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Original Article

Evaluation of Seed Yield of Nigerian Bambara Groundnut [*Vigna subterranea* (L.) Verdc.] Landraces under Varying Water Conditions

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Abstract

Seed yield of selected Nigerian Bambara Groundnut landraces under two varying water conditions was evaluated. Twenty eight (28) Bambara groundnut accessions were planted in a randomized complete block design with two treatments (Non-water stressed and Water stressed) and replicated five times. The experiment was conducted at the Experimental Garden of the Department of Biological Sciences, Federal University of Technology, Minna, Niger State. The accessions were planted in planting bags during the cropping season of 2016 between July and October. The two treatments were rain fed until maturity except during the period of exposure to water stress where the water stressed plants were transferred to a screen house made with polyvinyl ceiling to prevent water during the flowering stage for two weeks. It was observed that water stress reduced the yield of the Bambara groundnut landraces by 47%. Accessions NGB-01646-B, NGR-NI-20-H and NGB-01491 which had relatively high yield in the stressed and non- water stressed condition were considered the most drought tolerant accessions and accession NGR-KG-02-C with low yield both in stressed and non-stressed conditions was identified as the most susceptible accession. Accessions which had high yield only in water stressed conditions could serve as elite line for Bambara groundnut for areas which have problem of drought. These drought tolerant accessions identified in the research can serve as potential parent lines in breeding programmes aimed at the development of drought tolerant varieties of Bambara groundnut.

Keywords: accessions; breeding; drought tolerance; water stress; yield.

Introduction

Bambara groundnut is a leguminous crop that is well cultivated by farmers in Nigeria. It is believed to have originated from Nigeria and Cameroon as the distribution of wild Bambara groundnut was found to extend from Jos Plateau and Yola in Nigeria, to Garoua in Cameroon (Goli, 1997). It is in West Africa that most of the world's Bambara groundnut is grown and where the crop is most prominent in the traditions of rural communities. Bambara groundnut is now widely distributed in the semi-arid zone of sub-Saharan Africa (SSA) and most authors seem to support the view that it is the third most important food legume after cowpea (*Vigna unguiculata*) and groundnut (Mkandawire, 2007). In Nigeria, the Igbo people call it Okpa, Hausa call it Kwaruru or Gurjiya, Ebira call it Ezi, Igala call it Pangudu, Nupe call it Edzu and Gbaji call it Abwui.

It is an herbaceous annual crop that grows for about 0.30-0.35 m in height; it has both erect and prostrate forms (Bamshaiye *et al*., 2011). It forms seed and pods in sub-surface of the soil. The pods are round wrinkled and over half inch long each containing one or two seeds that are round smooth and very hard when dried. The seeds vary in terms of colour from white, cream, dark brown, red or black which may be patterned with combination of these colours.

The seed contain sufficient amount of protein (19%), carbohydrate (63%) and fat (6.5%). The red seeds are useful in areas where there is deficiency in iron because they contain almost twice iron as that of the cream seeds (Mayes *et al*., 2011). Bambara groundnut seeds have been processed

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and used in several ways. It is used to make a paste out of the dried seeds, which is then used in the preparation of various fried or steamed product such as "moin-moin" and "akara" (Okpuzor *et al*., 2010). In Nigeria this crop has been used as a favourable dish, "Okpa" which is a doughy paste that is wrapped in banana leaves and then boiled. The demand for Bambara groundnut is increasing due to its many uses, high nutritional value and medicinal value as it serves as a major diet for diabetic patients.

Despite its high nutritive value and many uses, the crop is under-utilized; landraces are unimproved due to neglect of the crop by scientists (Berchie *et al*., 2010). In Nigeria the cultivation of Bambara groundnut in the Sahel and Sudan Savannah zone has declined over the past two decades. Farmers in this region estimated that the cultivation of Bambara groundnut presently is about 5 to 20% of that of 20 years ago and attributed this reduction to drought (Vuraiyai *et al*., 2011a, Mohammed, *et al*., 2013). But this crop has been increasingly cultivated in the Guinea and Forest zone of Nigeria during this same period. The increase in the amount of crops produced in these areas is thought to be due to the fact that this crop brings higher prices now than it was before which makes the crop a potential crop to boost nutrition and alleviation of poverty for farmers.

