse de la stabilité

INTRODUCTION

The Ugandan National Sweetpotato Programme of the National Agricultural Research Organization (NARO) released twelve sweetpotato cultivars, six in 1995 (Mwanga *et al.* 2001a, b) and 6 in 1999 (Mwanga *et al*. 2003). The 6 cultivars released in 1995 were New Kawogo, Sowola, Tororo 3, Bwanjule, Tanzania and Wagabolige, and the NASPOT series 1 to 6 were released in 1999. New Kawogo, Tanzania and NASPOT 1 have gained importance in local Ugandan markets and in export trade to Europe especially the UK and the Netherlands, Wagabolige (WAG) and Tanzania (TZ) are being used as parental sources for high dry matter (>30%), sweetpotato virus disease (SPVD) (Mwanga *et al*. 2002a) and nematode resistance (Cervantes-Flores et al. 2002) in hybridisation schemes at the International Potato Center (CIP), Lima, Peru; North Carolina State University (NCSU), Raleigh, USA; and Namulonge Agricultural and Animal Production Research Institute (NAARI), Uganda. The two parents (WAG and TZ) are also important because of the genetic mapping work by the joint effort of NaCRRI/NARO, CIP, NCSU, and the Austrian Research Center, Seibersdorf (ARCS) in Austria (Kriegner *et al*. 2003, Mwanga et al. 2003). The other cultivars are of importance in specific agroecologies in the country. NARO released two orange-fleshed sweetpotato (OFSP) cultivars, namely Ejumula, and SPK004 (Kakamega) in April 2004 to contribute to combating the severe and widespread vitamin A deficiency in Uganda (UBS and ORC Macro, 2001).

Except for NASPOT 5 that is orange-fleshed the remaining 11 cultivars released before 2004 are white- or yellow-fleshed. Most white- or yellow-fleshed sweetpotato cultivars have very little or negligible β-carotene, the precursor for Vitamin A, whereas orange-fleshed sweetpotato (OFSP) cultivars are rich in β-carotene.

Vitamin A deficiency is one of the most widespread deficiencies in developing countries. Unfortunately, Uganda is among the more than 90 countries worldwide categorized by the World Healthy Organization (WHO) as having a public clinical (very severe) and/or sub-clinical (severe) vitamin A deficiency. According to the 2001 Uganda Demographic and Healthy Survey, 30% of children and 50% of women had vitamin A deficiency (UBS and ORC Macro, 2001).

Long-term measures, such as diet diversification will play a more sustainable approach in combating vitamin A deficiency than relying on any single strategy such as vitamin A capsule supplementation. Sweetpotato is a common staple food in about 90% of Ugandan households. OFSP can grow in remote areas where families have no access to the vitamin A supplements due to poverty.

The OFSP grows fast in most soils, produces high yields, and large roots. Promoting OFSP will complement development agencies' supplement and fortification approaches. OFSP has the additional advantage of its beta-carotene being more bioavailable compared to other common plant sources of beta-carotene from dark-green vegetables.

Two orange-fleshed cultivars, "Ejumula" and "SPK004" (Kakamega) with high β-carotene, were evaluated in Uganda. They performed well in yield, and their acceptability by producers, consumers and some processors is high. This paper highlights the major steps involved in their release and the experiences by the sweetpotato programme due to sustained activity.

MATERIALS AND METHODS

Routine procedures followed in Uganda leading to the release of a sweetpotato cultivar include, evaluation of introductions, polycross, seedling nursery, clonal observation, preliminary, intermediate, advanced and on-farm trials. The precise steps vary depending on the frequency of desirable traits in the base population. Ejumula is a local landrace cultivar (farmers' cultivar) collected from Aterai village, Wera Sub-county, Amuria County, Katakwi District (Abidin, 2004), while SPK004 (Kakamega) is an introduction that was widely tested and popularized in Kenya in 2001 (Ndolo *et al*., 2001). Four sites described by Mwanga *et al*. (2003) where data for determining genotype-by-environment (GxE) interactions were generated are: NAARI with tall grassland and high sweetpotato virus disease (SPVD) pressure, Kachwekano Agricultural Research and Development Center (ARDC) with high altitude and high Alternaria blight pressure and poor soils, Serere Agricultural and Animal Production Research Institute (SAARI) with short grassland and high sweetpotato weevil population, and Ngetta with a similar environment to SAARI. The two cultivars were evaluated in the routine breeding trials on-station and on-farm.

Each clone was planted in 4 rows, 1 m apart, 6 m long, 0.3 m between plants in a randomized complete block with 4 replications. Standard data on sweetpotato virus disease (SPVD) and Alternaria blight were scored at 2.5 and at harvest on stand count, vine weight, weevil damage and root characteristics, including taste and acceptability. The middle rows of each plot were harvested for data analysis. Sweetpotato weevil damage was scored at harvest. The disease and weevil damage, storage root sprouting, cracking and rotting ratings were based on a 1-5 scale, where 1 = no apparent damage/not present, 2 = very little damage/few present, 3 = moderate damage/numbers present, 4 = considerable damage/numbers present and 5 = severe damage/ very high numbers present. The trials were harvested 4-6 months after planting depending on altitude. Dry matter content (DMC) of storage roots was expressed as the average percentage of dry weight of fresh weight. DMC was determined after weighing two replications of 500 g samples of sliced roots and oven- drying to a constant weight at 65^0C. Taste characteristics were evaluated on a scale of 1-5 as follows: a) Wateriness, 1 = very dry, 2 = dry, 3 = moderately dry, 4 = watery, 5 = very watery; b) Firmness, 1 = Very soft, 2 = soft, 3 = moderately firm, 4 = firm, 5 = very firm (hard); c) Sweetness, 1 = not sweet, 2 = slightly sweet, 3 = moderately sweet, 4 = sweet, 5 = very sweet; d) Mealiness, 1 = not mealy, 2 = slightly mealy, 3 = moderately mealy, 4 = mealy, 5 = very mealy; e) Fibrousness, 1 = not fibrous, 2 = slightly fibrous, 3 = moderately fibrous, 4 = fibrous, 5 = very fibrous; e) General evaluation, 1 = very bad, 2 = bad, 3 = moderate, 4 = good, and 5 = very good.

