Genotype x environment interactions and participatory on-farm selection of sweet potato in the Northern highlands of Tanzania

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Abstract

Sweet potato genotype x environment (G x E) interactions, genotype response to environments, stability and participatory on-farm selection for fresh storage root yield were studied n the Northern highlands of Tanzania. Eight varieties were on-farm evaluated in a randomized complete block design whereby farmer's fields were treated as replicates at four locations. G x E interactions were analyzed using linear regression. Analysis of variance of total roots yield data showed significant mean square variation within varieties and environments *($p \leq 0.05$)*. Statistically significant varieties and environment interactions also occurred *($p \leq 0.05$)*. The pattern related mainly to the varietals response to differences in yield potential between environments and in varietals ability to yield at environment with poor yield potential. Local variety "Tengeru Red" and introduced one CIP 4400131 "Noveto" with respective slope values of 1.02 and 1.04, smaller standard error (s.e. = 0.09) values, relatively high total roots yield and a coefficient of determinations (R^2=0.98), could be considered the most widely adapted varieties. However, CIP 4400131 with negative intercept is not likely to perform better at poor environments. Considering farmers selection criterion used, all of the eight sweet potato varieties, were readily accepted by farmers.

Keywords: Adaptation; stability; sweet potato; genotype x environment interactions; on farm selection; Tanzania.

Introduction

Root and tuber crops particularly sweet potato (*Ipomoea batata,* Lam) is firmly established in the farming systems of Tanzania (Kapinga et *al.* 1995). In the Northern highlands of Tanzania, a future of subsistence production of sweet potato lies in the introduction and diversity of cultivars (Kuoko, 2004). The reasons for this include - (1)adoption for new improved high yielding varieties, (2) taste preference of the growers and consumers, (3) the need to produce sweet potato for human consumption and dairy cattle, and (4) apparent suitability of cultivar to specific environment i.e. genotype x environment interactions. In Tanzania, on-farm introduction and subsequent selection for sweet potato genotypes with high storage root yield will continue to be the priority objective of the National Root and Tuber Crops Research. In the 1990's the programme received diverse sweet potato varieties from the International Potato Centre (CIP), Sub Saharan. Only six promising varieties were selected for multilocational trials in the Northern highlands of Tanzania. The performance of the cultivars varied from location (environment) which suggested the presence of genotype x environment interaction. The G x E studies is of paramount importance in the specific environments in which the varieties are to be grown (Ortiz and Ilse de Cauwer, 1999). This is because sweet potatoes multilocational trials programmes generate phenotypic data for storage roots yield and other traits that enable us to obtain the most accurate estimates of variety performance that are possible, within the limitations imposed by time. Different attempts have been made to solve the challenges created by G x E interactions e.g. (Hanson *et al.* 1956; Comstock and Moll, 1963). Interest has been focused on the regression analysis. This technique was originally proposed by Yates and Cochran (1938) and later modified by Finlay and Wilkinson (1963); Eberhart and Russel (1966); Hildebrand and Russel (1996). In this technique we perform a linear regression between site average yield (environment index) and variety yield (treatment). The sweet potato varieties were then subjected to multilocational trials in diverse sweet potato growing areas of the Northern highlands of Tanzania. The objectives were – firstly to determine the nature of G x E interactions on the total roots yield (tones ha^{-1}); secondly to identify stable and adaptable varieties using different parameters; thirdly incorporate farmers selection criteria.

Material and methods

Experiment design. Eight varieties (Table 2): six selected from the introduced varieties by the CIP-Sub Sahara, and two local ones were evaluated between 2001 and 2003 cropping seasons at four locations of farming system zones of Northern Tanzania (Table 3). Farmers Research Groups involving 20 - 25 sweet potato growers in each district were involved in the trials. Each farmer was treated as a replicate and was given with 100 cuttings of each variety to plant and manage. The experiment was harvested after 135 – 145 days after planting during the long rainy season (February – July).

Data collection and analysis. Data collected were fresh storage roots yield, number of roots per plant, weevil infestation virus score and organoleptic taste using a standard method by NRI-National Root and Tuber Crops Improvement Programme. The analysis of variance was used using INSTAT (Reading University, UK) statistical package.

Farmer's assessments and selection. A pair wise method of ranking was used in collaboration with farmers to assess - plant vigor, appearance (root shape and color), and size. They also listed important selection criteria for best/poor variety. Data collected were not subjected to a statistical analysis using the

Stability analysis. The stability parameters suggested by Finlay and Wilkinson (1963), Eberhart and Russel (1966) and Hidelbrand and Russel (1996) were also calculated. This was done using data shown in Table 3. Four stability parameters were computed from individual linear regression between site mean yield (environment index) and variety mean yield: (1) *a* the intercept, (2) *b* value, slope or regression coefficient; (3) the mean square deviation from the regression of each variety (standard error s.e value) and (4) coefficient of determination (R^2 values) According to Eberhart and Russel (1966), for a variety to be considered stable, should meet criteria of high mean yields, slope equal to unity and standard error of the difference *s.e*. approaching zero. The slope measure the extent to which a variety responds to a unit difference in yield potential between sites. A steeper slope indicates greater response. Therefore, lower slope signify less variation in yield potential across sites. The intercept indicates the relative ability of the variety to yield at site with poor yield potential. Positive intercept mean that a particular variety is likely to perform better at poor site.