The shift in cultivation of Bambara groundnut from the dried part to the wet part of the country has declined the overall production of the crop because there are fewer farmers producing the crop in the wetter areas, the cost of land clearing is much, soil in the wet area are more difficult to cultivate as they are heavier and more prone to weeds and disease problems are encountered in wetter area because of the prevalent high humidity (Mohammed *et al*., 2013). The problem of drought and lack of improved varieties in Bambara groundnut requires that effort should be made towards the development of drought tolerant varieties hence the need to evaluate Bambara groundnut accessions for their seed yield in varying water conditions, so as to determine the best drought tolerant accessions that can be used for breeding purpose and to recommend accessions for different areas in Nigeria with different water availability. This will help to increase farmer's productivity of the crop. Being that farmers are interested in increasing their yield, so also plant breeders are interested in reducing the yield loss by farmers, there is therefore need to evaluate Bambara groundnut seed yield under varying water conditions so as to be able to recommend accessions for different parts of the country with varying water availability and to improve farmers yield.

The understanding to be gained would serve as a basis for selection of baseline parents with potentials for drought tolerance and high yielding to be adopted for overall productivity of the crop. This will help to increase farmer's productivity of the crop. The present effort will further stimulate farmer's interest in the cultivation of the crop to meet market demands thereby improving their livelihoods, alleviate poverty and facilitate food security in the face of many problems posed by climate change.

Materials and Methods

Source of seeds

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.

Description of study site

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° 31' and 90° 45' North and longitude 6° 31' and 6° 45' East of the equator. The area falls within the Southern Guinea savannah vegetation zone of Nigeria with an annual precipitation varying from 1,100-1,600 mm, mean temperature between 21 °C and 36.5 °C and relative humidity between 50 to 61% (The Nigerian Congress, 2007).

Experimental design

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 completely randomized block design with five replicates. Two seeds were sown per bag and the bags were given a spacing of 30 x 30 cm (inter and intra row spacing) and later thinned to one 2 weeks after planting.

Determination of seed yield

The seed yield was determined by counting the number of seeds (NS) produced per plant 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.

Determination of drought tolerant accessions

In order to determine the most drought tolerant accessions, drought tolerance indices were determined according to the method of Wonderwosen *et al.* (2012). The following drought tolerance indices were determined for each accession.

Mean productivity (MP) = $Yp_i + Ys_i / 2$ (Wondrwosen *et al*., 2012);

Geometric mean productivity (GMP) = $(Yp_i \cdot Ys_i)^{1/2}$ (Fernandez 1992);

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 = $2 \ (Yp_i \ x \ Ys_i) \ / \ Yp_i + Ys_i$ (Gavuzzi *et al*., 1997);

(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).

The accessions were ranked based on these drought tolerance indices, the rank sum was calculated and the mean rank sum was used to determine the most drought tolerant accession.

Statistical analysis

The yield parameters for all accessions were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS). Treatment means were compared using the Least Significance Difference (LSD) at probability level of 0.05.

Results

The Bambara groundnut accessions collected from farmers in the seven Northern States of Nigeria and from National Agency for Genetic Resources and Biotechnology (NACGRAB) were made up of a variety of seed coat and eye colours. The summary of the phenotypic characteristics of the seeds are represented in Table 1.

