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Root-yield performance of pre-release sweet potato genotypes in Kenya

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ABSTRACT

Objective: The focus of this study was to evaluate the yield and stability of superior sweet potato cultivars for release in Kenya. This is the first attempt to document experimental results that have led to the first and so far only sweet potato variety release in Kenya.

Methodology: Ten national performance trials laid out as randomized complete block designs were performed on 14 sweet potato (*Ipomoea batatas* (L.) Lam.) genotypes in two geographical locations of Kenya. The trials were conducted to select local and introduced genotypes that were high yielding, stable, and tasty. Four experiments involving all the 14 genotypes were carried out in Nairobi while six experiments involving nine of the genotypes were carried out at three sites in Western Kenya. The stability of root yield and palatability test ranking were determined using appropriate statistical tools.

Results: Significant ($P = 0.05$) differences in root yield between genotypes were observed for both locations. Mean root yield was higher in Nairobi (16,760 kg ha^{-1}) than in Western Kenya (15,150 kg ha^{-1}). The proportion of marketable roots was higher in Nairobi than in Western Kenya. Dry matter content was also higher in Nairobi (29.63%) than in Western Kenya (26.58%). Genotype x environment (G×E) interactions were significant ($P = 0.05$) in both locations.

Conclusion and applications: Recommendations on the suitable varieties for official release are given. KEMB 10 and Mugande were the best performers in both environments. These two varieties contribute to enhancing food security among small scale household farmers in rural Kenya. Since its release in 2000, SPK 004 has contributed to enhancing the availability of the beta carotene micronutrient.

Key Words: Environment, Genotype, Stability

INTRODUCTION

One of the major objectives of sweet potato (*Ipomoea batatas (*L.)Lam.) breeding programs is to improve root yield. Root yield is an important trait for both large-scale commercial farmers and small-scale subsistence farmers in poor communities. Consequently, breeding for higher root yield requires that breeders take into consideration all yield components which affect the total root yield. Such a focused approach with well-defined selection objectives ensures positive progress early in the breeding program. Interrelationships among yield components have been investigated by Grüneberg *et al*. (2005) in Peru and Çalişkan *et al*. (2007) in Turkey, who both found significant G x E interactions between location and root yield ;). Yildirim *et al.* (2011) also studied effects of G x E interactions in sweet potato and reported significant differences in root yield among the varieties tested. Abdissa *et al.* (2011) conclude that plant density has significant effects on marketable root yield. Other workers who have studied effects of the environment on yield and yield components include Etela and Anyanwu (2011) who also report significant differences between yields on different planting dates. Results from Parwada *et al.* (2011) suggest significant effects of ridge height and planting angle on root diameter and root yield. Such interactions are important in tropical environments, like Kenya, where rainy and dry seasons are unpredictable and differ in length and intensity. When combined with the effect of varied soil types in sweet potato growing regions the effects of the interactions are of significance. In Kenya, systematic multi-environment investigations on quantitative traits of sweet potato yield began in the 1990s as a collaborative project between the Kenya Agricultural Research Institute and the International Potato Center (CIP). Some of the results of this work have been published by Ndolo *et al*. (2001) and Mcharo *et al*. (2001).Investigations using quantitative traits do present great challenges to the breeder. However, with increasing availability of robust statistical packages and high computing power it is now possible to more easily investigate interrelationships among the various yield components. Even though knowledge of the magnitude of G × E interactions has assisted breeders in making progress, advances have so far been slow and expensive because of the hexaploid nature of sweet potato. This study evaluated the yield levels and yield stability of superior sweet potato cultivars for release in Kenya. These results subsequently constitute the outcome of national sweet potato performance trials conducted over multiple production seasons (1997 to 2000) in four locations. This study is the first to document experimental results that has led to the first and so far only sweet potato variety release in Kenya.

