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Infraspecific Delimitation of *Acacia senegal* (Fabaceae) in Uganda

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ABSTRACT

The wide variation in Acacia senegal has presented taxonomic uncertainties and unresolved contradictions in previous studies. In this study numerical taxonomic principles and multivariate analysis (*UPGMA PCoA and PCA*) *were used basing on* 69 *characters derived from growth form*, *branchlets*, *leaves*, *flowers*, *pods and seed. Three taxa*, *namely*; *variety senegal*, *leiorhachis and kerensis have been discerned and described significantly improving the delimitations of previous studies. The wide variation within var. senegal has been split into three recognizable variants and that of var. leiorhachis into two. The most important characters for differentiating the taxa include leaf breadth and length*, *pinna length and its ratio to pinna breadth*, *number of leaflet pairs*, *petiolar gland shape*, *petiolar and rachis gland size*, *stem and branch bark texture*, *stem and branchlet colour*, *under-bark colour for stem and branches*, *pod apical shape*, *growth form*, *crown shape*, *and prickly state of leaves. An identification key has been constructed which*, *for the first time*, *can be used to assign herbarium specimens to their respective taxa.*

***Keywords*:** *Acacia Senegal*, *Infraspecific*, *Multivariate Analysis*, *Numerical Taxonomy*, *Uganda*

1. Introduction

Acacia senegal (L.) Willd. was first described as *Mimosa senegal* L. as far back as 1753 [1] before it was transferred to the present genus *Acacia*. The species belongs to the sub-genus *Aculeiferum* which is known to be widely distributed in tropical and sub-tropical regions of the Americas, Africa and Asia [2]. The great variability in the species, however, has led to difficulty in its taxonomic delimitation and hence a long list of synonyms. Four varieties have been recognized, namely; var. *senegal* Brenan, var. *kerensis* Schweinf., var. *rostrata* Brenan and var. *leiorhachis* Brenan. However, these are surrounded by continuous contradictions, disagreements [3-5] and difficulty in assigning herbarium specimens to a variety without adequate field notes about the habit and habitat [6].

The delimitation of the botanical variation has been based on morphological characters that differentiate the varieties namely: presence or absence of hair on the inflorescence axis, color of the axis, shape of pod tips, number of pinnae pairs, occurrence of a distinct trunk, and shape of the crown as provided in the variety key by Brenan [4]. Despite this, there have been contradictions and discrepancies in the character usage. The four varieties are further reported to develop into different growth forms [6] ranging from low multistemmed shrubs (var. *kerensis* and var. *rostrata*), low bush with whip-like stems (var. *leiorhachis*) small trees, (var. *senegal* and var. *rostrata*) to larger trees (var. *senegal* and var. *leiorhachis*). The first numerical taxonomic study [7] based on vegetative characters revealed that three of the four varieties exist in Uganda but that their previous descriptions were not sufficient to discern and delimit them. The numerical taxonomic study, however, much as it improved the descriptions of the three varieties, it was based on only vegetative characters and it was not able to provide characters that can be used to identify herbarium specimens.

The aim of the study was to confirm whether there are distinct infraspecific taxa within *A. senegal* in Uganda. It was further intended to find out whether the wide variability in the infraspecific taxa, which has been the cause of taxonomic contradictions, can be further discerned into recognizable groups. This would provide a comprehensive set of the best characters for differentiating the infraspecific taxa hence developing a taxonomic identification key.

