Shoot morphology of some *Capparaceae* and *Combretaceae* plantations in the Kordofan region of the Sudan*

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Salih O. Tutu Kafe: PhD Student, Department of Natural Resources and Environmental Studies, University of Kordofan, Sudan

Kamal F. Elkhalifa✉: Prof., Faculty of Forestry, University of Khartoum, Sudan (kam-mal@hotmail.com)

Abstract

This study was conducted in the Kordofan region of Sudan during 2011–12. It was devoted to the morphology associated to the juvenile development and performance of tree species of *Capparaceae* and *Combretaceae* in a nursery and early field growth. The nursery experiment was conducted to study morphological characters to identify seedlings of tree species under study. Seedlings were transplanted to the field whereupon a field trial for sapling characters was carried out. A total of 19 species in eight genera were recorded, representing the two families. The main results related to the morphological characters of nursery seedlings and field saplings. Analysis of variance showed significant differences (P = <0.001) in seedlings' and saplings' growth parameters. Height growth varied significantly, across the *Capparaceae* species, maximum seedling height (17.75 cm), while highest collar diameter (0.133 cm) and leaf length (3.213 cm) were found in *Maerua crassifolia* followed by *Maerua angolensis* the lowest was in *Cadaba*. At the sapling stage, the mean leaf size (length and width) significantly varied and was highest in *Cadaba rotundifolia*, 2.850 × 2.650 cm (of *Capparaceae*) and in *Terminalia laxiflora*, 4.700 × 2.280 cm (of *Combretaceae*). Utilizing all these morphological characters (both qualitative and quantitative) at different growth stages of *Capparaceae* and *Combretaceae* members, coupled with photographic data, short dichotomous keys were developed for easy identification of seedlings and saplings of these families and might be used as a template for general plant identification in the region.

Keywords: *Cadaba rotundifolia*, growth performance, *Maerua angolensis*, *Maerua crassifolia*, *Terminalia laxiflora*

ریخت‌شناسی شاخه‌های کاشته شده برخی گونه‌های *Capparaceae* و *Combretaceae* در منطقه کردفان (سودان)

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صالح ا. توتو کافه: دانشجوی دکترای دانشکده مطالعات منابع طبیعی و محیطی دانشگاه خارطوم، سودان

کمال اف. الخلیفه✉: استاد دانشکده جنگل‌شناسی دانشگاه خارطوم، سودان (kam-mal@hotmail.com)

خلاصه

در این مطالعه که در منطقه کردفان کشور سودان طی سالهای ۱۲-۲۰۱۱ میلادی انجام گرفت، ریخت‌شناسی و عملکرد گونه‌های درختی دو تیره *Capparaceae* و *Combretaceae* در دو مرحله جوانه‌زنی در خزانه و رشد نهال در مزرعه مورد بررسی قرار گرفت. آزمایش‌های خزانه به منظور بررسی‌های مورفولوژیکی جهت شناسایی نهال‌های درختی مورد مطالعه انجام شد. نهال‌های جوان سپس به منظور مطالعه صفات مختلف به مزرعه منتقل گردیدند. در مجموع، ۱۹ گونه در هشت جنس متعلق به دو تیره گزارش شدند. نتایج اصلی مربوط به مقایسه بین صفات مورفولوژیکی گیاهچه‌های خزانه با نهال‌های مزرعه‌ای بود. تجزیه و تحلیل واریانس نشان داد که اختلاف قابل توجهی (P = <0.001) در پارامترهای رشد گیاهچه‌ها و نهال‌ها وجود داشت. تفاوت قابل توجهی در رشد اندازه‌های طولی در بین تمام گونه‌های تیره *Capparaceae*، با حداکثر ارتفاع نهال، ۱۷/۷۵ سانتی‌متر مشاهده گردید، در حالی که بیشترین قطر یقه (۰/۱۳۳ سانتی‌متر) و طول برگ (۳/۲۱۳ سانتی‌متر) به ترتیب در *Maerua crassifolia* و سپس در *Maerua angolensis* و کمترین آن در *Cadaba* اندازه‌گیری گردید. در مرحله نهال، متوسط اندازه طول و عرض برگ به شکل قابل توجهی متغیر بود به طوری‌که در *Cadaba rotundifolia* از تیره *Capparaceae*، ۲/۶۵۰ × ۲/۸۵۰ سانتی‌متر و متعاقبا در *Terminalia laxiflora* از تیره *Combretaceae*، ۲/۲۸۰ × ۴/۷۰۰ سانتی‌متر مشاهده گردید. بدین منظور، از تمام صفات مورفولوژیکی (کمی و کیفی) در مراحل مختلف رشد اعضای دو تیره تحت بررسی همراه با عکس‌هایی توام با کلید شناسایی برای سهولت در تشخیص گیاهچه‌ها و نهال‌ها استفاده گردید. شاید بتوان نتایج این تحقیق را به عنوان یک الگو برای شناسایی گیاهان منطقه به طور عام مورد استفاده قرار داد.