MATERIALS AND METHODS

Two sets of sweet potato varieties were used in this multi-location study. In the first set, fourteen sweet potato varieties that included KEMB 10 as the local control (Table 1) were tested in field trials over four growing seasons from 1997 to 2000 in Nairobi, Kenya. The Nairobi location represented the Central Kenya sweet potato growing region. The second set, a subset of nine clones from the first set including Jayalo as the local control, was tested over two seasons from 1997 to 1998 in three sites (Kabondo, Ndhiwa, and Rongo) in Western Kenya. The trials in both locations were laid out as a randomized complete block design with three replications. In both locations, each replication consisted of plots of the test clones and another plot of the local control clone. The test clones were sourced from the International Potato Center breeding program, the Ugandan national breeding program, and local Kenyan landraces. Each plot consisted of 48 plants planted on rows at 12 plants per row. Thirty-centimetre long disease free vine tip cuttings were used as planting material. At planting, two thirds of the length of each cutting was buried into the ground, with an inter-row spacing of 0.8 m and a within-row spacing of 0.3 m. No fertilizers or pesticides were used during the crop growth period. The two middle rows were hand harvested three months after planting to obtain agronomic data. Foliage was cut from the plants at ground level and the roots removed from the soil using hoes. Dry matter content was determined within 24 hr of harvesting by cutting 200 g from the middle portion of the fresh roots into thin slices and placing them in open trays and dried in an oven at 70 ˚C until a constant dry weight was achieved. This dry weight was then recorded and divided by the initial fresh weight to give percentage dry matter content. Marketability of roots was visually assessed based on general consumer demands that included roots with a diameter of at least 3cm and lesion free skin. Experimental field site data are presented in Table 2 (Jaetzold & Schmidt 1982; Jaetzold & Schmidt 1983). Samples of storage roots from each variety were boiled in separate pots following the local cooking procedures. The roots were then placed on separate plates on a table. An untrained panel of farmers and agricultural extension staff then assessed the cooked roots by tasting small portions of the cooked roots. Before tasting each variety, the panel members rinsed their mouths with water in order to avoid confounding the different tastes. Each panellist then rated each variety on a scale from 1 to 5, where 1 represented lowest palatability and 5 represented highest palatability. Each of the panel members also selected the best tasting variety by placing a marker next to the plate with the variety of choice. At the end of the evaluation the variety with the most number of markers was ranked best while the variety with the least number of markers was ranked last. Further group discussions were held to discuss the results and confirm if the results reflected their choices.

Data were analysed using MSTAT-C (1993) and STABLE (Kang & Magari 1995) statistical packages. Analysis of variance for individual and combined trial data followed the outline of Steel and Torrie (1980) and Gomez and Gomez (1984). In order to overcome the genetic complexities of polyploids, many workers have over time developed various methods to determine effects of G × E interaction on traits of economic importance. Models that have been used to study G × E interactions in sweet potato include the Additive Main Effects and Multiplicative Interaction, or AMMI model, (Mwololo *et al*. 2009; Osiru *et al*. 2009). The GGE Biplot analysis is also a recent method on stability analysis that is gaining currency (Yan & Kang 2002). This study used Kang's (1993) yield-stability statistic (YS_i) to evaluate sweet potato genotypes. The YS_i statistic combines yield and stability of performance into a single selection criterion whose efficiency decreases the effects of researcher probability Type II errors on farmers' yields (Kang & Magari 1995). Due to this versatility, the YS_i statistic was used for this study

TABLE 1: Experimental clones and their origin

Clone	Clone Origin	Flesh colour	Skin colour
Zapallo	CIP	Orange	Cream-white
Yan Shu 1	China	Cream	Purple-red
Santo Amaro	CIP	Cream	Brown
Mugande	Kenya	White	Red
Naveto	CIP	White	Cream
Jayalo (Western control)	Kenya	Cream	Red
Sowola	Uganda	Cream	Cream
KEMB 10 (Nairobi control)	Kenya	Cream	Cream-white
NIS/94/320	Uganda	Cream	Cream-white
Marooko	Kenya	Light cream	Brown
New Kawogo	Uganda	Cream	Purple-red
SPK 013	Kenya	Cream	Red
SPK 004	Kenya	Orange	Red
Bwanjule	Uganda	White	Purple-red

