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Agronomic and Physiological Performance of Bambara Groundnut (*Vigna subterranea* (L.) Verdc) in Southeastern Nigeria

Madukwe D.K. M.O. Onuh and I.E.C. Christo

Department of Crop Science and Biotechnology,
Evan Enwerem University, Owerri P.M.B. 2000, Owerri, Imo State, Nigeria

Abstract: Pot experiment was conducted under transparent shade at the Teaching and Research Farm of the Faculty of Agriculture and Veterinary Medicine, Evan Enwerem University, Owerri, Nigeria, to investigate the effects of water stress on the performance of Bambara groundnut. Four different regimes of water application (500ml of water supplied daily, 500ml of water supplied once in 4 days, 500ml of water supplied once in 7days and 500ml of water supplied once in 14 days) were used. Results showed that water stress affected the performance of Bambara groundnut. Plants in the control plots produced the highest mean number of nodules (50.0) at flowering stage and this was significantly different at $p<0.05$ from the mean number of nodules obtained in the legume plants that received 500 ml of water once at 4 days. In terms of yield, plants in the control plots also produced the highest seed yield of 243.3Kg/ha which was significantly different ($p<0.05$) from the mean seed yield (197.2Kg/ha) of Bambara groundnut recorded in plants that received 500 ml of water once at 4 days. It was observed that, Bambara groundnut is sensitive to severe water stress condition and therefore it was concluded that severe conditions of water stress should be avoided while cultivating Bambara groundnut.

Key word: Water stress · Bambara groundnut · Nodulation · Crop performance · Physiology

INTRODUCTION

Water stress in plants is commonly attributed to situations where the water loss exceeds sufficient absorption intensity, causing a decrease in plant water content, turgor reduction and, consequently, a decrease in cellular expansion and alterations of various essential physiological and biochemical processes that can affect growth or productivity [1]. Water deficiency causes various responses in plant metabolism, where osmotic adjustment is an extremely important physiological mechanism for preparing these plants to tolerate hydric stress where diverse organic compounds accumulate as osmoregulators [2].

Water deficit influences most metabolic processes, however, depending upon the severity of the stress [3]. Most grain legumes in tropical regions grow in an environment where they experience drought of varying intensity and duration [4]. The root nodules are mostly confined to the upper 5 to 15 cm of soil which often dries out during spells of drought. However, within certain limits, the plant does not necessarily display water stress effects because roots can tap water from lower zones of the soil [2].

For more than 100 years, biological nitrogen fixation (BNF) has commanded the attention of scientist concerned with plant mineral nutrition and it has been exploited extensively in agricultural practice [5]. However, it's importance as primary source of Nitrogen (N) for agriculture has diminished in recent times as increasing amounts of N-fertilizers have been used for the production of food and cash crops [6].

The effect of drought on biological nitrogen fixation has been widely reported by Martins [7]. It is considered to be by far the most important environmental factor resulting in crop yield loss [8]. A reduction in root nodule flux has also been associated with the inhibition of nitrogen fixation under drought [9]. Several environmental conditions are limiting factors to the growth and activity of the nitrogen fixing plants. In the words of Pita and

Corresponding Author: D.K. Madukwe, Department of Crop Science and Biotechnology, Evan Enwerem University, Owerri P.M.B. 2000, Owerri, Imo State, Nigeria, E-mail: donkele2002@yahoo.com.

Pardos [10], principle of limiting factors is such that "the level of crop production cannot be longer than that allowed by the maximum limiting factor". In the rhizobium-legume symbiosis, which is a nitrogen fixing system, the process is strongly related to the physiological state of the host plant [11]. Therefore, a competitive and persistent rhizobial strain is not expected to express its full capacity for nitrogen fixation if limiting factors (e.g. soil moisture stress) impose limitations on the vigor of the host legume [12].

Meinzer [13] reported that the occurrence of rhizobial populations in desert soils and the effective nodulation of legumes growing therein emphasize the fact that rhizobia can exist in soils with limiting moisture levels. However, population densities tend to be lowest under the most desiccated conditions and to increase as the moisture stress is relieved. Some free living rhizobia (*saprophytic*) are capable of survival under drought stress or low water potential. Soil moisture deficiency has a pronounced effect on nitrogen fixation because nodule orientation, growth and activity are all more sensitive to water stress than are general root and shoot metabolism.