واژه‌های کلیدی: عملکرد رشد، *Cadaba rotundifolia*، *Maerua angolensis*، *Maerua crassifolia*، *Terminalia laxiflora*

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Introduction

Through the studies of Elkhalifa & Aref (2004) seedlings of fourteen *Acacia* species were segregated by shoot characteristics. Moreover, Zhang & Dang (2007) suggested that differences in shoot morphology may be useful in defining taxa within the families.

Members of *Capparaceae* and *Combretaceae* families belong to Kordofan's Regional Flora and they were distributed widely in different parts of the study area where their members have multiple uses. El Tahir & Gebanuer (2004) identified many trees and shrubs of the region that utilized for fuel, fruits, tannins and fodder. Because these trees are important members of the flora it is essential to be able to identify the species not only as adults but also as seedlings and saplings. Members of the *Capparaceae* family, yield copious nectar when in flower and are important in providing food for honeybees, as are various species of *Acacia*.

In the present study, morphology of the shoots of the selected species of *Capparaceae* and *Combretaceae* at the seedling and sapling stage used as basis for vegetative identification keys. These two families, *Capparaceae* and *Combretaceae*, belong to order *Myrtales* in subclass *Rosidae* of Dicotyledonous plants. Morphological variation within and among populations can either be due to genotypic differentiation or to phenotypic plasticity. Morphology study, performance and characterization of seedlings and shoots in addition to roots of tree species were mentioned by Elkhalifa & Aref (2004), Semercu (2004), Lebon *et al*. (2004), Salm (2005), Baraloto & Forget (2007), Zhang & Dang (2007) and Bognovnou *et al*. (2010). Sapling structure, regeneration, morphology and phylogenetic states were mentioned for some species [Ackerly & Donoghuel (1998), Miyazawa *et al*. (2006) and Láposi *et al*. (2009)].

Similar investigation has been carried out in the present study for the members of the two families in the study area and utilized for easy identification keys. The key identification based on leaf characters and tree identification has been tackled by Smallidge (1999) and Spooner (2007).

There are many problems facing the area such as environmental and climatic changes, sand movements, rainfall fluctuations, drought spells and high temperature, which influence the tree species characters. There were difficulties and lack of information about identification of seedlings or regeneration saplings of most species and the behavior of their characters is to some extent different. There is a need for tree identification at early stages of development where reproductive characteristics are absent, besides the great similarities in vegetative characters. By utilizing measurable characters plus qualitative ones, different species at seedlings and saplings stages can be identified. Accordingly, botanical keys could be developed for easy, speedy and reliable identification.

The study aims generally to develop a speedy and reliable way of identification of members of *Capparaceae* and *Combretaceae* families at different stages of growth. However, the specific objectives could be summarized into: assessing the taxonomic distinctness of any entities present, investigating the environmental impacts on the tree morphological characters, studying the morphological variation within different tree species and developing keys for identification of seedlings and adults of different tree species within the two families.

