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Original article

EVALUATION OF DROUGHT TOLERANCE INDICES IN SOME NIGERIAN BAMBARA GROUNDNUT (*VIGNA SUBTERRANEA* L. VERDC.) LANDRACES

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Abstract

Bambara Groundnut is the third most commonly eaten legume and a major source of protein for resourced poor farmers in Nigeria. In order to identify variations in drought tolerance indices of bambara groundnut landraces in Nigeria and to investigate the relationships between seed yield and drought tolerance indices, an experiment was carried out using 28 bambara groundnut landraces collected from farmers from four geo-political zones of Nigeria, as well as National Centre for Genetic Resources and Biotechnology (NACGRAB). The experiment was carried out during the cropping season of 2016 between July and October. The accessions were grown in a randomized complete block design in two treatments: Water stressed (T1) and non-water stressed (T2) with five replicates. Seed yield in respective non-stress (YP) and stressed (YS) treatments ranged from14-51 and 6-28 seeds per plant respectively. Stress susceptibility index (SSI), Stress Tolerance index (STI), Mean Productivity (MP), Geometric mean Productivity (GMP),Tolerance index(TOL), Harmonic mean(HM), Yield index(YI), Yield reduction (YR) and Yield stability index(YSI) ranged from 0.19- 1.69, 0.08- 1.80, 7.75 – 38.63, 7.65- 36.59, 1-37, 7.55-37.06, 0.47-2.11, 0.10 - 0.86 and 0.14 - 0.93 respectively. Pearson's linear correlations between Ys and Yp, MP, GMP, STI, YSI, HM and YI were significantly positive ($P<0.01$). This experiment suggests the possibility of using MP, GMP, STI, HM and YI to improve Bambara groundnut yield under water stress and non- stressed environments.

Keywords: Bambara groundnut, drought, tolerance indices, stress, seed yield

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INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an indigenous African leguminous crop belonging to the family Fabaceae and sub-family Faboideae. It originated from West Africa and is now widely distributed throughout the semi-arid regions of Sub Saharan Africa

(Hillocks et al., 2012). It is an herbaceous annual crop growing up to about 0.30-0.35m in height with glabarous trifoliate leaves (Bamshaiye et al., 2011). It is cultivated majorly for its seeds which are produced in pods under the ground. The seeds may vary in coat colour having cream, brown, dark brown, red, dark red, speckled and black seed coats. There are also variations in the seed eye colour and pattern such as plain, black, brown, chalk-white, ash and red-butterfly patterns (Mohammed et al., 2013). Bambara groundnut is a potential crop in contributing to world food security. Ouedraogo et al. (2008) described bambara groundnut seeds as a complete balanced diet, making it a good supplement to cereal- based diets. The seed contains 63% carbohydrate, 19% protein, 6.5% oil (Goli, 1995), and minerals like calcium, 95.5- 99 mg/100 mg, iron 5.1- 9 mg/100 mg, potassium 11447-14355 mg/100 mg and sodium 2.9-10.6 mg/100 mg (Karikari et al., 1997). The red seeds are useful in areas where iron is deficient as they contain almost twice iron as the cream seeds. The seeds can be eaten fresh or boiled after drying. It can also be processed and used in diverse ways. Seeds can be milled to make flour; a paste is made out of the flour and then used in the preparation of various fried or steamed products, such as 'akara' and 'moin-moin' (Okpuzor et al., 2010). Another favorite Nigerian dish made from bambara groundnut is 'Okpa', which is obtained by wrapping the doughy paste in banana leaves or polythene and then boiled.

The high nutritive value of bambara groundnuts and its many uses have brought about an increase in demand of the crop in Nigeria which necessitates an increased supply. Although bambara groundnut is generally considered to be hardy and drought tolerant when compared with other leguminous crops like cowpea and groundnuts, The production is best suited between latitude of 20°C– 30°C, i.e. the tropical wet and dry and the subtropical dry summer climate zones. Optimal temperature is between 19°C and 30°C.Temperatures below 16°C and above 38°C are not suited for the production of bambara groundnut. The minimal annual rainfall requirement is about 300 mm and optimal annual rainfall is between 750 mm and 1400 mm and should not exceed 3000 mm (FAO, 2011).

Recent studies showed that drought has posed a threat to Bambara groundnut productivity especially in the semi- arid regions (Tanimu and Aliyu, 1995; Vuraiyai, 2011a). Mohammed (2014) reported that the area under bambara groundnut cultivation in the Sahel and Sudan Savanna zones of Nigeria has declined over the past two decades. Farmers in these areas estimated that the area under cultivation of bambara groundnut presently is about 5-20% of that of 20 years ago. They attributed this decline to drought. Drought has been reported by Bhaswatee et al. (2012) to be the most universal and significant environmental stress that limits plant growth and productivity worldwide. Therefore, increasing bambara groundnut yield in Nigeria will require developing improved varieties that are drought tolerant hence the need for determining suitable indices that can be used for the selection of drought tolerant accessions in Bambara Groundnut. Drought tolerance indices which provide a measure of drought tolerance based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). Such indices include tolerance index (TOL), susceptibility index (SSI), mean productivity (MP) and stress tolerance index (STI).