Parameter estimates (analysis of variance (ANOVA) for sweetpotato trait means was done using the General Linear Model (GLM) of the Statistical Analysis System (SAS Institute, Inc., Cary, NC, 1990). The data in this paper was presented to the Variety Release Committee for official release in Uganda. Data for 14 promising sweetpotato clones common across the test sites were processed for GxE interactions using the additive main effect and multiplicative interaction (AMMI) model (Gauch, 1992), regression analysis (Eberhart and Russeel, 1996), and Tai stability test (Tai, 1971). Parameter estimates were obtained using procedures of GLM (SAS Institute Inc., 1990) and IML (SAS Institute Inc., 1990).

RESULTS AND DISCUSSION

Highlights of the important steps of the results of the breeding and evaluation and the implications of the sustained programme are presented and discussed here. Over 100,000 sweetpotato clones were discarded from the different trials, seedling evaluation, clonal, preliminary, intermediate, advanced/uniform and on-farm trials between 1998 and 2003 (data not shown). Introduced clones, breeding lines and landrace varieties were discarded or selected based on mainly orange flesh colour (beta-carotene), high dry matter content (>30%), reaction of the clones to SPVD and Alternaria stem blight across the four sites (Tables 1-5).

The 19 OFSP clones (introductions from CIP) were easily infected by sweetpotato feathery mottle virus (SPFMV) and sweetpotato chlorotic

TABLE 1. Performance of orange-fleshed sweetpotato clones at NaCRRI, August-December 2002

CIP code	Clone name	Total root yield (t ha^{-1})	DMC[a] (%)	DM[b] yield (t ha^{-1})	Mkt rt yield[c] (t ha^{-1})	Vine yield kg plant^{-1}	SPVD[d]	Alternaria	Weevil	Cracking	Sprouting
NA[e]	Kala	47.0	30.8	14.5	42.1	3.7	2.8	1.0	1.0	2.5	1.3
440293	BP-SP-2	46.6	23.0	10.7	41.1	1.5	2.8	1.0	1.3	2.5	1.0
440090	CN 317	46.6	22.8	10.6	40.0	2.1	3.0	1.0	1.0	1.0	1.0
NA	Dimbuka	45.8	31.4	14.4	31.5	1.5	3.0	1.0	1.5	2.3	1.0
440189	Tainung No. 64	45.7	22.7	10.4	39.5	2.1	3.5	1.3	1.8	1.5	1.0
NA	Ejumula	42.8	35.3	15.1	34.6	3.2	3.0	1.0	1.5	1.0	1.0
187017.1	Salyboro	41.7	27.6	11.5	38.8	1.7	2.5	1.0	1.5	1.0	1.0
440018	W-223	40.5	31.1	12.6	30.5	2.3	3.5	1.5	1.0	1.3	1.0
NA	Mahuri	40.5	33.7	13.6	33.0	4.4	2.3	1.0	1.3	4.0	1.0
440060	TIB 4	39.5	28.3	11.2	33.7	0.8	2.3	1.0	1.0	1.3	1.0
440016	Excel	36.3	27.6	10.0	30.7	3.4	3.5	1.0	1.0	2.8	1.5
NA	SPK 004	35.5	34.4	12.2	31.0	3.3	2.0	1.0	1.0	1.5	1.3
420027	Zapallo	29.9	19.4	5.8	23.3	1.5	3.3	1.3	1.3	2.3	1.0
420005	Nemanete	26.4	28.1	7.4	17.3	1.9	3.3	1.0	1.5	1.0	1.0
440112	Centenial	26.2	33.6	8.8	20.0	1.8	3.8	1.0	1.0	1.3	1.0
440140	Kandee	25.0	33.8	8.5	10.0	0.9	3.0	1.0	1.3	1.0	1.5
440031	Jewel	23.6	25.6	6.0	16.0	1.4	3.8	1.0	1.0	1.8	1.0
NA	TZ	23.5	32.4	7.6	19.9	6.1	2.0	1.0	1.0	1.4	1.0
440005	W-151	21.0	25.8	5.4	19.0	1.1	3.5	1.3	1.0	1.5	1.0
NA	Sudan	20.3	30.0	6.1	17.8	3.4	3.0	1.0	1.0	3.5	1.0
420009	Japon Tresmesino	19.5	18.5	3.6	17.4	2.1	3.3	1.0	1.8	2.8	1.0
440215	Tainung No. 65	19.0	26.1	5.0	16.5	0.5	4.3	1.0	1.0	1.0	1.5
420014	Jonathan	19.0	19.4	3.7	10.1	1.2	3.5	2.0	1.0	1.8	1.0
440288	VSP 4	15.0	25.0	3.8	9.0	0.1	5.0	1.0	1.0	1.0	1.0
NA	Sowola-6	13.4	34.0	4.6	10.8	4.1	2.5	1.0	1.3	1.4	1.0
440141	Julian	5.8	32.2	1.9	5.0	0.3l	4.0	1.0	1.3	1.0	1.0
556638	Jewel	5.7	25.6	1.5	2.9	0.3l	5.0	1.0	1.3	1.3	2.0
Mean		29.7	NA	NA	23.8	2.1	3.2	1.1	1.2	1.7	1.1
$LCD_{0.05}$		5.3	NA	NA	3.9	0.7	0.8	0.4	0.5	0.9	0.4
CV (%)		12.8	NA	NA	11.8	25.1	18.9	27.1	33.5	38.7	24.8