The result showed significant differences ($P \leq 0.05$) in the number of seeds and weight of seeds produced by the Bambara groundnut accessions both in the non-stressed and stressed conditions (Table 2). It was also observed that water stress reduced the number of seeds produced by the Bambara groundnut accessions in the water stressed plants. In the non -water stressed plants, the seed yield of the Bambara groundnut accessions ranged from 13 to 51 seeds per plant with an average seed yield of 32 seeds per plant while in the stressed plants the seed yield of the Bambara groundnut accessions ranged from 6 to 28 seeds per plant with an average seed yield of 17 seeds per plant. (Table 3)

In the non-stressed plants, accession NGB-01646-B had the highest number of seeds per plant (51) which was significantly different from all other accessions except accessions NGR-NI-23-C and NGB-01646-C. This was followed by accession NGB-01646-C with 40 seeds per plant and the least number of seeds were produced by accession NGR-NI-18 with 13 seeds per plant. It was also significantly different from all other accessions. In the stressed plants, the highest number of seeds per plant was produced by accession NGR-NI-20-H (28 seeds per plant) which was significantly different from all other accessions. This was followed by accession NGB-01646-B with 26 seeds per plant. The least number of seeds per plant were produced by accessions NGB-01311, NGR-NI-23-C, NGB-01645-A, NGR-NI-22, NGR-KG-02-C, NGR-NI-20-B, NGR-NI-27, NGR-NI-25-A, NGR-PL-13, NGR-AD-27-B, NGR-JG-17-B and NGR-JG-17-C which were not significantly different from each other.The weight of seeds per plant also varied among the Bambara groundnut accessions in the stressed and non- stressed plants (Table 2). Accession NGR-AD-27-B had the highest weight (27g) and it was significantly different from all other accessions except for accessions, NGR-JG-17-B, NGR-NS-15, NGB-01486-A and NGB- 01493 while accession NGR-KG-02-C had the lowest weight (3.03g) in the non-stressed environment. It was significantly different from all other accessions except accession NGR-NI-18 (5.06g) but in the stressed environment, accession NGR-NI-20-H (15.5g) had the highest weight of seeds followed by accession NGR-JG-17-A (13.41g).They were not significantly different from each other but significantly different from all other accessions.

Table 1. Sources of Bambara groundnut accessions used in the study

S/NO	ACCESSION NUMBER	STATE	SEED COAT COLOUR AND PATTERN
1	NG-KG-O1	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. Number of seeds and weight of seeds produced by Bambara groundnut accessions in Non- water stressed and stressed conditions

