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Screening sweetpotato *(Ipomoea Batatas)* genotypes under soil moisture deficit condition using stress tolerance indices

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ABSTRACT

Sweet potato is generally known as drought tolerant crop, however cannot withstand drought during initial planting and during initial growth stages including development and tuber intitiation and thus there is need to identify appropriate genotypes adapted to drought conditions. The aim of this study was to evaluate different sweetpotato genotypes subjected to drought stress to identify the most drought tolerant genotypes and select the best index for investigating sweetpotato genotypes under stress and non-stress conditions. Twenty four sweetpotato genotypes were screened for drought tolerance under the screen house. The trial was assessed using a randomised complete block design with three replicates. The analysis of variance showed significant differences in genotypes under drought stress condition. Five different drought tolerant indices including mean product, geometric mean product, stress tolerance index, tolerance and stress susceptibility index were used to identify high yielding genotypes under both conditions. The stress susceptible index(SSI) is considered as suitable indices for sweetpotato where stress is severe while mean product (MP),geometric mean product (GMP), Stress tolerance index (STI), and Tolerance (TOL) were considered the potential indices for selecting high yielding sweetpotato genotypes under both conditions using harvest index yield component. Correlation analysis between harvest index yield under stress and non-stress condition showed positive correlation amongst GMP, MP and STI and showed that the most appropriate indices to identify drought tolerant genotypes were GMP, MP and STI.Principal component analysis through biplot was used to explain the variation between the harvest index yield component and the drought indices. The genotypes 1,2,3 and 5,were classed as drought tolerant and in group A while genotypes 4,8, and 7 were considered as group B and can produced high yield only under high soil moisture condition.

Key words: *sweetpotato landraces, genotypes, drought stress, tolerance indices, biplot analysis, correlation analysis, Stress tolerance index, stress susceptibility index*

INTRODUCTION

Drought, among other environmental factors, is the most important limiting factor in field crop production contributing to 75% yield looses worldwide (6,14) and especially in sweetpotato production, it reduces tuber and above ground biomass in areas where it is grown under rainfed conditions (19). Therefore, breeding for drought tolerance trait is not easily achievable and has been recognised to be a difficult challenge for breeders while progress in yield has been much better in favourable environments (21,2,7). Thus selection of drought tolerant plant is an important strategy in reducing the impact of plant water deficit.Sweetpotato is reported to be a moderately drought tolerant crop according (23). However, on the contrary sweetpotato cannot tolerate drought at the time of initial establishment and during initial growth stages including vine development and storage root initiation (23).

In Papua New Guinea sweetpotato remains the major staple crop as food and animal feed with major productions coming from the highlands region [4] apart from other tuber crops that provides 60-70 % of the local dietary needs. Currently, the available genotypes ability to produce sustainable yield under deficit water condition is not known with limited information available on their performance and this remains a challenge. Hence, screening and identifying improved drought tolerant sweetpotato gentotypes is of major importance. Identifying drought tolerant sweetpotato genotypes will improve profit margin for the resource poor farmers and will increase sweetpotato production in semi-arid regions of the country where seasonal drought and rainfall are major setbacks. Therefore, to identify drought tolerant genotypes under such conditions, drought tolerant and selection indices which provide a measure of drought based on yield loss under stress condition in comparison to non-stress conditions were employed in this study for screening drought tolerant genotypes (15,16) such as stress susceptibility index (SSI), mean product (MP), geometric mean product GMP, stress tolerance index (STI), tolerance,(TOL) which have been widely used in wheat, mungbean,chickpea and recently in sweetpotato(1,15,11,10,9) for drough tolerance screening were used. Among the indices (1,7,3,15,9) used drought tolerant indices in wheat, mungbean and orange flesh sweetpotato (OFSP) lines and found that MP, GMP and STI were more effective in selecting high yielding genotypes under both stress and non-stress condition and are also highly correlated with each other. According to Fernandez (9) genotypes can be divided into four groups, genotypes that express uniform superiority in stress and non-stress conditions (group A), genotypes which perform favourably only in non-stress conditions (group B), genotypes which yield relatively higher only in stress conditions (group C) and genotypes which perform poorly in both stressed and non-stressed make up (group D) by using principal component and biplot analysis to separate the genotypes accordingly. In this study harvest index yield component was used as the major trait to identify drought tolerant performing genotypes and the best indices for selection under stress and non-stress condition for sweet potato. Despite the above mentioned studies, information on drought tolerance ability of sweetpotato genotypes in Papua New Guinea is not known with limited information available causing a major setback for the number one staple crop.

