Available online at http://www.ifgdg.org

Int. J. Biol. Chem. Sci. 13(4): 2029-2040, August 2019

ISSN 1997-342X (Online), ISSN 1991-8631 (Print)

International Journal of Biological and Chemical Sciences

Original Paper http://ajol.info/index.php/ijbcs http://indexmedicus.afro.who.int

Variation in seed and seedling traits of *Faidherbia albida* (DEL.) A. Chev populations in the Sudano-Sahelian zone of Cameroon

Dorothy Tchapda TCHATCHOUA[1*], George Messo KOLYANG[1], Roseline Gusua CASPA[2], Simon Djakba BASGA[3] and Alphonse YOURI[4]

[1]*Department of Agriculture, Animal Husbandry and Derived Products, National Advanced school of engineering, University of Maroua, Cameroon.*
[2]*Institute of Agricultural Research for Development (IRAD), Forest and Wood. Program. P. O. Box 2123 Yaounde, Cameroon.*
[3]*Institute of Agricultural Research for Development (IRAD), Maroua. P.O. Box 33 Maroua Cameroon.*
[4]*Institute of Agricultural Research for Development (IRAD), P.O. Box 12 Yagoua, Cameroon.*
[*]*Corresponding author; E-mail: d.tchatchoua@yahoo.com; Tel.: +237 677598313*

ABSTRACT

The once sustainable agroforestry system in the Sudano-Sahelian zone of Cameroon has been abandoned and trees overexploited. A study on the variability in seed and seedling traits of *Faidherbia albida* (DEL.) A. Chev populations from different climatic zones was carried out. Six populations were selected from Sudanian (Poli, Garoua III, and Figuil) and Sahelian (Yagoua, Moulvoudaye and Maroua I) climatic zones and harvested seeds were transported to the experimental farm of IRAD Yagoua for pretreatment and growth experiment. Four pretreatments (98% sulfuric acid, hot water, scarification and soaking in water for 24 hours) were used to initiate the germination. After one month, the rate of germination (%) was recorded and seedlings were transplanted in three substrates for seedling growth evaluation. Growth traits (Survival, plant height, root collar diameter, number of leaves, root length, plant fresh weight and plant dry weight) were measured after three months. The experimental design was a single tree plot randomized complete block design with 30 blocks. Results indicated there was significant difference (p = 0.002) among pre-treatments for the germination. The highest rate of germination was recorded with seedlings from scarified seeds (78.33%), followed by those from seeds treated with sulfuric acid (76.67%). Seeds and seedling traits were significant among populations with Yagoua recording the highest in most of the traits measured. Scarification can assist in seed germination and movement of seeds between populations and climatic zones should be considered during conservation programs.

Keywords: *Faidherbia albida*, agroforestry parklands, seed pretreatments, seedling traits, conservation, Sudano-Sahelian, Cameroon.

INTRODUCTION

The Sahel regions of Cameroon are known for it low production in crops due to low fertility of the soil. The uneven distribution of rainfall, the poverty of the soil, the impossibility of mulching and the permanent presence of animals in the farmlands deplete the soil organic matters. An extraordinary agricultural method, capable of

DOI: https://dx.doi.org/10.4314/ijbcs.v13i4.10

producing crops under forest resources with a result that combines increase in field yields, improve farmers' incomes, preserve the quality of food products and preserve non-renewable resources was initiated in the early 90s. The Rural Development and Management Project (DPGT) encouraged farmers by giving subvention to anyone that will protect the regeneration of *Faidherbia albida* in farmlands. These led to an increased of *Faidherbia albida* population on farmlands and the creation of agroforestry parklands through natural regeneration (PPDAF, 1988; CTFT, 1989,). These agroforestry parklands had some socio-economic and environmental importance for the rural population (Pelissier, 1980; Bonkoungou, 1991; Dupraz, 2008; Djingui, 2015). High yields in sorghum, maize and groundnut have been reported (Liber and Eyog Matig, 1996; Louppe et al., 1996).

Fadherbia albida fertilizing and nitrogen fixing potentials with the inverse phenology makes it possible for crops to be grown under the trees during the raining season (FAO, 1999; Roupsard et al., 1999). The species is used as forage (World Agroforestry Center, 2009) and the wood is good for making furniture (Peltier, 1996). This once sustainable system is now abandoned and the trees overexploited. The agroforestry parklands are also being affected by the increase in human population and climate change. Various actions have been carried out at the national level for the management of these parklands but the later have largely focused on habitat and species diversity (Seignobos, 1982a; Raison, 1988; IRAD, unpublished) neglecting genetic diversity in the species. Genetic diversity provides the basis for conservation and management of the germplasm. *Faidherbia albida* seeds are also difficult to germinate because of the hard seed coat which prevents water from entering into the seed. Many studies on pre-germination has been reported (Aref et al., 2011; Clode, 2011) and results show provenance or population variation in seed pretreatment and seedling growth in the species (Fredrick et al., 2015). This work investigated the effect of pretreatment on seeds and variation in seeds and seedling growth of populations in the Sudano-Sahelian zone of Cameroon.

