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Selection, Yield Evaluation, Drought Tolerance Indices of Orange-Flesh Sweet potato (*Ipomoea batatas* Lam) Hybrid Clone

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Abstract

Orange-Fleshed Sweet Potato (OFSP) varieties have high pro-vitamin A and medium amounts of iron and zinc. Drought susceptibility is perceived as one of the major drawbacks of this crop type and currently available varieties do not allow sustainable and enduring production in drought affected regions. Screening and selection for OFSP for drought tolerance could have a positive impact on the livelihood and health of vitamin A deficient people in Sub-Saharan Afica (SSA). In this study 18 OFSP genotypes from Lima, Peru and two Kenyan check cultivars, Marooko (drought tolerant) and K566632 (susceptible) were screened for drought tolerance at Kiboko (Latitude 010 15' S; Longitude 360 44' E; Altitude 975 masl) and Marigat (Latitude 0° 38, 0" N; Longitude 36° 5, 0" E; Altitude 970 masl) during the years 2008-2009. A split-plot design was used with two levels of treatment, non-irrigated and irrigated as the main factor and the genotypes as the sub-factor. All the treatments were laid out in a randomized complete block design. Stress tolerance index was used to identify genotypes with high stress tolerance and high yield potential. In both site genotypes 194573.9, 420014, 440286, 189135.9, 187017.1 and 441725 showed high stress tolerance and yield potential compared with the check by registering higher stress index that ranged between 0.37- 0.96 and very low susceptibility index. The multidimensional preference analysis of the bi-plot distinguished the same genotypes as high yielding in both treatments imposed. Correlation analysis revealed that Yield potential (Yp) and Stress yield (Ys) had highly significant positive correlation coefficients with Stress Tolerance Index (STI), Mean Productivity (MP) and Geometric Mean Productivity (GMP) and they can be used as the most desirable indices for screening drought tolerance genotypes.

Keywords: Orange-fleshed sweet potato; Drought tolerance; Genotype; Stress Tolerance Index; Stress Intensity Index

Introduction

Sweet potato is one of the most widely grown root crops in Sub-Saharan Africa, covering around 2.9 million hectares with an estimated production of 12.6 million tons of roots in 2007 [1]. It is predominantly grown in small plots by poor farmers; hence it is known as the poor man's food [2]. It is regarded as a food security crop because of its low input requirements, ease of production and ability to produce under adverse weather and soil conditions [3]. Its role is changing from a reliable, low-input, low-output crop to an increasingly important market crop. It combines tremendous agronomic and nutritive qualities with a short maturity period of 3-8 months after planting which makes growing two crops season in a year possible [4].

Most Sweet potato varieties grown in Africa are white, cream or yellow fleshed [5] and supply little or no Vitamin A. To date Orange-fleshed varieties introduced from other parts of the world or bred locally have been readily accepted in pilot areas in East Africa and preliminary results have shown that they contain sufficient levels of β-carotene to play an important role in eliminating Vitamin A Deficiency (VAD) [6]. VAD is responsible for night blindness, increased susceptibility to infections and impaired growth and development. One of the easiest ways to introduce more vitamin A into the diet is to consume orange-fleshed Sweet potato. This type of Sweet potato is rich in beta-carotenes that the body converts easily into vitamin A, they are easy to grow and the average consumer can easily access them. Adding 100 g of the sweet potato to the daily diet can prevent vitamin A deficiency in children and dramatically reduce maternal mortality.

Two more recent studies [7,8] in South Africa and Mozambique respectively have demonstrated that regular consumption of orange-fleshed sweet potato (OFSP) significantly increased vitamin A status of children.

The drought susceptibility of Orange-Fleshed Sweet Potato (OFSP) is perceived as one of the major drawbacks of this crop type and currently available varieties do not allow sustainable and enduring production in drought prone regions. Traditional OFSP varieties on average produce 3t/ha which is a very low average yield compared with the introduced OFSP varieties that yield over 20t/ha. Development of improved, drought tolerant OFSP will increase Sweet potato yields especially in Arid and Semi Arid Lands (ASAL), where seasonal drought is a significant problem.

Considering the low heritability of drought tolerance and lack of efficient selection strategies, production of drought tolerance cultivars is difficult. Based on the relative yield of genotypes in both stressed and non-stressed conditions, we can identify effective traits for drought stress tolerance. In order to identify drought tolerant genotypes under such environment, some selection indices (GMP, MP, TOL, STI and SSI) have been used in different conditions [9,10] evaluated F3 and F4 generations obtained from the intersection of two durum wheat genotypes at different moisture regimes they calculated drought tolerance indices based on yield in both stressed and non-stressed

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conditions and concluded that there is meaningful correlation between yield in non-stressed environment and in stressed environment with indices MP, GMP and STI, so these indices can be appropriate predictors of yield of a genotype in normal irrigation condition (Yp) and and yield of agenotype in water deficient condition (Ys) as compared with SSI and TOL indices. Components analysis of above