MATERIALS AND METHODS

The seeds used for the study were collected from farmers in seven States in Northern Nigeria such as Niger, Kogi, Plateau, Kaduna, Nassarawa, Adamawa and Jigawa States. Some seeds were also collected from National Agency for Genetic Resources and Biotechnology (NACGRAB) Ibadan, Nigeria. The seeds were sown at the Department of Biological Sciences Experimental garden, Federal University of Technology Minna, Niger State. Minna is located between latitude $90^0 31'$ and $90^0 45'$ North and longitude $6^0 31'$ and $6^0 45'$ East of the equator. The area falls within the Southern Guinea savannah vegetation zone of Nigeria with an annual precipitation varying from 1,100-1,600mm, mean temperature between 21^0 C and 36.5^0 C and relative humidity between 50 to 61%. (The Nigerian Congress, 2007).

Bambara groundnut accessions were grown in two different treatments.T1- Non Water stressed condition (Plants were rain fed throughout the experiment) and T2- Stressed condition (Plants were deprived of water for 14 days during the flowering period by transferring plants to a shade house made of transparent polyvinyl ceiling). The accessions were grown in planting bags in a randomized complete block design with five replicates. Two seeds were sown per bag and the bags were given aspacing of 30 x 30 cm (inter andintra row spacing) and later thinned to one 2 weeks after planting.The number of seeds (NS) produced per plant were determined at the time of harvest by, sun drying and opening the pods and counting the number of seeds which was determined by their large size and firmness.

The following drought tolerance indices were determined according to the method of Wonderwosen *et al*., (2012) for each accession in each of the treatments.

Tolerance index (TOL) = Yp_i-Ys_i (Wonderwosen *et al*., 2012)

Mean productivity (MP) = $Yp_i + Ys_i / 2$ (Hossain *et al*., 1990)

Geometric mean productivity (GMP) = $(Yp_i . Ys_i)^{1/2}$ (Fernandez ,1992)

Stress intensity (SI) = 1- (Ys/Yp) (Wonderwosen *et al*., 2012)

Stress susceptibility index (SSI) = $(1-Ys_i / Yp_i) /SI$ (Gavuzzi*et al*., 1997)

Stress tolerance index (STI) = $Yp_i \times Ys_i / Yp^2$ (Fernandez, 1992)

Yield index (YI) = Ys_i / Ys (Gavuzzi *et al*., 1997)

Harmonic Mean = 2 (Yp x Ys) / Yp + Ys (Fernandez, 1992)

(Ys_i = Yield in stress environment,; Yp_i= Yield in Non- stress environment; Ys = Mean yield in stress environment; Yp=Mean yield in non-stress environment)

Simple correlations between yield and drought tolerance indices were determined for the bambara groundnut accessions.

Results and Discussion

The bambara groundnut accessions collected from farmers in the seven Northern States of Nigeria and from National agency of genetic resources and Biotechnology (NACGRAB) were made up of a variety of seed coat colours and also eye colours. The summary of the phenotypic characteristics of the seeds are represented in Table 1. Godwin and Moses (2013) who conducted a participatory rural appraisal of bambara Groundnut in Kogi and Benue States of Nigeria also reported that farmers possessed seeds with various seed coat colours and eye colours.

Bambara groundnut improvement for drought tolerance requires reliable assessment of drought tolerance variability among landraces. Loss of yield is the main concern of plant breeders and they hence emphasize on yield performance under stress conditions. Thus drought indices which provide a measure of drought based on loss of yield in drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes (Mitra, 2001).The yield of bambara groundnut accessions determined as a function of number of seeds produced per plant varied both in the stressed (Ys) and non-stressed plants (Yp). The number of seeds produced by accessions in non-stressed environment ranged from 14 (NGR- NI-18) to 51 (NGB-01646-B) seeds per plant while in the stressed condition, it ranged from 6 (NGR-NI-23C) to 28 (NGR-NI-20-H) seeds per plant. TOL,YR, SSI, STI, YI, MP, YSI, GMP, HM ranged from 1-37, 0.10- 0.86, 0.19- 1.69, 0.08- 1.80, 0.47- 2.11, 7.75 - 27.88, 0.14- 0.91, 7.65- 36.59 and 7.55- 37.06 respectively. (Table 2)