Therefore, the aim of this study was to evaluate the sweetpotato genotypes to identify the most drought tolerant lines lines and select the best index for investigating sweetpotato genotypes under stress and non-stress conditions.

MATERIALS AND METHODS

Sweetpotato germplasm material used

The germplasm consisted of 102 sweetpotato genotypes sourced from all National Agricultural Research Institute sub-regional research centres under the EU_ARD project. The 102 sweetpotato genotypes were evaluated for phenological traits and yield components were separated according their time of maturity at 70 days, 98 days and 126 days after planting. About 24 (Table 1) out of 102 were selected based on their ability to produce high storage tuber yield at 70 days and 98 days respectively for this study. The 24 selected lines were sprouted using tubers in April 2014 and multiplied together in field to generate more planting materials for the screen house trial.

Table 1. List of the genotypes used in the study and their codes

Gcode	Genotype	Gcode	Genotype
1	MASUNG	13	K-142
2	SIMAT	14	SI-85
3	AIYIB 174	15	ASPBL 4
4	BSPBL 2	16	B-11
5	SINATO	17	BSPBL 9
6	MIRIAM	18	AIYIB 168
7	NIB 0801 - 001	19	ASPBL 5
8	BL 8d	20	5 ML 7e
9	RAB-36	21	NORTHERN STAR
10	BSPBL 8	22	LPO-3
11	BSPBL 4	23	BSPBL 1
12	VSP-3	24	BSPBL 7

ASPBL- Aiyura breeding lines and BSPBL denotes Bubia breeding lines,AIYIB-seed 4 needs

Screen house evaluation trial

The experiment was conducted in the screen house at the National Agriculture Research Instititute (NARI) Momase regional centre at Bubia located 6°14 S°,146 °06 E° at 20 m a.s.l in the Morobe Province of Papua New Guinea between September and November 2014. The soil media used in the experiment was collected from Department of Agriculture and Livestock (DAL) Erap station and mixed with sand in a 1:1 ratio and pastuerized. The growth medium was then watered for three days to field capacity before the 24 sweetpotato genotypes were planted into each allocated treatments. Each individual genotypes tip cuttings of 10-20 cm collected from the field were planted in each individual treatment filled with sterilized soil weighing about 500 kilograms (kg) in an upward position. The soil was filled into the boxes constructed of 240 x120x30cm with black polythene sheet to minimise the amount of water draining freely at the base and each small experimental units were separated by tie wire.

The experiment was assessed in randomised completed block design with three replications under non-stress and stress condition under the screen house. The plots in the stress experiment receive water up to 14 days to allow all plants to grow after which water was withheld till harvest at 70 days while under non-stress experiment water was maintained at field capacity for every five days, carefully not to flood the plots until harvest at 98days after planting (DAP). The plant spacing was 20cm x 20cm within and between plants consisting of 6 rows (6 plants wide x12 plants long). The study consisted of two separate experiments and plants were evaluated for yield, yield components and importantly harvest index yield (% HI) component . The harvest index was calculated by dividing the fresh storage root weight over fresh biomass multiply by 100 to convert to percent.

Determination of stress tolerance index

To determine the appropriate drought tolerance indices and identify drought tolerant sweetpotato genotypes under stress and non-stress condition and yield potential (Ys) and (Yp) for the 24 sweetpotato genotypes evaluated under the screen house. The six drought tolerant index were mathematically calculated based on the harvest index (HI) yield component which is defined as the fresh storage root weight divided by fresh biomass under stress and non-stress trial under screen house (1,9,8,10,3,11), use similar indices in their various studies in determining drought tolerant genotypes. The drought tolerance index used were calculated following the method used by (10,22,12,2,5,8), as follows., Stress Susceptibility Index (SSI) = $(1 - Ys/Yp)/SI$ where SI= $(1-\bar{Y}s/\bar{Y}p)$, Mean Productivity (MP) =$(Yp + Ys)/2$, Tolerance(TOL) = $(Yp - Ys)$, Stress Tolerance Index (STI) = $(Yp*(Ys)/(\bar{Y}p)^2$ Geometric Mean Productivity (GMP) = $\sqrt{(Yp * Ys)}$