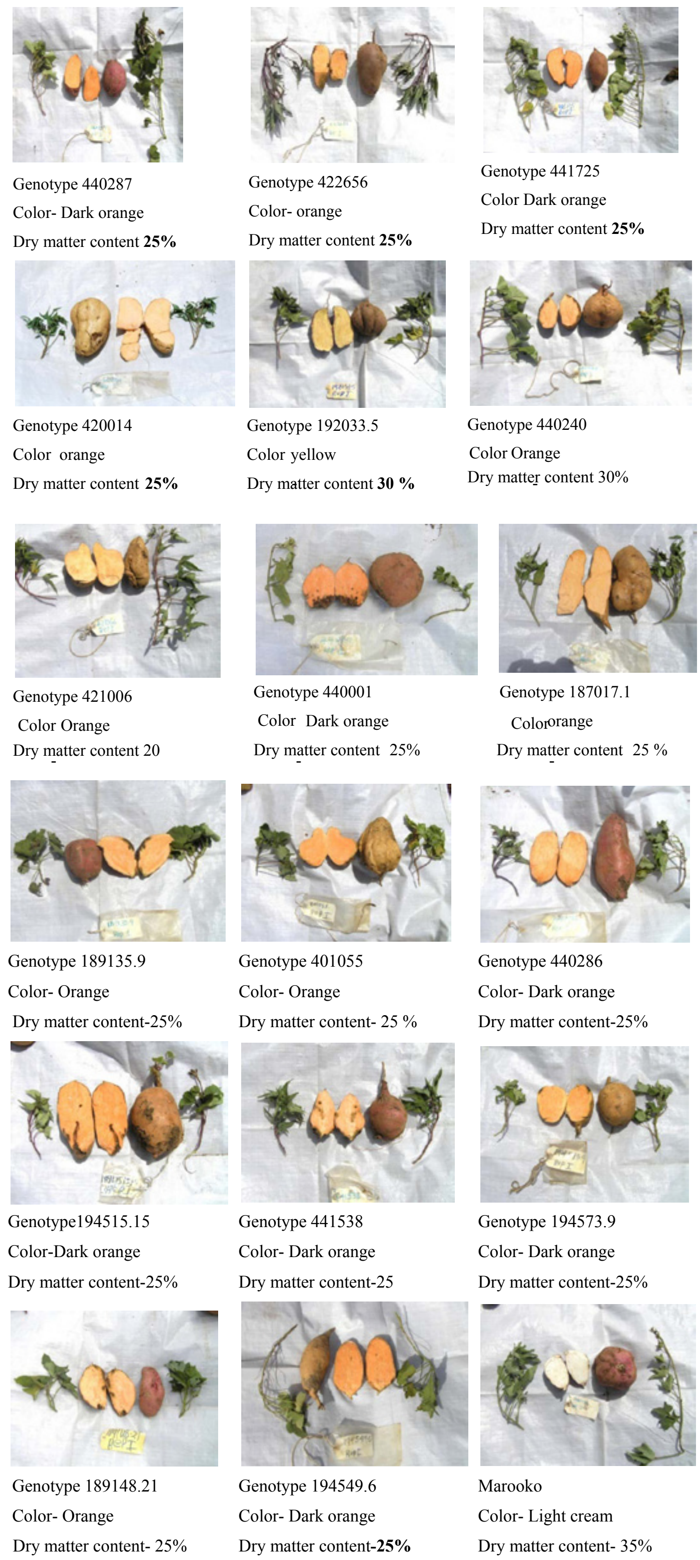

Figure 1: Genotypes screened and evaluated for drought tolerance at Kiboko and Marigat.

indices and biplot drawing in this experiment showed that genotypes with one addition component and two smaller components are suitable genotypes for moisture stressed and non stressed conditions. Fernandez [11] in his review used by-plot method to identify effective indices on evaluation and selection of Vetch genotypes stress tolerant plants and concluded that there is positive and meaningful correlation betweenYp and MP and STI indices and also between Yp and Ys with STI and MP indices. Therefore, the same indices can be introduced as appropriate indices to identify stress tolerant genotypes. Kaya et al. [12] in their study concluded that genotypes with large PC1 and small PC2 have higher yield in both stressed and non stressed conditions (stable) and genotypes with large PC1 and small PC2 have lower yield (unstable). Mollasadeghi [13] in their study on wheat genotypes concluded that indices MP, GMP and STI are very appropriate to identify high yield genotypes in both stressed and non-stressed conditions. Thus, drought indices providing a measure of drought based on yield loss under drought-conditions compared to normal conditions are being used in screening drought-tolerant genotypes [14].

A field evaluation study was conducted in two sites over a season to evaluate and select for drought tolerant orange-fleshed Sweet potato genotypes that are high in yield dry matter content and β-carotene levels.