Results and discussion

Statistical analysis. The experiments were harvested at 135-145 days after planting. Statistical analyses over three years did not show any year x treatment interactions. Therefore, the data were combined across years and the results are discussed as means over the three years of study. Combined analysis of variance for total roots yield, weevil percentage, and virus score is shown in Table 1. The effects of varieties and site on mean total root yield were significant *($p \leq 0.05$)*. There was also significant mean squares interaction between environment and genotypes *($p \leq 0.05$)* as was expected. These results were similar to those obtained by Ngeve (1993) and Ndolo *et al*. (1995) who reported significant interactions between sweet potato varieties and environment. The variations in yield between sites were due to variations in soil, weather characters and agronomic management. Weevil infestations were also significant affected *($p \leq 0.05$)* by the variety.

Table 1. Combined analysis of variance

Source	df	Mean sum of squares		
		Total root yield	%weevil infestation	Virus score (1-5)
Variety	7	173.56**	414.96**	2.1
Site	3	174.4**	54.51	1.3
Year	2	8.82	42.13	2.2
Variety x site	33	18.19**	61.64	1.3
Variety x year	22	11.72	32.34	1.8
Site x year	6	20.62	77.96	1.4
CV%		30.8	46.8	13.2

Crop performance. Table 2 shows combined total root yield, number of roots per plant, percentage weevil infestations and virus scores. Mean yield was 12.4 tones ha^{-1}, and CIP 4400123, 4400131, and local check Tengeru Red recorded higher mean root yield. The high yielding varieties were due their elevated root size and not to number of roots per plant. In the Northern Tanzania, sweet potato is a food and cash crop. The crop is retailed in heaps and the average number of roots per plant and roots size distribution is important characters. Similarly for household consumption the crop is peace meal harvested, and as Ndolo *et al* (1995) mentioned that the presence of small roots at the time of harvest may indicate continued potential yield for production. Number of roots per plant was consistent with mean value of 4.8. CIP 440024 recorded 6.6 roots per plant. All varieties were susceptible to the sweet potato weevils (*Cylas ssp*) infestations. The percentage of roots infested was greater in CIP 420009 (26.5%) and lowest in CIP 4400131 (9%). This later is attributed to deep rooting characteristics of the 4400131. This may show that probably this variety is resistant or tolerant to sweet potato weevils. Table 3 shows total root yield across the sites. Yield across the sites varied from 6.3 tones ha^{-1} for CIP 4400105 to 24.0 tones ha^{-1} for CIP 4400123. The range was 9.4 tones ha^{-1} at Mwanga to 15.4 tones ha^{-1} at Arumeru. Tengeru Red, CIP 4400123 and CIP 4400131 consistently performed better in all sites. The highest yields were obtained in the Arumeru, because despite a good climate, farmers irrigate their sweet potato crop. Lower yield were recorded in Mwanga due to the prolonged drought and declining fertility. Virus was not a serious problem, as no significant mean square differences and interactions were observed; therefore, virus might not be attributed to the discrepancies in yield. Total roots yield data from Table 3 were used for stability analysis by environmental index.

Table 2. Combined crop performance in Northern highlands of Tanzania

Variety	Root yield tones ha $^{1-}$	# roots/plant	%weevil Infestations	Virus score (1-5)
CIP 4400123	17.3a[1]	5.0	24.2b	1.8
Tengeru Red	16.8a	4.2	18.4bc	1.8
CIP 4400131	15.4ab	5.7	9.0d	2.3
CIP 4400117	12.9b	4.5	21.4ab	1.6
CIP 440024	12.2b	6.6	23.1b	1.7
CIP 4400105	8.7c	4.8	18.3bc	2.0
CIP 420009	8.5c	3.6	26.5a	1.8
SPN/O	8.0c	4.1	17.5bc	1.8
Mean	12.4	4.8	19.8	1.8.

[1]Means followed by similar letters are not significantly at P=0.05 using LSD.