MATERIALS AND METHODS

Geographical description of seed source and experimental site

Seeds were collected from six populations in the Sudanian (Poli, Garoua III, and Figuil) and Sahelian (Yagoua, Moulvoudaye and Maroua I) climatic zones of Cameroon and transported to the experimental farm of the Institute of Agricultural Research (IRAD) Yagoua (Figure 1). The seed source zones and experimental site are found in the Sudano-Sahelian regions characterized by seven to eight months of dry season and four to five months of rainy season. These zones represent the distribution range of the species in Cameroon. This regions in Cameroon is situated between latitude 9°-11° N and longitude 13°-15° E with altitude ranging from 350-450 m asl. It covers a surface area of 102.068 km² and comprises of great ecological regions of Mts Mandara, the Far-North and the Benoue plains. The temperature is between 20 °C and 45 °C and annual rainfall ranges from 700-1200 mm.

Method of sampling

Three agroforestry parklands (here designated as populations) were selected each from the two climatic zones and seeds were collected from 10-20 trees resulting from natural regeneration (seedlings were protected by farmers in the various populations) trees. The geographic and climatic conditions of the populations are presented in Table 1. These populations were separated by a distance of 30 - 100 km within climatic zones. Sampled trees were at least 100 m apart to avoid sampling individuals of the same genotype. In each location 10-20 ripe fruits (pods) were harvested on healthy trees and from the four cardinal points of each tree. Information on the morphological or phenotypic traits measured was put into a database whereas geographical positions of the sampled trees were recorded with a GPS Garmin and a map of the population distribution was created using ArcGIS Map Marker software (Fig. 1). Harvested fruits were dried in the sun for at least three days and seeds were extracted from the fruit by lightly pounding in a mortar without much muscular strength to avoid crushing the seeds.

This was followed by winnowing to separate seeds from pod debris. Broken grains were sorted and separated from healthy whole seeds and further dried in the shade for twenty four hours. These seeds were then transported to the experimental site of IRAD Yagoua where two experiments were carried out.

Experiment 1: Pretreatment test

About 480 healthy seeds where collected from each population and used for the pretreatment experiment. Before pretreatment, the length, width and weight of 100 randomly selected seeds per population were recorded. The four pretreatments were: -

Treatment 1: Sulfuric acid. This method consisted of immersing seeds for 30 minutes in 98% concentrated sulfuric acid followed by rinsing with great caution and dipping in water for 24 hours.

Treatment 2: Hot water at 100 degree. Scalding consists in immersing the seeds in the boiled water and left to cool for 24 hours

Treatment 3: Scarification of Seeds. A shallow incision was made with a blade in the hard shell of the seed, taking care not to pass through the seed coat and not to expose the seed.

Treatment 4: It consisted of soaking the seeds of *Faidherbia albida* in cold water for 24 hours.

The treated seeds were sown in sterilized sand using germinating containers under room temperature and observed for germination for one month. These containers were placed in a constructed shade (thatch of *Eragrostis tremula*) under *Azadirachta indica* A. Juss (Neem) tree and daily watering was provided in the early morning and late in the afternoon to maintain a high level of moisture.

Experiment 2: growth trial

After germination, the seedlings were grown in three growth substrate:-

Substrate 1: A mixture of sterilized sand, forest soil and well-decomposed cow dung in a ratio of 2:1:1

Substrate 2: Unsterilized sand, forest soil and well-decomposed cow dung in a ratio of 2:1:1

Substratum 3: Forest soil and well-decomposed cow dung in a ratio of 2:1

Polyethylene bags of 24 cm long and 13 cm wide of size were filled with the above substrates and placed in the constructed shade as described above. The experimental design was a single tree plot of randomized complete block design with 30 blocks. A total of 2160 individuals were established in the experiment (4 pretreatments x 6 populations x 3 substrates x 30 blocks).

Data collection and statistical analysis

After one month, germination rate was assessed before seedlings were transplanted into the different substrates. Each month survival, seedling height, root collar diameter and number of leaves were recorded while at three months of growth in the nursery which is reported in this article the following morphological parameters were measured: - survival (%), seedling height, root collar diameter, number of leaves, root length, plant fresh weight and dry weight. The seedling height and root length were measured with a gradated measuring rule while the root collar diameter of seedlings was measured with a vernier caliper. The survival (%) and number of leaves per seedling was counted and the fresh weight of the whole plant was measured using an electronic balance. The seedlings were dried at room temperature for four days and the dried weight measured and recorded.

Exploratory statistics for all the traits studied were carried out using explorative and descriptive analysis of IBM SPSS (Version 20) to test for normal distribution and equality of variance. To estimate differences among pretreatments, substrates, populations and climatic zones, a statistical analysis was performed for the measured traits using one way analysis of variance (ANOVA). Means were compared with the Duncan Multiple Range Test (DMRT) and Pearson correlation coefficient among measured parameters was also determined.