TABLE 2: Environmental conditions of the experimental sites

	Nairobi	Western Kenya		
		Kabondo	Ndhiwa	Rongo
Altitude (m.a.s.l)	1830	1400	1300	1400
Mean annual rainfall (mm)	1050	1500	1200	1700
Mean minimum temperature (^oC)	16.4	20.5	20.8	20.5
Mean maximum temperature (^oC)	17.4	21.7	22.7	21.7
Soil type	Humic nitosols	Chrome-luvic phaeozems	Pure vertisols and verto-luvic phaeozems	Humic acrisols

RESULTS

Tests of significance: In both locations, the clones exhibited significant differences in total root yield for genotypes and seasons (P = 0.01), while a significant genotype by season interaction at P = 0.01 was recorded only in Nairobi. Significant interactions for marketable root yield were recorded in both locations. Dry matter content exhibited significant season by location interactions in Western Kenya. These results show that the clones responded differently in the two environments.

Total root yield: In the Nairobi population, five varieties had root yields that were significantly higher than the mean. These varieties were Zapallo, Yan Shu 1, Santo Amaro, Mugande and Naveto (Table 3), and they all produced over 20,000 kg $ha^{-1}$of total root yield. Among the top five, it is only Mugande that was not an introduction from CIP. On the other hand, Bwanjule yielded less than 10,000 kg $ha^{-1}$to rank as the poorest yielder. Stability parameters for total root yield are presented in Table 3. Jayalo, KEMB 10, Mugande, New Kawogo, Santo Amaro, Sowola and Yan Shu 1 had regression coefficients not significantly different from slope (b) =1 and thus they were considered stable for total root yield. Bwanjule, SPK 013 and Zapallo had variance (s^2_d) values significantly different from 0. Based on Eberhart and Russell (1966) b and s^2_d statistics, the most desirable genotypes are Yan Shu 1, Santo Amaro and Mugande. According to Shukla's (1972) δ^2 statistic, KEMB 10, Mugande, New Kawogo, NIS/94/320 and SPK 013 were the most stable. After adjusting for environmental factors ($\hat{s}^2$), the previously unstable Bwanjule and Zapallo were found to be stable. Although genotype, location, and season showed significant differences in Western Kenya, the interactions involving genotypes were not significant. These results suggest that the relative ranking of the genotypes was not affected by any environmental factors. Even though Jayalo, Mugande, Naveto, and KEMB 10 produced higher yields than the mean, none of the test clones gave higher yields than the local control Jayalo. While the yield of SPK 004 was significantly lower than that of the top three varieties, it was stable across the environments. Stability parameters using Eberhart and Russell's (1966) method suggest that all the genotypes are stable in Western Kenya. The statistics from Shukla (1972) suggest that Mugande, New Kawogo, and NIS/94/320 were unstable for root yield, but after adjusting for environmental factors only New Kawogo was found unstable. Jayalo, KEMB 10, Mugande, Naveto, and Sowola had a YS_i greater than the mean of 3 and due to their high yield and stability, were selected to be considered for release.

Marketable yield: The mean marketable yield for Nairobi was almost three times that realized in Western Kenya. Marketable yield, as a percentage of the total root yield, ranged from 85% at Bwanjule to 98% at Santo Amaro in Nairobi. These values suggest that the environment in Nairobi is suitable for uniform yields that facilitate one time harvesting after three months of growth. The proportion of marketable yield as a percentage of total root yield in the Western Kenya trials was much lower than in the Nairobi trials. The proportion ranged from 34% in SPK 004 to 48% in NIS/94/320 (Table 3).

Dry matter content: The root dry matter content recorded in Western Kenya was 3% to 5% lower than that recorded in Nairobi. In Nairobi, Marooko recorded the highest root dry matter content followed by Jayalo and SPK 013. Other varieties that had higher dry matter than KEMB 10, the control, were Sowola and SPK 004. Although Jayalo had higher dry matter than KEMB 10 in Nairobi, its value was lower than that of KEMB 10 in Western Kenya. However, the differences between the two in each population were not significantly different.

