Journal of Applied Biosciences 200: 21163 - 21174
ISSN 1997-5902

Screening Bambara groundnut accessions for early Maturity in the sudano-sahelian zone of Cameroon

Chimène FANTA ABIB [1*], Félix Alain WASSOUO[2], HAOUA-OU[1], Albert NGAKOU[3], ADAMOU IBRAHIMA[3]
[1]Department of Biological Sciences, Faculty of Science, University of Maroua, Cameroon
[2]Department of Agriculture, Animal Husbandry and By-products, National Advanced School of Engineering, University of Maroua, Cameroon
[3]Department of Biological Sciences, Faculty of Science, University of Ngaoundere, Cameroon
***Corresponding author**: Chimène FANTA ABIB, Email:abibfany3@gmail.com
Phone: (+237) 697647259

Submission 11th July 2024. Published online at https://www.m.elewa.org/Journals/ on 30th September 2024.
https://doi.org/10.35759/JABs.200.5

ABSTRACT
Objective: this study was to identify Bambara groundnut accession with early maturing characteristics under pot conditions in the Sudano-sahelian zone
Methodology and Results: The experimental design was a Fisher block, comprising Bambara groundnut seed based on colour tegument as treatments (black, white, brown, red), each replicated four times. Early maturity black accession grew faster than the others (29.0 cm height) at 50 DAS. For the flowering, white accession is recorded as the late (39 DAS) and the black, early (34 DAS). Seed yield was more elevated for the black accession (1027.3 kg ha^{-1}). The ecophysiological parameters revealed that, apart from the photosynthetic yield, black accession had the best stomatic conductance (45.7µmol$H_2O.m^{-2}S^{-1}$), water used efficiency (5.42 kg m^{-3}), and transpiration (36.1 g hr^{-1}).
Conclusion and application of results: These pot's results under the Sudano-sahelian conditions suggest that the black Bambara groundnut accession compare to others accessions based on the colour of their teguments (red, brown and white) is the more adapted as far as the agro-ecophysiological parameters of this crop are concerned. Therefore, the black Bambara groundnut accession is suggested for promotion as a food security crop, especially in a contrasted drought stress area, such as that of the Far-North Region of Cameroon if growers expect to get a return net benefit from its cultivation and marketing. The results of this study will also help geneticists particularly the varietal improvement program by selecting genotypes of the early maturing Bambara groundnut accessions able to optimize the water uptake and use efficiency; that can help developing varieties with short development cycle which until now remains scientifically unknown in area like Farth-Nord Region of Cameroon which only have 3-4 months wet period.
Keywords: *Vigna subterranea*, ecophysiological parameters, grow, yield, sudano-sahelian zone**.**

INTRODUCTION

Vigna subterranea (L.) Verdcourt, commonly known as Bambara groundnut, is an indigenous staple crop to Sub-Saharan Africa. It is one of the subsistence grain legumes that are often neglected and under-utilized by communities in the region (Mkandawire, 2007). Bambara groundnut is adapted to diverse stressful climatic and ecological conditions (Onwubiko *et al*., 2011), with dry grains highly calorific (387 kcal. 100 g^{-1}) and nutritious containing 18-25 % proteins, 6-8 % lipids, 50-57 % of carbohydrates, 3-6 % of celluloses, 3-4 % ashes (Amarteifio *et al*., 2006; Basu *et al*., 2007; Gbaguidi *et al*., 2015), and antioxidants (Mbaiogaou *et al*., 2013). Despite this huge nutritive value, Bambara groundnut production worldwide remains very low, approximately 300.000 metric tons per year compared to that of other crop legumes such as cowpea (6.4 million t.$year^{-1}$) and soybean (350 million $tyear^{-1}$) (Kapso *et al*., 2011). In Cameroon, the yield production is approximately 36.639 t.$year^{-1}$ and 36% of this production comes from the Sahelian zone (Anonyme, 2006). This low yield of Bambara groundnut production is mainly attributed to the low soil fertility (Basu *et al*., 2004), and the long crop development cycle varying from 5-6 months, for only 3-4 months wet period. This means that the crop spends half of its development cycle within a water stress status. Therefore, it is imperative to strategize on selecting the early maturing accessions able to optimize the water uptake and use efficiency. The objective of this study was to identify Bambara groundnut accessions with early maturing characteristics under the Sudano-sahelian conditions in Cameroon.

MATERIAL AND METHODS

Description of the study area: The experiment was carried out at the Institute of Agricultural Research for Development (IRAD) of Maroua in the Far-North Cameroon. The experimental site is located at 10°35’29’’ north latitude and 14°18’55’’ east longitude. The climate is contrasted, with a long dry season (September to May), against a short wet season (June to September). The annual cumulated rainfall is 700 mm, whereas the mean annual temperature is 28°C (ONACC, 2022). The somewhat greenhouse in which the pots were established was to protect against attacks from insects and birds.

Biological material: The mature Bambara groundnut seeds belonged to four accessions (Table 1), all provided by Institute of Agricultural Research for Development (IRAD) of Maroua. There were distinguished by the colour of their tegument (Figure 1) and their growing cycles.

