A comparative study of *Grewia bicolor* Juss. and *Grewia flava* DC.

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Abstract

Grewia bicolor and *Gewia flava* have been recognized by earlier authors as separate species on the basis of the shape of the leaf base, the number of flower stalks on the peduncle and reticulate venation of the tertiary veins. These two "species" are extremely variable, and often characters from *G. bicolor* and *G. flava* are exhibited on the same specimen. This study aims at evaluating the distinction between the two "species", thereby testing whether they should be recognized as separate taxa, and if so, which characters can be used to delimit *G. bicolor* and *G. flava*. Numerical phenetic analyses of 11 characters investigated from 211 herbarium specimens revealed that the two "species" cannot be differentiated by the traditional characters. Univariate analysis showed that the diagnostic characters that have been used to date show continuous variation. Thus *G. bicolor* and *G. flava* cannot be recognized as separate species.

Contents

Introduction

The genus *Grewia* (Tiliaceae) is an inconspicuous, yet widespread genus of more than 400 species which are widely distributed in Africa, Asia and Australia. It comprises of a variety of shrubs or smallish trees (Wild, 1984). Economically this group is very important. The fruit have a high sugar and protein content (therefore the name wild raisin), and are consumed by indigenous people fresh or dried, and by birds (Palmer, 1977). The foliage is heavily browsed on by game and stock, especially when grass is scarce. The genus is often used by ecologists as indicator species for degraded vegetation (Coates Palgrave, 1984). The hard wood is used for making sticks, bows and arrows etc, and the fibrous bark for cords. The fruit and bark also have medicinal and magic uses (Palmer, 1977).

This genus is distinguished from the other Southern African genera of this family (*Sparmannia, Triumfetta* and *Corchorus*) by its indehiscent fruit, a one to four-lobed drupe with a somewhat fleshy mesocarp (Wild, 1984). Other important features include the 3-7 nerved leaves, scalloped or serrated leaf margin, the numerous showy stamens, the yellow or lilac to pink coloured petals and the hairy appendage or claw at the base of the petals (Wild, 1984). Twenty six species have been recorded from Southern Africa (Wild, 1984). The most well known species are: the Round-leaf raisin (*G. villosa*), the Rough-leaved raisin (*G. flavescens*), the Kalahari raisin (*G. retinervis*), the Two-coloured raisin (*G. bicolor*), the Brandybush (*G. flava*), the Kruisbessie (*G. occidentalis*), the Silver raisin (*G. monticola*) and the Giant raisin (*G. hexamita*) (Palmer, 1977).

Grewia bicolor is a shrub or occasionally a moderate sized tree up to 9m tall. It is widespread from South Africa (KwaZulu-Natal, Gauteng), Swaziland, Namibia, Angola, Botswana, Zimbabwe, Mozambique to Ethiopia and West Africa (Wild, 1984) (Fig. 1A). On the whole, this species prefers the deciduous woodland but does penetrate areas with an annual rainfall above 600 mm in special locations such as termite mounds (Wild, 1984). It is often associated with *Colophospermum mopane* but is also found in many other types of mixed woodlands (Wild, 1984). In large specimens the bark is dark grey and deeply fissured longitudinally; in smaller specimens the bark is grey and smooth, and in the very young branchlets grey or brown tomentellous (Wild, 1984). The leaves have an asymmetric base and a finely serrated margin, sometimes almost entire (Wild, 1984). The leaf surface is glabrous green to very shortly greenish tomentellous above, and shortly densely white tomentose below. Peduncles are 3-flowered. Fruits are deeply bilobed-globose, or globose, and sparsely stellate pubescent (Wild, 1984). The wood of larger specimens is used for making axe-handles and walking sticks. The fruit is edible

