PULA Journal of African Studies, vo.l 11 no.2 (1997)

The patterns of *Acacia albida* species from twenty provenances across Africa

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This study was carried out to determine genetic variation patterns among the Acacia albida species from different provenances in Africa. A wide genetic base would offer tree breeders a large amount of material from which to select and manipulate through breeding for genotypes that suit particular environmental conditions. Seeds of the species were collected from twenty provenances around Africa and seedlings raised in Canberra, Australia, and various traits measured over a six months period. Patterns were observed in the data set. Groups of countries with Acacia albida populations sharing the same genetic patterns (characteristics) were produced using the principal component analysis. Three groups of Acacia albida were obtained: the species that belong to Southern Africa, West Africa and Northeast Africa. The three groups obtained show some relationship with the phytogeography regions of Africa. However, the population within each group obtained are not compacted, which implies that they may still be some significant variation within each group. This paper therefore recommends that genetic patterns on Acacia albida at a local level should be further investigated.

Introduction

In recent years, Africa has been faced with dwindling natural forests. According to FAO (1981) quoted in Marunda (1993), nearly 0.44% of indigenous tree formations in west, east and southern Africa are cleared annually. Such a position is a result of the over dependence by Africa's rural populations on the natural forest resource for construction and home building timber, fuel wood and leaf fodder for grazing livestock. At the turn of the century, the building of railways, mining of minerals and construction of settlement infrastructure has lead to an unprecedented use of timber which has caused further depletion of natural forest resource (Marunda, 1993). To address this situation, African countries invested in industrial plantation forests emphasising primarily on exotic fast growing pines and eucalyptus species, with hope that these would reduce the pressure on natural woodlots (Tietema, 1984).

Most of the exotic species used in industrial plantations, however, require prime sites in terms of climatic and edaphic conditions. This specific requirement resulted in most of the plantations to be located on high quality sites (Marunda, 1993). The sites endowed with less productive natural forests were neglected leaving regenerations to maintain the forest status.

There is a need to know whether natural forests could be improved, especially in the fragile ecology of the savannas. Particular attention is given to improving the situation by planting *Acacia* species indigenous to Africa. Marunda (1993) and Walker (1992) noted that one of the species whose potential has been identified in many countries within Africa is *Acacia albida*. This potential lies in its versatility as a source of fodder, complementary in tree-crop agroforestry systems and ability to fix nitrogen. Farmers in semi-arid Africa and especially in Senegal, Sudan and Ethiopia intercrop or manage *Acacia albida* with cereal crops both for the benefit of the crop and especially to supply winter fodder or dry season fodder (Walker, 1992). *Acacia albida* is also important for construction timber, livestock kraals, firewood and fencing cultivated fields. Therefore, to take full advantage of this species, there is a need to improve it genetically. Like many other tree species, the first step is to identify the patterns of species variation throughout its natural range.

Purpose of the Study

The purpose of this study is to determine whether there is any phenotypic (genetic) variation patterns among the *Acacia albida* from different provenances in Africa. A wide genetic base would offer tree breeders a large amount of material from which to select and manipulate through breeding for genotypes that suit particular environmental conditions (Marunda, 1993). The study will also test the usefulness of the principal component analysis (PCA) in search for the patterns. The traits measured from seeds of different provenances in Africa will be used in the PCA to classify the provenances into similar groups (if any).

Table 1

The Provenances and Their Countries of Origin.

Accession No.	Provenance	Country
10000	Kuiseb	Namibia
20000	Taupye	Botswana
30000	Gonarezhou	Zimbabwe
40000	Lukunguni	Zimbabwe
50000	Gokwe	Zimbabwe
60000	Palm Tree	Zimbabwe
70000	Mana Pools	Zimbabwe
80000	Kafue Flats	Zimbabwe
90000	Chiyenda	Zimbabwe
100000	Chilanga	Zambia
110000	Chizombo	Malawi
120000	Bwanje	Malawi
130000	Lodwar	Kenya
140000	Wenji	Ethiopia
150000	Debrezeit	Ethiopia
160000	Kokologho	Burkina Faso
170000	Makary	Cameroon
180000	Bignoma	Senegal
190000	Tera	Niger
200000	Oursi	Burkina Faso

Materials and Methods

Field and Laboratory procedures

The data set used in this analysis represents part of the data that was collected by Chrispine Marunda of the Forestry Department at the Australian National University in

1991. Seeds of *Acacia albida* were collected from twenty provenances around Africa (Table 1 above), whose temperatures and latitudes were recorded.