2. Materials and Methods

2.1. Sampling and Specimen Collection

The study was undertaken in the cattle corridor of Uganda during the period March 2007 to July 2008. The term "cattle corridor" depicts the high concentration of livestock, particularly cattle, sheep and goats, in this area compared to other parts of the country. The cattle corridor stretches from the southern border of Uganda with Tanzania, across the country to the northeastern part of the country bordering Kenya and Sudan [7]. The corridor comprises the rangelands (used in a broad sense to cover grassland, bushland and woodland) which are variable in ecosystem and vegetation types [8]. The corridor is further characterized by the lowest rainfall in Uganda ranging from lower than 500 mm to over 1000 mm in the less dry areas [9]. Sampling followed the procedure outlined by [10] whereby a location was taken to be an area with a radius of 2.5 km. At each location identified, sampling was done along a linear transect on mature plants which were at least 50 - 100 m apart to minimize chances of sampling very similar individuals. Five to fifteen mature individuals per location were sampled per location resulting into a total of 217 individuals. Three to five branchlets were collected from each individual sampled to provide enough material for the study and also for herbarium specimens. The branchlets were immediately pressed and the herbarium vouchers kept at Entebbe Botanic Gardens with duplicates deposited at Makerere University Herbarium. Mature pods were harvested from each tree sampled and kept separately in a cloth bag. At dehiscence, not all the seed always fall out of the pod. Therefore in cases where the pods were found to have opened, as many pods as possible were collected to be able to raise enough seed for the study as well as for conservation. The seeds and pods from a given tree were kept in the same bag. The seeds were treated with pesticides in the lab to avoid insect damage and the lots for conservation were processed and kept in the National Genebank. Three to five inflorescences per tree were collected and placed either in a test tube or polythene tubing containing 95% ethanol. Inflorescences in full bloom were harvested to avoid partially opened or wilting flower parts.

2.2. Characters Scored and Methods of Scoring

A total number of 69 characters were selected for the study (**Table 1**) of which 11 were derived from the plant habit, eight were from the branchlets, 17 from the leaves, 13 from the inflorescence/flower, 11 from the pods and nine from the seed. Twenty nine of the characters were qualitative and 40 were quantitative. The characters included the ones used by [4,5,7,11] and from observations made in this study.

Table 1. Characters scored for the study of *Acacia senegal* in Uganda.

I. Plant Habit

C1. Form: shrub (1); tree (2)
C2. Crown shape: lax-rounded (1); flat-spreading (2); open-irregular (3)
C3. Stem height (m)
C4. Stem diameter at base
C5. Stem height/diameter ratio
C6. Tree height (m)
C7. Bark colour: green-yellow (1); grey- brown (2); bright orange- brown (3); dull grey (4); grey-yellow (199D*) (5)
C8. Underbark colour stem: creamy-white (155D*) (1); brown (2); red (178A and B*) (3); dark pink (181D*) (4)
C9. Underbark colour branch: creamy-white (155D*) (1); brown (2); red (178AandB*) (3); dark pink (181D*) (4)
C10. Stem bark texture: papery and peeling (1); smooth, not papery and peeling (2); fissured (3); flaking (4)
C11. Branch form: Straggling (1); straight (2); whippy (3)

II. Branchlets (scores done between 20 and 30 cm from tip)

C12. Colour: yellowish (1); greyish-brown (2); purplish-brown (3) purplish-black (4); purplish-grey (5)
C13. Hairiness: glabrous (1); sub-glabrous (2); pubescent (3); densely pubescent (4)
C14. Bark texture: papery and peeling (1); papery and not peeling (2); not papery and not peeling (3)
C15. Internodal length (cm)
C16. Number of nodes (between 20 and 30cm from tip)
C17. Vertical prickle length (mm)
C18. Downward prickle length (mm)
C19. Ratio of upward to downward prickle length

III. Leaves (at 20 to 30 cm from tip)

C20. Leaf length (cm)
C21. Petiole length (cm)

C22. Leaf/petiole ratio
C23. Leaf width (cm) at widest point
C24. Pinna length (cm)
C25. Pinna breadth (cm) at widest point
C26. No. of pinnae pairs
C27. No. of leaflet pairs
C28. Petiolar gland: present (1); absent (2)
C29. Petiolar gland length (μm)
C30. Petiolar gland breadth (μm)
C31. Petiolar gland shape: circular (1); oblong (2)
C32. Glands on rachis: absent (0); 1 (1); 2 (2); ≥3 (3)
C33. Rachis gland length (μm)
C34. Rachis gland breadth (μm)
C35. Hairiness: pubescent (1); glabrous (2); sub-glabrous (3)
C36. Midrib spines: absent (0); 1 (1); 2 (2); ≥3 (3)

