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Research Article

EVALUATION OF TEN BAMBARA GROUNDNUT (*Vigna subterranean* (L.) Verdc.) ACCESSIONS TO DROUGHT STRESS AT SAHELIAN ZONE OF NIGER

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ABSTRACT

Bambara groundnut is a legume mainly cultivated for these seeds in Africa. In the Sahelian zone, it sometimes suffered of significant yield losses linked to drought. The objective of this study is to identify the adapted genotypes to water deficit stress. The experimental design is randomly made up of four complete randomized blocks. Three variants of stress were applied during the growth of the plants, namely a water deficit stress for 14 days, a stress of 10 days and another stress of 7 days and a constantly watered control. The study revealed a systematic decline in yield under water deficit stress conditions in all ten accessions. However, the yields of accessions Ti 049 and Th 113 were the least affected, with decreases of -7.71% and -8.76% respectively compared to the control. However, the Di-3 082 accession recorded the greatest drop in yield (-36.06%). According to the indices determined, it appears that the genotypes Th 113, Ti 047, Ti 049 and Ma-2-65 are the most tolerant to water deficit stress, with considerable yield potential. Accession Di-3 082 was identified as the most sensitive to water deficit stress.

Keywords: *Vigna subterranea* L., Water deficit, Stress, Niger.

INTRODUCTION

Drought is the main environmental stressor often having devastating effects on crop productivity in many regions of the world (Fawzy *et al.*, 2014). According to Tellah (2016), water constitutes the main limiting factor in plant production in arid and semi-aridregions. Therefore, the improvement of drought tolerant varieties must be one of the major objectives in the breeding program in a Sahelian country like Niger.

Bambara groundnutis a highly caloric legume, rich in mineral elements, vitamins and proteins (Minka & Bruneteau, 2000). A 100g quantity of dried *Vigna subterranean* seeds contains between 37-128 mg of calcium, 1545-2200 mg of potassium, 159-335 mg of magnesium, 313–563 mg of phosphorus, and 2.3-15 mg of iron (Amarteifio *et al.*, 2006). It is a plant that has a remarkable capacity to adapt to tropical climates, depending on the genetic diversity of the seeds sown (Azam-Ali *et al.*, 2001). Indeed, according to Linnemann (1994), voandzou gives average yields ranging from 350 to 800 kg/ha in regions where the soilis poor and rainfall slow. Unfortunately in Niger, bambara groundnut is a neglected plant, because according to Harouna *et al.*, (2018), the plant is only cultivated by women on small areas. The main objective of this experiment is to determine the geno types most tolerant to water deficit stress.

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MATERIAL AND METHODS

Material

The test was carried out in the Botanical garden of the Faculty of Science and Technology (FAST) of the Abdou Moumouni University of Niamey in Niger. The plant material consists of the seeds of ten (10) accessions from six (6) regions of Niger (Table 1). The accessions were taken from the 2012 to 2013 collection (Harouna *et al.*, 2014) of the Department of Biology of the Faculty of Sciences and Technology (FAST)

Table 1. Ten (10) voandzou accessions studied and their provenance.

Numéros	Accessions	Origines
1.	Ti 047	Tillabéri/Niger
2.	Ti 049	Tillabéri/Niger
3.	Ma 3 062	Maradi/Niger
4.	Ma-2-65	Maradi/Niger
5.	Do 002	Dosso/Niger
6.	Do 040	Dosso/Niger
7.	Di-03-82	Diffa/Niger
8.	Zi 091	Zinder/Niger
9.	Zi 097	Zinder/Niger
10.	Th 113	Tahoua/Niger

Figure 1. Experimental setup.

Table 2. Calculation of drought tolerance parameters and yields.

Parameters	meanings of terms	Formula
Yield in stress environment	Ys	Total production under stress conditions converted into kg/ha.
Yield in Non- stress environment	Yp	Total production under stress-free conditions converted to kg/ha.
Mean yield in stress environment	Yms	Dry seed data taken from the average of five central plants under stress conditions, then converted to Kg/ha.
Mean yield in non-stress environment	Ymp	Dry seed data taken from the average of five central plants under non-stress conditions, then converted to Kg/ha
Mean productivity	MP	Yp + Ys/2 (Hossain *et al.*, 1990)
Stress tolerance index	STI	$Yp \times Ys/Yms^2$(Fernandez, 1992)
Yield index	YI	Ys/Yms(Gavuzzi *et al.*,1997)
Tolerance index	TI	Yp-Ys (Wonderwosen *et al.*, 2012)
Stress intensity	SI	1- (Yms / Ymp)(Wonderwosen *et al.*, 2012)
Stress susceptibility index	SSI	$\frac{1-(\frac{Ys}{Yp})}{1-(\frac{Yms}{Ymp})}$ (Fischer, 1978)

Methods

Ten (10) bambara groundnut accessions from the 2012-2013 collection of the FAST Biology Department were tested against water stress, in a randomized complete block design, with four (4) repetitions (Figure 1).