Materials and Methods

Plant material and propagation

The genetic materials used in this study consisted of 18 genotypes with contrasting beta carotene and mineral content that were provided by International Potato Center (CIP) (Figure 1). These were imported as invitro plantlets from Lima, Peru. For initial propagation the materials were transferred into in vitro and routinely propagated from the nodal cuttings. Each node consisted of 0.2-0.5 cm stem segment with axillary with each circle lasting 2-4 weeks. The plantlets were raised on Murashige and Skoog (MS) basal solid medium, (Murashige and Skoog, 1962) containing 30g/litre sucrose and 2,8g/litre of phytogel maintained at pH 5.7. These were grown under long day conditions (16 hours of light at 3,000 lux and at temperatures ranging from 25°C to 28°C. These were later transferred to sterilized vermiculate soil in polythene bags in the screen house for a period of 2 months for acclimatization, multiplication and bulking. At harvest 24 cuttings each having a length of 30 cm were obtained from each genotyped for planting in the field.

The 18 genotypes were tested against 2 local: Marooko (drought tolerant) and K566632 (drought susceptible).

Experimental site

The trial was conducted at Kenya Agricultural Research centre experimental fields Kiboko (Latitude 010 15' S; Longitude 360 44' E; Altitude 975 m above sea level) and Marigat (Latitude 0° 28, 0" N, Longitude 35° 59, 0" E; Altitude 1067m above sea level) during the years 2009. The results of soil test for both sites are presented in Table 1 and 2. Both fields had similar soil fertility conditions. The soil pH at the two sites ranged between 7.75 and 8.10 and this classified the soils as medium alkaline. This was too alkaline for crops growth. Very low values for total Nitrogen, organic carbon was also observed for both sides. Phosphorus levels were generally high in Kiboko than in Marigat before planting and after harvesting. There were adequate levels of most nutrients required throughout the growth period.

Field	Kiboko – Before planting		Kiboko- after planting	
Soil nutrient	Value	Class	Value	Class
Soil pH	8.10	Medium alkaline	7.93	Medium Alkaline
Total Nitrogen %	0.09	Low	0.11	Low
Org, Carbon %	0.35	Low	0.54	Low
Phosphorus ppm	55	High	40	High
Potassium me %	0.80	Adequate	0.70	Adequate
Calcium me %	7.8	Adequate	5.8	Adequate
Magnesium me %	5.70	High	6.31	High
Manganese me %	0.52	Adequate	0.54	Adequate
Copper ppm	6.19	Adequate	5.53	Adequate
Iron ppm	31.4	Adequate	32.1	Adequate
Zinc ppm	8.89	Adequate	13.9	Adequate
Sodium me %	0.86	Adequate	0.54	Adequate
Elect. Cond. Ms/cm	0.55	Adequate	0.40	Adequate

Table 1: Soil analysis test- Kiboko experimental field 2008 short rain season.

Field	Kiboko – Before planting		Kiboko- after planting	
Soil nutrient	Value	Class	Value	Class
Soil pH	7.75	Medium Alkaline	7.35	Slightly alkaline
Total Nitrogen %	0.07	Low	0.09	Low
Org, Carbon %	0.27	Low	0.47	Low
Phosphorus ppm	16	Adequate	20	High
Potassium me %	1.94	High	1.84	High
Calcium me %	7.6	Adequate	7.6	Adequate
Magnesium me %	7.24	High	6.37	High
Manganese me %	0.77	Adequate	0.92	Adequate
Copper ppm	2.81	Adequate	4.14	Adequate
Iron ppm	54	Adequate	70.4	Adequate
Zinc ppm	21.1	Adequate	17.8	Adequate
Sodium me %	0.30	Adequate	0.34	Adequate
Elect. Cond. Ms/cm	0.35	Adequate	0.60	Adequate

Table 2: Soil analysis test- Marigat experimental field short rain season.

	Mean average rainfall (mm)					
Site	**September**	**October**	**November**	**December**	**January**	**February**
Kiboko	0	10	80	8	30	17
Marigat	24	7	80	0	4	0
Kiboko	Month					
Temp (°C)	September	October	November	December	January	February
Maximum	30	32	29.5	30.1	30.5	33.4
Minimum	15.50	17.00	18.50	19.00	18.60	19.50

Table 3: Rainfall (mm) (Kiboko and Marigat) and Temperature (°C) for Kiboko during the evaluation of sweet potato genotypes.

High rainfall was recorded during the month of November 2008 for both sites (Table 3). The rest of the months recived very minimal amount of rainfall (<10mm) which allowed expression of drought tolerance of the clones evaluated. High temperatures were also recorded during the trial period at Kiboko.

Experimental layout, treatment and crop husbandry

At each location, 3 blocks were planted with irrigation and 3 without irrigation. In each block, the 18 genotypes plus the 2 checks were included. Selected non-rooted Sweet potato apical stem cuttings approximately 30cm long displaying 3 nodes were planted below the soil surface. Split plot design was used with two levels of treatment – non-irrigated and irrigated as the main factor and genotypes as the sub-factor. All the treatments were laid out in a randomized complete block design. Individual plots consisted of five 1.2m long ridges 1m apart with 4 Plants per ridge. Planting distance was 0.3 m.

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Normal agronomic practices were carried out including regular manual weeding and earthing-up when it was deemed necessary. Over head irrigation was done for all the blocks for 4 weeks until all the plants had established and thereafter stress treatment imposed throughout the growth period for the non-irrigated treatment but continued with irrigation for the irrigated treatment for a period of 5 months when harvesting was done.