IV. Inflorescence

C37. Inflorescence colour: white (1); cream (2)
C38. Spike length (cm)
C39. Peduncle length (cm)
C40. Spike/peduncle length ratio
C41. Hairiness of axis: glabrous (1); glabrous except for a few basal hairs (2); pubescent (3); densely pubescent (4)
C42.Corolla colour: white (1); cream (2)
C43. Corolla length (mm)
C44. Corolla/calyx ratio
C45. Calyx colour: green (1); purplish-green (2); red (3)
C46. Calyx length (mm)
C47. Calyx hairiness: glabrous (1); sub glabrous (2); pubescent (3)
C48. Stamen filaments length (mm)
C49. Pistil length (mm)

V. Pod

C50. Pod shape: oblong (1); elliptic (2)
C51. Pod color: grey (1); grey-yellow (2); grey-brown (3); yellowish-brown (4); brown (5)
C52. Pod length (cm)
C53. Pod width (cm)
C54. Pod apical shape: acuminate (1); acute (2) rostrate (3); rounded (4)
C55. Hairiness: densely pubescent and not appressed (1); sparsely pubescent and not appressed (2); densely pubescent and appressed (3); sparsely pubescent and appressed (4); puberous
C56. No. of seeds per pod
C57. Pod venation: pronounced (1); not pronounced (2)
C58. Pod thickness: papery (1); thick (2)
C59. Pod outlook: flat (1); bulging over seed (2)
C60. Surface protrusions: present (1); absent (2)

V. Seed

C61. Seed colour: yellow (1); grey-brown (2); brown (3)
C62. Seed length (mm)
C63. Seed width (mm)
C64. Seed apical shape: rounded (1) acute (2)
C65. Pleurogram colour: yellow (1); grey-brown (2); brown (3); dark brown (4)
C66. Pleurogram length (mm)
C67. Pleurogram breadth (mm)
C68. Pleurogram shape: broadly open (1); nearly closed (2)
C69. Funicle length (mm)

*Corresponding colour chart number from Standard Royal Horticultural Society (2001) colour chart.

Three flowers from each of three inflorescences were randomly selected and scored making a total of nine flowers scored per individual tree. Flowers were dissected under a microscope over a graduated graticule (in micrometers) to allow for measurements to be taken directly. Five mature and complete pods randomly picked from the lot were scored from each individual tree. Pod length was taken from the point of attachment to the stalk to the apex tip. Pod width was taken at mid-length of the pod. Pod surface protrusions (appearance of a pronounced pattern at the seed positions) were scored as present or absent. The seeds per pod were taken as the average from three pods. The shape of the pleurogram was scored on two character states, thus; broadly opening or nearly closed. Funicle length was taken as measurement from the point of attachment on the pod to the point of attachment on the seed. Data on colour shades was taken using the Royal Horticultural Society [12] colour chart. As much as possible colours were scored on freshly harvested seeds to reduce effect of aging on colour.

2.3. Data Analysis

The NTSYSpc (Numerical Taxonomy and Multivariate Analysis System version 2.1e; J. F. Rohlf, 2000) was used for the analysis. Raw data was first standardized using range for quantitative characters and standard deviation for qualitative characters. Cluster analyses were performed separately for the qualitative and the quantitative characters based on UPGMA. Levels of similarities and dissimilarities were computed using Eucledean coefficients for quantitative data, Simple Matching for multistate and Manhattan coefficients for binary qualitative data. Cophenetic correlation coefficients were calculated to examine the goodness of fit of the cluster analysis to the matrices. Quantitative data was further analysed using Principal Component Analysis (PCA) based on similarities derived from product moment correlation coefficient while qualitative data was further analysed using Principal Coordinate Analysis (PCoA) based on Simple Matching coefficient derived dissimilarities/similarities. Individuals in the resulting clusters were re-analysed separately to further discern the variation within each cluster. Univariate statistics for major discriminating quantitative characters were computed against the emergent groupings based on qualitative data and presented in form of box-plots.