Table 1: Characteristics of Bambara groundnut seeds

Selection code of accessions	Colour of seeds teguments	Form of seeds	Growing Cycle (DAS)
VBE37/21	White	Ovoid	200
VRE09/21	Red	Ovoid	200
VME60/22	Brown	Piriform	190
VNE11/20	Black	Ovoid	190

DAS: day after sowing

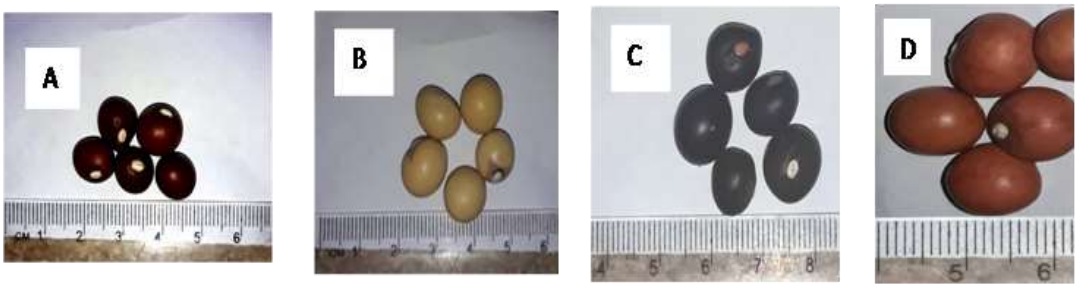


Figure 1: Bambara groundnut accessions used: **A** = Red accession; **B**= White accession; **C** = Black accession; **D** = Brown accession

Experimental device : The experimental device is a Fisher block comprising the Bambara groundnut accessions as treatments (black, white, brown, red), replicated four times. Each accession was represented by four pots. The seeds were sorting and the growing pots were preparing. A pot was a plastic bag of 18 cm long and 16 cm wide, perforated with two holes on the sites and two others at the bottom to drain out excess water. Each pot was filled with 2 kg of soil. At sowing, each pot received two seeds, but the seedlings were thinned to one, two weeks after germination.

Data collected

Agronomic parameters: Plant emergence was calculated as the ratio between the numbers of emerged plants over the total number of seeds sown; this was taken at 14 day after sowing. Plant height (PH), leave length (LL), and leave width (LW) were measured using a graduated decameter at 50 days after sowing on all the plants of each treatment. This corresponds to the beginning of the reproduction period preceding the vegetative growth phase (Yao Djè *et al*., 2005; Ndiang *et al.,* 2012; Wassouo *et al.*, 2019; Wang-Bara *et al*., 2021; Baina *et al.*, 2023). The number of stems per plant and the total number of leaves per plant were manually counted. The date of first flower bud emergence and 50% flowering were also recorded. The pods per plant, as well as the total number of pods at maturity (%) was counted at the end of the developmental growth cycle (200 days after sowing). The 100-seed weight (seed-index) was value using a 0.01g Kern PCB model electronic balance. The biological yield (BY) was calculated from the ITGC formula (2015):

BY(g m^{-2}) = Numbers of seeds m^{-2} x seed weight (g m^{-2}) and expressed in metric tons ha^{-1}**.**

The percentage of mature seeds was estimated at physiological maturity stage and was calculated as the ratio between the numbers of mature seeds after harvest over the total number of seeds harvesting; this was taken at 200 day after sowing.

Ecophysiological parameters: The eco-physiological parameters that refer to the physiological state of the plant were assessed from 20 to 200 days after sowing. These included the photosynthetic potential, also called net photosynthesis; the foliar transpiration, and the stomatic conductance, which were measured directly using the CO_2LCi modern CI-340 model analyser. The leaf photosynthetic rate was measured by enclosing a leaf in a transparent chamber, before measuring the decrease in carbon dioxide concentration as a function of time. Under these conditions, water vapour pressure is held constant in this chamber as a function of time by partially drying the recirculating air so that stomatic conductance is calculated from vapour pressure changes (if they occur) and the flow rate of dry recirculated air (Polley *et al*., 1992).

To calculate the hydric status of plants, the foliar hydric Potential (Ψ_f) was measured on 5 selected plant leaves, using a SF-Pres-100 model pressure room of Scholander type, previously sealed in a plastic bag for 4 hours to stop transpiration. Hence, with the transpiration stopped, the leave hydric potential was equilibrated with that of the soil, thus representing the hydric status of the entire plant (Konate, 2018). The intrinsic water used efficiency (iWUE) was calculated using the formula of Flexas *et al.*, (2010):

$$iWUE = \frac{\text{Net photosynthesis}}{\text{Foliar transpiration}}$$

Data analysis: The data collected were analysed using a Statgraphics Centurion Version XVII through analysis of variance. Significant treatment means were separated using the Fisher's least significant differences (LSD) at 5% level of significance.

RESULTS AND DISCUSSION

Agronomic parameters: Table 2 present some agronomics parameters of Bambara groundnut accessions 50 days after sowing. Significant variation (p=0,001) were observed in the average plant emergence, plant height, leave length, leave wide, number of stems, number of leaves, first flowering date and date of 50% flowering.