Arrangements were made to raise seedlings under quarantine restrictions since the species is prohibited in Australia (Marunda, 1993). Facilities at the Canberra CSIRO Division of Plant Industry were used. The seeds were grown under uniform conditions in a glasshouse and thirteen traits (Table 2) measured over a six months period, and the details about measurements are provided in Marunda (1993).

Table 2

Traits Measured From Seedlings and Abbreviations Used in the Analysis

Trait Name	*Abbreviation*	*Measurement unit*
Total root dry weight	Totr	g
Biomass	Bio	g
Latitude	Lat	
Temperature	Tep	°C
Seed weight	Sdwt	no.seeds/kg
Root collar diameter	RCD	mm
Height after 5 months	HT5	cm
Leaf numbers	Lfno	number
Stipule length	Stle	cm
Branch numbers	Brno	number
Stem dry weight	Stwt	g
Leaf dry weight	Lfwt	g
Total shoot dry weight	Tots	g
Fibrous root dry weight	Fbr	g
Hard (tap) root dry weight	Hrd	g

Seed weight was determined by counting four sets of fifty good seeds and weighing them on a Mettler electronic (p600) balance for each provenance. The weight of one seed was thereafter calculated using simple proportion. Some of the seed samples that were used to determine seed weight were also used to raise seedlings in a glasshouse experiment. Three seeds from each provenance were sown per pot (15 X 8 cm diameter) filled with perlite and vermiculite in a 50/50 mixture. Seeds of *Acacia albida* have hard seed coats. A nail cutter was used to scarify the seed coat by nicking on the micropylar end of the seed. A week after germination the weaker seedlings were culled leaving one, from which all the traits were measured.

After harvesting (at six months) and washing off excess growth media from the roots, the stems were separated from the roots at the soil line. The two parts were put in separate drying bags and were oven dried for 72 hours at a temperature of 70°C. The leaves were removed from the stem and weighed using a Satorius electronic balance, the weight of the stem together with the branches was also determined. The roots were divided into two parts: fibrous portion consisting of all rootlets attached to the tap root and the hard portion referring to the tap root. Some provenances had several large roots joined just below the soil line instead of one large tap root. These roots were classified as being hard. The dry weight of the two root portions was determined. The total biomass of the seedlings for each provenance was determined by summing up all the dry weights of each discussed component.

Statistical Analysis

Principal component analysis (PCA) was considered appropriate for the aims of the study because it allows one to take the traits and find combinations of these traits to produce principal components or factors which are uncorrelated (Manly, 1986). Simple cluster analysis test could have been used to explore for the patterns but it was not going to be able to show the degree of correlation between factors and variables. For more detailed discussions on principal component analysis refer to, Hotelling(1933), Daultry (1976), Manly (1986) and Nash (1979).

Results

The data set was first tested for the degree of correlation, since one of the most important requirements for the test is a high degree of correlation between the traits. The result shows a very high correlation (both negative and positive) amongst the traits (Table 3). The high degree of correlation might be that bigger seeds produce seedlings that grow faster (higher biomass, leaf weight, branch numbers etc.) and vice versa for smaller seeds. There are, however, few traits which are weakly correlated with each other. For example stem weight to leaf weight (-0.02255), leaf weight to branch numbers (0.02970), leaf weight to temperature (0.02282) and others (Table 3 on next page) are all weakly correlated.

There were fifteen traits in the data set, and fifteen principal components were produced. The first principal component (factor 1) accounted for 61.28% (9.192) of the variance in the original data set, the second for 13.94% and the third for 7.94%. The three components together explained 83.14% of the variation in the original data. The three factors were retained by the 'mineigen' criterion, which was set at 1 (only factors that explained more than 1 out of 15 variation were retained). The other 16.86% variation was explained by the other twelve principal components which have not been retained.

Table 4 below shows that the principal component or factor 1 was highly correlated to biomass (0.97670), latitude (0.87069), seed weight (0.89543), root collar diameter (0.95098), height after 5 months (0.95115), stipule length (0.944229), total shoot dry weight (0.98458), fibrous root dry weight(0.92614) and total root dry weight (0.93279).