[a]DMC = dry matter content, [b]DM = dry matter, [c]Mkt rt yield = marketable storage root yield, [d]SPVD (sweetpotato virus disease), Alternaria blight, Weevil (sweetpotato weevil), Crack (cracking), Sprout (sprouting) 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, [e]NA = not applicable

TABLE 2. Performance of orange-fleshed sweetpotato clones at Kachwekano, August – January 2002

CIP code	Clone	Total root yield (t ha^{-1})	DM[a] (%)	DM (t ha^{-1})	DM yield (t ha^{-1})	Mkt rt[b] yield (t ha^{-1})	Vine yield (t ha^{-1})	SPVD[c]	Alternaria	Weevil	Crack	Sprout
420027	Zapallo	47.5	20.2	9.6	9.6	45.5	1.2	1.0	1.0	1.3	1.5	1.0
440293	BP-SP-2	44.5	18.5	8.2	8.2	38.8	0.7	1.0	1.5	1.0	1.0	1.0
440189	Tainung No. 64	42.5	20.1	8.5	8.5	40.0	1.0	1.0	1.0	1.0	1.0	1.0
187017.1	Salyboro	41.9	26.3	11.0	11.0	37.3	1.4	1.0	1.3	1.0	1.0	1.0
440215	Tainung No. 65	33.5	22.8	7.6	7.6	29.2	0.5	1.0	1.5	1.0	1.0	1.0
556638	Jewel	32.5	20.4	6.6	6.6	22.5	0.4	1.0	1.3	1.0	1.0	1.8
NA	Mahuri	32.0	27.3	8.7	8.7	27.1	2.8	1.0	1.8	1.0	1.0	1.0
NA	Ejumula	29.4	33.9	10.0	10.0	25.0	1.1	1.0	1.3	1.0	1.0	1.0
440018	W-223	29.0	29	8.4	8.4	25.5	1.2	1.0	1.0	1.0	1.0	1.0
440090	CN 317	29.0	22.5	6.5	6.5	19.5	0.8	1.0	1.5	1.0	1.0	1.0
420005	Nemanete	27.8	23.0	6.4	6.4	22.1	1.8	1.3	1.3	1.0	1.0	1.0
NA	TZ	26.7	30.2	8.1	8.1	19.7	3.5	1.0	1.5	1.0	1.0	1.3
NA	SPK 004	24.9	31.7	7.9	7.9	19.3	1.3	1.0	1.3	1.0	1.0	1.3
440288	VSP 4	23.7	16.4	3.9	3.9	19.6	0.4	1.0	1.5	1.0	1.0	3.0
440031	Jewel	23.5	22.0	5.2	5.2	18.0	1.1	1.0	1.0	1.0	1.5	1.0
NA	Kala	22.5	30.7	6.9	6.9	17.5	1.6	1.0	1.5	1.0	1.0	1.0
NA	Sowola-6	22.3	35.0	7.8	7.8	10.2	1.4	1.0	2.0	1.0	1.0	2.0
440016	Excel	21.5	22.0	4.7	4.7	21.4	0.7	1.0	2.8	1.0	1.0	1.5
NA	Sudan	21.5	28.7	6.2	6.2	17.5	1.8	1.0	1.3	1.0	1.0	1.0
420009	Japon Tresmesino	21.4	20.0	4.3	4.3	18.7	2.5	1.0	1.0	1.0	1.8	1.8
440140	Kandee	18.9	23.9	4.5	4.5	14.4	0.6	1.3	1.0	1.0	2.0	1.8
420014	Jonathan	17.6	19.0	3.3	3.3	10.5	0.7	1.0	1.5	1.3	1.0	1.0
440005	W-151	16.8	28.3	4.8	4.8	11.5	0.5	1.0	1.5	1.0	1.0	2.0
440112	Centenial	14.5	26.6	3.9	3.9	9.1	0.6	1.3	1.3	1.0	1.0	1.8
440141	Julian	9.6	19.0	1.8	1.8	4.0	0.3	1.0	1.1	1.0	1.0	1.5
440060	TIB 4	9.0	29.6	2.7	2.7	6.7	0.2	1.0	1.0	1.0	1.0	1.5
Mean		26.1	24.9	NA	NA	21.2	1.2	1.03	1.4	1.0	1.1	1.3
LCD0.05		5.5	NA	NA	NA	5.8	0.3	0.23	0.7	NA	0.6	0.9
CV (%)		15.0	NA	NA	NA	19.5	18.6	15.8	37.9	NA	37.1	49.1

[a]DM = dry matter content,
[b]Mkt = Marketable
[c]SPVD (sweetpotato virus disease), Alternaria blight, Weevil (sweetpotato weevil), Crack (cracking), Sprout
[d]NA = Not applicable

(sprouting) 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 present
5 = severe damage/very high numbers present

stunt virus (SPCSV) resulting in SPVD (Table 3). These results indicate that it would be necessary to have a source of clean planting material if any of the 19 clones were to be grown, especially in the Lake Victoria Crescent where SPVD pressure is high. Clones, Jewel 440031 and Jewel 566638, VSP 4, Excel, TIB 4, W151, W-223, CN 317 and Japon Tresmesino had very low multiplication rates in vitro and in the field (data not shown). The low multiplication rate coupled with drought spells and/or prevalence of SPVD would lead to shortage of planting materials of those clones in the farming system. Clone Zapallo, BP-SP-2, Tainung 64, Salyboro, Tainung 65, and Jewel 556638 gave the highest fresh root yields (32.5 – 47.5 tha^{-1}) at Kachwekano (Table 2). However, these clones had lower dry matter content (<30.0%) than the local cultivars (Mahuri, Ejumula, Sudan, TZ, Kala). Across sites, the following clones gave the highest fresh storage root yields: BP-SP-2, Tainung 64, Ejumula, Kala, Mahuri, Salyboro, W-223, and SPK004. The common local check, TZ, yielded low across all sites (Table 6). The storage root of Kala has

