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EVALUATION OF PROMISING SWEET POTATO CLONES IN SELECTED AGRO ECOLOGICAL ZONES OF UGANDA

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Abstract

The majority of farmers in Uganda have limited access to and awareness of improved varieties and largely depend on own varieties, which are mostly low yielding; about 4.5 tons ha^{-1} due to factors such as low yielding potential of local varieties, diseases and pests. The objectives of on-farm study were to assess the agronomic performance and acceptability of ten promising genotypes on-farm at five sites for four successive growing seasons during 2010 and 2011. Data were collected on sweetpotato virus and *Alternaria* disease infection, root yield and weevil infestation. Palatability assessment was conducted using the pair-wise ranking method. Data were analysed using regression and AMMI model in GenStat. Genotypes, environments, and genotype x environment interactions accounted for 33.85%, 54.05% and 3.36% respectively, of the total variation for root yield. High yielding environments were Wakiso and Kabale while low yielding environments were Buikwe, Kamuli and Luwero districts. Genotypes 23/60/19, 23/60/31, Sowola (OP)/2, 282/94/3 and 91/282-5 had above average root yield under the favourable environments while 23/60/90, Jewel (OP)/2005/6, Diallel 3, Zapallo/94/8 and the standard checks Dimbuka and New Kawogo had below average root yield and fell under the unfavourable environments. Genotypes 23/60/19 and 23/60/31 were better adapted at Wakiso and Kabale. Jewel (OP)/2005/6, Zapallo/94/8 and 23/60/ were the most stable but least productive, while 91/282-5 was the most stable of the clones with root yields above the grand mean. Sowola (OP)/2 was the most preferred while 23/60/19, the highest yielding, was among the least preferred genotypes based on taste attributes.

KeyWords: Genotypes, multi-environment, stability, yield, acceptability, sweetpotato**.**

INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L) Lam) is the third most produced staple food crop in Uganda, after bananas (*Musa spp.)* and cassava (*Manihot esculenta* Crantz.) (Bashaasha *et al*. 1995). It is a food security crop adaptable to varied agro ecological zones in the country (Odongo *et al*., 2002). Uganda, with an estimated annual output of about 2.65 million metric tons of sweetpotato from 540,000 hectares annually, accounts for about 3% of the total world production and is ranked third largest producer after China and Nigeria (FAOSTAT 2013). Per capita sweetpotato production is estimated at 76 kg annually.

Sweetpotato farmers grow a large number of landraces, many of them relatively low yielding, narrowly adapted and susceptible to diseases and pests (Bashaasha *et al*. 1995). The varieties are mostly white- and cream-fleshed, with negligible amounts of beta-carotene, the precursor of vitamin A contained in plants (Woolfe, 1992; Odongo *et al*. 2002). It was estimated that 66% of children under 6 had sub-clinical vitamin A deficiency (VAD) which contributed up to 25% of child mortality due to related diseases such as malaria, diarrhea associated diseases, acute respiratory infections and vaccine preventable diseases (MNI 2004).

Since 1995, the National Agricultural Research Organization (NARO) of Uganda has released 20

Table 1: Rainfall data from Namulonge Agromet station (25 km south of Luwero site)

								2010					
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	11.8	18.6	133.9	190.1	208.4	29.9	3.8	68.9	89.4	146.1	100.4	67.2	1208.5
Rain days	4	17	15	20	14	9	2	12	13	14	13	9	155
								2011					
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Rainfall (mm)	18.7	22	122.1	95.2	162.1	92.7	54.5	190.7	127.5	99.8	226	104.1	1315.4
Rain days	2	6	14	13	10	9	10	17	14	18	11	10	144

varieties including non-orange and orange fleshed varieties (Mwanga *et al*. 2011). The released varieties were selected on the basis of consistently superior yield performance and disease resistance in multi-location yield trials, and their excellent consumer acceptance in taste tests. The releases presented Ugandan farmers with a choice of superior cultivars for improving sweetpotato production and cultivar development programs (Mwanga *et al*. 2001).