S/No	ACCESSIONS	NS (NON –STRESSED)	NS (STRESSED)	WS (NON STRESSED)	WS (STRESSED)
1.	NGB01491	35.50 ± 6.38[bc]	20.25 ± 3.94[abc]	22.81 ± 2.44[bc]	14.63 ± 1.99[c]
2.	NGB-01493	28.75 ± 2.17[abc]	18.25 ± 4.13[abc]	24.28 ± 1.49[c]	13.78 ± 2.62[bc]
3.	NGR-NI20-K	30.25 ± 3.49[bc]	13.25 ± 3.64[ab]	22.13 ± 2.16[bc]	10.18 ± 2.47[abc]
4.	NGB-01311	25.25 ± 7.66[abc]	8.00 ± 3.24[a]	21.18 ± 4.51[bc]	6.15 ± 1.65[ab]
5.	NGB-01486-A	36.25 ± 5.01[bc]	13.75 ± 1.97[ab]	25.88 ± 2.24[c]	10.48 ± 1.14[abc]
6.	NGR-NI-23-C	43.25 ± 19.39[c]	6.25 ± 1.89[a]	23.88 ± 1.25[bc]	3.10 ± 0.76[a]
7.	NGB-01645A	32.25 ± 13.11[bc]	10.00 ± 3.39[a]	17.10 ± 3.97[abc]	6.68 ± 1.96[ab]
8.	NGR-NI-18	13.75 ± 2.09[ab]	12.75 ± 1.93[ab]	5.64 ± 1.43[a]	5.40 ± 0.79[ab]
9.	NGR-NI-20-I	18.50 ± 5.08[ab]	16.75 ± 4.87[abc]	8.75 ± 2.18[ab]	7.43 ± 2.56[ab]
10.	NGR-NI-22	16.00 ± 4.71[abc]	7.00 ± 3.16[a]	12.33 ± 3.17[ab]	5.18 ± 2.15[ab]
11.	NGR-KG-02C	9.00 ± 4.38[a]	6.50 ± 4.09[a]	3.03 ± 1.50[a]	2.28 ± 1.41[a]
12.	NGR-KG-01	32.00 ± 5.31[bc]	15.25 ± 5.18[abc]	14.83 ± 1.52[abc]	8.58 ± 1.49[abc]
13.	NGR-NI-20-B	17.50 ± 6.02[abc]	9.75 ± 4.19[a]	8.46 ± 2.61[ab]	5.35± 1.06[ab]
14.	NGR-PL-12	35.25 ± 5.60[bc]	13.50 ± 1.89[ab]	23.14 ± 3.95[bc]	9.61 ± 2.85[abc]
15.	NGR-KD-08-E	19.50 ± 7.41[abc]	13.75 ± 5.88[ab]	12.14 ± 3.71[ab]	8.28 ± 3.10[abc]
16.	NGB-01496	29.75 ± 1.25[abc]	15.75 ± 4.09[abc]	19.97 ± 0.72[bc]	10.69 ± 1.97[abc]
17.	NGR-NI-27	25.00 ± 2.97[abc]	10.25 ± 3.59[a]	20.78 ± 1.71[bc]	8.58 ± 2.60[abc]
18.	NGR-NI-25-A	19.00 ± 1.29[abc]	6.50 ± 4.63[a]	14.20 ± 0.74[abc]	6.20 ± 2.82[ab]
19.	NGR-PL-13	20.00 ± 6.02[abc]	11.25 ± 4.33[a]	17 .00± 3.37[abc]	8.58 ± 2.38[abc]
20.	NGR-NS-15	25.50 ± 2.02[abc]	13.25 ± 3.42[ab]	26.00 ± 1.70[c]	13.00 ± 2.63[bc]
21.	NGR-NI-20-H	37.00 ± 4.56[bc]	28.25 ± 2.46[c]	20.90 ± 2.16[bc]	15.00 ± 1.53[c]
22.	NGB-01646-B	51.00 ± 7.61[c]	26.25 ± 5.20[bc]	25.32 ± 3.35[c]	13.25 ± 2.17[bc]
23.	NGB-01646-C	40.50 ± 9.81[c]	16.25 ± 8.50[abc]	14.90 ± 2.98[abc]	6.18 ± 2.76[ab]
24.	NGR-NI-20-J	17.00 ± 0.41[abc]	13.50 ± 1.32[ab]	15.11 ± 1.04[abc]	11.88 ± 1.66[bc]
25.	NGR-AD-27-B	27.50 ± 6.94[bc]	10.25 ± 0.85[a]	27.42 ± 0.24[c]	10.74 ± 0.62[bc]
26.	NGR-JG-17-A	25.25 ± 0.63[bc]	17.25 ± 5.17[abc]	20.27 ± 0.45[bc]	14.31 ± 3.93[c]
27.	NGR-JG-17-B	29.50 ±1.19[bc]	10.50 ± 3.23[a]	24.75 ± 0.76[c]	8.75 ± 2.21[abc]
28.	NGR-JG-17-C	27.00 ± 4.24[bc]	9.75 ± 3.01[a]	22.20 ± 2.62[bc]	8.40 ± 2.39[abc]

Note: Values are means ± standard error. Different letters between accessions denote significant differences (Duncan test, $p < 0.05$). NS: Number of seeds, WS: Weight of seeds.

The smallest weight of seeds per plant in the stressed environment was observed in Accession NGR-KG-02-C and it was not significantly different from accession NGR-NI-23-C but statistically different from all other accessions.

Some drought tolerance indices which provide a measure of drought based on loss of yield under stressed conditions in comparison to non-stressed conditions have been used for screening drought tolerant genotypes. Such drought tolerance indices derived from mathematical calculations such as stress tolerance index (STI), Mean Productivity (MP), Geometric mean productivity (GMP), Yield index and harmonic mean (HM) were used to determine drought tolerance in Bambara groundnut (Table 3).