Table 2: Agronomics parameters linked to Bambara groundnut accession growth at 50 DAS

Agronomic parameters	Accessions				p-value
	Black	White	Brown	Red	
Plant emergence (DAS)	09.0±0.3^{c}	06.0±0.5^{a}	07.0±0.5^{bc}	07.0±0.5^{bc}	0.001
Plant height (cm)	29.0±0.2^{d}	21.0±0.2^{a}	25.0±0.1^{c}	22.0±0.1^{ab}	0.003
Leave length (mm)	90.1±0.4^{d}	69.0±0.2^{a}	83.0±0.1^{c}	82.2±0.5^{b}	0.0001
Leave wide (mm)	32.0±0.2^{c}	26.0±0.1^{a}	26.1±0.5^{a}	30.0±0.3^{b}	0.003
Nbr of stems plant^{-1}	16.0±0.7^{c}	11.0±0.5^{a}	11.0±0.6^{a}	14.0±1.2^{b}	0.0001
Nbr of leaves plant^{-1}	117.0±0.6^{d}	55.0±0.7^{a}	109.0±0.8^{c}	93.0±1.1^{b}	0.0001
First flowering date (DAS)	35.0±0.4^{a}	39.0±0.4^{c}	38.0±0.3^{b}	37.0±0.3^{b}	0.001
Date of 50% flowering (DAS)	41.0±0.7^{a}	45.0±0.4^{c}	44.0±0.4^{b}	43.0±0.4^{b}	0.001

For each agronomics parameters, values bearing the same letter are not significantly different at the level of p<0.05% significance. DAS: days after sowing; Nbr: Number.

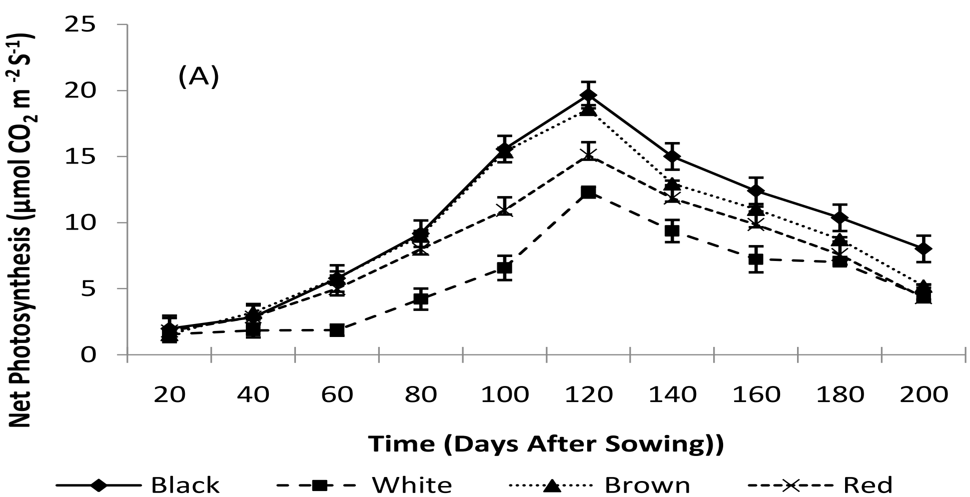
They were very height significant differences (p=0.001%) in plants emergencies among Bambara groundnut accessions, ranging from 6 to 9 days after sowing (Table 2). The white accession emerged 6 days after sowing; the brown and red accessions emerged 7 days after sowing, similar to previous results from Bonny *et al*. (2011) for white, brown and red accessions, which emerged between 6 and 7 days after sowing (DAS) in Ivory Coast. At last, the black accession emerged 9 days after sowing (DAS); also similar to the results of Toure *et al*. (2012) who found the emergence of Bambara groundnut plants of the black accession to be 6 to 15 DAS. These differences in the length of time in plants emergencies could be attributed to genetic and environmental conditions (Pérez-Fernández and *al*., 2005). As for the plants emergencies, very highly significant difference (p=0.001) was observed for the plant height, leaf length and wide, number of stems and leaves per plant (Table 2).The highest values accounted for the black accessions, while lowest were recorded with the white accessions under the studied conditions. These results are different from those of Saley *et al*. (2022) under the specific conditions of Niger. This shows that combined effects of genotypes and environment influences plant growth, because genotype × environment interactions imply that the differences in phenotypes between genotypes are not constant from one environment to another. In fact, different genotypes have been reported to exhibit different plasticities and responses to a change in environment according to Malosetti *et al*., (2013). From the phenological parameters, table 2 shows that the time taken after sowing for the first flower to appear varied significantly (p=0.001) between accessions. The white accessions flowered tardively (39 DAS), the black early (34 DAS) and the two others accessions (red and brown) intermediately (37 DAS). For all the accessions, 50% flowering was attained at least 6 days after the emergence of the first flower, thus later than 3 DAS as pointed out by Saley *et al*. (2022) in Niger, confirming the differences between the two study sites as far as the climatic conditions are concerned. These results suggest that, dates of flowering for Bambara groundnut significantly vary with the growing area because according to Voisin and Salon (2004), the precocity of flowering is an important mechanism for escaping drought in semi-arid climates. At harvest stage (Table 3), the percentage of seed maturity was statically and significantly different between accessions (p=0.002). The black accession provided almost 80% of mature seeds compared to only 50% for the white accessions. The red and brown accessions had approximately 70% mature seeds. The number of pods per plant also varied significantly (p=0.002) among accessions, the black accessions bearing 64 pods per plant, against 24 pods for the white accession. This result could be linked to a good development of the vegetative plant part, as previously mentioned by Taffouo *et al*. (2008).The seed index (SI) which refers to the 100 seed weight also differed significantly (p=0.041) between Bambara groundnut accessions. The seed index varied from 71.53g for the black accession, to 37.95g for the white accessions. Grain yield per plant also significantly differed (p=0.001) among Bambara groundnut accessions, with the black seed accession providing the highest yield (1027.33 kg ha^{-1}). This result could be attributed to the early flowering of the black, red and brown accessions compared to the white accessions. In fact, Kumar and Abbo (2001) noticed better seed yield from early flowering genotypes of chickpea in arid environments, as a form of adaptation to these conditions