Biological nitrogen fixation is an important source for supplying nitrogen for crop production. It is in the recognition of the importance of biological nitrogen fixation in modifying the soil for increased crop productivity that the present study was aimed at investigating the effects of water stress on the performance and nodulation potentials of Bambara groundnut.

MATERIALS AND METHODS

The study was carried out during the cropping season (March-August) of 2009 in the Teaching and Research Farm of the Faculty of Agriculture and Veterinary Medicine, Evan Enwerem University, Owerri. The climatic conditions of the study area during the experiment period were as seen in Table 1.

Bambara groundnut (*Vigna subterrenea* (L.) Verdc.) seeds sourced locally was used; 36 plastic buckets of 30 cm diameter and 30 cm depth were used for the planting. Four water treatment levels were used (500 ml applied once daily [T_1] = control, 500 ml applied once in four days [T_2], 500 ml applied once in seven days [T_3] and 500 ml applied once in 14 days [T_4]. Soil thermometer (°C), 500 ml beaker, electronic weighing scale (Model No STE-12) and a ruler calibrated in cm were also used. The 36 plastic buckets was divided into three replication of 12 buckets each. Each of the buckets was filled with 20kg top soil collected from the University's farm site, after perforating the base of the buckets to make for easy drainage and the experiment was laid out in a Completely Randomized Design. Soil samples were collected (before filling the buckets) from various spots in the farm site and bulked together for analysis to ascertain the physico-chemical properties of the soil. Seeds of Bambara groundnut were sown in the respective plastic buckets at the depth of 2-3 cm and a planting distance of 3 cm X 3 cm at the rate of six seeds per bucket; however, this was thinned down to four seedlings at 14 days after germination. Treatments were applied to the respective buckets according to the schedule of the water application. The experiment was monitored daily until harvest period, within which data were collected on the following parameters: number of days to germination, germination Percentage, soil temperature, number of leaves per plant, number of branches per plant, plant height (cm), crop growth rate (CGR), net assimilation rate (NAR), leaf area (LA), leaf area index (LAI), number of days to 50% flowering, number of days to 50% maturity, number of root nodules per plant, nodule dry weight (g), number of seeds per pod/plant, 100 seed weight (g) and seed yield (Kg/ha). The various data collected from the experiment were subjected to Analysis of Variance (ANOVA) and the treatment means were compared with the Least Significance Difference (LSD) test [15].

Table 1: Meteorological Data for March – August 2009

Months	Rainfall (mm)	Relative Humidity (%)	Temperature (°C) Max	Temperature (°C) Min
March	40.1	80	33.8	24.0
April	152.2	80	32.5	23.2
May	282.2	82	32.1	23.0
June	304.3	85	30.8	22.9
July	328.3	89	29.1	22.8
August	569.9	91	28.5	22.8

Source: [14]

RESULTS

Germination and Germination Percentage: The shortest number of days it took for Bambara groundnut seed to germinate was 7.0 in the control plots (that received 500 ml of water once daily) and this was significantly different from the other water treatment regimes. 100% seeds germination was recorded in the control plots which was significantly different compared with the 90%, 90% and 96% recorded from plots that received 500ml of water once in 14 days, once in 7 days and once in 4 days, respectively (Table 2).

Number of Leaves per Plant: At 14 days after planting (DAP), the highest (14.7) mean number of leaves was recorded from the plots that received 500 ml of water once in 4days and it was not significantly different from the values in the other treatment plots while the lowest (10.0) number of leaves was recorded from plots that received 500ml of water daily (Table 2). At 28 DAP, the control plots gave the highest (11.0) number of leaves which did not show significant difference from the lowest (9.0) mean number of leaves recorded from plots that received 500ml of water once in 4 days (Table 2). At flowering stage (40 DAP), the lowest (10.0) mean number of leaves was recorded from plots that received 500ml of water once in 4 days and this was not significantly different from the highest (11.0) number of leaves recorded from the control plots (Table 2).