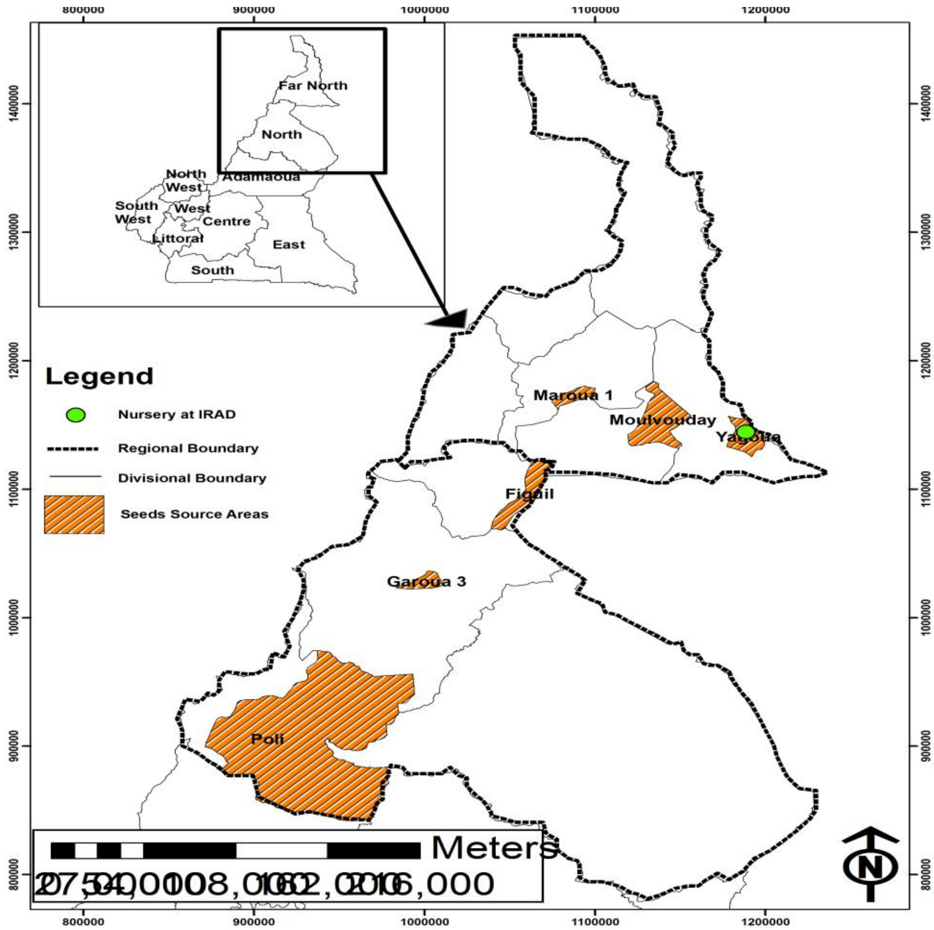

Figure 1: location of study areas and nursery trial site in the Sudano-Sahelian zone of Cameroon.

Table 1: Geographical and climatic conditions of the agroforestry parklands or populations.

Population	Climatic zones	Altitude (m)	Longitude	Latitude	Annual Precipitation (mm)	Temperature range (^{0}C)
Maroua	Sahelian	426	14^0 18’ 57”E	10^0 35’27”N	815	20 - 45
Moulvouday	Sahelian	335	14^0 51’ 01”E	10^0 24’21”N	800	30 - 45
Yagoua	Sahelian	356	15^0 14’ 26”E	10^0 20’34”N	789	20 -30
Figuil	Sudanian	277	13^0 57’ 53”E	09^0 45’21”N	900	26 - 39
Garoua	Sudanian	249	13^0 23’ 51”E	09^0 18’05”N	1000	28 - 45
Poli	Sudanian	477	13^0 14’ 27”E	08^0 28’32”N	1210	27 - 32

RESULTS

Effect of pretreatment on seed germination rate

Analysis of variance for rate of germination was significantly different (p = 0.000) among the different pretreatments. Germination rate was highest in pretreatment 3 (scarification) and least in pretreatment 4 (soaking in water) ranging from 36.1 to 78.3% respectively. The day of first germination was noted for each pretreatment and it was observed that there were significant differences among pretreatments with respect to the days of emergence. Earliest germination (5.39 days) was recorded in pretreatment 3 (Scarification) followed by pretreatment 1 (Sulfuric acid), while late germination (28.1 days) was found in pretreatment 4 (Table. 2). Earliest germination started on day 3 and ended on day 10 while late germination started on day 25 and ended on 30 i.e. a month after sowing with each pretreatment having a different day of germination.

There was also a significant difference (p = 0.002) in germination rates among populations with Yagoua registering the highest rate (75.0%) of germination followed by Moulvouday (72.5%). The lowest rate of germination was recorded in the population of Poli (44.2%). There was also significant difference among populations for the day of first emergence with germplasm from Garoua 3 being the earliest (9.7 days) and seeds from Yagoua were the latest (Table 3).

Effect of substrates on seedling traits

The highest survival rate was registered in substrate 1 (45 %) at the end of three months in the nursery followed by substrate 3 with no significant different among the substrates (data not shown). The analysis of variance results proved that number of leaves and shoot dry weight were significantly different ($p < 0.05$) among substrates, while the other growth parameters were not significantly different. Substrate 2 had highest value for plant height, number of leaves, root collar diameter, root length and plant fresh weight with values 20.1cm, 17.0, 0.19 cm, 23.4 cm and 1.2 g respectively. Substrate 3 recorded the highest value for plant dry weight (0.29 g) (Table 4).