The success of any newly introduced variety will depend not only on production characteristics, but also on its acceptability to consumers in terms of both sensory and utilisation characteristics (Tomlins *et al.* 2001). Consumer preferences appear to differ greatly between regions; for example, in East Africa only higher dry matter varieties are acceptable and good taste are important criteria (Kapinga *et al*. 1997a; 1997b). Other attributes include cooking quality (referring to the time needed for cooking) and the colour of the flesh and skin, low fibre content, good storability after purchase and root size (Tomlins *et al*. 2001). The criteria used by traders fit closely to those of the consumers, except that appearance is relatively more important, ranking equally with good taste. Sensory taste panels can be used to produce sensory profiles of varieties (Tomlins *et al*. 2001). Therefore, the objectives of the study were to evaluate promising genotypes for adaptability and acceptability in varied agro-ecological zones of Uganda.

MATERIALS AND METHODS

On-farm trials were planted in 5 selected districts of Buikwe, Luwero and Wakiso (central), Kamuli (eastern) and Kabale (western region). Ten promising sweetpotato genotypes, namely; 282/94/3, 23/60/31, 23/60/19, Sowola (OP)/2, Diallel 3, 23/60/92, 91/282-5, Jewel (OP)/2005/6, 23/60/90 and Zapallo/94/8 were evaluated against New Kawogo and Dimbuka as standard checks and farmer's variety as local check. A novel "mother and baby" trial design to systematically connect assessment of technologies by farmers with biological performance (Snapp 2002) was adopted. The Mother-Baby Trial (MBT) approach is an on-farm participatory mechanism to introduce and test a range of technology options suited to a heterogeneous community. The design consists of two types of trials; the "mother" trial which is replicated within-site to test a complete set of technologies, and the "baby" trial that comprises a number of satellite trials (each trial is one replicate) under farmer management and farm resources. Each "baby" trial compares one to four technologies (usually a subset of those tested in the mother trial chosen by the farmer or researcher). The MBT approach serves multiple functions: generating data on performance of alternative technologies; creating the basis for dialogue between farmers and researchers; and encouraging subsequent experimentation by farmers even in the absence of researchers (Snapp 2002). The approach is used to help characterize farmers' risk management strategies, target technology to specific groups, and to broaden the adoption of sustainable practices (Snapp 2002). The genotypes were tested in twelve "baby" trials (subsets of 3 new clones) and three "mother" trials at each site each season. New participating farmers were selected each season. Using 30 cm long vine cuttings, the trials were planted twice (April/May and September/October planting seasons) each year in 2010 and 2011 under rain-fed conditions. Readily available rainfall data for one location (Luwero) is presented in Table 1.

Gross plot size was 5 m wide x 6 m long (30 mounds) or 4 ridges x 7.5 m long (spaced 1 metre apart). Vine cuttings were planted in a single row at intervals of 30 cm along the ridge and 3 cuttings per mound (1 m^2) in a triangular pattern. The trials were researcher-designed but farmer-managed. Pre-harvest data on virus and *Alternaria* disease infections were collected at 45 days after planting (DAP) using the scale of 1 – 9 where 1 = no visible, 9 = severe symptoms. Harvesting took place at 4.5 - 5.5 MAP depending on altitude of the location. Net plot (harvest) area was 12 m^2, that is, 12 inner mounds or 2 central ridges each 6 m long. Data were recorded on number and weight of storage roots (marketable and unmarketable), vine weight, and weevil damage using the scale of 1-9, where 1 = no visible and 9 = severe damage.

Individual post-harvest taste panelists (Figure 1) assessed the palatability attributes, namely; appearance,

Figure 1: Taste panelists assessing sweetpotato genotypes at one of the on-farm trial sites

Table 2: Accumulated Analysis of Variance (Regression Analysis of Root Yield)

Change	d.f.	s.s.	m.s.	v.r.	F pr.
Clone	11	10.43149	0.94832	10.21	<.001
Location	4	11.20843	2.80211	30.18	<.001
Season	3	2.74742	0.91581	9.86	<.001
Residual	727	67.50306	0.09285		
Total	745	91.89039	0.12334		

taste, flavour, mealiness, fibers and general appreciation using a scale of 1-5, where 1 = very bad; 2 = bad; 3 = moderate; 4 = good; 5 = very good (Rees *et al*. 2003) then made pair-wise comparisons and overall ranking of genotypes.