Where: *Yp* = Yield of a genotype in normal stress condition, *Ys* = Yield of a genotype in water deficit or stress condition $\bar{Y}p$ = Mean yield in normal irrigation condition, $\bar{Y}s$ = Mean yield in water deficit or stress condition. The biplot analysis using principal component analysis and correlation analysis was used to identify stress tolerant and high yielding genotypes and their relationship between the two stress conditions (1,2,9,8,10)

Data Analysis

Data was subjected to analysis of variance (ANOVA) using genstat 14 edition, MS excel and statsgraphics software to determine the differences amongst the genotypes and the data variables assessed under the two different conditions. The mean comparison separation was done using Duncans multiple range test (DMRT). Biplot and principal component analysis was done using the genstat 14 edition version.

RESULTS AND DISCUSSION

Analysis of Variance

Results of the analysis of variance (ANOVA) of harvest index yield component (% HI) in both conditions showed that (Table 1) there was significant difference between the under study sweetpotato genotypes for harvest index (%) yield component in stress (drought) condition at ($P<0.05$) while it was observed that there was no significant or meaningful difference in non-stress conditions between the under study genotypes showing that there is existence of genetic variation amongst the sweetpotato genotypes. Similar results were reported by (3,7) in their various studies in bread wheat genotypes screening for drought tolerant indices respectively.

Mean comparison by Duncan method showed that (Table 2) under non stress condition the genotypes 1, 2 and 4 produced an average of 206.7, 262.8 and 288.6 (%HI) yield respectively. Under drought stress condition genotypes 7 produced 120(%HI) yield followed by 42, 2, 19 and 14. Under non-stress condition (Yp) the mean yield ranged from 30.7 to 288.6 % whereas under drought stress the yield mean (Ys) ranged from 1.6 to 120.00 (%HI) yield(Table 1). The average yield reduction due to drought was 31.5 %. The best yielding genotypes were 1, 2, 3, 4, under non –stress condition in terms of harvest yield index (% HI) due to high fresh vine weight, fresh storage root weight, marketable fresh storage weight and total biomass weight while the lowest was recorded in genotype 24. The HI was highest in non-stress condition compared to drought stress condition and this is in agreement with observation of (3) in their investigation in screening bread wheat genotypes for drought stress condition.

Table 1. Analysis of variance in two stress environments (stress (drought) and non -stress (irrigated)

Source	Df	Mean squares	
		Stress (drought)	Non-stress(irrigated)
Replication	2	7.423	3864
Genotypes	23	17.72**	15491^{ns}
Error	46	4.035	6695
CV %		19.1	9.0

Table 2. Mean comparison of sweetpotato cultivars by *Duncan Method (genstat)*

Genotype code	Stressed condition (drought)	Non-stress condition (irrigated)
1	58.2bcde	288.6a
2	70.6bc	262.8a
3	44.8cdef	266.0a
4	90.3ab	206.7a
5	41.8cdefg	187.2a
6	21.2defg	181.2a
7	120.0a	199.1a
8	57.0bcde	162.3a
9	30.5cdefg	182.1a
10	33.0cdefg	167.0a
11	32.4cdefg	153.5a
12	37.6cdefg	138.6a
13	35.7cdefg	123.3a
14	62.6bcd	107.5a
15	51.0bcdef	106.8a
16	1.6g	103.4a
17	45.5cdef	101.7a
18	17.6efg	99.7a
19	66.6bc	77.6a
20	46.0cdef	64.0a
21	34.0cdefg	59.0a
22	20.6defg	65.9a
23	32.5cdefg	39.3a
24	12.7fg	30.7a

Note: ASPBL- Aiyura breeding lines and BSPBL denotes Bubia breeding lines, (Gcode table 1)