Table 3

Pearson Correlation Coefficients Among the Traits

/ Prob > /R/ Under Ho: Rho=0 / N=15

	Totr	Bio	Lat	Tep	Sdwt	RCD	Ht5	Lfno	Stle	Brno	Stwt	Lfwt	Tots	Fbr	Hrd
Totr	1.0**	0.97**	0.66**	-0.62**	0.80**	0.81**	0.96**	-0.12	0.93**	-0.42	0.21	0.23	0.92**	0.92**	-0.51*
Bio	0.98**	1.0**	0.77**	-0.65**	0.86**	0.90**	0.97**	-0.20**	-0.95**	-0.42*	0.23	0.17	0.98**	0.96**	0.53*
Lat	0.66**	0.77**	1.0**	-0.63**	0.79**	0.93**	0.75**	-0.61**	0.77**	-0.47**	0.18	-0.21	0.85**	0.71**	-0.52*
Tep	-0.63**	-0.66**	-0.64**	1.0**	-0.62**	-0.68**	-0.72**	0.19	-0.53*	0.39	-0.11	0.02	-0.68**	-0.58	0.43
Sdwt	0.80**	0.86**	0.79**	-0.61**	1.0**	0.85**	0.82**	-0.33	-0.82**	-0.39**	0.15	0.04	0.87**	0.84**	-0.43*
RCD	0.81**	0.90**	0.93**	-0.68**	0.85**	1.0**	0.85**	-0.46*	0.88**	-0.45*	0.20	-0.07	0.96**	0.87**	-0.48*
Ht5	0.96**	0.97**	0.75**	-0.72**	0.82**	0.85**	1.0**	-0.18	0.92**	-0.44*	0.17	0.15	0.94**	0.92**	-0.45*
Lfno	-0.12	-0.20	-0.61**	0.19	-0.33	-0.46**	-0.18	1.0**	-0.27	0.28	-0.16	0.84**	-0.29	-0.13	0.15
Stle	0.93**	0.95**	0.77**	-0.52*	0.82**	0.88**	0.92**	-0.27	1.0**	-0.49*	0.21	0.15	0.93**	0.93**	-0.44*
Brno	-0.42	-0.42	-0.47*	0.39	-0.39	-0.45*	-0.44*	0.28	-0.49*	1.0**	-0.19	0.03	-0.42	-0.35	0.43
Stwt	0.21	0.19	0.18	-0.11	0.15	0.20	0.17	-0.16	-0.21	0.15	1.0**	-0.02	0.23	0.24	-0.27
Lfwt	0.22	0.17	-0.21	0.02	0.04	-0.07	0.15	0.84**	0.15	0.03	-0.02	1.0**	0.10	0.24	-0.10
Tots	0.92**	0.98**	0.85**	-0.68**	0.87**	0.96**	0.94**	-0.29	0.93**	-0.42	0.23	0.10	1.0**	0.93**	-0.56**
Fbr	0.92**	0.96**	0.71**	-0.58**	0.84**	0.87**	0.92**	-0.13	0.93**	-0.35	0.24	0.24	0.93**	1.0**	-0.39
Hdr	-0.51*	-0.53*	-0.52*	0.43	-0.48*	-0.48*	-0.45*	0.15	-0.44*	0.43	-0.27	-0.10	-0.55**	-0.39	1.0**

* $p<0.05$
** $p<0.01$

Table 4

The Correlation Coefficients of the Traits with the Three Retained Factors

Trait	*Factor 1*	*Factor 2*	*Factor 3*
Totr	0.93279	0.22932	0.01550
Bio	0.97670	0.15050	0.04128
Lat	0.87069	-0.35071	0.01639
Tep	-0.72110	0.04133	0.11003
Sdwt	0.89543	-0.02622	-0.01053
RCD	0.95098	-0.15756	0.01112
Ht5	0.95115	0.14467	0.02255
Lfno	-0.33666	0.92152	0.05746
Stle	0.94224	0.09341	0.00332
Brno	-0.50958	0.15068	0.61947
Stwt	0.23248	-0.04384	0.87920
Lfwt	0.06089	0.95352	0.04141
Tots	0.98458	0.04932	0.05140
Fbr	0.92614	0.22315	0.08559
Hrd	-0.57746	-0.011021	0.03562

**variance explained: factor1=9.192; factor2=2.090; factor3=1.188.*

Factor 1 had also some large negative loadings for temperature (-0.72110), hard root dry weight (-0.57746) and branch number (-0.50958). Factor 2 was highly correlated to leaf weight (0.95352) and leaf numbers (0.92152) only, while factor 3 was correlated to stem weight (0.87920) and branch numbers (0.61947).