Data on yield were subjected to log transformation first before doing regression analysis (takes care of missing data) using the General Model in GenStat (2011) statistical package to predict storage root and vine yield. The fitted terms were clone, location and season. Data on taste from individual taste panelists, pest infestation and disease infections were also analysed using GenStat. The additive main effect and multiplicative interaction (AMMI) model was used to analyze the genotype x environment interactions. The palatability scores for the genotypes were summarised using pair-wise comparisons and ranking.

RESULTS

Agronomic performance of genotypes

Regression analysis of root yield showed that effects of genotype, location and season were highly ($P < 0.001$) significant (Table 2).

Combined analysis of variance (ANOVA) using the AMMI model showed that there were highly significant ($p < 0.001$) differences among genotypes, environments and G x E interactions for root yield (Table 3). The main effects of genotypes and environments accounted for 33.85% and 54.05%, respectively, while the G x E interaction accounted for 3.36% of the total variation for root yield (Table 3). In this study, environment contributed higher variation than the genotype on the root yield. The interaction principle component axis 1 (IPCA1) explained 100% total interaction sum of squares percentage.

The highest storage root yield was recorded for genotypes 23/60/19, 23/60/31, 91/282-5, Sowola (OP)/2 and 282/94/3 while the lowest root yield was obtained in 23/60/90, Jewel (OP)/2005/6, Diallel 3, Zapallo/94/8 and the standard checks Dimbuka and New Kawogo (Table 4).

The biplot generated by AMMI model for G x E interaction permits visualization of differences in the

Table 3: Analysis of variance (ANOVA) based on the AMMI model for storage root yield for the four seasons (2010a-2011b)

Source	df	SS	MS	Total variation explained (%)	GxE explained (%)
Total	239	2747.9	11.50		
Treatments	59	2507.8	42.51		
Genotypes (G)	11	930.3	84.57***	33.85	
Environments (E)	4	1485.2	371.29***	54.05	
Block	15	226.1	15.07		
G x E	44	92.4	2.10***	3.36	
IPCA1	14	92.4	6.60***		100.00
Residuals	18	0.0	0.00		
Error	165	14.0	0.09		

Table 4. Mean storage root yield, IPCA1 and IPCA2 for 12 sweetpotato genotypes evaluated in five environments

No.	Genotype	Mean root yield	Rank	IPCA1	IPCA2
1	23/60/19	10.0	1	-1.0061	0.0448
2	23/60/31	9.4	2	-0.8176	0.0428
3	91/282-5	9.8	6	-0.3511	-0.0220
4	23/60/90	5.2	8	0.5304	-0.0309
5	23/60/92	8.1	5	-0.3806	-0.1630
6	282/94/3	8.4	4	-0.4694	-0.0855
7	Diallel 3	5.2	10	0.5525	0.0633
8	Dimbuka	5.2	9	0.5237	0.0595
9	Jewel (OP)/2	4.8	11	0.6425	0.0035
10	New Kawogo	4.0	12	0.9314	-0.0307
11	Sowola (OP)/2	8.7	3	-0.5695	0.1040
12	Zapallo/94/8	5.6	7	0.4139	0.0143
Location means					
Buikwe		5.5	3	0.5345	-0.0726
Kabale		8.0	2	-0.4488	0.0254
Kamuli		5.0	4	0.7487	-0.1395
Luwero		4.6	5	0.8885	0.1824
Wakiso		11.2	1	-1.723	0.0043

interaction main effects (Figure 2). Displacement along the abscissa reflected differences in main effects, whereas displacement along the ordinate exhibited differences in interaction effects. Genotypes or environments on the same parallel line, relative to the ordinate have similar root yields, and a genotype or environment on the right side of the mid-point of this axis has higher yield than that on the left hand side. Therefore, the high yielding environments were Wakiso and Kabale while the low yielding environments were Buikwe, Kamuli and Luwero. The genotypes categorized under favourable environments with above average root yield means were 23/60/19, 23/60/31, Sowola (OP)/2, 282/94/3 and 91/282-5. Genotypes lying in close proximity to a specific environment indicate better adaptation to that environment, for example, 23/60/19 and 23/60/31 were better adapted at Wakiso and Kabale. Genotypes which are close to each other tend to have similar root yield reaction to environment.