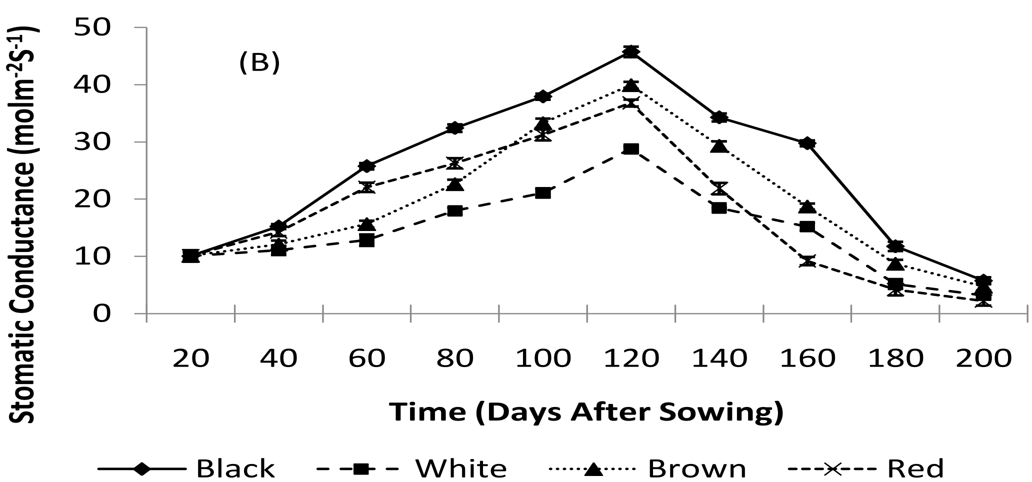
Table 3: Yields parameters at 200 DAS

Yields parameters	Accessions				p-value
	Black	White	Brown	Red	
Matured seeds (%)	80.9±0,6^{c}	50.1±0,6^{a}	71.2±0.5^{b}	70.1±0.4^{b}	0.002
Nbr of pods plant^{-1}	65.0±0.4^{c}	25.0±7.7^{a}	50.0±0.4^{b}	48.0±0.4^{b}	0.002
Seed Index (g)	71.5±0.8^{c}	37.95±0.4^{ab}	45.6±0.8^{a}	45.9±0.8^{a}	0.041
Nbr of Seeds plant^{-1}	25.0± 1.2^{d}	16.0± 0.8^{a}	23.0±1.4^{c}	19.0±1,0^{b}	0.001
Grains Yields (kg ha^{-1}**)**	1027.3±41. 8^{d}	635.2±27. 4^{a}	851.0±29.1^{c}	803.8±26.4^{b}	0.001

For each agronomics parameters, values bearing the same letter are not significantly different at the level of p<0.05% significance**.** Nbr: Number.

Ecophysiological parameters: Figure 2 illustrate the net photosynthesis **(A)**, stomatic conductance **(B)** and transpiration **(C)** between the Bambara groundnut accession over time. At 20 DAS, the net photosynthesis as well as the stomatic conductance did not change significantly (p>0.05) between the accessions, whereas transpiration of the black accessions (17.04 g hr^{-1}) was greater than that of the red accessions (15.04 g hr^{-1}), brown and white varieties (12 g hr^{-1}). At 120 DAS, photosynthesis and stomatic conductance attained their maximum, for all the accessions, while for the foliar transpiration the optimum is attained at 100 DAS, for brown, red and white accessions. After 120 DAS, all the parameters decrease progressively and tend to cancel at 200 DAS. This decline could be due to hydric stress effect, accounting for the reduced rain mostly observed in October. According to Gao (2000), the occurrence of hydric stress implies the reduction of water lost, through the closure of stomata's, occasioning the reduction of the photosynthetic activity, transpiration and soil water absorption by plant roots, thus the reduction of hydric potential. These results is similar with those of Radhouane (2013) on Sorghum; Vialet-Chabrand (2013) on oak, Bourou *et al* (2011) on *Tamarindus*, Damour (2008) on mangoes, who have revealed a relationship between transpiration, stomatic conductance and the net photosynthesis. In fact, the stomatic conductance was shown to be under the dependence of CO_2 within the leave, which itself depends on transpiration (Flexas, 2004). Moreover after 120 DAS, the foliar senescence was more pronounced and could explain the drop down of the three others parameters.