This paragraph considers the clusters that were produced by the PCA. Figure 1 (overleaf) shows a two dimensional plot of the provenances for the first two factors, which accounted for 75.22% of the variation in the data.

Figure 2 (overleaf) shows a three dimensional plot of the provenances for factor 1, 2, and 3, which among themselves accounted for 83.14% of the variation in the data. Three groups or clusters can be identified from the figures. The variables within each group are not compacted i.e. the distances between individuals in each group is substantial. The first group (A) has very high values of factor 1, low values of factor 2 and very high values of factor 3. The countries that fall under group A are listed in **Table 5** below.

Countries That Belong to Group A

Accession No.	*Country of Origin*
90000	Malawi
100000	Malawi
120000	Malawi
110000	Zambia
80000	Zambia
40000	Zimbabwe
50000	Zimbabwe
60000	Zimbabwe
30000	Zimbabwe
20000	Botswana
10000	Namibia

Figure 1

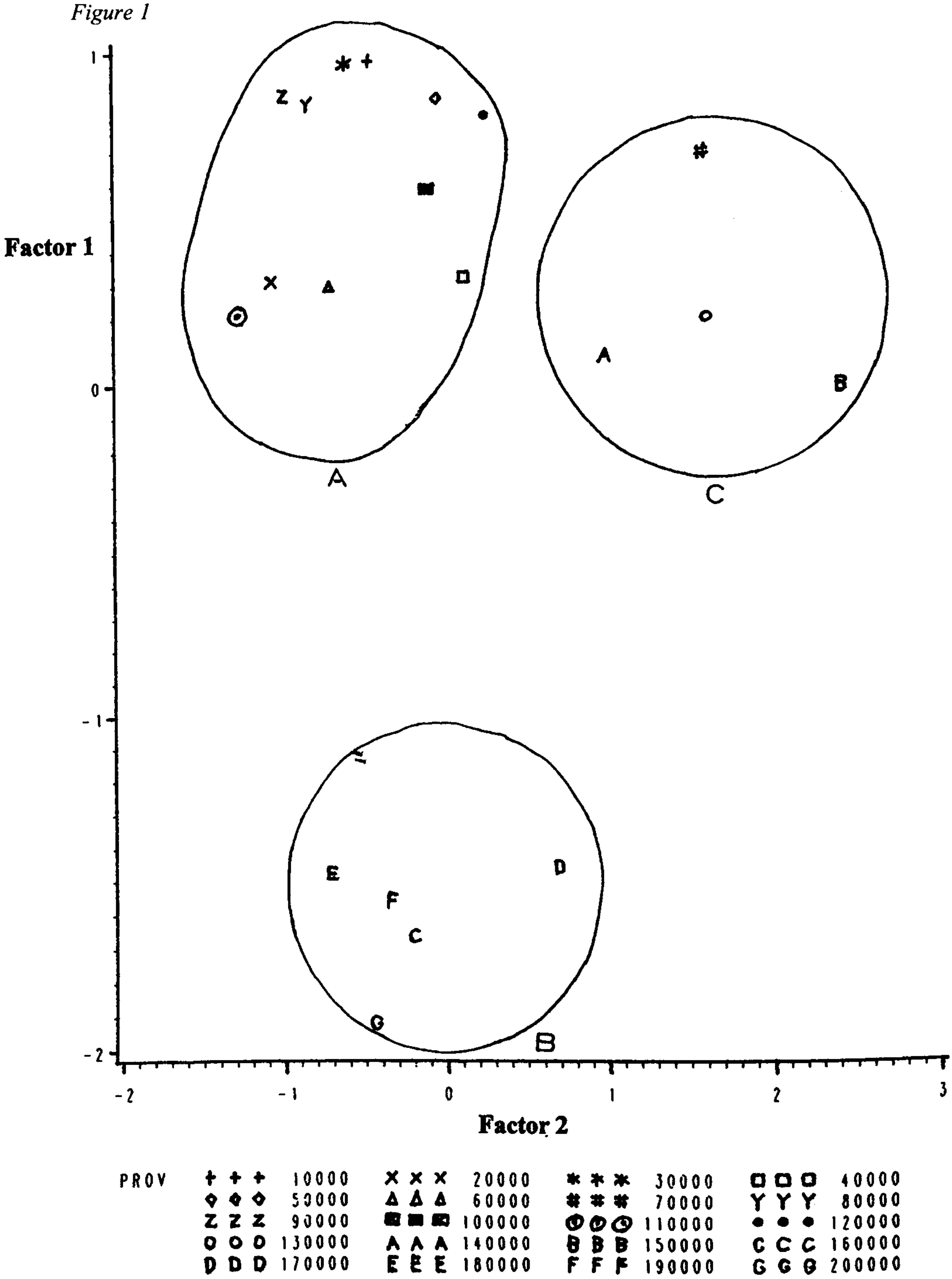

Figure 1: A Two Dimensional Plot of the Seed Sources on Factors 1 and 2.