Effect of population on seed and seedling traits

Analysis of variances for within and among population for seed and seedling characteristics were highly significant for most parameters (Table. 5), except plant fresh weight (p = 0. 070) and plant dry weight (p = 0.114). Percentage survival at the end of three months in the nursery among populations varied from 32-60% with Yagoua population having the highest survival (60%) followed by Moulvouday (52.5%). The survival percentage had the same trend as rate of germination among populations at the end of the third month in the nursery. For growth traits, the minimum (0.60, 0.40 and 0.25), maximum (0.95, 0.65, 0.40) and average (0.79, 0.50, 0.30) values were recorded for seed length, seed width and seed thickness respectively. The ranges for seedling traits were as follows: plant height (7.0 - 35.0 cm) with an average of 19.7 cm) and root collar diameter (0.10 - 0.31 cm and an average of 0.19 cm). The range for number of leaves was 6.0-30.0 cm, root length (8.0 - 40 cm), plant fresh weight (0.1-2.60 g) and plant dry weight was 0.01-1.17 g, while their averages were 16.30 cm, 22.52 cm, 1.1 g and 0.25 g respectively.

Yagoua population recorded the highest values for all seed traits, plant height, root length and plant dry weight. Garoua III was highest for number of leaves, Poli was highest for root collar diameter and Figuil was highest for plant fresh weight (Table 6).

Effect of climatic zone on seeds and seedling traits

Two climatic zones were considered in this study: The Sudanian and Sahelian climatic zones. Significant differences ($p < 0.05$) between climatic zones were obtained for all the traits except for seed width and plnt fresh weight (Table 7). An observed pattern of geographical variation could be noted. The sahelian zone was highest for all the seed traits and most of the seedling traits while the sudanian was highest for number of leaves and root collar diameter (Table 8). Survival and height decrease with increasing annual precipitation while they increase with Latitude (Fig. 2)

Trait - trait correlation

Strong positive and negative correlations were found between the studied traits with the strongest positive correlation recorded between root length and plant height (0.777) (Table 9). Weak correlation was found between fresh weight and root collar diameter (0.010).

Table 2: Mean comparison of germination rate and days of seed emergence among pretreatments.

Pretreatment	Days of seed emergence	Mean germination (%)
Hot water	12,74b	42,78b
Soaking in water for 24 hours	28,25a	36,11b
Scarification	5,39d	78,33a
98% sulfuric acid	6,04c	76,67a
p-value	0,000	0,000

Means with the same letter are not significantly different at $p < 0.05$

Table 3: Mean comparison of germination rate and days of seed emergence among populations.

Population	Days of seed emergence	Mean germination (%)
Poli	11,37bc	44,17b
Garoua 3	9,67d	49,17b
Figuil	10,00d	50,00b
Maroua 1	11,13c	60,00ab
Moulvouday	11,87ab	72,50a
Yagoua	12,25a	75,00a
p-value	0 ,000	0,002

Means with the same letter are not significantly different at $p < 0.05$

Table 4: Mean comparison of growth traits among substrates.

Substrates	Hgt (cm)	NL	Dia (cm)	RL (cm)	FW (g)	DW (g)
1	19,0113a	15,1887b	0,1797a	22,8526a	1,0393a	0,2060b
2	20,1160a	17,0408a	0,1901a	23,3520a	1,1595a	0,2664a
3	19,9079a	16,7404a	0,1894a	21,7135a	1,0934a	0,2928a
p-value	0,457	0,017	0,276	0,296	0,219	0,002

Hgt = eight, NL = Number of leaves, Dia = Root collar diameter, RL = Root length, FW = Plant fresh weight, DW = Plant dry weight. Means with the same letter are not significantly different at $p < 0.05$

Table 5: Analysis of variance (ANOVA) on the effect of population in seeds and seedling traits.

Traits	df	Sum of Square	Mean Square	F-Value	p-value
Seed lenght	5	1,288	0,258	73,503	0,000
Seed width	5	0,068	0,014	7.007	0,000
Seed thickness	5	0,032	0,006	9.997	0,000
Survival %	5	7312,500	1462,500	2,300	0,055
Plant height (cm)	5	2004,988	400,998	10,167	0,000
Nunber of leaves	5	387,049	77,409	3,188	0,008
Root collar diameter (mm)	5	0,144	0,029	12,618	0,000
Root length (cm)	5	1216,191	243,038	4,631	0,000
Plant fresh weight (g)	5	2,449	0,490	2,061	0,070
Plant dry weight (g)	5	0,294	0,059	1,796	0,114

df = degree of freedom

Table 6: Mean comparison of seed and seedling traits among population.