Number of Nodules per Plant: At 14 DAP, the highest (37.7) number of nodules was obtained from the control plots and this was significantly different from the number of nodules obtained from the other treatment plots. The lowest (15.7) number of nodules was obtained from plants that received 500ml of water once in 14 days (Table 2). At 28 DAP, the same trend was observed, with 40.1 as the highest number of nodules obtained from the control plots which was significantly different from the number of nodules recorded from the other treatment plots. However, the lowest (22.0) mean number of nodules was recorded from plots that received 500ml of water once in 4 days. At flowering stage, the highest (50.0) number of nodules was recorded from the control plots which was significantly different from the 26.3 number of nodules obtained from plants that received 500ml of water once in 4 days (Table 2). It was observed that at 28 DAP and above, the Bambara groundnut seedlings in the plots that received 500 ml of water once in 7 days and 14days had died.

Table 2: Effects of Water Stress on Germination, Germination Percentage, Nodulation and Growth of Bambara groundnut.

			Number Of Leaves/Plant			Number of nodules/Plant		
Treatments	Mean No of days to 100% germination	Percentage germination (%)	14DAP	28DAP	40 DAP (At flowering)	14DAP	28DAP	40 DAP (At flowering)
500ml of water daily (control)	7.0^{b}	100^{a}	10.0^{a}	11.0^{a}	11.0^{a}	37.7^{a}	40.1^{a}	50.0^{a}
500ml of water once in 4 days	9.0^{a}	96.0^{b}	14.7^{a}	9.0^{a}	10.0^{a}	22.0^{b}	22.0^{b}	26.3^{b}
500ml of water once in 7 days	9.0^{a}	90.0^{c}	12.0^{a}	-	-	17.3^{bc}	-	-
500ml of water once in 14 days	9.0^{a}	90.0^{c}	13.0^{a}	-	-	15.7^{bc}	-	-
LSD	0.02	2.43	6.09	3.71	1.11	15.93	15.20	11.74

Means in the same column, having the same letter are not significantly different according to LSD.

Table 3: Effects of Water Stress on the Net Assimilation Rate (NAR), Crop Growth Rate (CGR), Leaf Area (LA) and Leaf Area Index (LAI) of Bambara groundnut

Treatments	NAR	CGR	LA	LAI
500ml of water daily (control)	17.9^{a}	1.2^{a}	18.50^{a}	0.07^{a}
500ml of water once in 4 days	15.6^{b}	0.9^{a}	16.90^{a}	0.06^{a}
500ml of water once in 7 days	8.0^{b}	0.4^{b}	7.37^{c}	0.03^{b}
500ml of water once in 14 days	4.3^{d}	0.2^{bc}	6.80^{c}	0.03^{b}
LSD	2.33	0.57	8.01	0.03

Means in the same column, having the same letter(s) are not significantly different according to LSD.

Table 4: Effects of Water Stress on Yield and Yield Components of Bambara groundnut

Treatments	Mean days to 50% flowering	Mean days to 50% maturity	Mean number of Seeds per pod	Mean 100 seeds weight (g)	Mean seed yield (Kg/ha)
500ml of water daily (control)	54.0[b]	70.0[a]	3.3[a]	4.6.6[a]	243.3[a]
500ml of water once in 4 days	58.7[a]	71.3[a]	2.3[b]	34.5[a]	197.2[a]
500ml of water once in 7 days	-	-	-	-	-
500ml of water once in 14 days	-	-	-	-	-
LSD	0.88	6.86	0.84	13.25	76.89

Means in the same column, having the same letter are not significantly different according to LSD.

Net Assimilation Rate (NAR): The highest (17.9 (gm^{-2} (leaf) day^{-1}) NAR was obtained from the control plots and is significantly different from the lowest (4.3 gm^{-2} (leaf) day^{-1}) obtained from plants that received 500ml of water once in 14 days (Table 3).

Crop Growth Rate (CGR): The highest (1.2 (gm^{-2} (land) day^{-1}) crop growth rate was recorded from the control plots and was found to be significantly different from the lowest (0.2 gm^{-2} (land) day^{-1}) crop growth rate recorded from plants that received 500ml of water once in 14 days (Table 3).

Leaf Area (LA): The highest (18.50 cm^2) leaf area was obtained from the control plots and was found to be significantly different from the lowest (6.80cm^2) leaf area recorded from plot that received 500ml of water once in 14 days (Table 3).

Leaf Area Index (LAI): The highest (0.07) leaf area index was obtained from the control plots and was significantly different from the lowest (0.03) leaf area index obtained from plots that received 500ml of water once in 7 days and once in 14 days (Table 3).