Data measurement

During harvesting the two outer rows in each plot were left out and only the three inner rows with a net plot size of 2.4 m^2 was used for data collection. For root observation total number of roots per net plot were counted and recorded. These were further weighed in kg and later converted to yields in tones per hectare.

Evaluation of susceptibility and tolerance of the genotypes

Stress tolerance index was used to identify genotypes with high stress tolerance and high yield potential. The biplot display of principal component analysis (Gabriel 1971) was used to identify stress-tolerant and high yielding genotypes and to study the interrelationship between the stress-tolerant attributes.

For every genotype, the six drought tolerance indices were calculated based on their root yield in normal irrigation and water deficit conditions. The drought tolerance indices were calculated as follows:

- Stress Susceptibility Index [15]:

$$SSI=\left[1-\left(\frac{Y_s}{Y_p}\right)\right]/SI$$

Where: $SI=1\left(\overline{Y_s}/\overline{Y_P}\right)$

- Mean Productivity [16]:

$$MP=\frac{Y_P+Y_S}{2}$$

- Tolerance [16]:

$$TOL=Y_P-Y_S$$

- Stress Tolerance Index [11]:

$$GMP=\sqrt{Y_P.Y_s}$$

- Geometric Mean Productivity [11]:

$$GMP=\sqrt{Y_P.Y_s}$$

- Harmonic Mean Productivity [17]:

$$HAR=\frac{2(Y_p-Y_s)}{(Y_p+Y_s)}$$

Where:

Yp = Yield of a genotype in normal irrigation condition

Ys = Yield of a genotype in water deficit condition

$\overline{Y_P}$ = Mean yield in normal irrigation condition

$\overline{Y_s}$ = Mean yield in water deficit condition

The biplot display of principal component analysis was used to identify stress tolerant and high-yielding genotypes and to study the interrelationship among the drought tolerance indices.

Statistical analysis

The PC-SAS procedures, GLM, PRINCOMP, GPLOT (SAS 1988) and PRINQUAL (SAS 1988) were used in developing the SAS codes to display the biplots.

	Y_p	Y_s	SI	Mp	GMP	TOL	SSI	STI
Y_p	1.000	0.671	0.434	0.098	0.875	0.965	0.435	0.862
		0.0012	0.056	<0.0001	<0.0001	<0.0001	0.055	<0.0001
Y_S	0.671	1.000	-0.202	0.793	0.875	0.965	0.435	0.862
	0.001		0.393	<0.0001	<0.0001	<0.0001	0.055	<0.0001
SI	0.434	-0.202	1.000	0.308	0.875	0.965	0.435	0.862
	0.056	0.393		0.187	<0.0001	<0.0001	0.055	<0.0001
Mp	0.983	0.793	0.307	1.000	0.945	0.903	0.310	0.923
	<0.0001	<0.0001	0.187		<0.0001	<0.0001	0.184	<0.0001
GMP	0.875	0.935	0.818	0.945	1.000	0.722	0.085	0.968
	<0.0001	<0.0001	0.732	<0.0001		0.0003	0.723	<0.0001
TOL	0.965	0.454	0.593	0.903	0.722	1.000	0.594	0.722
	<0.0001	0.044	0.006	<0.0001	0.0003		0.006	0.0003
SSI	0.435	-0.199	1.000	0.310	0.085	0.594	1.000	0.080
	<0.0001	0.400	<0.0001	0.184	0.723	0.006		0.738
STI	0.862	0.889	0.0773	0.923	0.967	0.722	0.075	1.000
	<0.0001	<0.0001	0.746	<0.0001	<0.0001	0.0003	0.738	

Y_P: Total root yield under normal irrigation condition; Y_S: Total root yield under water deficit condition; SI Susceptible index; MP: Mean productivity; GMP: Geometric mean productivity; STI: Stress tolerance index; TOL: Tolerance; SSI: Stress susceptibility index

Table 4: Pearson Corrélation Coefficients (N = 20 Prob > |r| under H0: Rho=0) for various drought tolerant indices for 18 genotypes screened at Marigat.

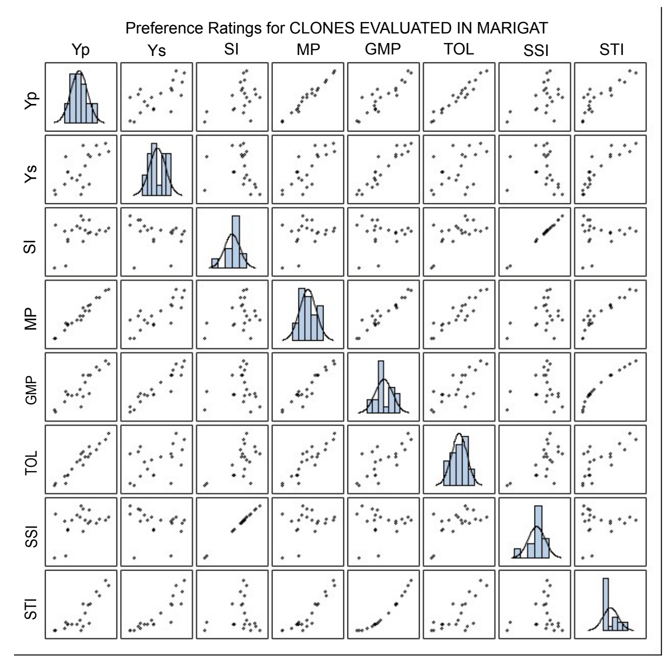

Figure 2: Scatter diagrams for various drought tolerant indices for the 18 genotypes screened at Marigat.