3. Results

3.1. Analysis Based on Qualitative Data

The results based on PCoA as well as UPGMA are suggestive of three distinctive clusters; cluster A, B and C (**Figures 1** and **2**). The first principle component is responsible for separating cluster B and C while the second principle component is more responsible for separating cluster A and B. The re-analysed cluster B revealed three sub-clusters; sub-cluster 1, 2 and 3 (**Figure 3**) while cluster C revealed two sub-clusters under cluster and ordination analyses (**Figure 4**). The most important characters in explaining the observed variation (characters with high loadings) included stem and branch bark texture, stem and branchlet colour, under-bark colour for stem and branches, pod apical shape, growth form, crown shape, calyx colour, pleurogram colour and prickly state of leaves. Cophenetic correlation coefficients for the simple matching coefficients plotted against their tree matrices ranged between 0.84 and 0.89 indicating good fit [9].

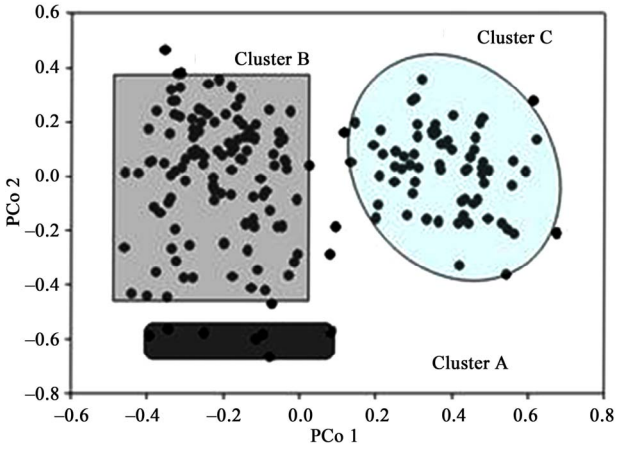

Figure 1. A 2-D plot of 217 individuals of *Acacia senegal* showing principal coordinates 1 and 2 derived from principal coordinate analysis based on 14 multistate characters.

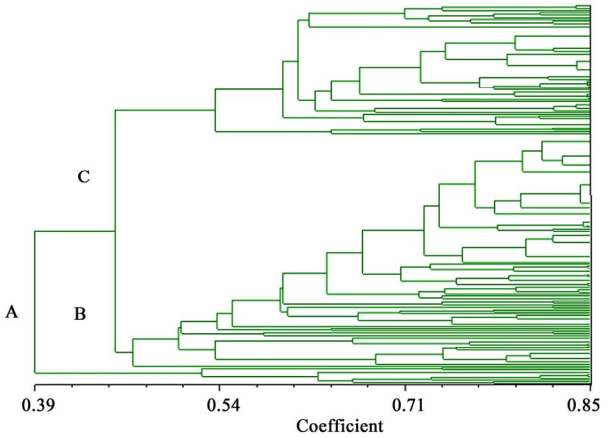

Figure 2. Phenogram of UPGMA clustering of Simple Matching coefficient based on 14 multistate characters and 217 individuals of *Acacia senegal*. Cophenetic correlation coefficient (r = 0.84).