TABLE 3. Performance of orange-fleshed sweetpotato clones across 4 environments in Uganda, August - December 2002

	CIP code	Clone	Site				Mean across sites	SPVD[a] across sites	SPVD (preliminary test:2 sites at NaCRRI)
			NaCRRI	Kachwe kano	Ngetta	SAARI			
			Storage root yield (t ha^{-1})						
1	440189	Tainung No. 64	45.7	42.5	33.3	32	38.4	2.6	3.9
2	420009	Japon Tresmesino	19.5	21.4	11.4	14.1	16.6	2.3	3.8
3	440016	Excel	36.3	21.5	22.0	10.4	22.5	2.4	3.8
4	440060	TIB 4	39.5	9.0	8.4	13.4	17.6	2.3	3.9
5	420027	Zapallo	29.9	47.5	20.9	22.4	30.2	2.5	3.6
6	187017.1	Salyboro	41.7	41.9	15.9	32.4	33.0	2.1	3.8
7	440140	Kandee	25.0	18.9	11.5	24.4	20.0	2.7	4.0
8	440005	W-151	21.0	16.8	18.5	18.5	18.7	2.4	4.5
9	440215	Tainung No. 65	19.0	33.5	10.1	47.0	27.4	2.9	3.6
10	420005	Nemanete	26.4	27.8	15.0	18.2	21.8	2.4	3.3
11	440112	Centenial	26.2	14.5	16.6	9.7	16.8	2.8	3.9
12	556638	Jewel	5.7	32.5	10.6	3.5	13.1	2.7	4.0
13	440288	VSP 4	15.0	23.7	11.1	28.5	19.6	2.9	4.0
14	420014	Jonathan	19.0	17.6	14.0	19.7	17.6	2.4	3.6
15	440031	Jewel	23.6	23.5	28.2	12.6	22.0	2.6	3.5
16	440141	Julian	5.8	9.6	12.9	6.7	8.7	2.8	4.3
17	440293	BP-SP-2	46.6	44.5	52.3	32.3	43.9	2.1	2.6
18	440018	W-223	40.5	29.0	29.9	30.0	32.4	2.8	4.0
19	440090	CN 317	46.6	29.0	16.7	14.4	26.7	2.8	4.0
20	NA[2]	Sudan	20.3	21.5	30.4	15.5	21.9	1.8	NA
21	NA	Ejumula	42.8	29.4	49.6	24.0	36.4	2.0	NA
22	NA	Kala	47.0	22.5	43.8	25.4	34.7	2.0	NA
23	NA	SPK 004	35.5	24.9	47.0	16.7	31.0	1.9	NA
24	NA	Mahuri	40.5	32.0	40.2	24.3	34.2	2.1	NA
25	NA	TZ (check 1)	23.5	26.7	44.0	9.5	25.9	1.8	NA
26	NA	Sowola-6	13.4	22.3	22.6	3.3	15.4	2.0	NA
27	NA	Local check 2	45.8	NA[b]	24.7	NA	NA	NA	NA
Mean			29.7	26.3	24.5	19.6	24.9	2.4	0.6
$LCD_{0.05}$			5.3	5.5	4.4	6	2.7	0.1	0.2
CV (%)			12.8	14.9	12.7	21.9	15.3	20.4	16.2

[a]SPVD = sweetpotato virus disease rating scale = 1-5:
1 = no apparent damage/not present; 4 = considerable damage/numbers present
2 = very little damage/few present; 5 = severe damage/very high numbers present
3 = moderate damage/numbers present; [b]NA = Not applicable

yellow flesh with orange spots. Due to non-uniformity of flesh colour of the root, Kala would not make a good parent in the polycross nursery. The storage roots of Mahuri cracked as the roots matured leading to reduced market value and easy attack by pathogens.

Overall acceptance of the two cultivars, Ejumula and SPK004 was high on-station and on-farm. The participants in all taste tests were farmers. Acceptability of these two OFSP by children was significantly higher than for adults in all sites (Fig. 1, only one site is shown).

TABLE 4. General taste characteristics of 27 sweetpotato clones1 (N = 48, farmers in 4 groups (n = 12); groups were treated as reps