Two treatments carried out:

- **T1:** Control, not subjected to water stress by receiving regular irrigations.
- **T2:** Water deficit stress for 14 days (with irrigation on the 15th day), Stress for 10 days followed by irrigation until saturation, Stress for 7 days followed by regular irrigation until haves. Irrigations were done twice a week.

Irrigation interruptions were applied during the critical stage of reproduction in order to simulated roughts linked to rainfall periods which are generally observed at the beginning and towards the end of the agricultural seasons in Niger (Directorate of National Meteorology (DMN) of Niger, 2020). Five seeds were sown in each pot to ensure germination. Then a single plant is unmarried which is monitored during its growth. The spacing is 0.50 m between the pots and 1 m between the blocks.

Data collection

Ten water stress indices were analyzed, based on the calculation methods recorded in Table 2.

Statistical Analysis

R software version 4.0.4 (2021-02-15) was used for correlation analyzes between quantitative variables, based on the Pearson correlation coefficient formula and for principal component analysis (PCA) allowing the relationships between different characters to be observed.

RESULTS AND DISCUSSION

Mean productivity (MP) is the average of performance in stressed and non-stressed environments. Higher values of average productivity mean tolerance and higher yield potential for accessions (Hossain *et al.,* 1990). Di-03-82, Th 113 and Ti 047 obtained the highest MP (Table 3). High Stress tolerance index (STI) suggest tolerance to water stress (Fernandez, 1992). Thus the ITS of accessions Di-03-82, Th 113 and Ti 047 were the highest (Table 3). Yield index (YI) were calculated as suggested by Gavuzzi *et al.,* (1997). These indix classify accessions solely on the basis of their performance under stress conditions. High values characterize tolerant accessions. Th 113, Ti 047, Ti 049, Di-03-82, Zi 091 and Ma-2-65 showed highest YI values (Table 3). The tolerance index (TI) is defined by Wonder wosen *et al.,* (2012), such as the difference in yield between yield under water stress and no stress conditions. Accessions with low tolerance index values are more stable to water stress. Accessions Ti 049, Ma-2-65, Do 040 and Th 113 had the smallest differences (Table 3). he Stress Sensitivity Index (SSI), estimates the rate of change for each accession in yield between the stress and non-stress environment relative to the average change for all accessions. According to Guttieri *et al.*, (2001) an SSI < 1 shows high yield stability. Th 113, Ti 049, Ma-2-65 and Ti 047 obtained SSI < 1. Accessions Zi 097, Zi 091, Do 002, Do 040, Ma 3 062 presented SSI > 1. Accession Di- 03-82 had an SSI >1, up to 2.47 (Table 3). The tolerance indix (TI), stress sensitivity index (SSI) and stress tolerance (ITS) are low for accessions Th 113, Ti 047, Ti 049 and Ma-2-65. On the other hand, the average productivity(MP) and yield under stress conditions are high for these accessions. Accession Di-3-82 had the highest value of mean productivity, tolerance index, stress sensitivity index and stress tolerance index (Table 3).

Table 3. Values of water stress indices.

Ecotype	Ys (kg/ha)	Yp (kg/ha)	MP	STI	YI	TI	SSI
Zi 097	345.43	503.69	424.56	0.87	0.77	158.26	1.50
Di-03-82	432.62	899.73	666.18	1.94	0.97	467.11	2.47
Zi 091	436.5	556.58	496.54	1.21	0.97	120.08	1.03
Th 113	572.6	667.96	620.28	1.90	1.28	95.36	0.68
Do 002	371.82	484.71	428.27	0.90	0.83	112.89	1.11
Do 040	265.99	343.16	304.57	0.45	0.59	77.17	1.07
Ma 3 062	318.77	542.89	430.83	0.86	0.71	224.12	1.97
Ti 049	439.86	513.33	476.60	1.12	0.98	73.47	0.68
Ma-2-65	418.39	495.29	456.84	1.03	0.93	76.90	0.74
Ti 047	552.42	657.07	604.74	1.81	1.23	104.65	0.76

MP : mean productivity, Ys : Yield in stress environment, Yp : Yield in Non- stress environment, STI : Stress tolerance index, YI : Yield index, TI : Tolerance index, SSI : Stress susceptibility index.