Table 1. Harvest index yield in non stress, stress and drought stress indices

Genotype code	YP	YS	SSI	MP	TOL	STI	GMP
1	288.6	58.2	2.53	173.4	230.4	0.85	129.6
2	262.8	70.6	2.32	166.7	192.2	0.94	136.2
3	266	44.8	2.63	155.4	221.2	0.6	109.2
4	206.7	90.3	1.78	148.5	116.4	0.94	136.6
5	187.2	41.8	2.46	114.5	145.4	0.4	88.5
6	181.2	21.2	2.80	101.2	160.0	0.19	62.0
7	199.1	120.0	1.26	159.6	79.1	1.21	154.6
8	162.3	57.0	2.05	109.7	105.3	0.47	96.2
9	182.1	30.5	2.64	106.3	151.6	0.28	74.5
10	167	33.0	2.54	100.0	134.0	0.28	74.2
11	153.5	32.4	2.5	93.0	121.1	0.25	70.5
12	138.6	37.6	2.31	88.1	101.0	0.26	72.2
13	123.3	35.7	2.25	79.5	87.6	0.22	66.3
14	107.5	62.6	1.32	85.1	44.9	0.34	82.0
15	106.8	51	1.65	78.9	55.8	0.28	73.8
16	103.4	1.6	3.12	52.5	101.8	0.01	12.9
17	101.7	45.5	1.75	73.6	56.2	0.23	68.0
18	99.7	17.6	2.61	58.7	82.1	0.09	41.9
19	77.6	66.6	0.45	72.1	11.0	0.26	71.9
20	64.0	46.0	0.89	55.0	18.0	0.15	54.3
21	59.0	34.0	1.34	46.5	25.0	0.1	44.8
22	65.9	20.6	2.18	43.3	45.3	0.07	36.8
23	39.3	32.5	0.55	35.9	6.8	0.06	35.7
24	30.7	12.7	1.86	21.7	18.0	0.02	19.7
Mean	140.6	44.4	1.99	92.45	96.26	0.35	75.52

Data on the selected drought stress indices are presented in (Table 3).The estimation of stress tolerance and identification of drought tolerant crop genotypes based on single trait is contradictory (8). Using the Fernandez stress index (STI) and other various indices of drought tolerance to determine the yield potential of sweetpotato genotypes in stress and normal condition revealed that genotypes with high STI values have high yield difference in two different environments and thus, represents high drought tolerant genotypes and its high yielding potential (1,20). Genotypes 7,4,2,1 had the highest STI and GMP rates while genotype 16 and 24 had the lowest rate (Table 3) (a high STI rate for genotype signify its high drought resistant and its yield potential) with similar results reported on drought toleranc studies in 30 wheat genotypes in Iran (20) and high GMP rates for genotypes showed its high drought resistance which is very useful in differentiating group A from other groups (20). Genotype 23 and 1 and 3, displayed the minimum and maximum amount of TOL (a high TOL rate for genotypes represents susceptibility to stress), also this index cannot separate group C from group A (Table 3). Our findings are consistent with those of

(2,9,11) in their studies in screening wheat for drought tolerance. Genotype 24 had the lowest rate of MP compared to genotype 1 which has the largest rate (selecting based on this index will result in an increase in average amount of yield between the two environments) [16] and can not separate group B from group A genotypes. On the other hand, gentopye 16 recorded the highest susceptible index of SSI while genotype 19,23 and 20 recorded the lowest SSI index and were considered the most desirable drought tolerant genotype (resistant) because they exhibit smaller yield reduction under stress condition compared with non-stressed condition than the mean of alls genotypes (7). A large rate of SSI index indicates the genotype's susceptibility to drought and thus not separate group A genotypes from group C. Similar results were reported by (1) on 18 orange flesh (OFSP) sweetpotato genotypes in Kenya and [13] on screening 84 genotypes for drought tolerance under screen house and field using drought tolerance index (DSI) which is also similar to SSI.

Correlation Analysis

Correlations between the two stressed conditions (Yp) and (Ys) and the five quantitative drought tolerant indices are presented in Table 3. The indices were calculated to determine the appropriate drought tolerant indices for screening sweetpotato. The results of the correlation analysis showed that there was significant and positive correlation between STI and GMP, STI and MP (Table 4 and Figure 1) and are considered suitable drought tolerant indices for screening drought tolerant genotypes in sweetpotato. Similar results were reported by (9,8,3,2), in bread wheat (11,17) on durum wheat, (1) orange flesh sweetpotato (OFSP), (15,7,20), in wheat genotypes and (24) in mungbean on their various study on screening for drought tolerance indices found these indices most desirable in selecting potential genotypes under stress and non-stress condition. The yield in non-stress condition is highly correlated with indices GMP, MP, STI, and TOL (Table 4 and Figure1) with similar results reported by (24) in their multivariate analysis on wheat. The sweetpotato harvest index (%) under stress had positive and significant correlation with MP, GMP and STI but was negatively correlated with SSI and TOL index (Table 4 and Figure 1). These results are in agreement with findings of (20,10,9,11,1). This results suggested that with the positive correlation found among STI, GMP , MP and their positive relationship with harvest index (%) of sweetpotato genotypes, these indices are introduced as the best indices for selection in both conditions. Our study corresponds with previous investigation in wheat and sweetpotato (11, 20,15,1).