CIP code	Clone	Skin[a] colour	Flesh colour	Wateri ness	Firm ness	Sweet ness	Meali ness	Fibrous ness	General evaluation	Comments
440189	Tainung No. 64	C	O	3.7	1.7	3.7	1.0	1.3	2.3	Slight flavour
420009	Japon Tresmesino	LP	LO	4.0	1.5	4.5	1.0	1.0	3.0	No flavour
440016	Excel	LO	O	2.0	2.0	4.0	1.0	2.0	2.7	No flavour
440060	TIB 4	O	O	2.0	4.0	4.0	3.0	1.0	3.0	No flavour
420027	Zapallo	LP	O	3.5	2.0	4.0	1.0	1.0	3.0	No flavour
187017	Salyboro	C	O	2.0	4.0	4.0	3.0	1.0	3.0	No flavour
440140	Kandee	LO	DO	3.0	3.0	4.0	2.5	1.0	3.5	No flavour
440005	W-151	LP	O	4.5	1.5	4.5	1.5	1.5	1.5	No flavour
440215	Tainung No. 65	C	DO	4.3	1.3	3.3	1.0	4.0	1.3	Strong flavour
420005	Nemanete	R	O	2.5	3.5	4.0	1.0	1.0	4.0	No flavour
440112	Centenial	LB	O	2.5	2.0	3.5	1.0	2.5	2.5	Strong flavour
556638	Jewel	O	DO	3.3	2.0	3.5	1.0	3.3	2.0	Slight flavour
440288	VSP 4	R	DO	2.5	2.0	3.0	1.0	1.5	2.0	Slight flavour
420014	Jonathan	C	LO	3.3	1.7	4.0	1.0	1.3	2.7	Slight flavour
440031	Jewel	DO	O	3.0	1.5	4.0	1.0	1.0	2.5	Slight flavour
440141	Julian	O	DO	3.3	2.0	3.3	1.3	1.3	2.3	No flavour
440293	BP-SP-2	C	C	2.3	2.7	3.3	2.0	1.3	3.3	No flavour
440018	W-223	C	C	2.0	3.8	3.8	3.3	1.0	3.8	No flavour
440090	CN 317	O	DO	3.3	2.0	3.3	1.3	1.3	2.3	No flavour
NA2	Sudan	C	LO	2.0	3.7	4.0	2.3	1.0	4.0	No flavour
NA	Ejumula	C	LO	2.0	4.0	4.0	1.0	1.0	4.0	Slight flavour
NA	Kala	C	Y/O	2.0	3.3	3.3	1.7	1.3	3.7	No flavour
NA	SPK 004	LR	LO/Y	2.0	4.0	3.8	4.0	1.0	4.0	No flavour
NA	Mahuri	C	LO	2.0	3.3	3.3	1.7	1.3	3.7	Slight flavour
NA	TZ (local check 1)	C	LY	2.0	4.1	4.0	4.1	1.1	4.4	No flavour
NA	Sowola-6	C	LO	2.0	3.7	3.3	2.7	1.0	4.0	No flavour
NA	Otada (local check)	P	C	2.0	4.1	4.0	4.1	1.1	4.4	No flavour
Mean									3.1	
LCD0.05									0.8	
CV (%)									17.6	

aColour: B = brown; C = cream; D = dark, L = light, O = orange, P = purple

Acceptability of SPK004 in West Nile in villages around Abi, and in 20 counties in the Districts of Apac, Gulu and Lira and in refuge settlement camps in northern Uganda was high where OFSP had been planted and consumed. The local popular landraces had yellow- or white-fleshed roots and had very little or negligible amounts of β-carotene; hence, the release of the two OFSP cultivars in 2004 for wide dissemination in the country was a significant step in combating VAD.

Regression analysis and Tai's statistics were similar in not identifying any clone with stable total root yield performance (Table 7, and Fig. 2-4). However, according to Langer et al. (1979) and Bilbro and Ray (1976), the regression coefficient concept is used as a measure for response to variations of the environment and deviation from regression (S^2_d) as a stability measure. Clones BP-SP-2 (code 1), Tainung 64 (3), Salyboro (7), and Tainung 65 (11) show the lowest values of S^2_d and Tai's statistic ë locates those clone in the region (clustered) with stability above the average (Fig. 4). Although none of the tested clones were located in the average stability region (α=0 and λ=1), Ejumula (4) yielded (30.4 tha^{-1}) above the average root yield (27.6 tha^{-1}) while

TABLE 5. Performance of orange-fleshed sweetpotato (OFSP) clones at NaCRRI, 8 May – 3 October, 2003

CIP code	Clone name	Total root yield ($t\ ha^{-1}$)	DMC[a] (%)	DM[b] yield ($t\ ha^{-1}$)	Mkt rt yield[c] $t\ ha^{-1}$)	Vine yield (kg $plant^{-1}$)	Biomass yield ($t\ ha^{-1}$)	SPVD[d]	Alternalia	Weevil	Cracking	Sprouting
440031	Jewel	45.8	24.2	11.1	29.6	59.9	105.7	2.8	2.8	1.3	1.0	1.8
NA	Ejumula	31.7	34.0	10.8	22.3	99.6	131.3	3.3	1.0	2.0	1.0	1.3
NA	Dimbuka	30.5	30.8	9.4	26.2	33.8	64.3	2.8	1.3	1.8	1.3	1.0
NA	Sudan	28.2	30.0	8.5	21.4	60.8	89.0	3.5	1.3	1.5	2.0	1.5
NA	TZ	26.8	33.0	8.8	22.1	54.0	80.8	2.8	1.0	1.3	1.0	1.0
440215	Tainung 65	25.4	27.4	7.0	23.3	21.6	47.0	3.3	1.3	2.0	1.3	1.3
440293	BP-SP-2	24.8	26.7	6.6	23.4	22.5	47.2	2.8	1.0	1.5	1.3	1.0
NA[5]	Kala	23.1	32.0	7.4	20.3	69.6	92.7	3.3	1.5	1.5	1.0	1.5
440189	Tainung 64	21.9	26.4	5.8	11.6	25.0	46.9	3.8	1.3	1.3	1.0	1.0
187017	Salyboro	21.2	29.7	6.3	9.8	52.7	73.9	3.5	1.0	1.3	1.8	1.5
NA	SPK 004	19.8	34.0	6.7	17.0	49.0	68.8	2.3	1.0	1.5	1.0	2.0
440018	W-223	18.7	31.0	5.8	4.0	48.9	67.6	4.3	1.0	1.3	1.0	1.8
NA	Mahuri	17.4	33.9	6.0	14.5	58.3	75.7	3.5	1.8	1.3	2.5	1.0
440288	VSP 4	16.2	24.1	3.9	12.7	24.7	40.9	3.5	1.0	1.3	1.0	3.5
NA	Sowola-6	14.5	35.0	5.1	5.0	102.7	117.2	3.3	1.3	1.0	1.0	1.0
440005	W-151	12.8	26.7	3.4	8.7	14.9	27.7	3.5	1.3	1.5	1.0	2.3
440060	TIB 4	11.8	29.3	3.5	7.2	10.5	22.3	3.0	1.0	1.3	1.0	1.3
440090	CN 317	11.6	25.8	3.0	2.3	22.7	34.3	3.8	1.0	1.0	1.3	1.5
440016	Excel	10.3	28.1	2.9	7.0	9.4	19.7	4.5	3.8	1.8	1.0	1.0
440141	Julian	10.0	32.3	3.2	0.1	5.3	15.3	3.3	2.5	1.0	1.0	1.3
556638	Jewel	9.1	22.2	2.0	2.2	5.4	14.5	3.3	1.0	1.0	1.0	2.8
440140	Kandee	9.0	33.2	3.0	2.9	10.2	19.2	4.0	2.0	1.3	1.0	3.0
420014	Jonathan	8.5	22.0	1.9	0.5	29.4	37.8	4.0	1.8	1.3	1.3	1.5
440112	Centenial	8.2	31.1	2.6	2.1	21.7	29.9	4.0	1.3	1.8	1.0	1.8
420027	Zapallo	7.9	21.5	1.7	6.5	14.6	22.5	3.8	1.5	1.5	2.5	1.3
420009	Japon Tres	7.7	19.5	1.5	6.2	14.8	22.5	3.5	1.3	1.0	1.8	1.3
420005	Nemanete	3.5	27.5	1.0	0.1	18.5	22.0	3.0	1.0	1.3	1.0	1.3
NA	NKA	3.0	34.7	1.0	0.8	137.0	140.0	2.3	1.8	1.0	1.0	1.0
Mean		17.1	NA	NA	11.1	39.2	56.3	3.4	1.4	1.4	1.2	1.5
LCD (0.05)		4.2	NA	NA	2.7	14.3	16.3	0.7	0.9	0.7	0.8	0.9
CV (%)		17.8	NA	NA	17.7	26.1	20.6	15.6	49.1	40.1	47.5	42.5