Figure 2

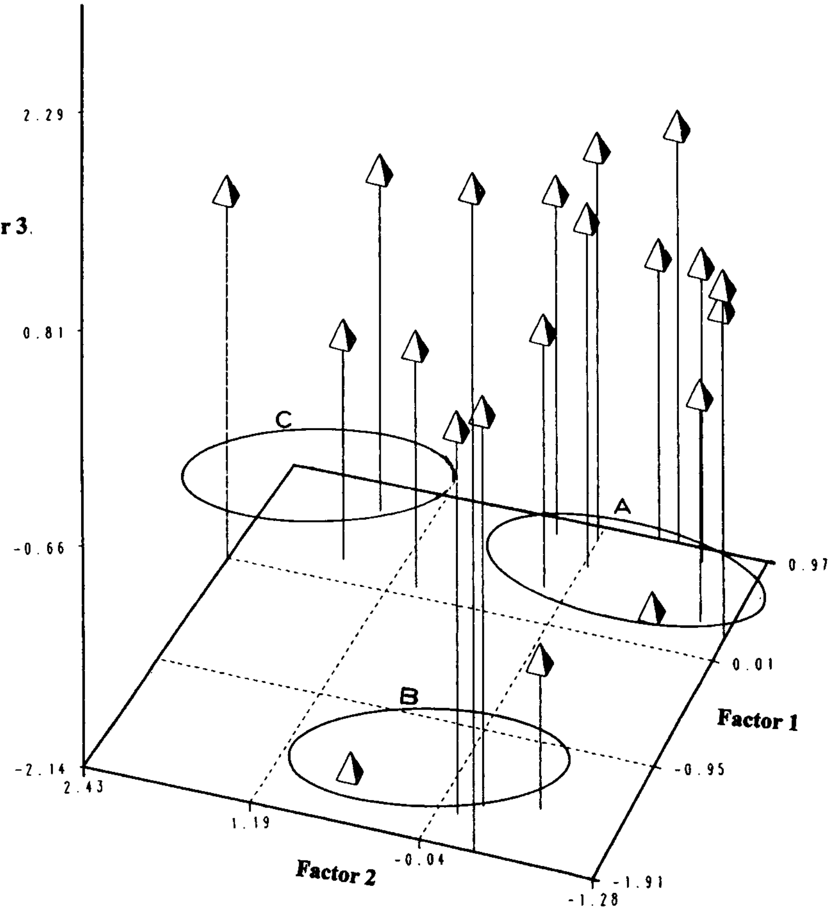

Figure 2: A Three Dimensional Plot of Seed Sources on Factors 1, 2 and 3

The second cluster (B) has very low values of factor 1, low values of factor 2 and very high values for factor 3. These are the seeds from the countries listed in Table 6.

Table 6

Countries That Belong to Group B

Accession No.	*Country of Origin*
180000	Senegal
190000	Niger
200000	Burkina Faso
160000	Burkina Faso
170000	Cameroon

The third cluster (C) has high values of factor 1, very high values of factor 2 and very high values of factor 3. These are the seeds from countries shown in Table 7.

Table 7

Countries That Belong to Group C

Accession No.	*Country of Origin*
140000	Ethiopia
150000	Ethiopia
130000	Kenya
70000	Zimbabwe

The groups depicted in this illustration are logical for reasons to be discussed in a later section of this paper. Factor 3 contributes very little in the separation of the three clusters and it accounts for only 7.92 % of the variance in the data set.

Discussion

The PCA produced groups of countries where *Acacia albida* populations are generally sharing the same phenotypic/genetic characteristics. However, it should be noted that there is a great variation among cluster individuals which is indicated by the lack of compaction within each group. This is attributed to the few variables which are uncorrelated in the original data set that led to the 16.86% variation unexplained by the three factors which were retained.