Genotypes with IPCA1 scores near zero had little interaction across environments and, vice versa for environments. Genotypes Jewel (OP)/2005/6, Zapallo/94/8 and 23/60/ were the most stable, but least productive (Fig. 2). Genotype 91/282-5 was the most stable of the clones which had root yields above the grand mean. Wakiso was the most stable and high yielding environment, followed closely by Kabale.

Genotypes 23/60/31, 282/94/3 and Sowola (OP)/2 were more susceptible to sweetpotato virus disease (SPVD) disease than the standard checks (Table 5). Generally,

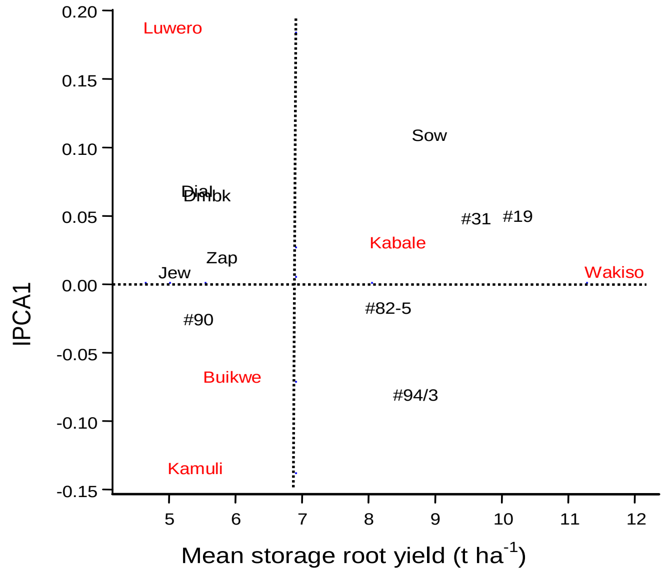

Figure 2: Biplot of interaction principle component axis 1 (IPCA1) score versus storage root yield for 12 sweetpotato genotypes and 5 environments.

Table 5. Overall mean scores on agronomic attributes of different sweetpotato genotypes tested for four successive seasons during 2010a-2011b

Clone	SPVD	Alternaria	Weevil
23/60/19	2.8	2.3	2.3
23/60/31	3.6	2.5	2.4
282/94/3	4.0	2.6	2.2
Sowola (OP)/2	3.5	2.8	2.5
23/60/92	2.8	2.5	2.4
91/282-5	2.8	2.4	1.9
Zapallo/94/8	2.8	2.2	2.0
Diallel 3	2.8	2.0	1.9
23/60/90	3.2	2.5	1.7
Dimbuka	3.3	2.7	1.8
New Kawogo	2.5	2.8	1.5
Jewel (OP)/2005/6	3.8	2.2	1.7
Mean	3.2	2.4	2.0
SEM	0.1	0.2	0.1

SPVD (Sweetpotato virus disease), Alternaria and weevil damage scored on a scale of 1-9: 1 = no symptoms, 9 = very severe

all the test genotypes were more tolerant to *Alternaria* disease but more susceptible to weevil damage than the standard checks.

Sensory results

Sowola (OP)/2 was the most preferred genotype with all taste attributes having good scores (range 4.0 - 4.4), whereas 23/60/19, Diallel 3 and Dimbuka (standard check) were among the least preferred genotypes with low scores (range 2.0 – 3.7) (Table 6).

Performance of genotypes in "mother" and "baby" trials compared

Genotypes had higher storage root yields in "mother" trials (mean 8.6 t ha^{-1}) than in "baby" trials (mean 6.8 t ha^{-1}) (Table 7). Evaluating the genotypes in "mother" trials had a 26.5% yield advantage over "baby" trials.

Table 6. Overall mean scores of palatability assessment and preference ranking of different genotypes during 2010a-2011b

Clone	Scores						Pair-wise rank
	Appearance	Taste	Flavor	Fiber	Mealy	Gen Appreciation	
Sowola (OP)/2	4.4	4.1	4.0	4.2	4.0	4.2	1
282/94/3	4.0	4.0	3.7	3.9	3.7	3.8	2
91/282-5	3.9	3.8	3.7	3.9	3.3	3.7	3
23/60/31	3.5	3.8	3.7	3.7	3.5	3.7	4
23/60/90	3.7	3.8	3.4	3.8	3.4	3.7	5
23/60/92	3.4	3.4	3.3	3.7	3.1	3.3	6
Jewel	3.2	3.6	3.2	3.3	3.3	3.2	7
Zapallo/94/8	3.4	3.3	3.1	3.6	3.2	3.2	8
23/60/19	3.3	3.3	3.2	3.7	2.9	3.2	9
Diallel 3	2.9	2.9	2.8	3.3	2.4	2.7	10
Dimbuka	3.0	2.0	2.0	2.9	2.3	1.9	11
Mean	3.3	3.3	3.2	3.7	2.9	3.2	NA
SEM	0.1	0.2	0.1	0.2	0.2	0.2	NA