Traits	Yagoua	Moulvouday	Maroua I	Figuil	Garoua III	Poli
SL (cm)	$0,89^{a} \pm 0,03$	$0,81^{b} \pm 0.06$	$0,73^{d} \pm 0. 07$	$0,75^{c} \pm 0.074$	$0,71^{d} \pm 0.06$	$0,83^{b} \pm 0.051$
SW(cm)	$0,52^{a} \pm 0,06$	$0,48^{c} \pm 0,042$	$0,51^{b} \pm 0 ,05$	$0,51^{b} \pm 0,39$	$0,48^{c} \pm 0,28$	$0,51^{b} \pm 0,04$
ST (cm)	$0,32^{a} \pm 0,03$	$0,29^{b} \pm 0,02$	$0,30^{b} \pm ,030$	$0,29^{b} \pm ,024$	$0,29^{c} \pm ,024$	$0,29^{bc} \pm ,03$
% Sur.	$60^{a} \pm 27.3$	$52,5^{ab} \pm 23.4$	$45^{ab} \pm 25,3$	$38^{ab} \pm 25,6$	$33^{b} \pm 23,1$	$32^{b} \pm 26,3$
Hgt (cm)	$22,80^{a} \pm 7,62$	$21,00^{a} \pm 6,78$	$21,06^{a} \pm 6,32$	$16,70^{b} \pm 5,38$	$17,46^{b} \pm 5,06$	$16,10^{b} \pm 4,74$
NL	$15,67^{b} \pm 4,99$	$15,45^{b} \pm 4,90$	$15,33^{b} \pm 4,77$	$16,78^{ab} \pm 4,27$	$18,79^{a} \pm 4.99$	$17,00^{ab} \pm 5,59$
Dia (cm)	$0,16^{d} \pm 0,042$	$0,17^{d} \pm 0,042$	$0,18^{cd} \pm 0,04$	$0,21^{ab} \pm 0 ,04$	$0,19^{bc} \pm 0,06$	$0,22^{a} \pm 0,057$
RL (cm)	$24,47^{a} \pm 7,83$	$23,23^{a} \pm 7,52$	$23,89^{a} \pm 6,80$	$22,68^{a} \pm 7,32$	$19,04^{b} \pm 6,00$	$19,67^{b} \pm 7,29$
FW (g)	$1,11^{ab} \pm 0,51$	$1,17^{a} \pm 0,46$	$1,13^{ab} \pm 0,49$	$1,18^{a} \pm 0 ,55$	$0,97^{ab} \pm 0,39$	$0,94^{b} \pm 0,49$
DW (g)	$0,29^{a} \pm 0,24$	$0,22^{a} \pm 0,10$	$0,29^{a} \pm 0 ,24$	$0.24^{a} \pm 0 ,17$	$0,26^{a} \pm 0,150$	$0,21^{a} \pm 0,127$

Means with the same letter are not significantly different at $p < 0.05$. SL = seed Length, SW = Seed width, ST = Seed thickness, % Sur = percentage survival, Hgt = Height, NL = Number of Leaves, Dia = Root collar diameter, RL = Root length, FW = Plant fresh weight, DW = Plant dry weight.

Table 7: Analysis of variance of climatic zone in seed and seedling traits.

Traits	df	Sum of Square	Mean Square	F-Value	p-value
Seed length	1	0,199	,199	28,366	0,000
Seed width	1	0,006	0,006	4,665	0,097
Seed thickness	1	0,015	0,015	17,926	0,000
Survival %	1	5868,056	5868,056	9,460	0,003
Plant height (cm)	1	1833,140	1833,140	46,423	0,000
Nunber of leaves	1	286,117	286,117	11,779	0,001
Root collar diameter (mm)	1	0,122	0,122	52,432	0,000
Root length (cm)	1	831,387	831,387	15,672	0,000
Plant fresh weight (g)	1	0,784	0,784	3,268	0,072
Plant dry weight (g)	1	0, ,078	0 ,078	2,367	0,125

Table 8: Comparison of mean seed and seedling traits in different climatic zones.

Climatic zone / Traits	Sudanian	Sahelian
Seed length	0,7644b ± 0.079	0,8162a ± 0,087
Seed Width	0,5010a ± 0,037	0,5099a ± 0,051
Seed Thickness	0,2925b ± 0,025	0,3068a ± ,027
% Survival	34,7222b ± 24,43	52,7778a ± 25,36
Plant height (cm)	16,7335b ± 5,07	21,6954a ± 6,99
Nunber of leaves	17,4603a ± 5,00	15,5000b ± 4,87
Root collar diameter (mm)	0,2102a ± 0,054	0,1697b ± 0. 044
Root length (cm)	20,5490b ± 7,08	23,8907a ± 7,41
Plant fresh weight (g)	1,0352a ± 0,49	1,1378a ± 0,49
Plant dry weight (g)	0,2354a ± 0,16	0,2678a ± 0,19

Means with the same letter are not significantly different at $p < 0.05$.