- Study area

Kordofan includes the two states of North and South Kordofan, each of which absorbed part of the territory of a third state formerly named West Kordofan in January 2005. The two states have a combined size of 380,000 square kilometers and a population of about 3.8 million people; about 75 percent of the population lives in rural areas. Their social and ethnic composition is rather complex, with a variety of groups that can be

differentiated on the basis of location, tribal affiliation and form of livelihood (which in many cases is characterized by some form of mobility). The North–South conflict formally concluded with a Comprehensive Peace Agreement in January 2005 has resulted in internal displacement, particularly in South Kordofan and in the Nuba Mountains in particular. Parts of South Kordofan thus host a sizeable population of internally displaced persons (El Tahir & Gemauer 2004).

Kordofan region is located in the central parts of western Sudan between latitudes 9º 50' and 16º 40' North and longitudes 27º and 32º East. The area of Kordofan is 380,000 km² about 25 % of total Sudan area. The population is around 3.8 millions about 15 % of total Sudan population.

Kordofan has located in tropical climate with high temperature in summer (March-July) moderate to dry cold in winter (November-February) and rainy in (July-October). The region is characterized by varied climatic conditions where, the dry and semi-dry climate is dominated in north parts and savanna climate in South (El Obeid Agricultural Research Station 1998 and 1999).

The rainy season is about three months in the north and five months in southern parts. The daily temperature ranges from 10–35° C. Wind direction changes according to seasons its north-east in winter and south-west in summer (El Tahir & Gemauer 2004).

Soils in Kordofan region are sandy in north and heavy cracking clays in the southern parts (Nuba Mountains). Between the two soil types there is Gardud soil (like a mixture of both). The sandy soil covers 60 % of the area. It is described as deep soil, rough in texture, poor in minerals and organic matters. It is found as stabilized sand dunes known as Goz soils. The clay soil is described as dark, cracking, poor in nitrogen and phosphorus content. The Gardud soil described as compacted soil type, impenetrable of water; found in high lands and beds of water channels (El Tahir & Gemauer 2004).

The vegetation of the area varies in composition and size due to large variations in soil types and rainfall. According to Harrison & Jackson (1958) Kordofan region is classified into five vegetation types, namely, semi-desert, short grass savanna, tall grass savanna, flood areas and montane plants. According to this classification, North Kordofan area is semi-desert where *Acacia tortilis* subsp. *tortilis* and *Maerua crassifolia* are the dominant species. In south of this belt other species is found such as: *Acacia senegal* (Hashab), *Leptadenia pyrotechnica* (Marakh) and *Terminalia laxiflora* (Darout). But in the lowlands and water channels *Faidherba albida* (Haraz), *Adansonia digitata* (Tebeldi), *Tamarindus indica* (Aradeib), *Grewia tenax* (Guddeium), *Ziziphus spina-christi* (Sidir) and *Dobera glabra* (Meikah) are found. South Kordofan state is located in short and tall grass savanna. The vegetation types of this area vary according to soil types and rainfall amount and distribution (AACMC 1993).

The majority of the population of the region depends on activities based on the utilization of natural resources. Cultivable land is used both by settled communities and by semi-nomadic agro-pastoralists for the production of food and cash crops. Settled communities include both smallholders, who represent the vast majority of farmers in the region and owners of large mechanized farms, who are merchants and civil servants originally from the North or from Khartoum. Pastureland is also a key resource for both semi-nomadic pastoralists and settled farmers, some of whom raise livestock.

Traditional agricultural systems and mechanizing are the economic skeleton of the area in addition to forest products (timber, fuel wood, fruits and gums), grazing and animal herding is a second economic production systems.

Materials and Methods

Observations and measurements were conducted on seedlings and young plants of members of families *Combretaceae* and *Capparaceae* raised in the nursery and transplanted to the field.