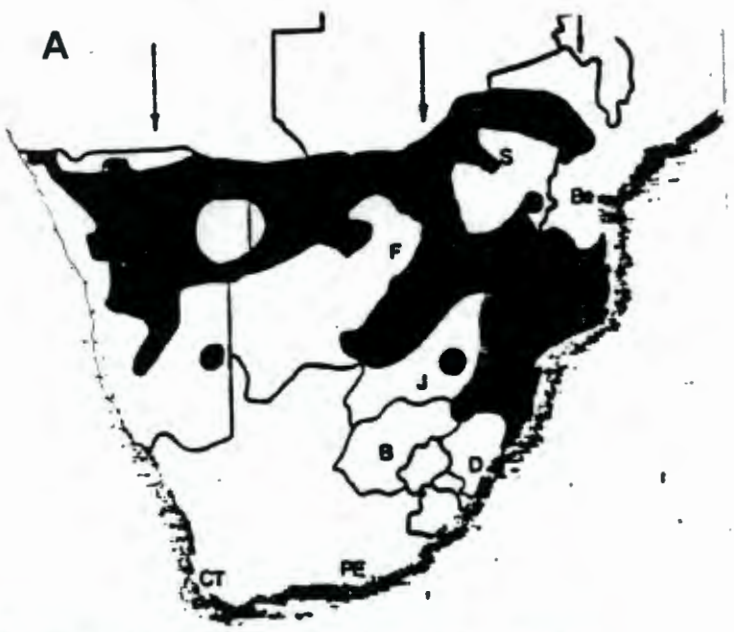


Fig 1A: Distribution of *G. bicolor* in Southern Africa

Grewia flava occurs in the drier types of deciduous woodland and bushland in Gauteng, Orange Free State, the northern Cape, Namibia, Botswana and Zimbabwe (Wild, 1984) (Fig. 1B). It is a compact shrub about 2 m tall, with geyish to greyish brown, tomentellous young branchlets and dark purplish to black older branches. Leaves are symmetric at the base with a fine serrulate to dentate margin. The leaf surface is very finely and densely tomentellous below. The venation is fairly prominent and reticulate (Wild, 1984). The fruits are globose or bilobed-globose, sparsely setulose. Peduncles are usually 1-flowered, but specimens with 2- or even 3-flowered peduncles do occur (Wild, 1984). The fruits, which have only a thin layer of flesh, are edible and sweet, although slightly astringent, and are often used for making an intoxicating drink (Wild, 1984). The tough bark is used for basket making. The leaves are heavily browsed on by game and stock, especially when grass is scarce. This species is often used by ecologists as an indicator for overgrazing and pasture mismanagement (Coates Palgrave, 1984).

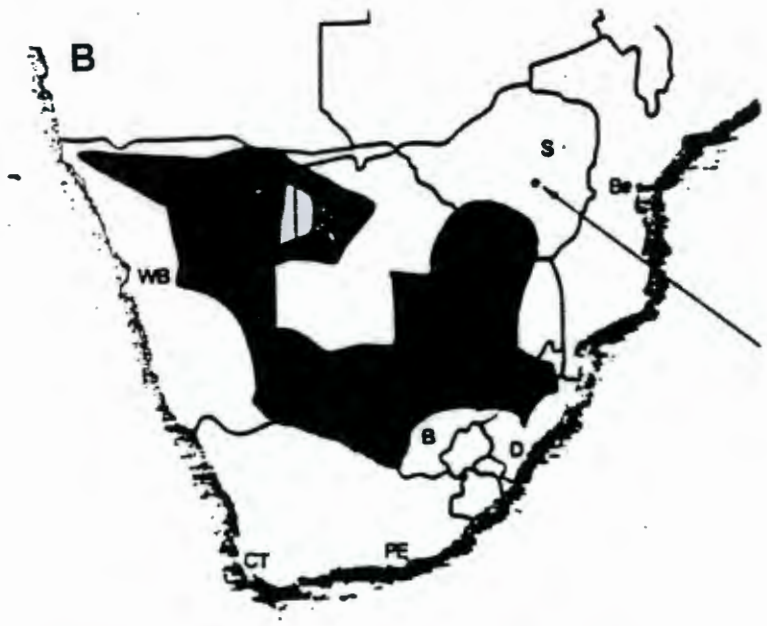


Fig. 1B: Distribution of *Grewia flava* in Southern Africa

The delimitation of these two species has always been regarded taxonomically difficult. Both species are extremely variable (Wild, 1963) and often specimens would show a combination of characteristics of both species, for example have a 1-flowered peduncle, but a distinct asymmetric leaf base. In *G. bicolor* much of the variation might be accounted for by the hybridization with *G. monticola* (Wild, 1984). *G. monticola* resembles *G. flava* in the irregular, coarse serrations on the leaf margin and the rough texture of the leaf. It also seems that the characters used to delimit the two species are inconsistent, and may vary within the species, for example the number of flower stalks on the peduncle. *G. bicolor* is recognized by a 2-3 flowered peduncle, while G. flava has a 1-flowered peduncle. Although the great majority of *G. flava* has 1-flowered peduncles, specimens with 2- and 3-flowered peduncles occur (Wild, 1984).