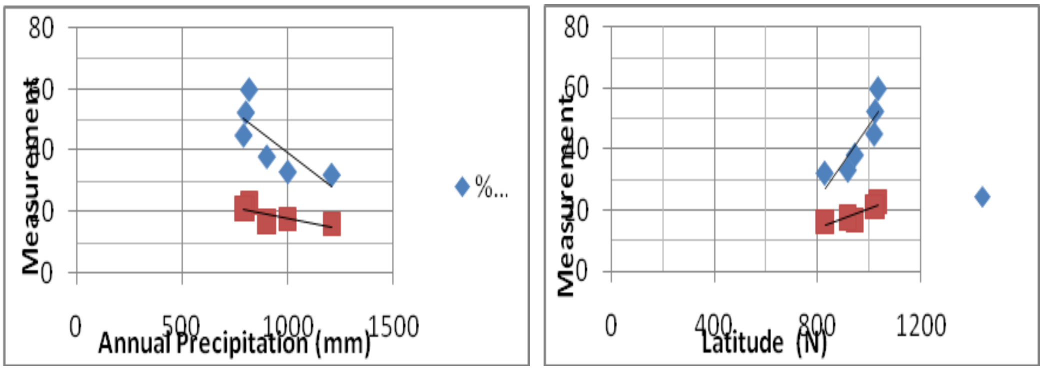

Figure 2: Relationship between a) Annual precipitation on % survival and plant height b) latitude on % Survival and plant height.

Table 9: Trait-trait correlation.

Trait/Trait	SL (cm)	SW(cm)	ST (cm)	Hgt (cm)	NL	Dia (cm)	RL (cm)	FW (g)	DW (g)
SL (cm)	**1**								
SW(cm)	0,262**	**1**							
ST (cm)	0,218**	0,445**	**1**						
Hgt (cm)	0,136*	0,056	0,144*	**1**					
NL	0-,062	0,034	-0,021	0,375**	**1**				
Dia (cm)	0-,145*	0,027	-0,017	-0,025	0,040	**1**			
RL (cm)	0,070	0,035	0,084	0,777**	0,382**	-0,018	**1**		
FW (g)	0-,043	-0,059	-0,049	0,451**	0,208**	0,010	0,622**	**1**	
DW (g)	-0,080	-0,048	0,107	0,351**	0,256**	-0,033	0,362**	0,587**	**1**

** Significant level at $p \leq 0.01$, * Significant level at $p \leq 0.05$. SL, SW, ST, Hgt, NL, Dia, RL and FW as described above.

DISCUSSION

The aim of this work was to improve the agroforestry parklands conservation and management techniques in the Sudano-Sahelian zone of Cameroun. Rate of germination was significantly different among pretreatments and scarification recorded the highest rate of germination and earliest day of germination. Results showed that scarification is the best methods for breaking seed dormancy in *F. albida* populations in Cameroon and populations in Eastern and South Africa (Koech et al., 2016). Sulphuric acid was the best pretreatment method for breaking seed dormancy in populations from Senegal (Diallo et al., 1996). It was noticed that populations germinated at the same period within each pretreatment. Substrate was only significant for number of leaves and plant dry weight indicating substrate was not an important variable for this experiment and seeds can be grown in any type of soil in the range of occurrence of the species.

Variability in seed and seedling traits was highly significant within and among populations with Yagoua population having the highest followed by Moulvouday for seed traits and most seedling traits. These populations are found in the Sahelian zone of the distribution range of the species. No significant difference was found among provenances for height at field trial located in Mouda, Cameroon and Niamey, Niger after five years of planting (Harmand and Njiti, 1991; Vandenbeldt, 1992).This was associated to poor management activities after establishment of the field trial. Significant population variation was identified in Kongola, Cameroon (Zeh-Nlo and Joly, 1992) and in seed/seedling growth traits in Kenya and Zimbabwe (Sniezko and Stewart, 1989; Dangasuk et al., 1997; Dangasuk et al., 2001). The growth traits measured are an important parameter for firewood and forage production. Research on the uses of forest genetic resources in this region indicated fire wood is used for cooking in every household (Njiti and Sharpe, 1994). Variation among population in these traits will help in the selection of populations and individuals within the populations can be used for firewood production. Another important use of trees in these zones is for forage production as animal feed. Heavy pruning which was reported by (Montagne, 1984; Depommier and Guerin, 1996) still goes on in these parklands which call for particular attention for the large scale production of the species to assist animal farming. The distribution of genetic variation between and within populations in the present study parallels earlier finding by Dangasuk and Gudu, 2000 from some populations using isozymes. Morphological traits are quantitative traits with many genes controlling the inheritance of these traits and the variation usually contains a strong environmental influence which may lead to bias for the estimation. A more appropriate method for the genetic diversity studies which is the use of molecular markers is recommended to confirm these research findings.

The morphological traits were also significantly different in the climatic zones. The populations from the sahelian zone had significantly higher values for most of the traits than population from the sudanian zone. This could be due to the range in climatic conditions with survival and height decreasing with increase in Latitude, and increases with increase in moisture content. Comparison of this result on climatic variable can only be made with other studies in Africa. There was observed significant differences in morphological traits in Baobab in relation to climatic conditions (Assobadjo et al., 2010; Maranz and Wiesman, 2005) in Shea tree (*Vitellaria paradoxa*) and (Soloviev, 2007) in *Balanites aegyptiaca* and *Tamarindus indica*.