Palatability: KEMB 10, New Kawogo, and SPK 013 received the highest, and also equal, scores. Also, KEMB 10 was the best ranked followed by New Kawogo, SPK 013 and SPK 004, which tied in the second position. Mugande was sixth in terms of mean scores and fifth in ranking. On the other hand Zapallo, Yan Shu 1, and Naveto were the last three in terms of mean scores. These three varieties were also ranked last.

TABLE 3: Stability and yield statistics for root yield components

Site	Clone	Yield statistics					Total root yield (kg ha^{-1})	Marketable root yield (kg ha^{-1})	Dry matter content (%)
		b^a	s^2_d ^{a}	δ^{2b}	$\hat{s}^{2b}$	YS_i			
Nairobi	Zapallo	1.78**	7.60*	371.61**	21.58	9[c]	26330	25570	21.01
	Yan Shu 1	1.91	120.14	759.93**	415.65**	8[c]	23870	22130	25.40
	Santo Amaro	0.85	15.74	38.61	50.10	15[c]	23660	23220	27.65
	Mugande	1.06	10.46	14.88	31.71	13[c]	21290	20460	30.93
	Naveto	1.54*	26.26	220.16**	86.90*	4	20720	20170	26.31
	Jayalo	0.72	32.39	110.67**	108.32*	2	18060	17110	32.22
	Sowola	0.94	1.49	6.32	0.21	9[c]	17840	16890	32.01
	KEMB 10	0.88	11.58	24.27	35.60	6[c]	15720	14940	31.77
	NIS/94/320	0.76*	4.92	33.12	12.24	5[c]	14400	13350	31.73
	Marooko	0.44**	13.26	203.07**	41.38	-5	11950	11050	32.75
	New Kawogo	1.07	8.43	10.99	24.55	2	11760	11260	30.35
	SPK 013	0.73**	1.84*	35.81	1.46	1	11090	10650	32.15
	SPK 004	0.86**	1.08	2.64	1.22	0	10930	10300	31.88
	Bwanjule	0.46**	4.78*	174.18**	11.75	-10	6970	5930	28.61
	Mean					4.2			
	L.S.D (P = 0.05)						3780	3700	2.51
	CV %						27.86	28.70	10.47
Western	Jayalo	1.36	7.17	40.78	23.45	9[c]	19890	8410	27.86
	Mugande	1.53	1.12	50.03*	0.04	6[c]	18010	6210	25.44
	Naveto	1.06	8.97	22.94	30.33	8[c]	17110	6870	23.75
	KEMB 10	0.81	6.62	21.98	21.28	7[c]	15870	5850	28.33
	Sowola	0.98	11.31	29.75	39.94	4[c]	14770	5080	27.03
	New Kawogo	1.15	16.42	49.95*	59.08*	-1	14300	5600	25.61
	SPK 013	0.73	7.43	31.24	24.41	2	13910	5430	26.69
	SPK 004	0.76	11.20	39.89	38.96	-2	12630	4310	26.71
	NIS/94/320	0.63	9.13	47.69*	30.94	-6	9900	4800	27.83
	Mean					3			
	L.S.D (P = 0.05)						3310	2150	2.60
	CV %						33.04	55.77	14.82

[a]**, *b value significantly different from b=1; s^2_d >0 at P=0.01 and P=0.05 respectively (Eberhart and Russell, 1966)
[b]**, * Significantly unstable at P=0.01 and P=0.05 respectively (Shukla, 1972)
[c]Selected genotype according to Kang's criterion (Kang, 1993)

DISCUSSION

Total root yield: Results from this study showed wide variations among the clones for root yield performance. In a recent study using the AMMI model, Osiru *et al*. (2009) have found similar variations in yield stability among sweet potato genotypes with Tanzania (called KEMB 10 in Kenya) as one of the most stable ones. The mean of Kang's yield-stability statistic YS_i is 4.2 and, therefore, genotypes with a greater YS_i were good candidates for further assessment before release because they represented an optimal combination of high yields and stability. In another study, Mwololo *et al*. (2009) report that SPK 004 also was stable across a range of environments. Further assessment criteria were based on visual and palatability perceptions as presented in Table 4.