Days to 50% Flowering and 50% Maturity: Bambara groundnut plants in the plots that received 500ml of water once in 4 days took the highest (58.7) number of days to 50% flowering and this was significantly different from the 54.0 mean number of days to 50% flowering recorded from the control plots. The highest (71.3) number of days to 50% maturity was recorded from plots that received 500ml of water once in 4 days and was not significantly different from the lowest mean (70.0) in the control (Table 4).

Number of Seeds per Pod: The highest (3.3) mean number of seeds per pod of Bambara groundnut was recorded from the control plots and this had significant difference from the lowest (2.3) number of seeds per pod recorded from plants in the plots that received 500ml of water once in 4 days(Table 4).

100-seeds Weight of Bambara Groundnut: Highest 100 seed weight of at 46.6g was recorded from the control plots which was not significantly different from the lowest (34.5g) 100 seed weight recorded from plots that received 500ml of water once in 4 days (Table 4).

Seed Yield: The highest (243.3kg/ha) seed yield of Bambara groundnut, was obtained from the control plots, though it did not show significant difference from the lowest (197.2kg/ha) seed yield of Bambara groundnut recorded from plots that received 500ml of water once in 4 days (Table 4).

DISCUSSION

The germination percentage obtained from the control plots was 100% but it was lower in the plants that received 500 ml of water once in 4 days, 7 days and 14 days, respectively. This difference in germination percentage could be that the water supply in the plots other than the control plots was not enough to soften the seed coat and to activate completely the enzymes responsible for germination, possibly due to the seed size of the Bambara groundnut. This was corroborated by Hale and Orcutt [16], who stated that the amount of water needed for seed germination, is relative to the seeds dry weight. However, the adequacy of water during germination is evident in the variation in number of days to 100% germination between the Bambara groundnut seeds in the control plots and the other treatment plots. The control plots had the shortest days to 100% germination and the number of days in other plots increased as the level of water stress increased.

The highest number of leaves was recorded from the control plants while plants in the water-regimented plot produced lesser number of leaves. This could be perceived as an adaptive feature by plants to water stress condition which is in line with the findings of Holbrook [17] who reported that drought tolerant plants produce lesser leaves so as to conserve water. However, at 28 DAP, all the plants that were receiving 500ml of water once in 7 days and once in 14 days were observed dead. This observation shows that at 28 DAP, the plants required more water for metabolism and that the water supply was no more enough to sustain the growth of the plants, thus this imposed a condition of severe water stress which led to permanent wilting and eventually desiccation and death [16].

The control plots produced the highest number of nodules throughout the period of the experiment especially at 14 DAP. This result could be due to high temperature imposed by severe water deficit on the water regimented plots which confirms the findings of Bjorkman [18] who stated that high temperatures have adverse effects on nodule formation and development. The reduced leaf area and leaf area index observed in the treatments plots other than the control plots could be attributed to loss of turgor that is normally common in plants under stress which could had led to reduction in leaf area [16].

The crop growth rate and net assimilation rate of the Bambara groundnut plant was also affected by water stress. However, these activities were observed to be higher in the control plots than in the other plots and could be an indication that the photosynthetic activities per unit leaf area in the control plant was more than that of the plants in the other treatment plots [19]. The variations in the number of days to 50% flowering and maturity in the various treatment plots could be due partly to the inherent genetic constituents of the plants or partly to delay in formation and translocation of assimilates due to water deficit [20]. Differences were also observed in the yield and yield components of the Bambara groundnut plant. Most of the pods harvested from the plots that received 500ml of water once in 4 days, were observed either to be empty or having lesser number of seeds. This could be due to low photosynthate formation and is in agreement with the report [21] that plants under water stress during pod filling produce lower weights of individual seeds.

CONCLUSION

The result of this study indicated that Bambara groundnut is sensitive to severe water stress. However, at moderate stress condition, the plant can thrive; though there was no significant difference observed between the yield obtained from the control plot and the plots that received 500ml of water once in 4 days. But the death of the plants in the other plot was a clear evidence of the susceptibility of Bambara groundnut to water stress. Thus Bambara groundnut should not be cultivated in areas with acute water stress conditions.