[a]DMC = dry matter content,[b]DM = dry matter, NA = not applicable, [c]Mkt rt yield = marketable storage root yield, [d]SPVD (sweetpotato virus disease, 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
SPVD, Aternaria, weevil, cracking, and sprouting rating scale, 1 – 5

TABLE 6. Performance of orange-fleshed sweetpotato clones across 4 environments in Uganda, May – November 2003.

Serial No.	CIP code	Clone	Site				Mean across sites	SPVD[a] across sites
			NaCRRI	Kachwe	Ngetta	SAARI		
			Storage root yield (t ha^{-1})					
1	440189	Tainung No. 64	21.9	20.4	30.5	17.7	22.6	2.5
2	420009	Japon Tresmesino	7.7	28.2	11.6	18.3	16.5	2.0
3	440016	Excel	10.3	42.3	26.0	11.9	22.6	2.1
4	440060	TIB 4	11.8	11.6	10.4	9	10.7	2.1
5	420027	Zapallo	7.9	25.4	15.5	19.3	17.0	2.1
6	187017.1	Salyboro	21.2	33.1	16.1	24.5	23.7	2.1
7	440140	Kandee	9.0	27.7	18.0	13.8	17.1	2.1
8	440005	W-151	12.8	18.5	20.8	13.7	16.5	2.0
9	440215	Tainung No. 65	25.4	16.6	23.5	16.6	20.5	1.9
10	420005	Nemanete	3.5	19.3	10.0	11.4	11.1	1.8
11	440112	Centenial	8.2	14.8	22.0	18.9	16.0	2.4
12	556638	Jewel	9.1	17.2	17.0	9.6	13.2	2.2
13	440288	VSP 4	16.2	26.6	30.0	16.6	22.4	2.0
14	420014	Jonathan	8.5	24.0	25.7	18	19.1	2.2
15	440031	Jewel	45.8	30.3	46.0	22.7	36.2	1.9
16	440141	Julian	10.0	14.1	52.0	5.4	20.4	2.3
17	440293	BP-SP-2	24.8	18.3	35.0	38.1	29.1	1.9
18	440018	W-223	18.7	17.9	31.7	19.1	21.9	1.9
19	440090	CN 317	11.6	27.1	14.2	13.6	16.6	2.3
20	NA[2]	Sudan	28.2	24.3	21.8	22.2	24.1	2.3
21	NA	Ejumula	31.7	27.1	22.0	17.2	24.5	2.3
22	NA	Kala	23.1	22.5	26.0	41.5	28.3	2.3
23	NA	SPK 004	19.8	22.5	29.6	15.3	21.8	1.6
24	NA	Mahuri	17.4	33.8	14.8	26.2	23.1	2.1
25	NA	TZ (check 1)	26.8	22.4	26.4	14.4	22.5	1.9
26	NA	Sowola-6	14.5	20.2	21.9	14	17.7	2.3
27	NA	Local check 2	30.5	32.3	35.0	52.3	NA	NA
28	NA	Local check 3	3.0	NA	22.9	18.9	NA	NA
Mean			17.1	23.6	24.2	19.2	20.6	2.1
$LCD_{0.05}$			4.2	7.1	6.0	5.7	2.9	0.4
CV (%)			17.8	21.4	17.8	21.1	21.0	28.9

[a]SPVD = sweetpotato virus disease rating scale (1-5):
1 = no apparent damage, 2 = very little damage, 3 = moderate damage, 4 = considerable damage/numbers present; 5 = severe damage/very high numbers present, NA = not applicable

SPK004 (9) was in the region of the average root yield (26.4 tha^{-1}). Clones Kala (code 2), Tanzania (10), Zapallo (12), Ejumula (4), and SPK004 (9) appeared far away to the right of the graph, indicating strong influence in the significance of GxE interaction.