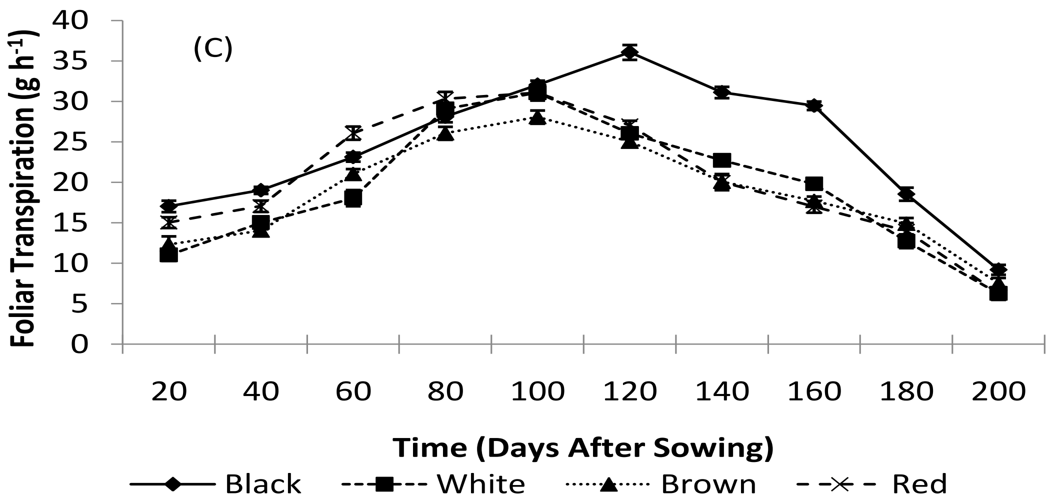


Figure 2: Dynamic of the net photosynthesis (A), stomatic conductance (B) and foliar transpiration (C) during the growing cycle of Bambara groundnut accessions.

The foliar hydric potential varied from -0.15 MPa to -0.82 MPa (Figure 3). It was constant up to 40 DAS, and then started decrease up to the end of the cycle. Black accession indicated the most elevated values, varying from -0.12 MPa at 20 DAS, to -0.65 MPa at 200 DAS.

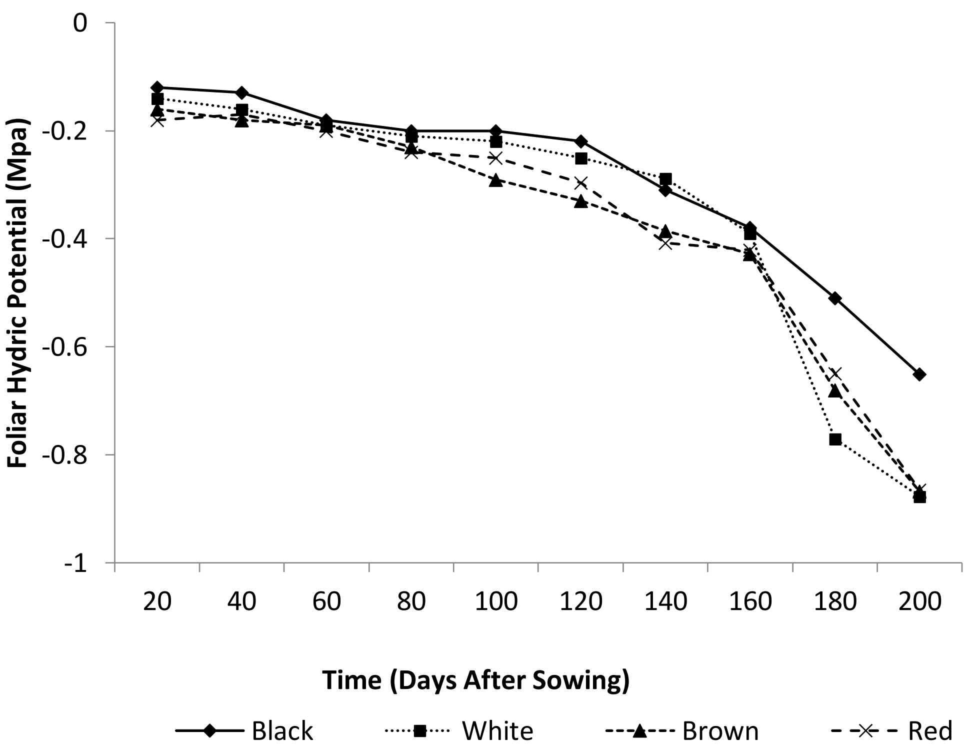


Figure 3: Variation of the foliar hydric potential between accessions over time (DAS)