To determine the most desirable drought tolerance criteria, the correlation between YS, YP, and the other quantitative indices of drought tolerance were determined (Table 3). The results showed that there were significant positive correlations among YS and (YP,STI, YI,MP,YSI,GMP and HM) , YP and (TOL, YR, STI, YI, MP, GMP and HM). Significant negative correlations were observed between SSI and (YS, YP, YSI),YSI and (TOL, YR). The highest positive correlation was found between GMP and STI (0.978) and between GMP and MP (0.962), while highest negative correlation was observed between YSI and YR (-1.00) and between YSI and SSI (-0.999). The observed correlations were consistent with those observed by Golabi *et al.*, (2006) in Durum wheat. Toorchie*et al.*,(2012) also reported similar significant positive correlations between YS, YP, MP and GMP. Significant negative correlation between SSI and YS, YP was also observed by Farshadfar *et al.*, (2012b) in landrace wheat. The positive significant correlation observed between yield in stressed conditions (YS) and the yield in normal or non-stressed (YP) is an indication that high yield performance under favourable conditions resulted in relatively high yield under stressed condition.

According to Fernandez (1992) the best measure for selection of the best drought tolerance indices should be able to separate landraces which have desirable and similar yield in both stressed and non-stressed conditions. Drought resistance is defined by Itall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. From the result, it was observed that YI, MP, GMP, STI and HM had high significant positive correlation with yield both in stressed and non-stressed conditions. Hence they can be used as better indicators of drought tolerance in bambara groundnut breeding programs. Jafari *et al.* (2009) found that STI, GMP indices which showed the highest correlation with grain yield under both optimal and stress conditions can be used as the best indices for selection of drought tolerant genotypes in maize. Ilker *et al.* (2011) also concluded that MP,GMP and STI values are convenient parameters to select high yielding wheat genotypes in both stress and non-stress conditions.

Conclusion

From this experiment, it can be concluded that water stress reduced yield of Bambara Groundnut Landraces in Nigeria. Also Drought Tolerance indices such as STI, MP, GMP,YI and HM which showed significantly high positive correlations with yield in both stressed and non-stressed conditions are good indicators or parameters to be used for the screening and selection of drought tolerant genotypes in Bambara groundnut.

Table1. Sources of Bambara Groundnut accessions used in the study.

S/NO	ACCESSION NUMBER	STATE	SEED COAT COLOUR AND PATTERN
1	NG-KG-01	Kogi	Brownish Red
2.	NG-KG-02-C	Kogi	Light red
3.	NG-KD-08-E	Kaduna	Dark red
4.	NGR-PL-12	Plateau	Brownish red seeds

5.	NGR-PL-13	Plateau	Cream Brown spots/stripes
6.	NGR-NS-15	Nassarawa	Cream black stripes
7.	NGR-JG-17-A	Jigawa	Cream purplish stripes
8.	NGR-JG-17-B	Jigawa	Cream
9.	NGR-JG-17-C	Jigawa	Cream
10	NGR-NI-18	Niger	Black
11.	NGR-NI-20-B	Niger	Light red
12.	NGR-NI-20-H	Niger	Brown/ brown below hilum
13.	NGR-NI-20-I	Niger	Black
14.	NGR-NI-20-J	Niger	Brown
15.	NGR-NI-20-K	Niger	Cream
16.	NGR-NI-22	Niger	Variegated cream black
17.	NGR-NI-23-C	Niger	Cream
18.	NGR-NI-25-A	Niger	cream brown spots/ stripe
19.	NGR-NI-27	Niger	Cream purplish spots
20.	NGR-AD-28-B	Adamawa	Grey brown
21.	NGB-01486-A	NACGRAB	Cream
22..	NGB- 01493	NACGRAB	Cream
23.	NGB-01496	NACGRAB	Cream purplish spots
24.	NGB-01491	NACGRAB	Cream
25..	NGB-01311	NACGRAB	Cream
26.	NGB-01646-B	NACGRAB	Cream with brown spots
27.	NGB-01646-C	NACGRAB	Grey black
28.	NGB-01645-A	NACGRAB	Cream