In Cameroon, seed movement from different climatic zones has never been studied in any species because there is no policy controlling these activities. However, this will be considered as the country's forest management activities improve in the future especially with projects on reforestation in the Lake Chad Basin, the AFR100 and the operation Green Sahel projects (WRI, 2015) The result of correlation indicates that in order to make an improvement in both traits in a breeding program, the ideal will be to find individual trees within the populations that have both high positive correlation values in the two traits. The management of these parklands and any *ex-situ* conservation should collect seeds from all the populations in the different climatic zones to maintain diversity in the collection. Further research including more populations, families within population in each climatic zone and more traits is needed in this useful species.

Conclusion

There was a significant effect within and among the populations for the studied parameters ($p < 0.05$). The wide diversity observed among the population indicates that selection potential in a breeding program can be possible. Significant differences between climatic conditions for all the traits were obtained. The presence of variation among climatic conditions indicates seeds may not be moved from one climatic zone to the other during planting programs. Morphological characterization is influenced by environmental conditions and may reveal little about the fundamental genetic diversity on the traits measured. However, field testing of these populations and molecular marker application for the study of genetic diversity is on the way to confirm the result for subsequent application.

CONPETING INTERESTS

The authors declare that they have no competing interests.

AUTHOR'S CONTRIBUTIONS

T.D.T. conceived, designed the experiment, analyzed the data and wrote the article; K.G.M. performed the experiment and wrote the first draft of the manuscript; C.R.G. wrote the article with literature searches; *B.S.D and Y.A.* contributed for reagents and nursery facilities; all authors read and approved the final manuscript.

ACKNOWLEDGMENTS

The authors thanked the Institute of Agricultural Research for Development for accepting KGM for an internship position. Partial funding received by TDT from the University of Maroua research subvention for lecturers is gratefully acknowledged.

REFERENCES

Aref IM, Ali H, Atta E, Alshahrani T, Ismail A. 2011. Effects of seed pretreatment and seed source on germination of five Acacia spp. *Africa Journal of Biotechnology,* **10**(7): 15901-15910. DOI: 10.5897/AJB11.1763

Assobadjo AE, Glele KR, Kyndt T, Sinsin B. 2010. Conservation Genetics of Baobab (*Adansonia digitata* L.) in the Parklands Agroforestry Systems of Benin (West Africa). *Not. Bot. Hort. Agrobot. Cluj.*, **38** (2): 136-140.

Bonkoungou EG. 1991. Sociocultural and Economic Functions of *Acacia albida* in West Africa in *Faidherbia albida* in the West African Semi-Arid Tropics – *Proceedings of a Workshop*. USAID, http://pdf.usaid.gov/pdf_docs/PNABN008.pdf

CTFT. 1989**.** *Faidherbia albida (Del.) A. Chev. Synonyme Acacia albida Del., monographie*. Nogent-sur-Marne : France.

Clode D. 2011. Direct seeding *Faidherbia albida* (Sym.*Acacia albida*) in the Sahel. http://reforestation.files.worldpress.com/2011/09/direct-faidherbia-albida-in-the-Sahel-final.pdf.

Dangasuk OG, Seurei P, Gudu S. 1997. Genetic variation in seed and seedling traits in 12 African provenances of *Faidherbia albida* (DEL.) A. Chev. At Lodwar, Kenya. *Agroforestry Systems,* **37** : 133-141. DOI : https://doi.org/10.1023/A:1005865502289.

Dangasuk OG, Gudu S. 2000. Allozyme variation in 16 natural populations of *Faidherbia albida* (Del.) A Chev. *Hereditas :* **133**: 133-145. DOI :

https://doi.org/10.1111/j.1601-5223.2000.00133.x

Dangasuk OG, Gudu S, Okalebo JR. 2001. Early growth performance of sixteen populations of *Faidherbia* albidain Semi Arid Baringo District of Kenya, Stoth DE, Sternhardt GC (ed); 412-418.

Depommier D, Guerin H. 1996. Émondage traditionnel de *Faidherbia albida*. Production fourragère, valeur nutritive et récolte de bois à Dossi et Watinoma (Burkina Faso). In *Les Parcs à Faidherbia*" (*Acacia albida* Parklands). Cahiers scientifiques du Cirad-Forêt ; 55-84.

Diallo I, Danthu P, Sambou DD, Goudiaby A, Poulsen K. 1996. Effects of different pretreatment on germination of Faidherbia albida (DEL.) A. CHEV. Seeds. *International Tree crops Journal*, **9** : 31-36. DOI: 10.1080/01435698.1996.9752957

Djingui SL. 2015. Évaluation des potentialités socio-économiques des parcs a *Faidherbia albida* (Del). A. Chev. dans la région de l'Extrême-nord Cameroun : cas des terroirs de Mambang et Kodek. Mémoire du diplôme d'ingénieur, Institute Supérieur de Sahel, Université de Maroua, Cameroun, p. 80.

Dupraz C, Liagre F. 2008. *Agroforesterie : des Arbres et des Cultures* (éd). France Agricole.