The analysis of the relationships between the different water stress index (figure 2) shows the existence of positive and significant correlations between the yield obtained in stress-free conditions with the stress tolerance index (r=0.90), the yield index (r = 0.60), the tolerance index (r=0.76) and mean productivity (r=0.94). The performance obtained under stressful conditions is also positively correlated with the stress tolerance index (r=0.88), the yield index (r=1) and mean productivity (r=0.84). However, it is negatively correlated with the tolerance index (r=-0.07) and the stress sensitivity index (r=-0.40). The principal component analysis shows the existence of relationships between water stress indices and the different genotypes (Figures 3 and 4). A $\cos^2$ close to 1 assumes that the individual is well projected onto the dimension. Accessions Di-3 082, Th 113, Ti 047, and Do 002 have squared cosines closest to 1. Additionally the cosines of all genotypes are close to 1. According to both figures, accession Di-3 082 is correlated with the stress sensitivity index and the tolerance index; accessions Th 113 and Ti 047 are correlated with the stress tolerance index, the yield index and the yield under stress.

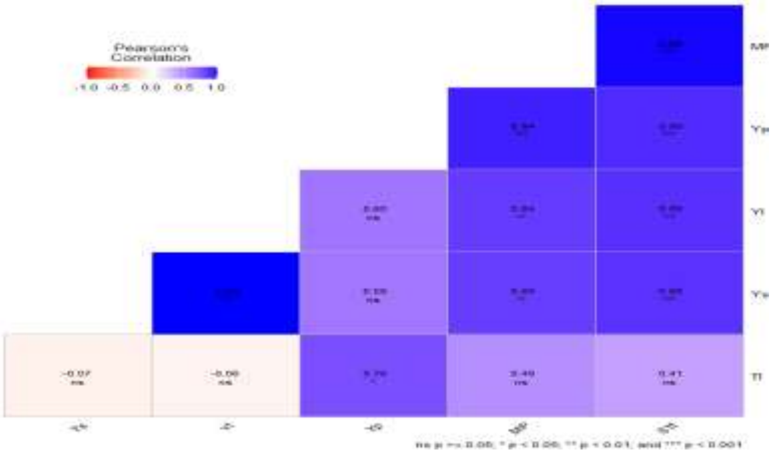

Figure 2. Correlation matrix.

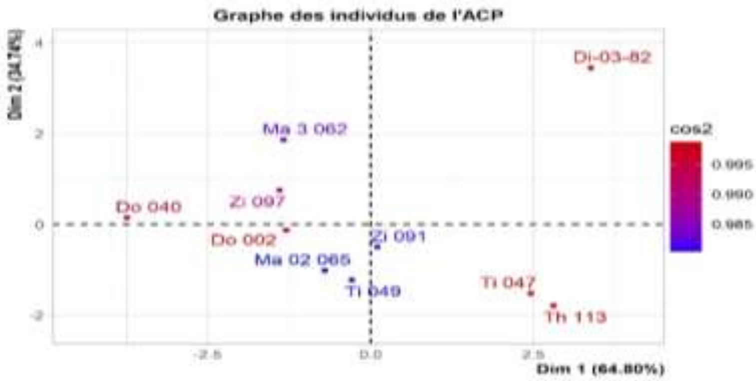

Figure 3. Correlations between accessions and the first two main axes.

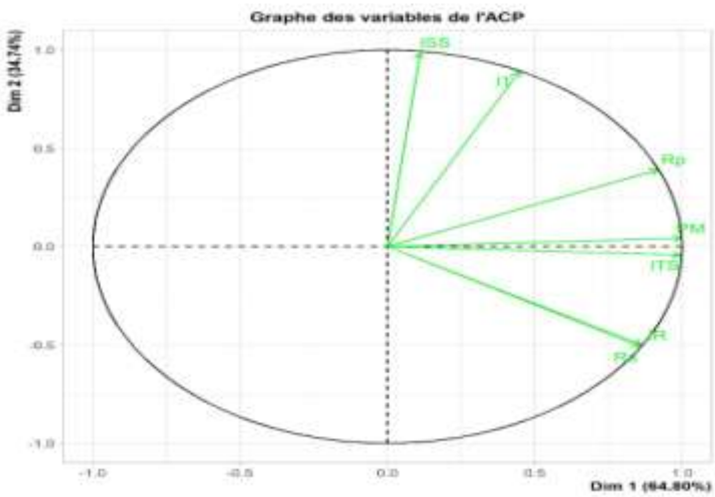

Figure 4.Circle of correlations between the variables and the first two main axes.