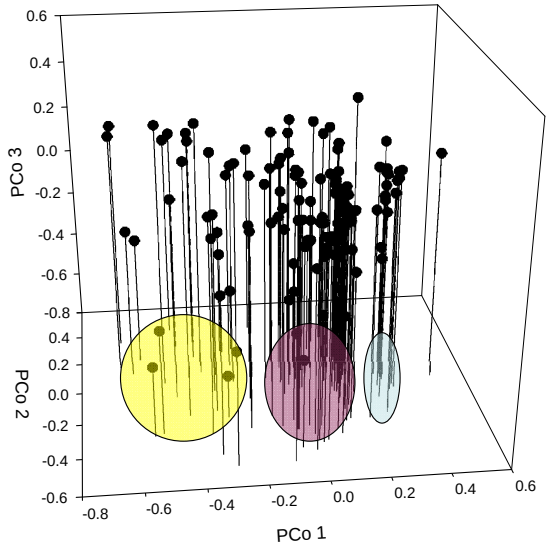

Figure 3. A 3-D plot of 143 individuals of *Acacia senegal* var. *senegal* showing principal coordinates 1, 2 and 3 derived from principal coordinate analysis based on 14 multistate characters.

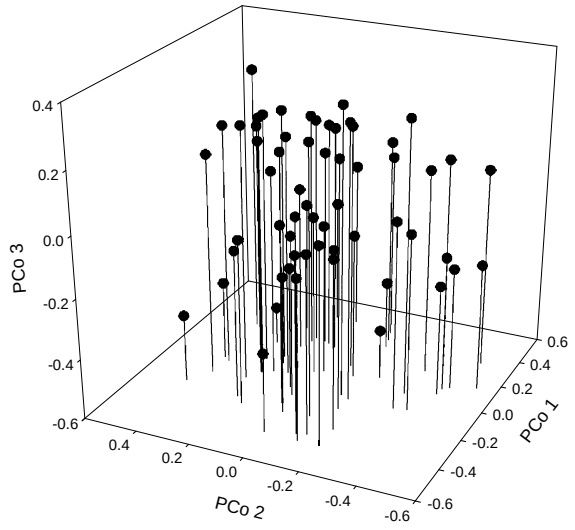

Figure 4. A 3-D plot of 66 individuals of *Acacia senegal* var. *leiorhachis* showing principal coordinates 1, 2 and 3 derived from principal coordinate analysis based on 14 multistate characters.

3.2. Analysis Based on Quantitative Data

The PCA based on the forty quantitative characters displayed a wide variability but the first four components explained less than 40% of the total variation. No clear clustering of individuals was displayed. The PCA using 19 characters selected from the first analysis based on their relatively higher loadings equally displayed great variation in the individuals with minimal clustering (**Figure 5**).

The first and second principal components explained 43% of the total variation while the first four components explained 63% and the first six components explained 77%. The key characters responsible for the variation along PC1 (**Table 2**) were tree height and stem diameter at ground level (DGL), leaf breadth, leaf length, pinna length, the ratio of pinna length to pinna breadth, number of leaflet pairs, size of petiolar glands and peduncle length. Leaf breadth and length, pinna length and its ratio to pinna breadth, and number of leaflet pairs had loadings of 0.7 and above suggesting that they were of higher importance in explaining the variation along PC1. The characters responsible for the variation along PC2 relate to size of petiolar and rachis glands and seed length. Internodal length, the related number of nodes per unit length, and length of upward prickles were responsible for the variation along PC3 while size of flower parts, namely, filament length and pistil length were responsible for the variation along PC4.

The results of the cluster analysis based on UPGMA agreed with the ordination results. Box plot analysis (Figure not shown) however, showed a high degree of overlap of characters across the groupings making it difficult to use them independent of qualitative characters.