Results

Correlation matrix and estimation of drought tolerance indices

Correlation coefficients between Ys and Yp and other quantitative indices of drought tolerance were calculated for both sites (Table 4 and Figure 2 for Marigat and Table 5 and Figure 3 for Kiboko) to determine the most desirable drought tolerance criteria. High significant

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	Y_p	Y_s	SI	Mp	GMP	TOL	SSI	STI
Y_p	1.00	0.071	0.660	0.991	0.760	0.991	0.655	0.718
		0.767	0.002	<.0001	0.0001	<.0001	0.002	0.0004
Y_s	0.071	1.000	-0.569	0.203	0.676	-0.065	-0.574	0.660
			0.009	0.391	0.001	0.785	0.008	0.002
SI	0.660	-0.569	1.000	0.572	0.165	0.737	1.000	0.139
	0.002	0.009		0.009	0.488	0.0002	<.0001	0.558
Mp	0.991	0.203	0.572	1.000	0.836	0.964	0.566	0.792
	<.0001	0.391	0.009	1.000	<.0001	<.0001	0.009	<.0001
GMP	0.760	0.676	0.165	0.836	1.000	0.668	0.158	0.975
	0.0001	0.001	0.488	<.0001		0.001	0.507	<.0001
TOL	0.991	-0.065	0.737	0.964	0.668	1.000	0.733	0.628
	<.0001	0.785	0.0002	<.0001	0.001		0.0002	0.582
SSI	0.655	-0.574	1.000	0.566	0.158	0.733	1.000	0.131
	0.002	0.008	<.0001	0.009	0.507	0.0002		0.582
STI	0.718	0.660	0.139	0.792	0.975	0.628	0.131	1.000
	0.0004	0.002	0.558	<.0001	<.0001	0.003	0.582	

Y_p: Total root yield under normal irrigation condition; Y_S: Total root yield under water deficit condition; SI: Susceptible index; MP: Mean productivity; GMP: Geometric mean productivity; STI: Stress tolerance index; TOL: Tolerance; SSI: Stress susceptibility index

Table 5: Pearson Corrélation Coefficients (N = 20 Prob > |r| under H0: Rho=0) for various drought tolerant indices for genotypes screened at Kiboko.

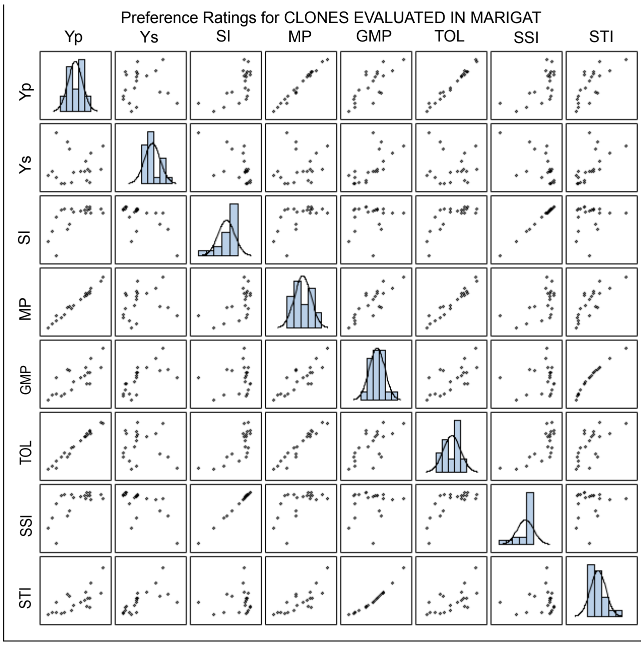

Figure 3: Scatter diagrams for various drought tolerant indices for the 18 genotypes screened at Kiboko.