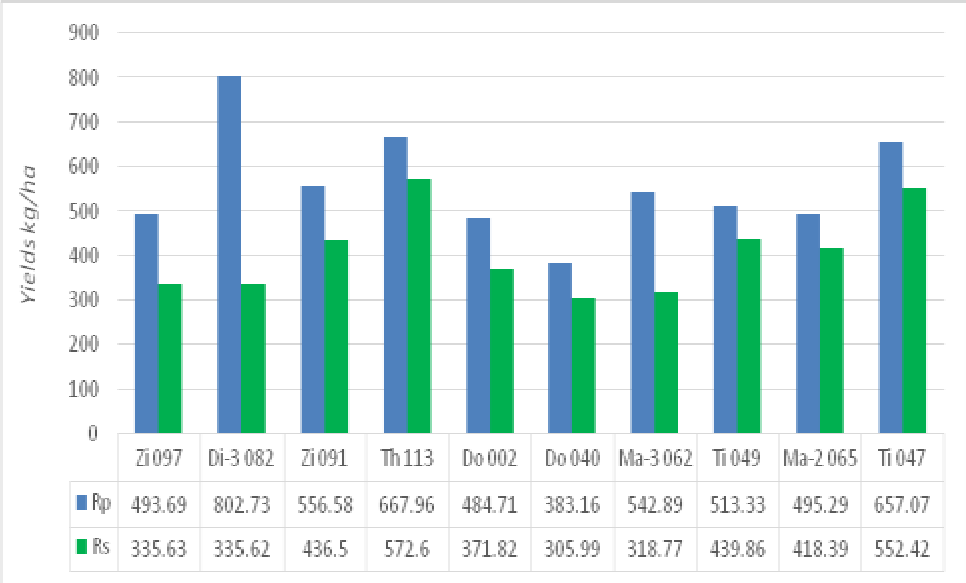

Figure 5. Comparison of yields of accessions tested in stressed and non-stressed situations.

Figure 5 shows the comparisons of yields obtained by each accession, under growing conditions under stress and without stress. It showed that the yields of all 10 accessions decreased under water stress conditions. The most remarkable drop in yield was observed in accession Di-3 082, with -467.62 kg/ha (i.e. -36.06%) and the smallest drop in accession Ti 049 with -73.47 kg/ha (-7.71%). Strong correlations were observed between the yield obtained in stress-free conditions with the stress tolerance index, the average productivity and the tolerance index, on the one hand and between the yields in stress environment with the stress index. Stress tolerance, mean productivity, yield index and negative correlations with the tolerance index and the stress sensitivity index, on the other hand. Talebi *et al.,* (2009) in Kurdistan in Iran, also obtained positive correlations between the tolerance index with the yield of durum wheat in stress-free conditions and negative with the yield in stress conditions. The same observation is that the higher the tolerance index, the greater the drop in yield in situations of water stress and the greater the sensitivity to stress. Furthermore, the correlations, which are positive between the yields obtained under stress-free growth conditions and negative between the yields obtained under stress conditions and the tolerance index, imply that a selection based on this index will lead to a drop in yield even in crop conditions without water stress. Similar results were reported by Farshadfar *et al.,* (2012), Abejide *et al.,* (2017), Abebe *et al.,* (2020). Mean productivity, water stress tolerance index and yield index had significant positive correlations with yields under stress and non-stress conditions. These indices can therefore be used as indicators of tolerance to water stress in the selection program for the *Vigna subterranean* species. Abejide *et al.,* (2017) assumed that these same indices are effective in the selection of drought-tolerant geno types in bambara groundnut.

The stress sensitivity index and the tolerance index are the highest indices for accession Di-3 082, with a yield drop of more than 35%. Which ranks this accession at the top of the least drought-resistant genotypes, among the ten (10) studied. It appears from the analysis of most of the determined indices that the genotypes Th 113, Ti 047, Ti 049 and Ma-2-65 are the most tolerant individuals to water stress, with considerable yield potential in both conditions water supply. These accessions, like accessions Di-03-82 and Zi 091, all gave yields greater than 350 kg/ha, which is acceptable for bambara groundnut which gives average yields of around 350 to 800 kg/ha. , in regions where the soilis poor and rainfall is low (Linnemann & Azam-ali, 1993; Linnemann, 1994). According to Daniel (1990), If we were to make an estimate of the influence of different types of deficiencies on the balance sheet of world agricultural production, the lack of water would appear as one of the most important limiting factors. The water deficitis a permanent constraint on agricultural production (Marguerit, 2010). Water stress indices provide a measure of water stress based on yield loss under water stress conditions compared to normal conditions (Mitra, 2001).

CONCLUSION

The results of this experiment showed significant variations in the yields of bambara groundnut accessions tested under water deficit stress and non-stress conditions. Water stress had an impact on yield which resulted in a drop in yield ranging from -7.71% (accession Ti 049) to -35.06% (D1 03 32). The mean productivity, the stress tolerance index and the yield index are important for the identification of genotypes resilient to water deficit stress conditions in bambara groundnut. Based on this index, accessions Th 113, Ti 047, Ti 049 and Ma-2-65 were identified as being the most resilient to drought. Accession Di-3 082, with high sensitivity and tolerance index, has a yield that is high in stress-free growing conditions, but low in water stress situations. Therefore, it is less resilient to drought.

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