Table 3. Mean storage root yield of sweet potato varieties planted at four sites

Varieties	Arumeru	Mwanga	Lushoto	Mbulu
CIP 4400123	24.0	10.5	21.0	14.0
Tengeru Red	20.0	13.0	18.7	15.6
CIP 4400131	19.7	11.3	17.0	13.7
CIP 4400117	14.3	12.7	13.3	11.3
CIP 440024	16.3	8.7	13.5	10.0
CIP 4400105	9.6	6.3	11.0	8
CIP 420009	11.6	5.0	9.0	8.4
SPN/O	7.2	8.0	8.3	8.5
Site mean	15.4	9.4	14.0	11.2

Stability analysis. Table 4 shows summary of the parameters for individual fitted regressions. CIP's 4400105, CIP 4400117, SPN/O, and Tengeru Red had positive intercept, indicating that they are likely to perform better at site with poor yield potential. Slopes ranged from -0.04 for SPN/O to 2.01 for CIP 4400123. Four varieties CIP's 4400131, CIP 4400123, CIP 440024 and Tengeru Red had regression coefficients significantly greater than 1.0; they were sensitive to environment change. The goodness of the fit of the individual variety regressions i.e. R^2 value is an estimate of the stability of a variety's response to different sites. Then, SPN/O and to a lesser extent CIP 4400105 and 4400117 gave the least predictable performance i.e. lower R^2 values. In terms of a variety selection, an ideal variety would be one which was both responsive i.e. had high slope and gave some yield at low yield potential sites i.e. had a positive intercept. In this case Tengeru Red had a high slope (*b*=1.12), and positive intercept (*a*=2.769), standard error approaching zero (*s.e* 0.0958), high total yield (16.8 tones ha^{-1}) at R^2= 0.98 is the best variety and is likely to perform better even in poor sites. This shows that the local check is well adapted to this environment. CIP 4400131 despite having negative intercept (-1.153) is not likely to perform better at poor yield potential sites, but is a good variety to be promoted. This is because is tolerant to weevils, has high yield (15.4 tones ha^{-1}); standard error of the slope near zero (0.0983) and R^2=0.98. The yield trend might be explained as due to variety genetic potential, fertility, management and cool weather normally experienced in the Northern highlands during the vegetative stage of the sweet potato. Farmer plant their crop close the end of the rainy season i.e. April/May after finishing with other crops like maize and beans. This exposes the crop to unfavorable conditions like drought and cool temperature that might affect growth and development of the crop. Farmers seldom fertilize sweet potato.

Table 4. Stability parameters for total storage root yield

Variety	Yield	Intercept			Slopes			
		a	*s.e*	*t*	*b*	*s.e*	*t*	R^2
CIP 4400123	17.3	-7.154	3.054	3.17	2.01	0.2447	8.3	0.97
Tengeru Red	16.8	2.768	1.196	2.32	1.02	0.0958	11.7	0.98
CIP 4400131	15.4	-1.153	1.227	-0.94	1.04	0.0983	13.4	0.98
CIP 4400117	12.9	7.923	2.499	3.17	0.37	0.2002	1.8	0.63
CIP 440024	12.2	-3.462	2.391	-1.45	1.24	0.1916	6.5	0.95
CIP 420009	8.5	-1.154	2.107	-0.55	0.75	0.1688	4.4	0.90
CIP 4400105	8.7	0.693	3.587	0.19	0.63	0.2874	2.2	0.71
CIP 420009	8.5	-1.154	2.107	-0.55	0.75	0.1688	4.4	0.90
SPN/O	8.0	8.538	2.588	3.30	-0.04	0.2073	-0.21	0.02

Farmer assessment and selection. Table 5 shows selection criteria used by farmers in selecting sweet potato varieties. Yield and maturity were the most important characteristics as most farmers prefer high yielding and early maturing varieties. Ranking of varieties by farmers on basis of crop performance is shown in Tables 6.

Table 5. Farmer's criteria in selection of sweet potato varieties

Criterion	Arumeru	Mwanga	Lushoto	Mbulu
Size/shape	5	5	5	5
Yield	2	2	1	1
Maturity	3	4	2	3
Taste	6	3	3	2
Shape	4	6	7	6
Drought tolerance	7	1	4	4
Market	1	7	6	7

Table 6. Variety ranking based on crop performance

	Arumeru	Mwanga	Lushoto	Mbulu
CIP 4400117	3	7	7	6
CIP 4400131	7	6	6	8
CIP 420009	9	5	4	1
CIP 4400105	5	4	3	2
CIP 4400123	2	2	2	5
CIP 440024	6	1	1	7
SPN/O	8	8	8	3
Tengeru Red	1	3	5	4

Table 7. Ranking of variety on basis of crop performance – canopy/yield/taste

	Arumeru	Mwanga	Lushoto	Mbulu
CIP 4400117	3	1	7	3
CIP 4400131	4	2	6	6
CIP 420009	7	5	5	5
CIP 4400105	6	4	3	2
CIP 4400123	2	6	2	1
CIP 440024	5	7	1	7
SPN/O	8	8	8	8
Tengeru Red	1	3	4	4

Conclusion

Two genotypes, local variety "Tengeru Red" and CIP 4400131 "Noveto" could be considered the most widely adapted genotypes. However, CIP 4400131 with negative intercept is not likely to perform better at poor environments. Considering farmers selection criterion all eight sweet potato varieties, were readily accepted by farmers.

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