Table 2: Some Drought Tolerance indices of Bambara groundnut accessions

S/NO	ACCESSION	YS	YP	TOL	YR	SSI	STI	YI	MP	YSI	GMP	HM
1.	NGB01491	20.25	35.50	15.00	0.45	0.88	0.97	1.52	27.88	0.57	26.81	25.79
2.	NGB-01493	18.25	28.75	10.50	0.37	0.73	0.71	1.37	23.50	0.63	22.91	22.33
3.	NGR-NI20-K	13.25	30.25	17.00	0.56	1.09	0.54	0.99	21.75	0.44	20.02	18.43
4.	NGB-01311	8.00	25.25	17.25	0.68	1.33	0.27	0.59	16.63	0.32	14.21	29.98
5.	NGB-01486-A	13.75	36.25	22.25	0.62	1.23	0.67	1.03	25.00	0.38	22.33	19.94
6.	NGR-NI-23-C	6.25	43.25	37.00	0.86	1.69	0.36	0.47	24.75	0.14	16.44	10.92
7.	NGB-01645A	10.00	32.25	22.25	0.69	1.35	0.43	0.75	21.13	0.31	17.96	15.27
8.	NGR-NI-18	12.75	13.75	1.00	0.10	0.19	0.24	0.95	13.25	0.93	13.24	13.23
9.	NGR-NI-20-I	16.75	18.50	1.75	0.10	0.20	0.42	1.25	17.63	0.91	17.60	17.58
10.	NGR-NI-22	7.00	16.00	9.00	0.56	1.09	0.15	0.52	11.50	0.44	10.58	9.74
11.	NGR-KG-02C	6.50	9.00	2.50	0.28	0.55	0.08	0.49	7.75	0.72	7.65	7.55
12.	NGR-KG-01	15.25	32.00	16.75	0.52	1.02	0.66	1.14	23.63	0.48	22.09	20.66
13.	NGR-NI-20-B	9.75	17.50	7.75	0.44	0.86	0.23	0.73	13.63	0.56	13.06	12.52
14.	NGR-PL-12	13.50	35.25	21.75	0.62	1.22	0.64	1.01	24.38	0.38	22.02	19.52
15.	NGR-KD-08-E	13.75	19.50	5.75	0.29	0.57	0.36	1.03	16.63	0.71	16.37	16.1
16.	NGB-01496	15.75	29.75	14.00	0.47	0.92	0.63	1.18	22.75	0.53	21.65	20.5
17.	NGR-NI-27	10.25	25.00	14.75	0.59	1.16	0.34	0.77	17.63	0.41	16.01	14.5
18.	NGR-NI-25-A	6.50	19.00	12.50	0.66	`1.29	0.17	0.49	12.75	0.34	11.11	9.69
19.	NGR-PL-13	11.25	20.00	8.75	0.44	0.86	0.30	0.84	15.63	0.56	15.00	14,4
20.	NGR-NS-15	13.25	25.50	12.25	0.48	0.94	0.45	0.99	19.38	0.52	18.38	17.4
21.	NGR-NI-20-H	28.25	37.00	8.75	0.24	0.47	1.41	2.11	32.63	0.76	32.33	32.0
22.	NGB-01646B	26.25	51.00	24.75	0.49	0.96	1.80	1.96	38.63	0.51	36.59	37.0
23.	NGB-01646-C	16.25	40.50	24.25	0.60	1.16	0.88	1.22	23.38	0.40	25.65	23.1
24.	NGR-NI-20-J	13.50	17.00	3.50	0.21	0.41	0.31	1.01	15.25	0.79	15.15	15.0
25.	NGR-AD-27-B	10.25	27.50	17.25	0.63	1.24	0.38	0.77	18.88	0.37	16.79	15.1
26.	NGR-JG-17-A	17.25	25.25	8.00	0.32	0.63	0.59	1.29	21.25	0.68	20.87	20.4
27.	NGR-JG-17-B	10.50	29.50	19.00	0.64	1.25	0.42	0.79	20.00	0.36	17.59	15.4
28.	NGR-JG-17-C	9.75	27.00	17.25	0.64	1.25	0.35	0.73	18.38	0.36	16.22	14.3

Ys: Yield in stressed environment, Yp:Yield potential, TOL:Stress tolerance , YR:Yield Reduction ,SSR:Stress susceptibility index , STI:Stress tolerance index , YI:Yield index , MP:Mean productivity ,YSI:Yield stability index ,GMP:Geometric mean productivity , HM: Harmonic mean

Table 3. Pearsons Linear Correlation of Yield and some drought tolerance indices in Bambara Groundnut.

YS	YP	TOL	YR	SSI	STI	YI	MP	YSI	GMP	HM
1										
0.501**	1									
-0.061	0.833**	1								
-0.420*	0.506**	0.853**	1							
-0.394*	-0.552**	0.872**	1.000**	1						
0.895**	0.784**	0.333	-0.026	0.007	1					
0.993**	0.536**	-0.017	-0.355	-0.326	0.913**	1				
0.777**	0.920**	0.565**	0.188	0.239	0.934**	0.799**	1			
0.419*	-0.505**	-0.851**	-1.000**	-0.999**	0.026	0.355	-0.188	1		
0.892**	0.829**	0.386*	0.016	0.060	0.978**	0.910**	0.962**	-0.016	1	
0.807**	0.664**	0.249	-0.030	0.012	0.867**	0.819**	0.813**	0.030	0.867**	1

**. Correlation is significant at the 0.01 level *. Correlation is significant at the 0.05 level

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