Stress Tolerance index is usually used to identify genotypes that produce high yield under both stress and non-stress conditions. The highest STI was observed in Accession NGB-01646-B (1.80) followed by accession NGR-NI-20-H (1.41) and then accession NGB-01491 (0.96). The least STI was observed in accession NGR-KG-O2C (0.08) which was followed by accession NGR-NI-22 (0.15) and then accession NGR-NI-25-A (0.17). The mean STI is 0.53 with 39.29% of the accessions having above average stress tolerance index. Accessions with above average stress tolerance include accessions NGB- 01491, NGB-01493, NGR-NI-20-K, NGB-01486-A, NGR-KG-01, NGR-PL-12, NGB-01496, NGR-NI-20-H, NGB-01646-B, NGB-01646-C,NGR-JG-17-A while accessions with below average stress tolerance index include NGB-01311, NGR-NI-23-C, NGB-01645-A, NGR-NI-18, NGR-NI-20-I, NGR-NI-22, NGR-KG-02-C, NGR-NI-20B, NGR-KD-08-E, NGR-NI-27, NGR-NI-25-A, NGR-PL-13, NGR-NS-15, NGR-NI-20-J, NGR- AD-27-B, NGR- JG-17-B, NGR-JG-17-C.

Table 3. Some drought tolerance indices of Bambara groundnut accessions

S/NO	ACCESSION	YS	YP	STI	YI	MP	GMP	HM
1.	NGB01491	20.25	35.50	0.97	1.52	27.88	26.81	25.79
2.	NGB-01493	18.25	28.75	0.71	1.37	23.50	22.91	22.33
3.	NGR-NI20-K	13.25	30.25	0.54	0.99	21.75	20.02	18.43
4.	NGB-01311	8.00	25.25	0.27	0.59	16.63	14.21	29.98
5.	NGB-01486-A	13.75	36.25	0.67	1.03	25.00	22.33	19.94
6.	NGR-NI-23-C	6.25	43.25	0.36	0.47	24.75	16.44	10.92
7.	NGB-01645A	10.00	32.25	0.43	0.75	21.13	17.96	15.27
8.	NGR-NI-18	12.75	13.75	0.24	0.95	13.25	13.24	13.23
9.	NGR-NI-20-I	16.75	18.50	0.42	1.25	17.63	17.60	17.58
10.	NGR-NI-22	7.00	16.00	0.15	0.52	11.50	10.58	9.74
11.	NGR-KG-02C	6.50	9.00	0.08	0.49	7.75	7.65	7.55
12.	NGR-KG-01	15.25	32.00	0.66	1.14	23.63	22.09	20.66
13.	NGR-NI-20-B	9.75	17.50	0.23	0.73	13.63	13.06	12.52
14.	NGR-PL-12	13.50	35.25	0.64	1.01	24.38	22.02	19.52
15.	NGR-KD-08-E	13.75	19.50	0.36	1.03	16.63	16.37	16.13
16.	NGB-01496	15.75	29.75	0.63	1.18	22.75	21.65	20.59
17.	NGR-NI-27	10.25	25.00	0.34	0.77	17.63	16.01	14.54
18.	NGR-NI-25-A	6.50	19.00	0.17	0.49	12.75	11.11	9.69
19.	NGR-PL-13	11.25	20.00	0.30	0.84	15.63	15.00	14,40
20.	NGR-NS-15	13.25	25.50	0.45	0.99	19.38	18.38	17.44
21.	NGR-NI-20-H	28.25	37.00	1.41	2.11	32.63	32.33	32.04
22.	NGB-01646B	26.25	51.00	1.80	1.96	38.63	36.59	37.06
23.	NGB-01646-C	16.25	40.50	0.88	1.22	23.38	25.65	23.19
24.	NGR-NI-20-J	13.50	17.00	0.31	1.01	15.25	15.15	15.05
25.	NGR-AD-27-B	10.25	27.50	0.38	0.77	18.88	16.79	15.13
26.	NGR-JG-17-A	17.25	25.25	0.59	1.29	21.25	20.87	20.49
27.	NGR-JG-17-B	10.50	29.50	0.42	0.79	20.00	17.59	15.49
28.	NGR-JG-17-C	9.75	27.00	0.35	0.73	18.38	16.22	14.33