The variation of the foliar hydric potential was reported to be related to the soil humidity, since it refers to soil water availability, while providing details on the plant hydric status (Tardieu, 2005). At 120 DAS, the study area was still very wet, then rain start to drop down as from 140 DAS, indicating the end of the raining season, and therefore the progressive reduction of the potential. According to Van Leuween and Vivin (2008), when Ψ_f >-0.6 MPa, there is hydric deficit and which is perceptible in the range $-0.6<\Psi_f<-0.9$MPa. Hence, the black accession was less affected by hydric deficit with a value of Ψ_f >-0.6 at 200 DAS. The obtained Ψ_f values were more elevated than those reported by Brou *et al.* (2007), Kihindo *et al*. (2016) on cowpea, implying that cowpea is less resistant to hydric stress in the dry season than Bambara groundnut. However, the figure shape was the same as those pointed out by Bourou *et al*. (2011) and Radhouane (2013), respectively on *Tamarindus* and *Sorghum*. The water use efficiency (WUE) was statistically and significantly greater (p=0.001) for the black accession than the brown, red and white accessions (Figure 4), confirming the greater transpiration, better photosynthesis and elevated stomatic conductance accounting for by this accession over the others previously ones reported (Cernuzak *et al.* (2007).

The WUE was revealed to have established the link between the biomass production and the monitoring of water, thus indirectly the relationship between water and carbon cycles (Guehl *et al*., 1994). These findings explain why black accession was the most productive, in agreement with research results, which emphasized the efficient production of plants with great WUE under unfavourable hydric stress (Damour, 2008; Bourou *et al*., 2011; Konate, 2018). For this parameter, whereas the black accession could be most indicated, the white accession was least suitable because of its relatively high water requirement.

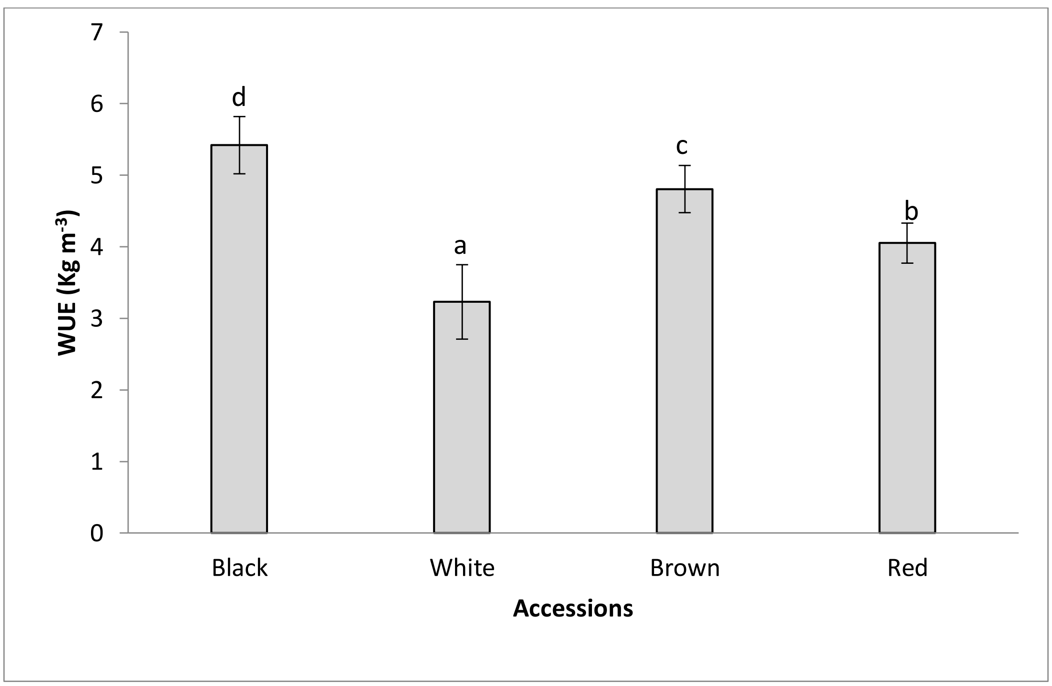


Figure 4: Water Used Efficiency (WUE) between Bambara groundnut accessions at 200 days after sowing

CONCLUSION AND APPLICATION OF RESULTS

The outcomes of this research are that, white accession of Bambara groundnut emerge early (6 DAS) compared to the late emerging red accessions (9 DAS). As far as the development growth, cycle is concerned, the early maturity black accessions grow faster than the others do, and bear large and long leaves. From the ecophysiological parameters, black accessions has revealed to possess not only the best transpiration and net photosynthesis, but also the most elevated stomatic conductance, reflecting a better intrinsic Water Used Efficiency that leads to a good yield expressed in tons ha^{-1}. Therefore, the black accession is suggested for promotion as a food security crop, especially in a contrasted drought stress area, such as that of the Far-North region of Cameroon, if growers expect to get a return net benefit from its cultivation.

REFERENCES

Amarteifio JO, Tibe O, Njogu RM. 2006. The mineral composition of Bambara groundnut (*Vigna subterranea* (L.) Verdc) grown in Southern Africa. African Journal of Biotechnology 5, 2408-2411.

Anonyme. 2006. Annuaire des statistiques du secteur agricole du Cameroun, campagne 2005/2006. Direction des enquêtes et statistiques agricoles. 84pp.