Fredrick C, Muthuri C, Ngamau K, Sinclair F. 2015. Provenance variation in seed morphological characteristics, germination and early seedling growth of *Faidherbia albida*. *J. Horticulture For.*, **7**(5): 127-140. DOI: 10.1007/s10457-016-9974-3

Harmand JM, Njiti CF. 1992. *Faidherbia albida* in northern Cameroon: provenance trials and crop associations. In *Faidherbia albida* in the West African semi-arid tropics: *proceedings of a workshop*, 22-26. Apr 1991. Niamey, Niger, p. 79-81.

Koech G, Ofori D, Muigai WTA, Muriuki J, Anjarwalla P, De Leeuw J, Mowo GJ. 2016. Variation in the response of Eastern and Southern Africa provenances of *Faidherbia albida* (Delile A. Chev) seedlings to water supply: A greenhouse experiment. *Global Ecology and Conservation*, **8 :** 31-40. DOI : https://doi.org/10.1016/j.gecco.2016.08.005

Liber C, Eyog Matig O. 1996. *Faidherbia albida* et production cotonnière. Modification du régime hydrique et des paramètres de rendement du cotonnier sous couvert du parc arboré au Nord-Cameroun. In *Les Parcs à Faidherbia*. Cahiers scientifiques n°12, CIRAD : Montpellier, France ; 103-122.

Louppe D, N'Dour B, Samba SAN. 1996. Influence de *Faidherbia albida* sur l'arachide et le mil au Sénégal. *Cahiers Scientifiques*, **12** :123-193. DOI : https://www.researchgate.net/publication/303251350

Maranz S, Wiesman Z. 2005. Evidence for indigenous selection and distribution of the shea tree, V*itellaria paradoxa*, and its potential significance to prevailing parkland savanna tree patterns in sub-Saharan Africa north of the equator. *Journal of Biogeography*, **30**: 1505-1516. DOI: 10.1046/j.1365-2699.2003.00892.x

Montagne PP. 1984. *Faid/herbia albida*: un arbre, un projet. *Bois de Feu*, 15-20.

Njiti CF, Sharpe DM. 1994. A goal programming approach to the management of competition and conflict among land users in the tropics: The Cameroon example. *AMBIO.*, **23**: 112-119.

Pelissier P. 1980. L'arbre dans les paysages agraires de I'Afrique noire. L'arbre en Afrique tropicale:] a fonction et le signe. *Cahiers ORSTOM, Séries Sciences Humaines*, **17** (3-4): 131-136.

Peltier R. 1996. Les Parcs à *Faidherbia*. *Cahier scientifique n°12*, CIRAD : Montpellier, France.

PPDAF. 1988. Projet pilote de developpement agroforestier annual report of 1988 activities and provisional workplan for 1989. PPDAF, Dosso, Niger.

Raison 1P. 1988. Les" parcs" en Afrique. Etat des connaissances et perspectives de recherche. Centre d'études africaines, multigr. Paris.

Roupsard O, Ferhi A, Granier A, Pallo F, Depommier D, Mallet B, Roupsard, ED. 1999. Reverse phenology and dry-season water uptake by *Faidherbia albida* (Del.) A. Chev. in an agroforestry parkland of Sudanese west *Africa. Funct. Ecol*., **13**(4) : 460–472.

Seignobos C. 1982. Végétations anthropiques dans la zone soudano-sahélienne la problématique des parcs. *Revue de Géographie du Cameroun*, **3**(1): 1-23.

Sniezko RA, Stewart HTL. 1989. Range-wide provenance variation in growth and nutrition of *Acacia albida* seedlings propagated in Zimbabwe. *Forest Ecology and Management*, **27**: 179-197. DOI: https://doi.org/10.1016/0378-1127(89)90106-0

Soloviev PT, Niang D, Gaye A, Totte A. 2007. Variabilité des caractères physico chimiques des fruits de trois espèces ligneuses de cueillette, récoltés au Sénégal: *Adansonia digitata*, *Balanites aegyptiaca* et *Tamarindus indic*a. *Fruits*, **59** : 109-119. DOI : http://dx.doi.org/10.1051/fruits:2004011

United Nations Food and Agricultural Organisation (FAO) 1999. Agroforestry parklands in sub-Saharan Africa. FAO. http://www.fao.org/docrep/005/x3940e/X3040E00.htm#TOC-

Vandenbeldt RJ. 1992. Problems with range wide provenance trials of *Faidherbia albida* on sandy soil in Niger. In Faidherbia albida in the West African Semi arid tropics: proceedings of a workshop, 22 -26 April 1991, Niamey Niger, p. 83 – 86

World Agroforestry Centre. 2009. Press Release: Unique *Acacia* Tree Could Nourish Soils and Life in Africa. World Agroforestry Centre. http://www.worldagroforestrycentre.org/newsroom/press-releases/press-releaseunique-acacia-tree-could-nourish-soils-and-life-africa.

World Resource Institute. 2015. AFR100. Africa restoring 100 million hectares of deforestated and degraded land by 2030. World Resource Institute.

Zeh-Nlo M, Joly H. 1992. First observations on the phenology of *Acacia alhida*: study of a population in northern Cameroon. In *Faidlicrbia alhida* in the West African semi-arid tropics: proceedings of a workshop, 22-26 Apr 1991, Niamey, Niger, p. 63-66.