Marketable yield: The lower value of marketable yield in Western Kenya may have been due to the lower rainfall amounts recorded in the west. The lower rainfall contributed to a decrease in the rate of root expansion, and if harvesting was done during the fourth month, the proportion of marketable roots would have been much higher. It is worth noting that, this characteristic of a prolonged expansion period is not a disadvantage but is actually desirable in Western Kenya since most farmers harvest piecemeal, whether for home consumption or for sale in the local market. Similar to the results published by Abdissa *et al.* (2011), the significant differences in marketable yield provide opportunities for further progress in breeding and selection.

Dry matter content: We also observed variation in dry matter content, which is expected since the varieties had different origins. Tsegaye *et al*. (2007) also reported significant differences in dry matter content with its genetic variance contributing 43.04% of the phenotypic variance. In Kenya, high dry matter varieties with a mealy texture are preferred to low dry matter varieties. On the other hand, Mukhtar *et al.* (2010) did not find any significant effects of fertilizer on dry matter content.

Palatability: The best-ranked varieties have been selected by local farmers over many generations. Their superior performance in this study is, therefore, a reflection of their importance in the farmers' farming enterprises and households. The factors that mainly contributed to good palatability scores and ranking included high sugar content, high dry matter content, and low fibre content of the roots. Although New Kawogo and Marooko were ranked second and fourth respectively, using mean scores and palatability ranking, their poor agronomic characteristics denied them inclusion into the list of selected varieties.

In conclusion, at the time of conducting these trials no official variety release of sweet potatoes had been done in Kenya. Naveto performed well agronomically and it had an additional advantage of producing substantial foliage (Mcharo *et al*. 2001); however, it was not palatable to the consumers due to its bland taste. Despite New Kawogo having a high palatability rank, its yield was lower than that of the controls. Therefore, the varieties that were recommended for official release to farmers were Mugande, KEMB 10, and SPK 004. Mugande had an attractive red skin in addition to its large roots. In spite of KEMB 10 having relatively smaller roots, it had the advantage of being yellow fleshed and having a good taste (Ndolo *et al*. 2001). The yellow flesh indicates the presence of beta carotene. The deeper orange flesh of SPK 004 is an indication of even greater amounts of beta carotene (Hagenimana *et al*. 1998). Hagenimana *et al*. (1998) also show that SPK 004 contains high sugar content, significant amounts of beta carotene and cooks fast. These nutrition and visual factors make it a favourite among consumers (Ndolo *et al*. 2001). Morphological characteristics of this variety are described by Mwanga et al. (2007). Although high root yield is a major determinant for the adoption of a variety, a high root dry matter content is also critical among African consumers. Roots that have a high dry matter content are also preferable because of their crunchy texture. In the present study, and in Ndolo et al. (2001), KEMB 10, SPK 013, SPK 004, and Mugande were found to have acceptable dry matter content, high yield and acceptable taste. Therefore, KEMB 10 and Mugande were released in late 2000 for commercial production in Central Kenya while all these four varieties were released for production in Western Kenya. Currently, KEMB 10 is one of the dominant varieties being produced and consumed in Kenya.

TABLE 4: Palatability assessment of roots

Clone	Mean palatability score[a]	Palatability rank	Released clones
Zapallo	2.8	13	
Yan Shu 1	3.0	11	
Santo Amaro	3.2	7	
Mugande	4.1	5	+
Naveto	3.1	10	
Jayalo (Western control)	4.4	5	
Sowola	4.0	9	
KEMB 10 (Nairobi control)	4.8	1	+
NIS/94/320	4.1	6	
Marooko	4.5	4	
New Kawogo	4.8	2	
SPK 013	4.8	2	+
SPK 004	4.0	2	+
Bwanjule	3.7	8	

[a]Palatability scores are based on a scale of 1 to 5 where 1 = very unpalatable and 5 = very palatable

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