correlations were found between root yield under stress environment and the drought indices Mp, GMP STI, TOL. Under irrigated condition significant correlation were found for root yield with Mp, GMP TOL and STI. The results showed high significant correlations among some drought tolerant parameters for root yield. A correlation of nearly one was found between STI and GMP and these were positively correlated with Mp and not with SSI. SSI was found to be correlated with TOL only at both sites. Using Fernandez's [11] parameter, STI, genotypes 421066, 194573.9, 192033.5, 187017.1 and 189135.9 with the highest values in both sites were considered to be tolerant genotypes, whereas genotypes 422656, 440240, 440001, Marooko and 401055 with the lowest STI were intolerant (Table 6 and 7). In case of the parameter TOL, the lowest difference between yields in both conditions (TOL) was observed for genotypes 401055, 440001, 422656, 441725 and 189135.9 but the highest difference belonged to genotypes 187017.1, 421066, 440286, 441097 and 194573.9. These results indicate genotypes with high STI usually have high difference in yield in two different conditions. In general, similar ranks for the genotypes were observed by GMP and MP parameters as well STI, suggesting that these three parameters are in equal for selecting genotypes. According to Fischer and Maurer's [15] parameter, SSI, the genotypes 441725, 401055, 189135.9, 194515.2 and 440001 for Kiboko and 187017.1, 189135.9, 440287, 194549.6 and 440286 for Marigat were in the lowest, which were considered as genotypes with low drought susceptibility and high yield stability in the both conditions, whereas the genotypes 440001 and 422656 for Marigat and genotypes 440286 and 189148.2 for Kiboko with SSI values higher than unit can be identified as high drought susceptibility and poor yield stability genotypes. Similar ranks for genotypes were also found by Yield Stability Index (YSI) (Table 6). In case of comparison between the parameters to selection of the genotypes, the TOL, SSI and YSI gave same results.

Biplot analysis

Present results obtained from biplot analysis for Marigat (Table 8, Figure 4) and Kiboko (Table 9, Figure 5) confirmed correlation analysis between studied criteria. Principal Component Analysis (PCA) for both sites revealed that the first PCA explained 66.05% for Kiboko and 73.08% for Marigat of the variation with Yp, Ys, MP, GMP and STI. Thus, the first dimension can be named as the yield potential and drought tolerance. The second PCA explained 30.59% (Kiboko) and 23.14% (Marigat) of the total variability. Therefore, the second component

Genotype	Y_p	Y_s	Mp	GMP	TOL	SSI	STI
421066	53.1	6.1	29.69	18.00	47.0	1.006	0.375
194573.9	42.6	5.3	23.95	15.03	37.3	0.995	0.261
192033.3	38.1	4.2	21.15	12.65	33.9	1.011	0.185
187017.1	51.3	3.1	27.20	12.61	48.2	1.068	0.184
189135.9	21.8	6.7	14.25	12.09	15.1	0.787	0.169
194515.2	23.3	5.8	14.55	11.62	17.5	0.853	0.156
420014	39.4	3.1	21.25	11.05	36.3	1.047	0.141
441097	41.8	2.9	22.35	11.01	38.9	1.058	0.140
K566632	36.9	2.9	19.90	10.34	34.0	1.047	0.124
440287	33.1	2.9	18.00	9.80	30.2	1.037	0.111
441725	12.2	7.8	10.00	9.76	4.4	0.410	0.110
194549.6	26.9	2.7	14.80	8.52	24.2	1.022	0.084
189148.2	38.8	1.7	20.25	8.12	37.1	1.087	0.076
440286	41.4	1.5	21.45	7.88	39.9	1.095	0.072
441538	25.3	1.5	13.40	6.16	23.8	1.069	0.044
422656	12.5	2.1	7.30	5.13	10.4	0.945	0.030
440240	19.6	1.3	10.45	5.05	18.3	1.061	0.029
440001	8.5	2.9	5.70	4.97	5.6	0.749	0.029
Marooko	16.5	1.3	8.90	4.64	15.2	1.047	0.025
401055	5.0	2.3	3.65	3.39	2.7	0.614	0.013
Mean	29.41	3.41	16.41	9..39	26.00	0.95	0.12
LSD(0.05)	5.64	1.35	6.51	3.73	10.32	0.38	0.05

Y_p: Total root yield under normal irrigation condition; Y_S: Total root yield under water deficit condition; MP: Mean productivity; GMP: Geometric mean productivity; STI: Stress tolerance index; TOL: Tolerance; SSI: Stress susceptibility index

Table 6: Estimation of drought tolerance indices based on total root yield of sweet potato genotypes under normal irrigation and water deficit conditions in Kiboko (SI= 0.84).

Genotype	Y_p	Y_S	Mp	GMP	TOL	SSI	STI
421066	30.7	8.00	19.35	15.67	22.70	0.999	0.959
194573.9	32.3	6.80	19.55	14.82	22.50	1.067	0.858
192033.3	25.0	7.70	16.35	13.87	17.30	0.935	0.752
187017.1	26.8	6.30	16.55	12.99	20.50	0.034	0.660
189135.9	17.4	7.60	12.50	11.50	9.80	0.761	0.517
194515.2	21.6	6.00	13.80	11.38	15.60	0.976	0.506
420014	20.4	6.29	13.30	11.25	14.20	0.941	0.494
441097	18.4	4.60	11.50	9.20	13.80	1.014	0.331
K566632	15.7	3.22	9.46	7.11	12.48	1.074	0.197
440287	7.1	6.00	6.55	6.52	1.10	0.209	0.166
441725	20.9	1.70	11.30	5.96	19.20	1.241	0.139
194549.6	8.7	3.60	6.15	5.59	5.10	0.792	0.122
189148.2	13.6	2.30	7.95	5.59	11.30	1.123	0.122
440286	8.4	3.60	6.00	5.50	4.80	0.772	0.118
441538	10.6	2.70	6.65	5.35	7.90	1.007	0.112
422656	17.6	1.30	9.45	4.79	16.30	1.252	0.089
440240	6.4	1.70	4.05	3.30	4.70	0.992	0.043
440001	15.9	0.20	8.05	1.79	15.70	1.334	0.012
Marooko	0.9	0.80	0.85	0.84	0.10	0.150	0.003
401055	1.2	0.18	0.69	0.45	1.02	1.149	0.001
Mean	15.98	4.03	7.67	7.67	11.96	0.94	0.31
LSD(0.05)	3.56	1.04	2.16	1.84	2.96	0.12	0.10