Ys: Yield in stressed environment, Yp:Yield potential, STI:Stress tolerance index , YI:Yield index , MP:Mean productivity GMP:Geometric mean productivity , HM: Harmonic mean

Mean productivity is the average yield of plants in stress condition (Ys) and non-stress condition (Yp). The highest mean productivity was observed in accession NGB-01646-B (38.63), followed by Accession NGR-NI-20-H (32.63) and then accession NGB-01491 (27.88). The lowest mean productivity was observed in accession NGR-KG-02-C (7.75) followed by accession NGR-NI-22 (11.50)

The Geometric Mean productivity is often used by breeders interested in relative performance since drought stress can vary in severity in field environment. Accession NGB-01646-B also had the highest geometric mean productivity (36.59) followed by accession NGR-NI-20-H (32.63) and then accession NGB-01491 with Geometric mean productivity of 26.81. The least geometric mean productivity was observed in accession NGR-KG-02-C(7.65) followed by accession NGR-NI-22 (10.58). For the Harmonic mean, the highest harmonic mean was observed in accession NGB-01646-B followed by accession NGR-NI-20-H. The least was observed in accession NGR-KG-02-C.

All the accessions used in the study were grouped under four categories based on their performance in stressed and non-stressed conditions. Accessions which had high yield under both non- stressed and stressed conditions were put in group A. These accessions include accessions NGB-01646-B, NGR- NI-20-H, NGB-01491, NGB-01646-C, NGB-01493, NGB-01486-A, NGB-01646-C, NGR-KG-01, NGR-PL-12, NGR-NI-20-K. Group B are made up of accessions which have high yield only in the non-stressed conditions such as accessions NGR-NI-23-C, NGB-01645-A and NGR-JG-17-B. Group C are made up of accessions with good yield only in the stressed conditions, such accessions include accessions NGR-NI-20-I, NGR-NI-18, NGR-KD-08-E, NGR-PL-13,, NGR-NS-15, NGR-NI-20-J, NGR-JG-17-A while accessions in group D are accessions with low yield both in the stressed and non- stressed conditions. They are accessions NGR-KG-02-C, NGB-01311, NGR-NI-22, NGR-NI-20-B, NGR-NI-27, NGR-NI-25-A, NGR-AD-27-B, NGR-JG-17-C.

The estimate indicators of drought tolerance (Table 3) indicated that the identification of drought tolerant accessions based on a single criterion may be contradictory. To determine the most desirable drought tolerant accession according to all indices determined, rank sum and mean rank of the drought tolerance indices were calculated and based on these criteria, the most desirable drought tolerant cultivars was identified as accession NGB-01646-B with a mean rank of 1.29. This was followed by accession NGR-NI-20-H with a mean rank of 2.00 and then accession NGB-01491 with a mean rank of 3.57. The most susceptible accession was identified as accession NGR-KG-02-C with a mean rank of 25.29, this was followed by accession NGR-NI-22 with a mean rank of 24 and then accession NGR-NI-25-A with a mean rank of 23.43 (Table 4).

Table 4. Rank, rank sum, rank mean of some drought tolerance indices and drought tolerant ranking