Taste attributes were rated on a scale of 1-5; where 1 = very bad; 2 = bad; 3 = moderate; 4 = good; 5 = very good

Table 7. Mean root yield of sweetpotato clones tested in “mother” and “baby” trials compared

Clone	Root yield (t ha^{-1})		
	“Mother” Trial	“Baby” Trial	MT-BT
23/60/19	12.4	9.4	+3.0
23/60/31	12.5	8.9	+3.6
23/60/90	6.5	4.9	+1.6
23/60/92	10.1	7.6	+2.5
282/94/3	9.3	7.9	+1.4
91/282-5	9.8	7.5	+2.3
Diallel 3	8.0	4.8	+3.2
Jewel (OP)/2005/6	5.7	4.6	+1.1
Sowola (OP)/2	10.6	8.2	+2.4
Zapallo/8	6.9	5.2	+1.7
Dimbuka	6.9	4.9	+2.0
New Kawogo	4.8	3.8	+1.0
Mean	8.6	6.8	+1.8

DISCUSSION

The main effects of environment were highly significant and contributed higher variation than the genotype to the total variation in root yield, implying that the differential genotypic responses to environments were related to location differences in terms of factors such as soil type and soil moisture conditions during the four growing seasons. A similar view was held by Moussa et al. (2011). The most favourable season was 2011a; 2010a and 201b were moderate and similar; while 2011b was the least favourable, indicative of climatic variability. Genotype x environment effects were highly significant for storage root yield, indicating variable genotypic responses for yield across environments. Although rainfall data was not readily accessible for 4 out of 5 locations, information available on the internet (http://wwww.weatherspark.com), though not indicating the amount of rainfall, showed that rainfall distribution may have negatively affected crop growth and root yields. Earlier work by Gong *et al*. (1990) showed that drought stress lasting for more than 20 days during any part of the growing period decreased storage root yield of sweetpotato by 15-39 %. Similar results were reported by Turyagenda *et al*. (2013) for cassava with 37% reduction in fresh root yield due to drought stress. Van de Fliert and Braun (1999) reported that favorable conditions during the first month after planting (MAP) are of vital importance for storage root initiation and will determine the number of roots on a plant. Pest and disease pressure was low suggesting that these biotic factors had little influence on genotype performance.

Genotype Sowola (OP)/2 which had moderate root yield was the most preferred by taste panelists whereas the highest yielding 23/60/19 was ranked among the least preferred genotypes. This implies that taste attributes may be as important as agronomic traits when farmers are making decisions on which varieties to adopt or reject. This is in agreement with Tomlins *et al*. (2001, unpublished) who reported that the success of any newly introduced variety will depend not only on production characteristics, but also on its acceptability to consumers in terms of both sensory and utilisation characteristics. Farmers' main criteria are high yield, early maturity, disease and pest tolerance, sweetness, low fiber content, root firmness and extended in-ground storability (Kapinga et al. 1997).

CONCLUSIONS

Genotype Sowola (OP)/2 had superior organoleptic traits compared to 23/60/19, though the former's root yield was lower. It is, therefore, not enough for a variety to possess good agronomic traits; it must also have desirable sensory and utilisation characteristics. Genotype 23/60/31 which had the second highest root yield was moderately liked by taste panelists. However, some of its storage roots had symptoms of a corky center; this condition is similar to internal corking caused by the "russet crack" strain of the sweetpotato featherly mottle virus – an aphid-transmitted potyvirus (Ames *et al*. 1996). This problem was observed in Kabale (mainly) and Buikwe districts; therefore, 23/60/31 could be deployed in Kamuli, Luwero and Wakiso districts. Sowola (OP)/2 is recommended for deployment in all test and similar sites.

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