Baina D, Issa ZM, Mahamadou MA, Abdou RIBY. 2023. Etude de la variabilité agro morphologique de 81 accessions de voandzou [*Vigna subterranea* (L.) Verdc] au Niger. Journal of Applied Biosciences 183, 19181-19196.

Basu S, Roberts J, Mithen R, Azam-Ali S, Pasquet R. 2004. The genetics of Bambara groundnut and the construction of a genetic linkage map. In New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress, Brisbane, Australia. pp 7.

Basu S., Mayes S., Davey M., Jeremy A., Azam-Ali S.N., Mithen R. and Pasquet R.S. 2007. Inheritance of domestication traits in Bambara groundnut [Vigna subterranean (L.) Verdc.]. 59-68. DOI: 10.1007/s10681-007-9396-4
https://doi.org/10.1007/s10681-007-9396-4

Bonny SB, Dje Yao. 2011. Morphologic and agronomic variability of traditional varieties of *Vigna subterranea* (L.) verdc. (Fabaceae)] in Ivory Coast. Journal of Applied Biosciences 41, 2820-2835.

Bourou S, Ndiaye F, Diouf M, Van Damme P. 2011. Effects of mycorrhizal inoculation on the agro-physiologic behavior of Tamarindus ecotypes (Tamarindus indica L.) in Senegal. Journal of Applied Biosciences 46, 3093-3102.

Brou YC, Diouf O, Zeze A, Eyletters M. 2007. Hydric status and photosynthetic capacities of two cowpea varieties (*Vigna Unguiculata* (L.) walp) submitted to hydric stress. Agronomie Africaine 19(1), 29-40.

Cernusak L, Arand J, Marshall J, Winter K. 2007. Large variation in whole-plant water-use efficiency among tropical tree species. New Phytologist 173, 294-305. https://doi.org/10.1111/j.1469-8137.2006.01913.x

Damour G. 2008. Theoretical and experimental approaches basis of the modelisation effects of hydric constraints on foliar gaseous exchanges of mango and litchi. Doctorate Thesis. Reunion University. 74-105.

Flexas J, Galmés J, Gallé A, Gulías J, Pou A, Ribas-Carbo M, Tomàs M, Medrano H. 2010. Improving water use efficiency in grapevines: potential physiological targets for biotechnological improvement. Australian Journal Grape Wine Research 16, 106-121. https://doi.org/10.1111/j.1755-0238.2009.00057.x

Gao WJ. 2000. The experimental technology of plant physiology. Xian, China, World Book Press. pp.89-258.

Gbaguidi A.A., Faouziath S., Orobiyi A., Dansi M., Akouegninou B.A. et Dansi A., 2015. Connaissances endogènes et perceptions paysannes de l'impact des changements climatiques sur la production et la diversité du niébé (*Vigna unguiculate* (L.) Walp.) et du voandzou (*Vigna subterranea* (L.) Verdc.) au Bénin. International Journal of Biological and Chemical Sciences, 9(5): 2520-2541. DOI: http://dx.doi.org/10.4314/ijbcs.v9i5.23

https://doi.org/10.4314/ijbcs.v9i5.23

Guehl JM, Nguyen-Queyrens A, Loustau D, Ferhi A. 1994. Genetic and environmental determinants of water use efficiency and carbon isotope discrimination in forest trees. In: Sandermann H.J., B M M., eds, EUROSILVA. Contribution to Forest Tree Physiology. INRA, Versailles, France. pp.297-321.

ITGC. 2015. Technical Institute of Great Cultures. Evaluation Methods of cereale yield at the laiteux-paststure state.12p.

Kaptso KG, Fombang E, Njintang YN, Mbofung CMF. 2001. Effect of irradiation on physico-chemical properties and in vitro digestibility of 258 hard bean (Phaseolus vulgaris) seed sand flours. Biosciences Proceeding 8, 252-262.

Kapto KG, Fombang E, Njintang YN, and Mbofung CMF, 2001. Effect of irradiation on physic-chemical properties and in vitro digestibility of 258 hard bean (*Phaseolus vulgaris*) seed sand flours. Biosciences Proceeding 8: 252-262.

Kihindo AP, Bazie HR, Razacswendé FO, Some PP, Dondasse E, Zombre G, Koffi T. 2016. Variation of the physiological and agronomic réponses of cowpea (*Vigna unguiculata* L.Walp) at different sowing dates in Burkina Faso. Journal of Applied Biosciences 107, 10353-10361.

https://doi.org/10.4314/jab.v107i1.1

Konate NM. 2018. Interspecific diversity of water used efficiency by sahelian and Australian Acacia. Doctorate Thesis, Henri Poincare University, Nancy-I, France. 120pp.