4. Discussion

The taxonomic delimitation of *Acacia senegal* infraspecific taxa has been a source of contradiction and uncertainties due to the wide variation there-in [3-5,11,14, 15]. Although our previous study [7] reduced the delimitation uncertainties, it relied on only vegetative characters and the key developed could not be used to differentiate herbarium specimens; neither could it clarify on

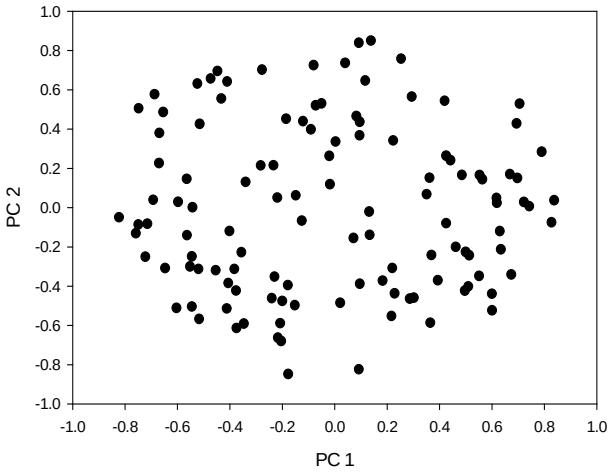

Figure 5. A 2-D plot of 217 individuals of *Acacia senegal* showing principal component 1 and 2 derived from principal component analysis based on 19 quantitative characters.

Table 2. Character loadings for the Principal Component Analysis based on Product Moment Correlation Coefficient for quantitative characters.

Character	PC 1	PC 2	PC 3	PC 4
C4	**0.6567**	0.2177	0.1206	0.1343
C6	**0.6458**	0.2881	0.1226	0.0332
C15	0.4334	0.0261	**–0.6725**	–0.4541
C17	–0.0919	0.1359	**–0.5030**	0.1437
C20	**0.7040**	–0.0490	0.0521	0.0124
C21	**0.8620**	0.1006	0.1467	–0.0191
C24	**0.8787**	0.1139	0.1410	0.0023
C30	**0.5198**	**–0.7355**	0.0607	0.1111
C33	**0.5637**	**–0.7328**	–0.0723	0.1108
C34	**0.5779**	**–0.7405**	–0.0576	0.0857
C39	**0.5762**	0.1283	0.0094	–0.1729
C48	0.2408	0.0981	–0.3735	**0.7746**
C49	0.0745	0.0962	-0.3582	**0.7973**
C62	0.3462	**0.5329**	–0.0131	0.0584
C63	0.3385	0.4335	–0.0673	0.1518
C19	–0.4314	–0.0657	**0.7021**	0.4400
C27	**0.7920**	0.2128	0.1239	–0.0785

variability within-in a given variety. The aim of the study was to confirm whether there are distinct infraspecific taxa within *A. senegal* in Uganda and to find out whether the wide variability at the infraspecific level, which has been the cause of taxonomic contradictions, can be further discerned into recognizable groups. This would provide a comprehensive set of the best characters for differentiating the infraspecific taxa hence developing a taxonomic identification key suitable for field and herbarium use.

4.1. Infraspecific Groupings

The findings of this study have shown effective delimitation of six groups at two levels. The first level of differentiation (**Figures 1** and **2**) defined the previously known three varieties of *A. senegal* namely; var. *kerensis* (cluster A), var. *senegal* (cluster B), and var. *leiorhachis* (cluster C) and confirmed their presence in Uganda.

The variety *kerensis* is here described as mainly a shrub (2.1 - 5 m ht.) with a lax-rounded to mainly open irregular crown. It has a papery and peeling, green-yellow stem

bark and dark pink underbark. The branches are dominantly straggling with a dark pink underbark colour while the branchlets are mainly papery and peeling with some individuals peeling but not papery. Leaves are dominantly prickly with leaf breadth (1.43 - 6 cm), pinna length (0.86 - 2.1 cm), number of leaflet pairs (10 - 14 {16}) and number of pinna pairs (3 - 4). The taxon bears characteristically more oblong than circular petiolar glands of length (4.0 - 7.4 µm) and breadth (2 - 3.4 µm) while the rachis glands length varies from 3 to 4.4 µm and breadth from 2 to 2.8 µm. The taxon therefore has petiolar glands whose length to breadth ratio is ≥ 2.0 making the glands characteristically more oblong than circular. The calyx is purplish-green to red and the pods bear mainly rounded apical shapes.