- Sampling of field study

A number of populations from Kordofan Region was sampled. Over half of the populations (9 to 10 sites) were drawn from the South Kordofan State as in these regions most of the two families' members grow naturally. All these populations were spread over the range of the two families' species to maximize capture of the variation among populations over a wide geographic range, although the furthest extremes of the distribution were not sampled due to practical limitations.

Seeds were collected from the field and information was recorded about seed zones and origin. During collection a number of species were found in their fruit maturity and directly collected while others were at the flowering stage and immature form like *Crateva adansonii* which was collected later. During seed collection, specimens were collected for identification and documentation and photographs of each species and their parts were taken.

- Seedlings experiment

A completely randomized design (CRD) with four replicates was adopted, resulting into 16 x 4 = 64 experimental units. The experimental units were prepared as polythene bags (of 20 cm diameter) filled with sandy soil in the forest traditional nursery, at the Gum Arabic Research Center (GARC), University of Kordofan, El Obeid. One hundred seeds for each species were taken (1600 seeds for the whole experiment). Twenty five seeds from each individual for each species were sown randomly in each unit into four replicates and left to germinate, with daily irrigation.

The obtained seedlings were under care for two months, whereupon, at the end of the experiment, the total numbers of leaves in each seedling were counted. Five seedlings from each replication were randomly selected very carefully to estimate the seedling random samples; three seedlings from each unit were taken for measurement. All seedlings were measured for shoot length (cm), collar diameter, leaf length (cm), leaf width (cm), leaf length\width ratio. In addition, observations of some qualitative characters were recorded. These included foliage and stem colour, leaf shape and these were used to derive a total of 14 seedling characters for each individual. Pots were randomized at eight months.

- Saplings experiment

After the seedlings' growth was terminated, five seedlings per species were transplanted to the open woodland at Gum Arabic Research Center to establish the trial in the field. The height of the seedlings was recorded before transplantation and recorded at an interval of two months for a course of eight months. Species survival and the growth of the saplings of the two families were assessed. These plots were protected against grazing, weeds were cleared and the plantations were watered once a week during the dry season.

Parameters determined after transplantation included sapling height, diameter, leaf length, leaf width and petiole length in addition to qualitative characters like stem and leaf colours.

- Key development

For key development, reliable manuals of adult forest trees in Sudan and abroad were consulted. These included Andrews (1950, 1952 and 1954), Sahni (1968), El-Amin (1990), Elkhalifa (1996), Aref *et al*. (2000), Carney 2003, Elkhalifa & Aref (2004), Elkhalifa (2006) and Scharf (2009). Field trips were carried out at different seasons and colour photographs were taken for the different organs of the different

Capparaceae and *Combretaceae* species. From the field observations, photographic data and the literature reviewed the characteristic features of each *Capparaceae* and *Combretaceae* species were detected. These features were then put into contrasting couplets, whereupon by the method of elimination, a dichotomous key was developed for adult species of the two families under study.

- Data analysis

The quantitative data were statistically analyzed by using computer software Microsoft Excel 2007, SPSS ver. 15.00 for Windows, 2006 and Jandel SIGMASTAT version 2.0 of Jandel Scientific Software, 1992–1995 Analysis packages to explore possible species variations in the field and nursery stages. The Analysis of Variance (ANOVA) and means were separated using L.S.D. The quantitative and qualitative data were used to develop a key for identification of the adults and seedlings of the 16 *Capparaceae* and *Combretaceae* species.

Two analyses were conducted, one for seedling characters and the other for saplings.

Results and Discussion

The results of this investigation showed some similarities and differences that are taxonomically important for comparing taxonomical grouping with morphological data to verify validity of the current classification of *Capparaceae* and *Combretaceae* morphologically. In the morphological study focus has been given to vegetative characters to test if it would be possible to create an identification key based on vegetative morphological data.

- Nursery results

Growth parameters were determined through measurement of seedling height, collar diameter, leaves/plant, after six to eight months of sowing under nursery condition.

Height growth varied significantly, across the *Capparaceae* species, maximum seedling height (17.75 cm) was recorded in *Capparis decidua* while minimum (2.083 cm) in *Cadaba glandulosa*.