ACCESSION	YS	YP	STI	YI	MP	GMP	HM	Rank sum	Rank mean	DTR
NGB-01646B	2	1	1	2	1	1	1	9	1.29	1
NGR-NI-20-H	1	4	2	1	2	2	2	14	2	2
NGB01491	3	6	3	3	3	3	4	25	3.57	3
NGB-01646-C	7	3	4	7	9	4	5	39	5.57	4
NGB-01493	4	13	5	4	8	5	6	45	6.43	5
NGB-01486-A	10	5	6	10	4	6	10	51	7.29	6
NGR-KG-01	9	9	7	9	7	7	7	55	7.86	7
NGR-PL-12	11	7	8	11	6	8	11	62	8.86	8
NGB-01496	8	11	9	8	10	9	8	63	9	9
NGR-JG-17-A	5	18	10	5	12	10	9	69	9.86	10
NGR-NI20-K	12	10	11	12	11	11	12	79	11.29	11
NGR-NS-15	12	16	12	12	15	12	14	93	13.28	12
NGR-NI-20-I	6	23	14	6	18	14	13	94	13.43	13
NGB-01645A	16	8	13	17	13	13	17	97	13.85	14
NGR-JG-17-B	14	12	14	15	14	14	16	99	14.14	15
NGR-NI-23-C	21	2	16	22	5	16	25	107	15.29	16
NGR-KD-08-E	10	21	16	10	19	18	15	109	15.57	17
NGR-AD-27B	15	14	15	16	16	16	18	110	15.71	18
NGB-01311	18	17	21	19	19	23	3	120	17.14	19
NGR-JG-17-C	17	15	17	18	17	19	22	125	17.85	20
NGR-NI-27	15	19	18	16	18	20	20	126	18	21
NGR-NI-20-J	11	25	19	11	21	21	19	127	18.14	22
NGR-PL-13	13	20	20	14	20	22	21	130	18.57	23
NGR-NI-18	13	27	22	13	23	24	23	145	20.71	24
NGR-NI-20-B	17	24	23	18	22	25	24	153	21.86	25
NGR-NI-25-A	20	22	24	21	24	26	27	164	23.43	26
NGR-NI-22	19	26	25	20	25	27	26	168	24	27
NGR-KG-02C	20	28	26	21	26	28	28	177	25.29	28

Ys: Yield in stressed environment, Yp:Yield potential, STI:Stress tolerance index , YI:Yield index , MP:Mean productivity,GMP:Geometric mean productivity , HM: Harmonic mean, DTR: Drought tolerance ranking

Discussion

The reduced seed yield observed in the Bambara groundnut accessions in the water stressed plants is an indication that water stress reduced seed yield through reduced seed number and weight. Although the accessions were shown to be still productive under limited water condition. Even though Bambara groundnut has been known to be drought tolerant, water stress still reduced the yield. These results are similar to others such as Berchie *et al.* (2012) and Mabhaudi *et al.* (2013) which all reported reduced seed yield in Bambara Groundnut landraces in response to limited water availability under field conditions. According to Berchie *et al.* (2012) the production of seeds despite the drought experienced during the flowering stage confirms Bambara groundnuts resilience under drought stress. The reduction in the number of seeds produced by the Bambara groundnut in the stressed accessions therefore means that water should be provided to Bambara groundnut where possible in order to have maximum seed production.

The significant differences observed in the number of seeds produced by the Bambara groundnut accessions both in the non-stressed and stressed conditions is an indication that genetic variation exists among the Bambara groundnut accessions with respect to seed yield. These variations in yield parameters provide a basis for selection of the best accessions that will perform well in places with different water availability.

Mitra (2001), reported that the most suitable indices for selection of drought tolerant genotypes are indicators which show a relatively high correlation with seed yield in both stress and non-stress condition. Abejide *et al.* (2017) also reported that the best drought tolerant indices to be used in the determination of drought tolerant accessions in Bambara Groundnut are STI, YI, MP, GMP and HM because they had significant positive correlations with seed yield in the stressed and non-stressed condition.

Based on the performances of the Bambara groundnut accessions used in the study, accessions which fall in group A and B are recommended for areas with good water availability while accessions in group A and C which performed well in water stressed conditions are recommended for semi-arid regions of Nigeria experiencing the problem of drought. Based on the values of STI,YI, MP, GMP, HM and their ranking, accession NGR-NI-20-H having the best rank mean was considered the most drought tolerant accession and NGR-KG-02-C the most susceptible. The drought tolerant accessions and the susceptible accessions identified in the research can serve as potential parent lines in breeding programmes aimed at the development of drought tolerant varieties in Bambara groundnut.

Conclusions

The study revealed that the most drought tolerant accessions are NGB-01646-B, NGR-NI-20-H, NGB-01491, NGB-01493, NGB-01646 while the most susceptible are NGR-KG-02-C, NGR-NI-22, NGR-NI-25A, NGR-NI-20-B, NGR-JG-17C. The drought tolerant accessions and the susceptible accessions identified in this study provide excellent genetic resources for further studies underlying mechanisms regulating drought responses and gene discovery. This result provides vital information to support the effort of molecular breeding and genetic Engineering to improve drought tolerance of Bambara Groundnut.