This description fits and even improves the previous descriptions of the variety *kerensis* [4,7]. **Figure 1** also clearly brings out the closer relationship between this variety and var. *senegal* (cluster B) which could have led to the conclusion by [11] that the two varieties blend into each other and are therefore one variety.

The variety *senegal* is here described as mainly a tree with some shrubs, (1.8 - 7.1 m ht.) with a very variable crown shape (lax-rounded, flat spreading to open irregular). The stem bark is papery and peeling to fissured, green-yellow, but also grey-brown, dull grey and occasional bright orange brown, while the underbark is cream-white, dark pink but predominantly dark pink. The branches are straight to straggling, papery and peeling while the young branchlets are yellowish to purplish black. The leaves are seldom prickly, with a leaf breadth of 2.1 - 3.8 cm, pinna length of 1.3 - 2 cm, number of leaflet pairs 12 - 15 (16) and number of pinna pairs (3 - 5). The petiolar gland length varies from 4.0 to 5.8 µm while the breadth varies between 2.0 and 3.2 µm. The rachis gland length is 3.4 - 4.4 µm while the breadth is 2 - 3.2 µm. The calyx is purplish-green and the pods apices acute to rounded. This description agrees with and further augments the findings of [7,11]. Neither the degree of pubescence on the branchlets nor on the inflorescence axis, which were used ambiguously by earlier studies [14] to separate the varieties, has been found to be important in this study. No wonder [3] retracted this position and later conceded [4] together with [5] that the taxonomy of the species was far from clear. This study has therefore provided better delimitation of the taxon significantly removing previous contradictions.

From these findings, *Acacia senegal* var. *leiorhachis* can be described as a tree (4.2 - 13.9 m ht.) with a lax-rounded to flat spreading crown. The stem bark is fissured, grey-brown to dull grey whereas the underbark is red. The branches are straight to straggling, purplish-grey to purplish-black, papery and peeling, peeling and not papery, to papery and not peeling with a red underbark. The leaves are seldom prickly with leaf breadth (2.7 - 5.6 cm), pinna length (1.7 - 3.26 cm), number of leaflet pairs (16 - 20) and pinna pairs (4 - 5). The petiolar gland length varies between 2.4 and 5.4 µm while the breadth varies between 2.4 and 5 µm and characteristically more circular than oblong. The rachis gland length varies between 2.6 and 4.6 µm and the breadth from 2.0 and 4.2 µm. The calyx is purplish green while the pod apical shape is acute to round. The description agrees with and complements that of [7] together with the arguments thereof. Due to the absence of sufficiently distinguishing characters on herbarium specimens, [15] decided that the differences between *A. senegal* and *A. circummarginata* were not distinct and merged the two into A. *leiorhachis*. The present study has identified characters that can be used to distinguish the different taxa in herbaria (as well as in the field) thus agreeing with [5,11] that the taxa are distinct. However, [11] preferred to maintain this taxon as a species (*A. circummarginata*) following [3] as opposed to a variety (*leiorhachis*) as given by [5] and subsequently followed by [3]. Our opinion based on the findings of this study is that this taxon (var. *leiorhachis*) as well as var. *senegal* are better treated as varieties of *A. senegal.*

The second level of taxonomic differentiation delimited three groups from var. *senegal* (**Figure 3**) and two from var. *leiorhachis* (**Figure 4**). The three groups delimited from var. *senegal* can be described as follows. The first group, represented as cluster 1 (**Figure 3**), presents as a tree with a lax-round crown, fissured green-yellow stem bark, yellowish papery and peeling branchlets, purplish-green calyx and round pod apices. The second group, represented as cluster 2, differs from the first one by having dull-grey to grey-brown, papery and peeling stem bark, purplish-black branchlets, and acute to acuminate pod apices. This group was most dominant. The third group, represented as cluster 3, presents as a shrub with flat spreading to open irregular crown.