Shoot length of the seedlings developed under nursery stage was highest (17.75 cm) in *Capparis decidua* followed by *Maerua angolensis* and *Maerua crassifolia* (Table 1). Highest collar diameter of *Capparaceae* species seedlings was found in *Maerua crassifolia* (0.133 cm) followed by *Maerua angolensis* and lowest was in *Cadaba rotundifolia*. Mean leaf length of the *Capparaceae* seedlings was found highest (3.213 cm) in *Maerua crassifolia* followed by *Maerua angolensis* and *Capparis decidua* species. The leaf width is significantly varied due to the species and found highest in *Cadaba rotundifolia* (1.675 cm) followed by *Cadaba glandulosa* and the lowest (0.183 cm) was in *Capparis decidua*. Mean petiole length of the *Capparaceae* seedlings was found highest (1.313 cm) in *Cadaba rotundifolia* followed by *Cadaba glandulosa* and *Maerua angolensis*. Seedling length of the family *Combretaceae* was varied also and it was highest (24.87 cm) in *Combretum aculeatum* followed by *Guiera senegalensis* which was significantly higher than that of *Terminalia laxiflora* and *Combretum collinum* (Tables 1–2). Mean leaf length of the *Combretaceae* seedlings was found highest (6.220 cm) in *Terminalia laxiflora* followed by *Combretum collinum* and *Combretum glutinosum* species. The leaf width is significantly varied due to the species and found highest in *Combretum collinum* (2.570 cm) followed by *Terminalia laxiflora* and the lowest (0.878 cm) was in *Guiera senegalensis*. Mean petiole length of the *Combretaceae* seedlings was found highest (0.338 cm) in *Combretum glutinosum* and *Combretum collinum* followed by *Terminalia laxiflora* and *Guiera senegalensis*. The environment effects on seed germination parameters may be high for species individuals of the two families. Many studies showed that seeds germination parameters can be markedly influenced by environmental factors such as day length, temperature, light quality, water availability, altitude, latitude, soil nutrient and fire related cues such as heat and smoke (Baskin & Baskin 1998).

Table 1. Mean seedling heights and leaf and petiole lengths of studied *Capparaceae* members (8 months old)

Species	Parameter			
	Seedling height (cm)	**Leaf length (cm)**	**Leaf width (cm)**	**Petiole length (cm)**
Capparis decidua	17.75 ± 4.737	1.986 ± 0.238	0.183 ± 0.020	0.133 ± 0.040
Cadaba glandulosa	2.083 ± 0.376	1.400 ± 0.245	1.033 ± 0.121	0.567 ± 0.052
C. rotundifolia	3.125 ± 1.026	1.925 ± 0.345	1.675 ± 0.212	1.313 ± 0.136
Maerua angolensis	4.167 ± 1.041	2.300 ± 0.458	0.867 ± 0.208	0.267 ± 0.058
M. crassifolia	3.988 ± 0.762	3.213 ± 0.861	0.350 ± 0.053	-

Table 2. Mean seedling height and leaf and petiole length of studied *Combretaceae* members (8 months old)

Species	Parameter			
	Seedling height (cm)	**Leaf length (cm)**	**Leaf width (cm)**	**Petiole length (cm)**
Combretum aculeatum	24.87 ± 7.019	2.668 ± 0.458	1.573 ± 0.260	0.138 ± 0.033
C. collinum	6.275 ± 1.484	4.275 ± 0.780	2.570 ± 0.540	0.338 ± 0.275
C. glutinosum	6.275 ± 1.484	3.275 ± 0.377	1.550 ± 0.600	0.338 ± 0.275
C. hartmannianum	4.500 ± 3.536	2.750 ± 1.768	1.000 ± 0.710	0.100 ± 0.000
C. molle	5.933 ± 2.136	2.900 ± 0.557	1.500 ± 0.1000	0.133 ± 0.050
Guiera senegalensis	11.245 ± 2.923	1.928 ± 0.529	0.878 ± 0.260	0.168 ± 0.047
Terminalia laxiflora	9.108 ± 0.909	6.220 ± 0.658	2.228 ± 0.504	0.268 ± 0.083

The spatial heterogeneity, climatic factors and interaction effect could explain the variation of the germination parameters within species.