The formation of the PCA groups is both logical and clear. Group A represents the countries of southern Africa, group B are those countries which belong to west Africa and group C are countries in north-east Africa (with the exception of one region in Kenya and one in Zimbabwe). This pattern in the groups can be explained, as each region has similar climatic conditions to those of the members of the group. de Vos (1975) and Werger (1978) conclude that the existing vegetation in Africa is dependent upon the amount and seasonal distribution of rainfall. Altitude can also play an important role in determining phytogeography.

Groups A, B and C belong to the Zambezian, Sudanian and Oriental Domains respectively, which together fall under the Sudano-Zambezian phytogeography region (Werger, 1978). This region is characterised by a rich flora that extends into southern Africa. It comprises the vast stretches of woodland, savanna and grassland vegetation with occasional dry forests and thickets, and patches of edaphically controlled swampy vegetation (Werger and Coetze, 1978).

The Zambezian Domain has a rich flora and ecological diversity due to a wide range of altitudes and related climatic conditions (de Vos, 1975). The seasonal character is very clear in this domain. Rainfall and temperature ranges are very wide in this zone due to the diversity of heights. Precipitation decreases from about 1800mm in the North to 250mm in the South (de Vos, 1975; Werger and Coetze, 1978). There is also a decrease in precipitation from the east coast westward, and precipitation is normally received during the period November-May. A large proportion of the species have a very wide distribution area, hence centres of endeminism can be distinguished rather than subzones.

The Sudanian Domain is an area of extensive semi-arid lands south of the Sahelian zone. Rainfall varies between 600-1250mm, and temperature differences between day and night are high and increase near the Sahelian zone (de Vos, 1975). During the dry season the Harmattan (a dry wind) blows from the north-east. Temperatures are high throughout the year. The major differences between the Zambezian Domain and the Sudanian Domain which probably results in different vegetation characteristics, and possibly different *Acacia albida* species traits, are in precipitation and relief. The Sudanian Domain is more uniform in relief and the coefficient of variation of annual precipitation is lower than in the Zambezian domain.

Acacia albida in group C belongs to the Oriental Domain, which is constituted of highlands and is situated astride the equator (de Vos, 1975). Ecological systems vary from desert (characterised by low rainfall of maximum 150mm per annum and little or no vegetatition at all) to evergreen vegetation (2000mm annual rainfall). The vegetation in this region reflects the distribution pattern of rainfall and can also be influenced by the broken topography of this zone (Werger, 1978; Werger and Coetze, 1978 and de Vos, 1975). This is the most diversified zone, ecologically.

If the groups produced are a true representation, then each of the countries within that group have an *Acacia albida* of almost the same genetic pattern. Group A *Acacia albida* (the Zambezian Domain) can be differentiated from the other groups by its high positive correlation with total roots dry weight, biomass, latitude, seed weight, root collar diameter, height after 5 months, stipule length, total shoot weight and fibrous roots dry weight and it is negatively correlated to temperature, branch numbers and hard roots dry weight. The Zambezian Domain *Acacia albida* has more roots, probably longer vertical and horizontal roots to extract the limited moisture from a wider area.

The *Acacia albida* from group B, the Sudanian Domain is characterised by more of stem weight and branch numbers than the other groups, with less leaves (see Table 4). *Acacia albida* of the Oriental Domain has much more leaf numbers and leaf weight. The Oriental Domain *Acacia albida* like the Zambezian Domain *Acacia albida* has very high loadings of total root dry weight, biomass, latitude, seed weight, root collar diameter, height after 5 months, stipule length, total shoot weight, fibrous roots dry weight and low temperature, branch numbers and hard root dry weight. However, the Oriental Domain *Acacia albida* can be differentiated from the Zambezian Domain species with its very high leaf numbers and leaf dry weight. The Oriental Domain probably has more and broader leaves than all the groups obtained (see Table 4 and Figure 2).

Note should however be taken that all the three groups have relatively high values for factor 3, indicating that they are positively correlated to stem weight and branch numbers (see Table 4).

Conclusion

This analysis therefore concludes that there are some major phenotypic/genetic variations among the *Acacia albida* species from the different provenances in Africa. The groups of *Acacia albida* species obtained show some relationship with the phytogeography groups of Africa. However, the populations within each group are not compacted, which implies that there may still be some significant variation within each group. It is therefore recommended that genetic or phenotypic patterns on *Acacia albida* at a local level

(Domain and individual countries) should be further investigated. Many more groups could be discovered if data is collected uniformly across Africa.

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