In general, none of the high yielding clones showed an acceptable level of stability, confirming similar previous observations (Manrique and Herman, 2002; Ngeve, 1993; Tai, 1971). The GxE component of the AMMI model is based on the product of PCA scores. The AMMI biplot involving the first two significant axes (PC1 and PC2) for total root yield show the genotypes and the four locations dispersed around the center of the biplot indicating that

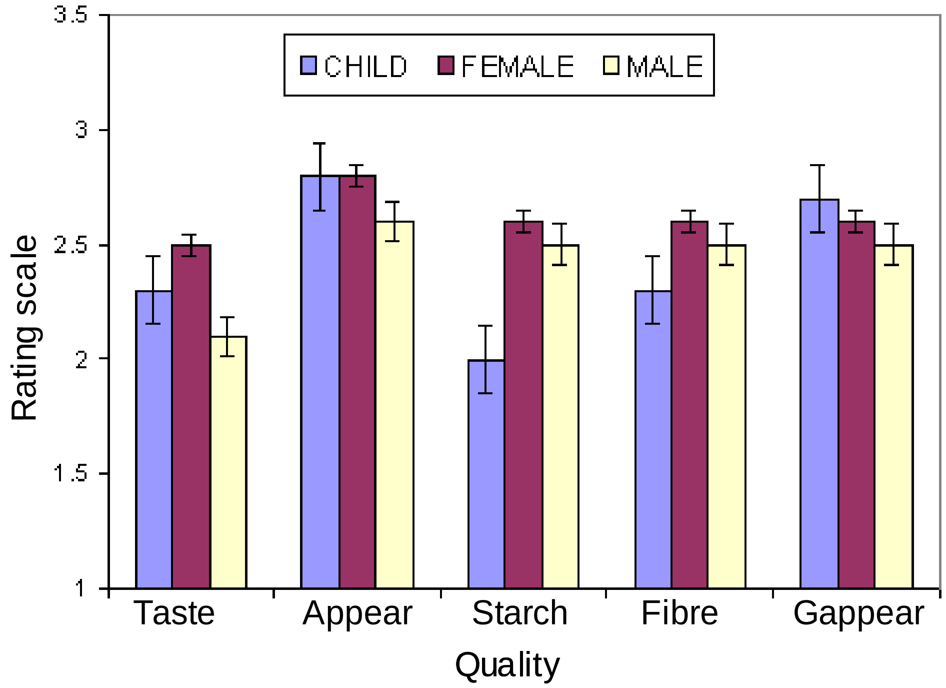

Figure 1. Post harvest qualitative evaluation of orange-fleshed sweetpotato storage roots by sex and age in Kalule zone, Luwero, 2001A (children n = 20, female n = 25, male n = 15). Rating scale: 1= very bad; 2 = bad; 3 = moderate; 4 = good; 5 = very good; appear = appearance; gappear = general appearance.

TABLE 7. Means and estimates of four stability parameters of regression analysis (Eberhart and Russell, 1996) and Tai stability test (Tai, 1971) for storage root yield of 14 sweetpotato clones

Cultivar/clone name	Mean root yield (t ha^{-1})	Regression analysis		Tai test				
		b	S^2_d (δ)	α	Sign.	λ	Sign.	Prob.
BP-SP-2	36.5	0.06	0.24	-0.95	*	0.58	ns	0.56
Kala	31.5	0.78	280.76	-0.22	ns	72.86	*	0.00
Tainung 64	30.5	-0.05	2.58	-1.06	*	0.67	ns	0.51
Ejumula	30.4	1.01	446.86	0.02	ns	116.00	*	0.00
Jewel 440031	29.1	0.04	0.24	-0.97	*	0.06	*	0.94
Mahuri	28.6	0.40	20.61	-0.61	ns	5.35	*	0.01
Salyboro	28.3	0.05	2.11	-0.95	*	0.55	ns	0.58
W-223	27.1	0.53	50.30	-0.47	ns	13.05	*	0.00
SPK 004	26.4	1.24	465.55	0.25	ns	120.80	*	0.00
TZ	24.2	1.10	355.30	0.10	ns	92.20	*	0.00
Tainung 65	24.0	-0.25	13.20	-1.26	ns	3.43	ns	0.04
Zapallo	23.6	-1.02	356.26	-2.04	ns	92.43	*	0.00
Sudan	23.0	0.35	18.18	-0.66	ns	4.72	*	0.01
Excel	22.6	0.39	69.23	-0.61	ns	17.96	*	0.00

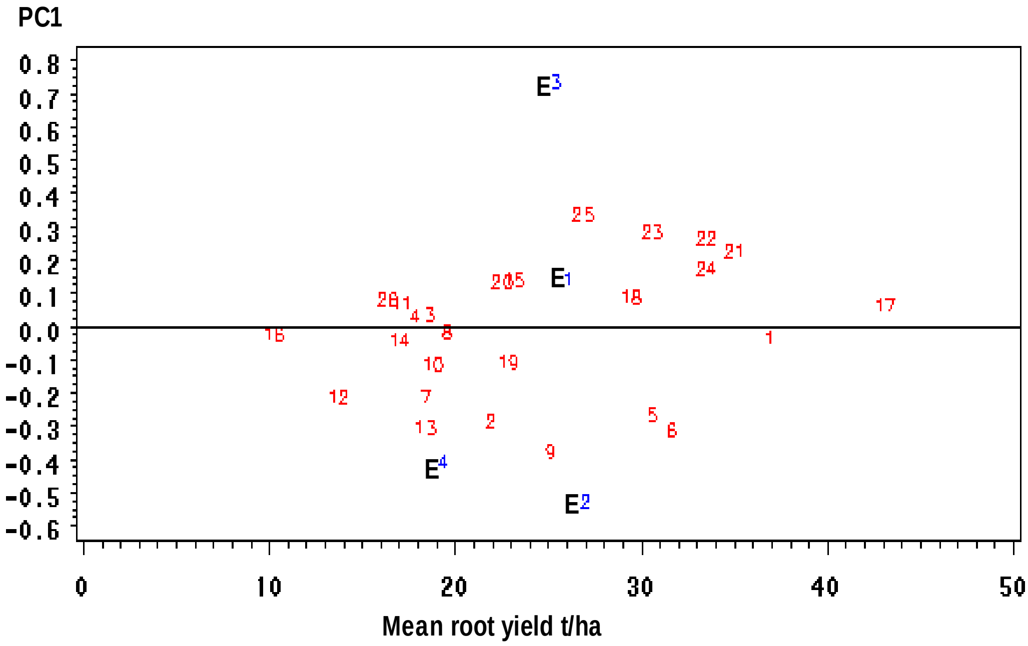

Figure 2. Biplot of principal components analysis (PCA) axis 1 vs mean root yield (t/ha) for 26 sweetpotato clones grown in two seasons, 2002a and 2003b in four sites [environments (E)]: E1 = NaCRRI, E2 = Kachwekano ARDC, E3 = Ngetta ARDC, E4 = Serere.