General increment in growth variables (i.e. collar diameter, seedling height and leave size and petiole length) during the 12 week assessment across the seed species is an indication of growth, which is a common characteristic of biological organisms. Variations in the growth of seedlings may be due to a genetic factor.

It is expected that there should be significant variation in growth variables of the seedlings among the species except in the petiole length and that was the observation in the study. Therefore, seedling height could serve as trait for identifying genetically superior progenies. El Amin (1992) made the similar observation while studying the Trees and Shrubs of the Sudan. He reported that *Combretaceae* species were showed high variability in different Sudan areas. Therefore, the strong and positive correlations recorded for most of the growth characters studied looks promising for further improvement and management programs.

Accordingly, the seedling data revealed a number of patterns in the different features. *Capparaceae* seedlings, in particular, are readily identified by the many morphological characters. *Cadaba glandulosa* seedlings are not clearly distinguished from those of *Cadaba rotundifolia*, although they tend to have same leaf shape, except the appearance of tomentose hairs the *Cadaba glandulosa* leaf surface. Andrews (1950) and El Amin (1992) found similar results.

In the *Capparaceae*, there are also several taxa where the seedling characteristics differ from those of the adults. For example, size of leaf is divergent in juveniles of *Maerua angolensis* rather in the adults.

- Saplings results

The saplings morphological characters of the two families exhibited variation as well. and the sapling height is highest (33.00 cm) in *Capparis decidua* followed by *Maerua angolensis* and *Cadaba rotundifolia* (Tables 3–4). The analysis of variance showed that the differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). All Pair wise Multiple Comparison Procedures (Fisher LSD Method) appeared that the all means are different from each species in saplings height except between *Maerua angolensis* and *Maerua crassifolia* and between *Cadaba glandulosa* and *Cadaba rotundifolia*.

Mean sapling diameter of the *Capparaceae* saplings was found highest (0.200 cm) in *Cadaba glandulosa* followed by *Capparis decidua* and *Cadaba rotundifolia*. The analysis of variance showed that the differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

All Pair wise Multiple Comparison Procedures (Fisher LSD Method) appeared that the all means are different from each species in sapling diameter except between *Cadaba rotundifolia* and *Maerua angolensis* and *Maerua crassifolia* and between *Cadaba glandulosa* and *Maerua angolensis* and *Maerua crassifolia* and between *Maerua crassifolia* and *Maerua angolensis*. The sapling leaf length is significantly varied and found highest in *Cadaba rotundifolia* (2.850 cm) followed by *Maerua crassifolia* and *Cadaba glandulosa*.

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.201). Mean leaf width of *Capparaceae* saplings was found highest (2.650 cm) in *Cadaba rotundifolia* followed by *Cadaba glandulosa* and *Maerua angolensis*. The analysis of variance showed that the differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). All Pair wise Multiple Comparison Procedures (Fisher LSD Method) appeared that the all means are different from each species in saplings leaf width except between *Maerua angolensis* and *Maerua crassifolia* and between *Maerua crassifolia* and *Capparis decidua*. The petiole length is significantly varied and found highest in *Cadaba rotundifolia* (1.800 cm) followed by *Cadaba glandulosa* and the lowest (0.100 cm) was in *Capparis decidua*. The analysis of variance showed that the differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001). All Pair wise Multiple Comparison Procedures (Fisher LSD Method) appeared that the all means are different from each species in saplings petiole length except between *Maerua angolensis* and *Capparis decidua* and *Maerua crassifolia* and between *Maerua crassifolia* and *Capparis decidua*.