The two groups delimited from var. *leiorhachis* (**Figure 4**) can be described as follows; the first presents as a tree with grey-brown stem bark and mainly straight branches while the second one presents as a tree with dull-grey stem bark and straggling branches.

The groups delimited at the second level of differentiation can be based described as variants of variety *senegal* and *leiorhachis* respectively agreeing with [6] that varieties of *Acacia senegal* can develop into different growth forms. A taxonomic key is hereby presented but since the individuals studied were from only Uganda, the key cannot be treated as a universal one until similar studies are done across the species range of occurrence. The ecological significance of this differentiation will be further investigated in our subsequent study.

Proposed taxonomic key

1. Plant a tree----------2
1. Plant a shrub or bush----------5

2. Tree height 4 - 14 m, bark fissured, underbark red, young branchlets purplish-grey to purplish-black, leaf breadth 2.7 - 5.6 cm, pinna length 1.7 - 3.3 cm, number of leaflet pairs 16 - 20, petiolar gland shape more circular than oblong, petiolar gland length 2.4 - 5.4 µm, petiolar gland breadth 2.4 - 5 µm, rachis gland length 2.6 - 4.6 µm, rachis gland breadth 2.0 - 4.2 µm----------3

2. Tree height 2 - 7 m, bark papery and peeling to fissured, underbark dark pink, young branchlets yellowish to purplish-black, leaf breadth 2.1 - 3.8 cm, pinna length 1.3 - 2.0 cm, number of leaflet pairs 12 - 16, petiolar gland shape oblong, petiolar gland length 4 - 5.8 µm, petiolar gland breadth 2.0 - 3.2 µm, rachis gland length is 3.4 - 4.4 µm and rachis gland breadth 2 - 3.2 µm----------4

3. Stem bark grey-brown, branches mainly straight----------**Var. *leiorhachis***[1]

3. Stem bark dull-grey, branches straggling----------**Var. *leiorhachis***[2]

4. Branchlets yellowish papery and peeling, pod apices round----------**Var. *senegal***[3]

4. Branchlets purplish-black and peeling, pod apices acute to round (variable)----------**Var. *senegal***[4]

5. Crown flat spreading to open irregular, stem bark papery and peeling mainly green-yellow, underbark red, branchlets purplish-black papery and peeling to peeling and not papery, petiolar gland length (3.2 - 4.4 µm)----------**Var. *senegal***[5]

5. Crown Lax-round, underbark dark pink, branches dominantly straggling, Leaves dominantly prickly, leaf breadth (1.4 - 3.6 cm), pinna length (0.86 - 2.1 cm), number of leaflet pairs (10 - 14 {16}), number of pinna pairs (3 - 4), petiolar gland shape oblong, petiolar gland length (4.0 - 7.4 µm) and breadth (2 - 3.4 µm), rachis glands length (3 - 4.4 µm), and breadth 2 - 2.8 µm, calyx purplish—green to red, pods with mainly rounded apices----------**Var. *kerensis***

[1] and [2] are two groups that have emerged out of var. *leiorhachis* while [3], [4] and [5] have emerged out of var. *senegal* as variants.

4.2. Usefulness for Identification of Herbarium Specimens

One of the problems in studying this species has been difficulty in identification of herbarium specimens without adequate field notes. This study has revealed that characters, namely; size of glands, particularly petiolar gland length and breadth and their ratio which ultimately determines their shape; number of leaflet pairs; leaf breadth and pinna length; colour of branchlets; prickly nature of leaves and to a lesser extent number of pinna pairs can be important characters for differentiating herbarium specimens and assigning them to their respective taxa. This study further confirms that quantitative characters overlap in this species as earlier reported [4,7,11]. This resulted in groups of clusters which although not so taxonomically important by themselves, the analysis was essential in identifying the most important quantitative characters which have formed the bulk for the overall taxonomic delimitation and in particular for the identification of herbarium specimens.

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