Table 4. Multiple variable analysis correlation between five stress indicators (statgraphics)

	YP	YS	GMP	MP	SSI	STI	TOL
YP	1	0.44**	0.82**	0.96**	0.50**	0.79**	0.93**
YS	0.44**	1	0.86**	0.66**	-0.44**	0.86**	0.09
GMP	0.82**	0.86**	1	0.94**	0.00	0.97**	0.57**
MP	0.96**	0.66**	0.94**	1	0.28	0.91**	0.80**
SSI	0.50**	-0.44	0.00	0.28	1	-0.01	0.73**
STI	0.79**	0.86**	0.97**	0.91**	-0.01	1	0.53**
TOL	0.93**	0.09	0.57**	0.80**	0.73**	0.53**	1

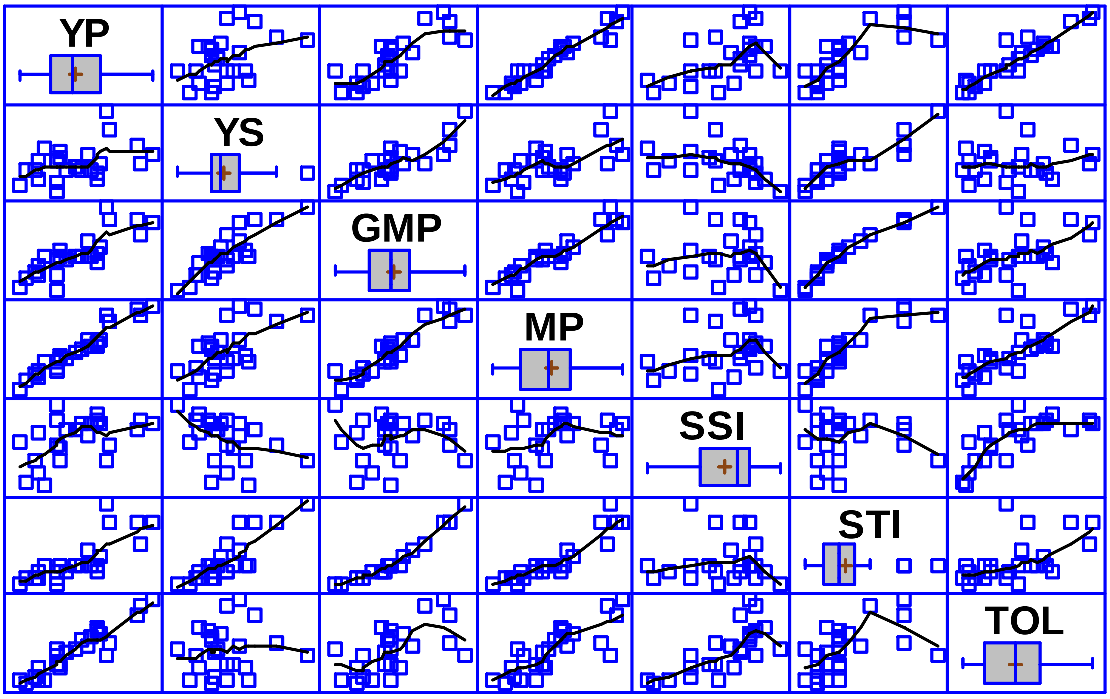

Figure 1.Multiple variable correlation graph based on matrix plot of the drought indices

Table 5. Principal components

Drought indices	Principal components	
	1	2
YP	0.432	0.211
YS	0.316	-0.501
GMP	0.434	-0.199
MP	0.453	0.026
SSI	0.120	0.658
STI	0.426	-0.212
TOL	0.353	0.433
Eigenvalue	4.1	1.9
Cumulative (%)	69.2	28.3