Table 3. Mean saplings height, diameter and leaf size and petiole length of studied *Capparaceae* members (12 months old)

Species	Parameters				
	Height (cm)	**Diameter (cm)**	**Leaf length (cm)**	**Leaf width (cm)**	**Petiole length (cm)**
Capparis decidua	33.000 ± 1.000	0.055 ± 0.001	1.933 ± 0.416	0.200 ± 0.000	0.100 ± 0.000
Cadaba glandulosa	2.750 ± 0.354	0.200 ± 0.008	2.200 ± 0.000	2.050 ± 0.070	1.650 ± 0.350
C. rotundifolia	2.950 ± 0.900	0.025 ± 0.019	2.850 ± 0.440	2.650 ± 0.443	1.800 ± 0.497
Maerua angolensis	4.000 ± 0.000	0.0120 ± 0.000	2.200 ± 0.000	1.000 ± 0.000	0.300 ± 0.000
M. crassifolia	2.475 ± 1.087	0.018 ± 0.007	2.600 ± 0.616	0.350 ± 0.058	0.300 ± 0.000

While in the *Combretaceae* species sapling morphological characters differed in height, it is high (37.93 cm) in *Combretum aculeatum* and low (15.830 cm) in *Terminalia laxiflora* and the sapling diameter is high (0.606 cm) in *Terminalia laxiflora* and low (0.209 cm) in *Combretum aculeatum* (Tables 5–6). The sapling leaf length is high in *Terminalia laxiflora* (4.700 cm) and low in *Combretum aculeatum* (2.342 cm). The sapling leaf width is (2.280 cm) of *Terminalia laxiflora* and (1.483 cm) of *Combretum aculeatum*. The sapling petiole length is (0.417 cm) of *Terminalia laxiflora* and (0.325 cm) of *Combretum aculeatum*. The out-planted seedlings of *Cadaba rotundifolia*, *C. glandulosa*, *Capparis decidua*, *Maerua angolensis* and *Maerua crassifolia* (*Capparaceae*) and *C. aculeatum*, *C. glutinosum*, *Terminalia laxiflora* and *Guiera senegalensis* (*Combretaceae*) showed the highest survival and growth rate, followed by *Capparis decidua* and *C. aculeatum* and last by *Maerua angolensis* and *C. glutinosum.*

Although, these are optimistic results, a multitude of factors influence the establishment of seedling (Baskin & Baskin 1998) hence, the variation of establishment between and within species (Moulaert *et al*. 2002). Seedling death could occur as a direct result of drought or non-drought stressors, such as herbivores, pathogens and competition exacerbated by drought.

The survival and the growth of out-planted seedlings of *Capparaceae* and *Combretaceae* are favored on open area. So, the recommended management would be to use these species on bare soil. This could be related to the intact root system of container-grown seedlings, which resulted in lower resistance to water flow through the soil-plant-atmosphere continuum.

Table 4. Mean saplings height, diameter and leaf size and petiole length of studied *Combretaceae* members (12 months old)

Species	Parameters				
	Height (cm)	**Diameter (cm)**	**Leaf length (cm)**	**Leaf width (cm)**	**Petiole length (cm)**
Combretum aculeatum	37.930 ± 14.484	0.209 ± 0.059	2.342 ± 0.730	1.483 ± 0.386	0.325 ± 0.196
Terminalia laxiflora	15.830 ± 5.845	0.606 ± 0.552	4.700 ± 2.644	2.280 ± 1.093	0.417 ± 0.200

Water supplement does not affect the survival of transplanted seedlings of some tropical woody species. The plasticity of the species could also be an explanation. On the other hand, watering, weeding and protection favored the growth of the two species. The recommended management would be weeding around trans-planted seedlings and established seedlings that are not expensive management tool when compared to total cost of common practices used to restore woodlands in tropical zone. In contrast, saplings of *Combretum aculeatum*, *Cadaba rotundifolia*, *C. glandulosa*, *Capparis decidua*, *Maerua angolensis* and *M. crassifolia* species showed high survival among the study species. Although there are numerous studies dealing with leaf morphological trends in response to environmental changes, their functional interpretation should be carefully considered, as it could be different depending on the scale of the survey or on the factors which provoke such trends. Since seedlings were grown under identical conditions, patterns of difference in seedling morphology must have underlying genetic bases; by contrast, the same cannot necessarily be claimed for trends in sapling and adult morphology.