Y_P: Total root yield under normal irrigation condition; Y_S: Total root yield under water deficit condition; MP: Mean productivity; GMP: Geometric mean productivity; STI: Stress tolerance index; TOL: Tolerance; SSI: Stress susceptibility index

Table 7: Estimation of drought tolerance indices based on total root yield of sweet-potato genotypes under normal irrigation and water deficit conditions in Marigat (SI= 0.84).

Component	Cumulative %	Y^p	Y^S	Mp	TOL	SSI	STI
1	73.08	0.471	0.370	0.476	0.435	0.169	0.444
2	96.22	0.107	-0.032	-0.032	0.304	0.763	-0.254
3	99.04	-0.259	0.509	-0.090	-0.491	0.624	0.191
4	100.00	0.158	0.463	0.241	0.026	0.00	-0.838
5	100.00	0.335	0.307	-0.084	0.295	0.000	0.000
6	100.00	-0.750	0.220	0.000	0.624	0.000	0.000

Table 8: Principal component loadings for drought tolerance indices on the 18 sweet potato genotypes screened at Marigat.

can be named as stress-tolerant dimension and it separates the stress-tolerant genotypes from non-stress tolerant ones. Thus, selection of genotypes that have high PCA1 and low PCA2 are suitable for both stress and non-stress environments. PCs axes divided the genotypes into four groups. Group 1- genotypes with good performance and high drought tolerant, this included genotypes 420014,440286, 189148.2, 440287 and 441097 for Kiboko and genotypes 440286, 420014, 421006 and 189135.9 and 441725 for Marigat. These genotypes also had the highest amount of Yp, Ys, GMP, MP and STI. Group 2 which include genotypes with low performance are stable and less sensitive to drought. This group consisted of genotypes 401055, 194573.9 and 194549.6 for Marigat and genotypes 441538, 440240, 422656, 440001 and 194549.6 for Kiboko. Group 3 that included genotypes with low to moderate-yield performance and low relative sensitivity/ tolerance to drought. Genotypes that fell under this group included 422656, 440240, 441097, 194515.2, 192033.5 and 441538. Group 4 included genotypes with good performance but very sensitive to drought. Genotypes identified under this group included 421066 and 194573.9 for Kiboko and 440001 and 440287 for Marigat.

Discussion

STI, GMP and MP were strongly correlated with yield under both conditions, suggesting that these parameters are suitable to screen drought-tolerant, high yielding genotypes in both rainfed and irrigated conditions. Similar results were reported by Fernandez [11], Mohammadi et al. [18], Golabadi et al. [10]; Sio Se-Mardeh [9] and Mohammadi et al. [19], all of whom found these parameters to be suitable for discriminating the best genotypes under stress and irrigated conditions. In stress condition, root yield showed negative association with TOL and SSI. Similar observations were made by Bansal and Sinha [20], in wheat grain yield. Therefore, TOL and SSI indices are suitable factors to identify Sweet potato genotypes with low yield and tolerant to drought because under stress yield decreased with increasing SSI. In this study, genotypes 441725, 401055, 189135.9, 194515.2 and 440001 for Kiboko and 187017.1, 189135.9, 440287, 194549.6 and 440286 for Marigat had the lowest SSI value and therefore these genotypes had low drought susceptibility and high yield stability in both conditions, whereas genotype. 440001 and 422656 for Marigat and genotypes 440286 and 189148.2 for Kiboko with SSI values higher than unit were identified as high drought susceptible and poor yield stability genotypes.

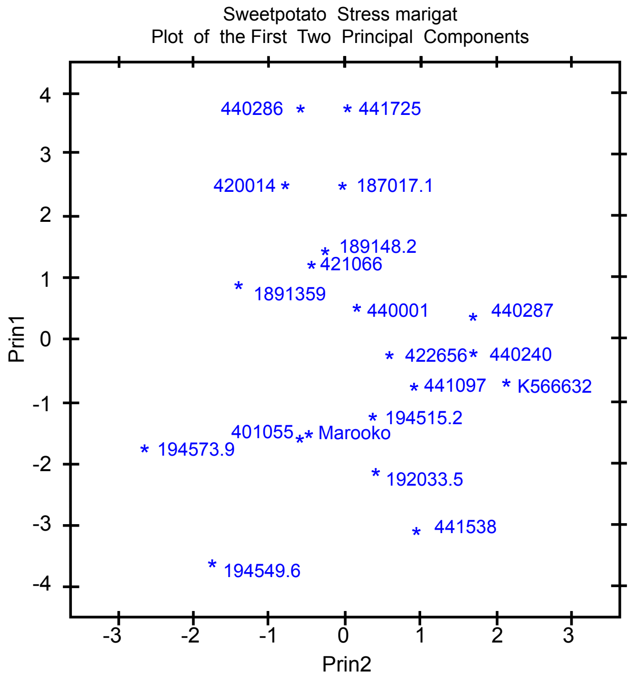

Figure 4: Biplot based on first two principal component axes (PC 1 and 2) for 18 sweet potato genotypes evaluated in Marigat.