REFERENCES

1. Parsons, R. and R.J. Sunley, 2001. Nitrogen nutrition and the role of root shoot nitrogen signaling particularly in symbiotic system. J. Experimental Botany. 52: 435-443.
2. Otieno, D.O., M.W.T. Schmidt, S. Adiku and J. Tenhunen, 2005. Physiological and morphological response to water stress in two *Acacia* species from contrasting habitats. Tree Physiol., 25: 361-371.
3. Marino, D., P. Frendo, R. Ladrera, A. Zabalza, A. Puppo, C. Arrese-Igor and E.M.. Gonzalez, 2007. Nitrogen fixation control under drought stress. Localizes or systemic. Plant Physiol., 143: 1968-1974.
4. Serraj, R., V. Vadez and T.R. Sinclair, 2001. Feedback regulation of symbiotic N_2 fixation under drought stress. Agronomie, 21: 621-626.
5. Krasova-Wade, T., O. Diouf, I. Ndoye, C. Elimane Sall, S. Braconnier and M. Neyra, 2006. Water condition effects on rhizobia competition for cowpea nodule occupancy. African J. Biotechnol., 5(16):1457-1463.
6. Yordanov, I., V. Velikova and T. Tsonev, 2000. Plant response to rought acclamation and stress tolerance. Photosynthetica, 38: 171-186.
7. Martins, M.V., G.R. Xavier, F.W. Rangel, J.R.A. Ribeiro, M.C.P. Neves, L.B. Morgado and N.G. Rumjanek, 2003. Contribution of biological nitrogen fixation to cowpea; a strategy for improving grain yield in the semi-arid region of Brazil. Biological Fertilization of Soil., 23: 110-112.
8. Egharevba, R.K.A. and K.E. Law-Ogbomo, 2007. Comparative effects of two nitrogen sources on the growth and yield of Roselle (*Hibiscus sabdariffa*) in the rain forest region: a case study of Benin City, Edo State, Nigeria. J. Agronomy. 6(1): 142-146.
9. Sanginga, N., G. Tholtappilly and K. Dashiell, 2000. Effectiveness of rhizobia nodulating recent promiscuous soybean selection in the moist Savana of Nigeria. Soil Biology and Biochemis., 32: 127-133.
10. Pita, P. and J.A. Pardos, 2001. Growth, leaf morphology, water use and tissue water relations of *Eucalyptus globules* clones in response to water deficit. Tree Physiol., 21: 599-607.
11. Cochard, H., L. Coll, X. Le Roux and T. Ameglio, 2002. Unraveling the effects of plant hydraulics on stomatal closure during water stress in Walnut. Plant Physiol., 128: 282-290.

12. Cavender-Bares, J. and F.A. Bazzaz, 2000. Changes in drought response strategies with ontogeny in *Quercus ruba*: implications for scaling from seedling tomature trees. Oecologia, 124: 8-18.
13. Meinzer, C.F., 2000. Co-ordination of vapour and liquid phase water transport properties in plant. Plant Cell Environ., 25: 265-274.
14. NIMET, 2009. Nigeria Meteorological Agency, Annual Report for 2008.
15. Onuh, M.O. and A.A. Igwemma, 2000. *Applied statistical techniques for business and basic sciences*. 2nd edition. Skillmark Media Ltd, Owerri. pp: 341.
16. Hale, M.G. and D.M. Orcutt, 1987. The Physiology of Plants under Stress. John Wiley and Sons, Inc. New York. pp: 206.
17. Holbrook, N.M., V.R. Shashidhar, R.A. James and R. Munns, 2002. Stomatal control in tomato with ABA-deficient roots: response of grafted plants to soil drying. J. Experimental Botany, 53: 1503-1514.
18. Bjorkman, O., M.R. Badger and P.A. Armond, 1980. Response and Adaptation of Photosynthesis to High Temperatures. In: Turner, N.C. and Kramer, P.J. (Eds), Adaptation of Plants to Water and High Temperature Stress. Wiley- Interscience, New York. pp: 233-249.
19. Hsiao, T.C., 1973. Plant response to water stress. Annual Review. Plant Physiol., 24: 519-570.
20. Wardlaw, I.F., 1967. The effect of water stress on translocation in relation to photosynthesis and growth. I. Effects during grain development in wheat. Australian J. Biological Sci., 20: 25-39.
21. O' Toole, J.C. and T.T. Chang, 1979. Drought Resistance in Cereals-Rice: A case Study. In Mussell, H. and Staples, R.C. (Eds.), Stress Physiology of Crop Plants. Wiley, New York, pp: 374-405.