- Key results

Depending on the botanical features detected from the field, photography work and literature, dichotomous dendrological keys were developed. According to the importance and wide distribution of *Capparaceae* and *Combretaceae* in Kordofan, Sudan and arid regions and the lack of simple speedy way for their identification and the scanty published information on their seedling morphology, the present work has been carried out to facilitate their early recognition and to produces a dichotomous key for such a purpose. The key has been built on the characteristic vegetative features that detected from field observations, colour photographs taken and reliable relevant literature consulted. The key is believed to be simple, speedy and reliable, as it makes use of the distinctive morphological characters in a dichotomous nature. Its dichotomous nature should make it easy for computerization in an interactive program. This is of paramount importance in regeneration and conservation projects and also to build up morphological information of taxonomic interest.

Such identification, from solely vegetative characteristics, was preceded by Elkhalifa (1993) which dealt with mature trees in the Sudan. This work can also be considered as a continuation to Aref (2000) that compared among *Acacia* seeds and gave an observation on the shoot and root lengths of some Acacia seedlings. The present work fulfilled these aims by giving reliable identification based on statistical analysis of quantitative data, hence forms a pioneer study in the field of seedling identification in the arid regions. Out of the six parameters analyzed, three were found to be important to distinguish the different *Acacia*.

Observed qualitative characters included leaf type, leaf colour, leaf shape, leaf margin and leaf venation in the seedlings while adding stem features in the case of saplings. Hence, the identification was simple as it is displayed in the form of keys (Tables 5–6). The keys can easily be computerized and it is hoped that it could be expanded to cover different stages of plant species development (adults and seedlings). It might also form a pattern for future keys for seedlings and adults of other important genera and families in the arid regions.

The result of this study confirms the possibility of using leaves characters to discriminate between *Capparaceae* and *Combretaceae* species in the different growth stages. According to these results the use of vegetative characters can be practically important to differentiate between the species in the absence of fruits and flowers. More studies are needed to confirm the value of the vegetative characters in the identification of many of *Capparaceae* and *Combretaceae* species is in different areas of the two families' species in Sudan.

Table 5. A dendrological key for identification of *Capparaceae* seedlings found in Kordofan (Sudan)

No.	Feature		Species
10	Leaves simple alternate	→ 20	
	Leaves simple opposite (and ovate shape)		*Crateva adansonii*
20	Spines present (and leaves linear around 1.99 × 0.18 cm)		*Capparis decidua*
	Spines not present	→ 30	
30	Leaves whorled	→ 50	
	Leaves not whorled	→ 40	
40	Leaves oblanceolate to ovate-elliptic 3.21 × 0.35 cm		*Maerua crassifolia*
	Leaves ovate and 2.30 × 0.87 cm		*M. angolensis*
50	Leaves rounded with rough surface (tomentose)		*Cadaba glandulosa*
	Leaves rounded with smooth surface		*C. rotundifolia*

Table 6. A dendrological key for identification of *Combretaceae* seedlings found in Kordofan (Sudan)

No.	Feature		Species
20	Leaves ovate 2.67 × 1.57 cm		*Combretum aculeatum*
	Leaves not ovate and > 2.6 × 1.57 cm	→ 30	
30	Leaves oblong 2.75 × 1.00 cm and green in colour		*C. hartmannianum*
	Leaves oblong 2.28 × 1.55 cm and pale brown in colour		*C. glutinosum*
40	Leaves oblanceolate 4.28 × 2.57 cm and red green in colour		*C. collinum*
	Leaves oblanceolate 6.22 × 2.23 cm and white brown in colour		*Terminalia laxiflora*

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