Kumar J, Abbo S. 2001. Genetics of flowering time in chickpea and its bearing on productivity in semi-arid environments. Agronomy 72, 107-138. https://doi.org/10.1016/S0065-2113 (01)72012-3

Malosetti M, Ribaut J, Van Eeuwijk F. 2013. The statistical analysis of multi-environment data: modelling genotype by environment interaction and its genetic basis. Frontiers in Physiology 4(44), 17-29.

https://doi.org/10.3389/fphys.2013.00044

Mbaiogaou A, Héma A, Ouédraogo M, Pale E, Naitormbaide M, Mahamout M, Nacro M. 2013. Etude comparative des teneurs en polyphenol et en antioxydant totaux d'extraits de grains de 44 variétés de voandzou [*Vigna subterranea* (L.) Verdcourt]. International Journal of Biological Chemical Sciences 7(2), 861-871.

https://doi.org/10.4314/ijbcs.v7i2.41

Mkandawire C.H. 2007. Review of Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) production in Sub-Sahara Africa. Agricultural Journal 2(4), 464-470.

Ndiang Z, Bell JM, Missoup AD, Fokam PE, et Amougou Akoa, 2012. Etude de la variabilité agro morphologique de quelques variétés de voandzou [*Vigna subterranea* (L.) Verdc] au Cameroun. Journal of Applied Biosciences 60, 410-420.

ONACC. 2022. National Observatory on Climatic Changes. Previsions and climatic signs in Cameroon. Newsletter N°13. 12p.

Onwubiko NIC, Odum OB, Utazi CO, Poly-Mbah PC. 2011. Studies on the adaptation of Bambara Groundnut [*Vigna subterranea* (L.) Verdc] in Owerri Southeastern Nigeria. New York Science Journal 4(2), 60-67.

https://doi.org/10.3923/aj.2011.60.65

Pérez-Fernánde MA, Calvo-Magro E, Montanero-Fernández J, Oyola-Velasco JA. 2006. Seed germination in response to chemicals: Effect of nitrogen and pH in the media. Journal of Environmental Biology 27(1), 13-20.

Polley HW, Norman JM, Arkebauer TJ, Walter-Shea WA, Greegor DH, Bramer B. 1992. Leaf gas exchange of Andorpogon gerardii Vitman, Panicum virgatum L., and Sorghastrum nutans (L) NASH in a tall grass prairie. Journal of Geophysycal Research 97 (18), 837-844.

https://doi.org/10.1029/92JD00883

Radhouane L, Nesrine A, Leila R. 2013. Effects of a hydric stress applied at different stages of development on the quantitative and qualitative aspects of seeds in autochtone sorghum seeds ecotypes (Sorghum bicolor). Journal of Applied Biosciences 74, 6149-6156.

https://doi.org/10.4314/jab.v74i1.6

Saley MD, Amadou HI, Boukar KK. 2022. Agro-morphological characterization of 30 Voandzea accessions [*Vigna subterranea* (L.) verdc] cultivated in the sudanian zone of Niger. International Journal of Innovation and Applied Studies 36(2), 553-563.

Taffouo VD, Djiotie NL, Kenne M, Din N, Priso JR, Dibong S, Akoa A, 2008. Effect of salt stress on physiological and agronomic characteristics of three tropical cucurbit species. Journal of applied biosciences 10, 434-441.

Tardieu F. 2005. Plant tolerance to water deficit: physical limits and possibilities for progress. Geoscience 337, 57-67.

https://doi.org/10.1016/j.crte.2004.09.015

Toure Y, Kone M, Kouakou TH, Koné D. 2012. Agromorphological and Phenological Variability of 10 Bambara Groundnut [*Vigna subterranea* (L.) Verdc. (Fabaceae)] Landraces cultivated in the Ivory Coast. Tropicultura 30(4), 216-221.

Van Leeuwen C, Vivin P. 2008. Alimentation hydrique de la vigne et qualité des raisins. Innovations agronomiques 2, 159-167.

Vialet-Chabrand S. 2013. Modelization of daily variations of stomatic conductance: A dynamic approach and consequences on the intrinsic Water Used Efficiency in chene. Doctorate Thesis. Lorraine University, France. 15-39.

Voisin A., Salon C. 2004. Efficience de la nutrition azotée. In B. V. Munier-Jolain Na., Chaillet I., Lecoeur J., Jeufrroy M.H., ed. Agrophysiologie du pois protéagineux. INRA-Arvalis, Paris. 94-98.

Wang-Bara B, Amedep D, Housseini D, Guiwa G. 2021. Evaluation des effets des doses de mycorrhizes sur les paramètres de croissance et de la production de trois variétés de voandzou dans la localité de Dschang, Ouest-Cameroun. European Scientific Journal 17(17), 213. https://doi.org/10.19044/esj.2021.v17n17p213

Wassouo FA, Madi A, Sobda G, Koubala BB, Mvondo Awono JP. 2019. Diversités agro-morphologiques de trente-six accessions de voandzou [*Vigna subterranea* (L.) Verdcourt] cultivées dans la Région de l'Extrême-Nord Cameroun. Journal of Applied Biosciences 140, 14227-14234. https://doi.org/10.4314/jab.v140i1.2

Yao Djè, Beket S., Bonny, Irié A. et Zoro B., 2005. Observation préliminaire de la variabilité entre quelques morphotypes de voandzou [*Vigna subterranea* L. Verdc] de Côte d'Ivoire, Biotechnologie, Agronomie, Société et Environnement 9 (4): 249-258.