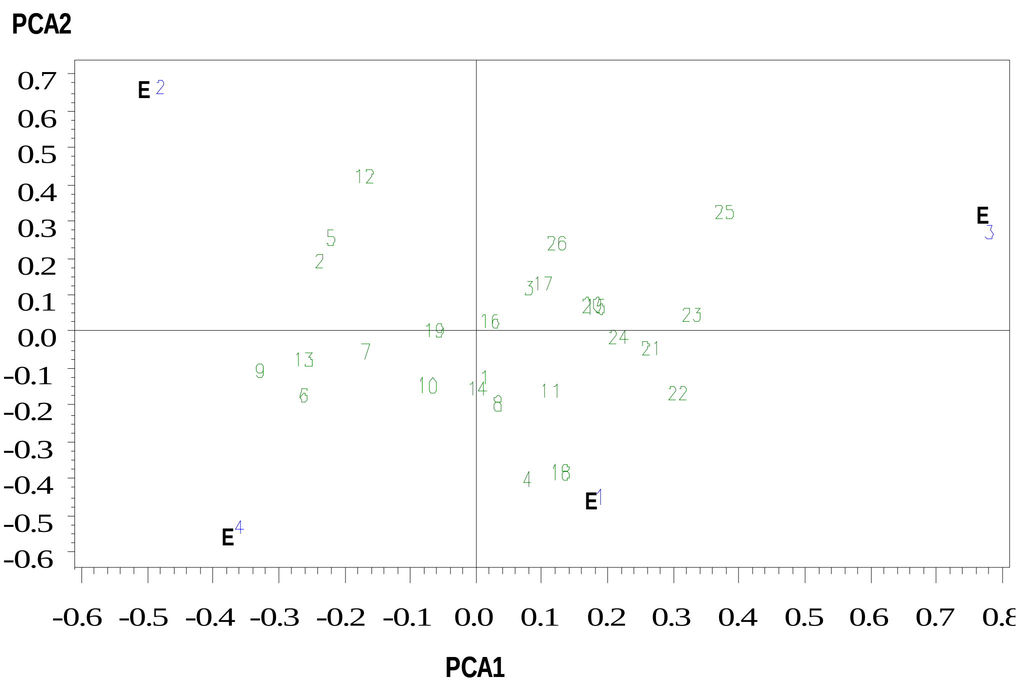

Figure 3. Biplot of G x E interaction showing biplot of principal components analysis (PCA) axis 2 vs axis 1 for mean root yield (t/ha) for 26 sweetpotato clones grown in two seasons, 2002a and 2003b in four sites [environments (E)]: E1 = NaCRRI, E2 = Kachwekano ARDC, E3 = Ngetta ARDC, E4 = Serere.

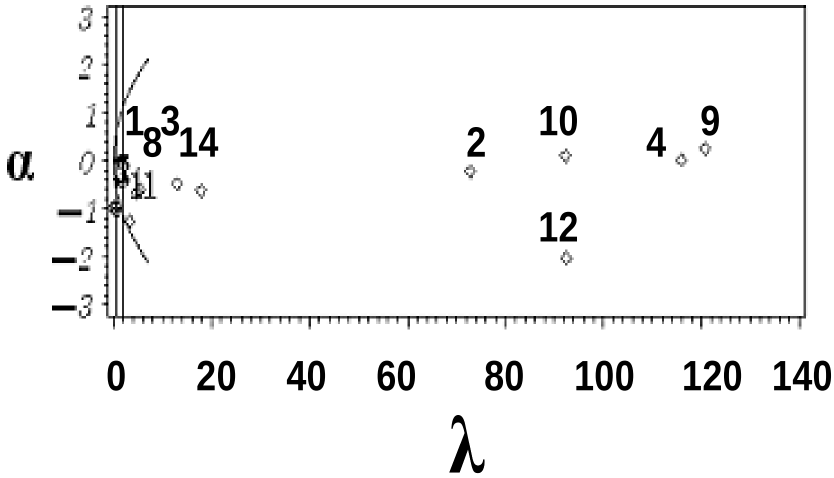

Figure 4. Tai stability plot (alpha = 0.05). Tai's average stability region is defined by the intersection area of the hyperbola representing a 95% prediction interval for $\alpha = 0$; and the vertical lines that limit a 95% confidence interval for $\lambda = 1$. 1 to 14 = sweetpotato clones.

existence of a large amount of variability in genotypes and environments (biplots not shown). However, when plotting PCA1 axis vs. root yield mean (Fig. 2), clusters are identified.

In stability analysis, sites, seasons, clones, site x clone, clone x season, and site x clone x season interactions were highly significant on-station (Tables 2, 3 and 6). No single clone was superior in all desirable traits across the four on-station test sites (Tables 7). Ejumula and Kakamega were not ideal varieties in terms of yield stability although Ejumula was slightly more stable than Kakamega (Figs. 2-4, and Tables 7). According to Tai stability parameters, both cultivars are best described as stable but with low reliability unlike clones such as Tainung 65 that shows high reliability (but has low dry matter and is highly susceptible to SPVD). The specific examples of trials referred to in this paper were conducted over a period of seven years.

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