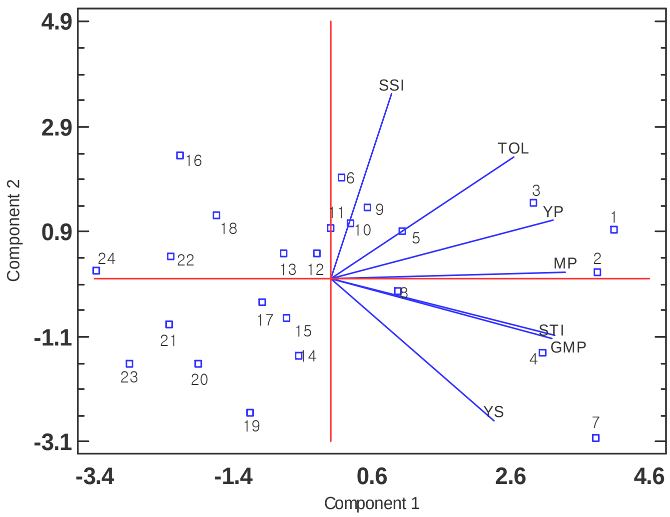

Figure 2. Biplot of sweetpotato genotypes and drought tolerant indices based on first and second principal components in two drought stress and non-drought stress conditions (see table 1 for details on genotype code)

Principal component and Biplot analysis

To assess the relationship between sweetpotato genotypes and drought tolerance indices, principal component analysis was utilised (Table 5) that condenses the five indices to only two components. The total variation expressed between the two components was 97.5%.The first PCA1 vector shows 69.2% of variation. This dimension emphasized the sweetpotato yield (HI%) stress and normal conditions of Yp,Ys, GMP, MP, and STI and can distinguish genotypes A from other groups (20). Considering the positive values of principal component 1 analysis (PCA 1) on biplot, selected sweetpotato genotypes will be high yielding under stress and non-stress conditions. The second component shows 28.3% of the variation and was postitively correlated with TOL and YS and is considered as the susceptible component (Table 5 & Figure 2) and refers mostly to yield (HI%) in normal condition. Therefore, selection of genotypes that have high PCA1 and low or negative PCA 2 values (Table 5) are suitable for stress and non-stress conditions. According to (11,9) obtain similar results in durum wheat and mungbean respectively. Moreover, this result confirms the investigation of Normand (18) in wheat and (24) in mungbean. In the current study, significant positive correlation between STI, GMP, STI, MP, STI, YS and STI, YP were revealed in the biplot (Figure 1). The biplot analysis relationship amongst the above indices revealed that the most appropriate criteria for selecting genotypes under stress and non-stress conditions are GMP, MP and STI. The result obtained from principal component through biplot analysis provides valuable information in data analysis and confirms correlation analysis. These results are in compatible with the findings of (7,3,1,9,11). The value of the first components identifies the maximum genotype as 1 and minimum as 24 (Figure 1). Furthermore, genotype 1 displayed maximum yield under normal condition while 23 and 24 has less yield in both stress and normal condition as a result genotype 1 was placed in group A while 23 and 24 was placed in group C and D respectively. With regard to the aforementioned Fernandez classification, genotypes 1,2, 3,5,10,9 and 6 are classed as group A genotypes and are considered drought tolerant and produced good harvest index (%) in both stressed and non-stressed conditions. The genotypes that performed well in non-stress conditions are classed as group B and made up of the following genotypes 7,4 and 8. The group C genotypes are genotypes that yield highly in stress conditions and consisted of genotypes 16,18,13,12,22 and 24, however, genotrypes in group A can also move into group C. The final grouping is group D genotypes and this includes genotypes, 14,15,17,19, 20, 21 and 23, produced low yields in either stress or normal conditions. Regarding the biplot of figure 1, the genotypes 2,1,3 and 5 which located between the yield figure of stress and normal condition and the indices of MP, GMP, and STI are identified as the most stress tolerant genotypes and are recommended for low water stress regions while under high soil moisture or non-stress conditions the genotypes 8,4,and 7 are recommended based on the above indices and the biplot (Figure 2).

CONCLUSION

The general finding of this study revealed that sweetpotato genotypes 1,2,3 and 5 were identified as genotypes with good harvest index (%) under both stressed and non-tressed condition and highly drought tolerant while genotypes 4,8 and 7 were identified as best genotypes under group B and cannot compared with those in group C. The same genotypes had higher STI, GMP and MP values suggesting that they are highly tolerant under both conditions. Correlation analysis revealed that the yield potential (YP) and stressed yield (YS) were highly positive with stress tolerance indices STI, MP, and GMP and can be used as the most appropriate indices for selecting of drought tolerance genotypes. SSI is suggested as a useful indicator for places where stress is severer.

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