References

Abejide DR, Falusi OA, Gana SA, Adebola MO, Daudu OAY, Muhammad LM (2017). Evaluation of drought tolerance indices in Nigerian Bambara groundnut landraces. Book of Proceedings of the Biotechnology Society of Nigeria. 30th Annual International Conference, Federal University of Technology, Minna, 27- 30 August.

Anchirinah VM, Yiridoe EK, Bennet-Lartey SO (2001). Enhancing sustainable production and genetic resource conservation of Bambara groundnut: A survey of indigenous agricultural knowledge systems. Outlook Agriculture 30(4):281-288.

Azam-Ali SN, Sesay A, Karikari SK, Massawe FJ, Agullar-Manjarrez, J, Brennan M, Hampson KJ (2001). Assessing the potential of an underutilized crop - a case study using Bambara groundnut. Experimental Agriculture 37:433-472.

Bamshaiye OM, Adegbola JA, Bamshaiye EI (2011). Bambara groundnut: an under-utilized nut in Africa. Advances in Agricultural Biotechnology 1:60-72.

Berchie JN, du- Daapah HK, Nelson QF, Haleegoah J, Asafu-Agyei JN, Addo JK (2010). Practices and constraints in Bambara groundnut production, marketing and consumption in the Brong Ahafo and upper- east regions of Ghana. Journal of Agronomy 9:111-118.

Fernandez GC (1992). Effective selection criteria for assessing plant stress tolerance. In: Kuo CG (Ed). Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress. Asian Vegetable Research and Development Centre, Taiwan.

Goli AE (1997). Bibliographical Review, pp 4-10. In: Bambara grounndnut (*Vigna subterranean* [L.] Verdc.), In: Heller J, Begemann F, Mushonga J (Eds). Proceedings of the Workshop on Conservation and Improvement of Bambara groundnut (*Vigna subterranea* [L.] Verdc.) 14-16 November, 1995, Harare, Zimbabwe, International Plant Genetic Resources Institute, Rome, Italy, pp 162.

Gavuzzi P, Rizza F, Palumbo M, Campaline RG, Ricciardi GL, Borghi B (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Canadian Journal of Plant Science 77:523-531.

Mabhaudhi T, Modi AT, Beletse YG (2013). Growth, phonological and yield responses of a Bambara groundnut (*Vigna subterranean* L.Verdc) landrace to imposed water stress: II Rain shelter conditions. Water South Africa 39(2):191-198.

Mayes S, Massawe FJ, Alderson PG, Roberts JA, Azam-Ali SN, Hermann M (2011) The potential for underutilized crops to improve security of food production. Journal of Experimental Botany 63:1075-1079.

Mitra J (2001). Genetics and genetic improvement of drought resistance in crop plants. Current Science 80:758-762.

Mkandawire CH (2007). Review of Bambara groundnut production in Sub-Saharan Africa. Agricultural Journal 2:464-470.

Mohammed MS, Shimelis H, Laing MD (2013). Preliminary investigation on the genetic diversity of Bambara groundnut landraces using seed morphology. Poster presented at the Combined Congress, in Durban. 21-24 January, 2013. South African Society of Crop Production, pp 222.

Okpuzor J, Ogbunugafor HA, Okafor U, Sofidiya MO (2010). Identification of protein types in Bambara nut seeds: Perspectives for dietary protein supply in developing countries. EXCLI Journal 9:17-28.

Vurayai R, Emongor V, Moseki B (2011a). Physiological responses of Bambara groundnut (*Vigna subterranean* L. Verdc) to short periods of water stress during different developmental stages. Asian Journal of Agricultural Science 3(1):37-43.

Wonderwosen S, Alemayehu B, Hussein M (2012). Evaluation of drought tolerance indices in Tef (Eragrostistef (Zucc.) Trotter. African Journal of Agricultural Research 7(23):3433-3438.