Component	Cumulative %	Y^p	Y^S	Mp	TOL	SSI	STI
1	66.05	0.499	0.057	0.497	0.491	0.333	0.385
2	96.64	-0.027	0.723	0.070	-0.125	-0.511	0.440
3	99.10	-0.029	0.177	-0.259	-0.031	0.709	0.467
4	100.00	0.069	0.638	0.153	-0.018	0.354	-0.066
5	100.00	-0.814	0.002	0.407	0.414	0.000	0.000
6	100.00	0.000	0.187	-0.070	0.688	0.000	0.000

Table 9: Principal component loadings for drought tolerance indices on the 18 sweet potato genotypes screened at Kiboko.

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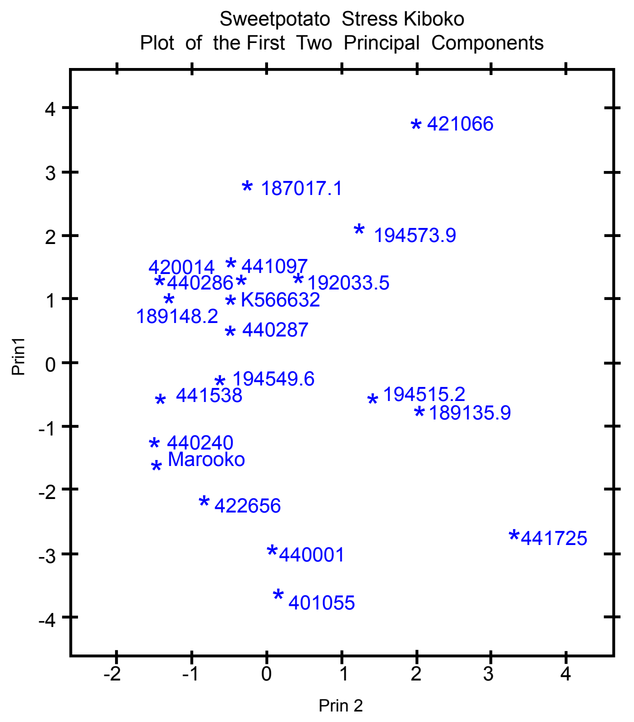

Figure 5: Biplot based on first two principal component axes (PC 1 and 2) for 18 sweet potato genotypes evaluated in Kiboko.

Similar results were reported by Golabadi et al. [10] and Talebi et al. [21], who showed that SSI can be a more useful index in discriminating better genotypes under rainfed condition. In the present study SSI and TOL were negatively correlated with Ys for both sites. Larger TOL and SSI values represent relatively more sensitivity to stress, thus smaller TOL and SSI values are favoured. Selection based on these two criteria favours genotypes with high yield potential under non-stressed conditions and low yield under stressed conditions [11]. In this study, genotypes 441725, 401055, 189135.9, 194515.2 and 440001 for Kiboko and 187017.1, 189135.9, 440287, 194549.6 and 440286 for Marigat had the lowest SSI value and therefore these genotypes had low drought susceptibility and high yield stability in both conditions, whereas genotype.440001 and 422656 for Marigat and genotypes 440286 and 189148.2 for Kiboko with SSI values higher than unit were identified as high drought susceptible and poor yield stability genotypes.

PCA was performed to assess the relationships between all attributes at once. The results obtained from biplots confirmed correlation analyses. Thomas et al. [22] observed that some 25 accessions of meadowfescue from seven countries investigated in four experiments could be distinguished based on a biplot display. The observed relations were also in agreement with those reported by Fernandez [11] in mungbean, Farshadfar and Sutka [17] in maize and Golabadi et al. [10] in durum wheat. In the present study, genotypes 420014,440286, 189148.2, 440287 and 44097 for Kiboko and genotypes 440286, 420014, 421006 and 189135.9 and 441725 for Marigat were identified as genotypes with good performance and high drought tolerant.

Conclusion

Genotypes 420014, 440286, 189148.7, 44109, 440287 and 187017.1 for Kiboko and genotypes 421066, 420014, 421006 194573.9, 192033.3 and 189135.9 for Marigat were identified as genotypes with good performance, high drought tolerance, high dry matter and high levels of beta carotene. The same genotypes had higher values of STI and very low suscepttability index in both sites. Correlation analysis revealed that Yield potential (Yp) and stress yield (Ys) had highly significant positive correlation coefficients with Stress Tolerance Index (STI), Mean Productivity (MP) and Geometric Mean Productivity (GMP) and they can be used as the most desirable indices for screening drought tolerance genotypes.

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