G. bicolor was first described by D.E. Jussae in 1804 and G. flava by De Candolle in 1813 (literature not available). The earliest comparative account of the two species appeared in *Prodromus, einer Flora von Südwestafrika* (1824, literature not available). In the revised version Merxmüller (1967) separated *G. flava* from *G. bicolor* on the base of the number of flower stalks on the peduncle and the symmetric leaf base. *G. bicolor* has an asymmetric leaf base and a 2-3 flowered peduncle, while G. *flava* has a symmetric leaf base and a 1-flowered peduncle.

Burret (1910) divided *G. bicolor* into three varieties: *G. bicolor* var. *canescens*, *G. bicolor* var. *dinteri* and *G. bicolor* var. *tephrodermis*. He

described the characteristic *G. bicolor* as having a finely serrulate margin, a rounded apex, a cordate leaf base and a sparsely pubescent leaf surface. *G. bicolor* var. *canescens* deviates from the type by having a coarser leaf texture, coarse, irregular serrations on the leaf margin, felty pubescence on the leaf surface and a tapering leaf base. In these characters it closely resembles *G. flava*, but can be distinguished from it by the 3-flowered peduncles and the tapering leaf apex, while *G. flava* has a 1-flowered peduncle and a rounded apex. *G. bicolor* var. *dinteri* also has a felty leaf surface, but differs from var. *canescens* and *G. flava* in having a finely serrulate leaf margin, and a rounded leaf base. *G. bicolor* var. *tephrodermis* is distinguished by the sparsely pubescent leaf surface, the coarse serrated margin and the numerous lenticels on the young branches.

Wild (1963) published a revision of this genus for Flora Zambesiaca, which include Botswana, Malawi, Mozambique, Zimbabwe and Zambia. Another revision for Flora of Southern Africa (incuding SA, Ciskei, Transkei, Lesotho, Swaziland, Botswana and Namibia) followed in 1984. In both publications Wild separated *G. bicolor* from *G. flava* by the shape of the leaf base (asymmetric in *G. bicolor* versus symmetric in *G. flava*) and the number of flowers on the peduncles (2-3 flowered in *G. bicolor* versus 1-flowered in *G.flava*). However, a 1-flowered peduncle in *G. flava* is not always consistent, as specimens with 2- and 3-flowered peduncles do occur. With such material, the separation of *G. flava* from *G.bicolor* presents some difficulty. Wild (1963, 1984) suggests, that in these cases the coarser texture of the leaves, the more prominent lateral nerves, the reticulation of the tertiary nerves and

above all the symmetrically cuneate leaf-bases can be used to separate *G. flava* from *G. bicolor*.

For specimens from Swaziland, Compton (1976) separated the two species by the pubescence of the leaf surface. *G. bicolor* has a hairless upper surface, while *G. flava* is finely grey-downy above.

The aim of this study was (1) to evaluate the distinction between the two "species", to determine whether they should really be recognized; and if so, (2) to find the main diagnostic characters, and (3) to evaluate the previous treatments by Merxmüller, Burret and Wild. Quantitative phenetic analyses were performed on 211 herbarium specimens from 6 countries.

Materials and Methods

Materials

This study incorporated 211 herbarium specimens from South Africa, Namibia, Botswana, Zimbabwe, Mozambique and Kenya. Fifty three specimens were obtained on loan from the National Herbarium in Pretoria and 159 specimens on loan from the National Herbarium in Windhoek (WIN). Sterile and flowering/ fruiting specimens were used, since most of the diagnostic characters are vegetative. Each specimen served as an operational taxonomic unit (OTU), and was assigned a numerical code for reference. Details of each specimen are provided in Appendix 1.

Methods

Herbarium specimens were sorted into floristic regions, using *Prodromus Einer Flora von Südwestafrika* for the specimens from Namibia, and *Flora Zambesiaca* for the remaining countries. Ten vegetative characters and one floral character were measured on each specimen (appendix 2). All vegetative measurements were done on the largest intact leaf. Leaf length and width and widest point to base were measured with calipers (Fig. 2a, b and c), while the other vegetative characters were assessed under a Leica MS5 Stereo microscope. Width of the angles at the leaf base were assessed by drawing the leaf base under the camera lucida and then the angle was measured with a protractor (Fig. 2d). Serrations were counted and measured at a magnification of X1.0 using the eye piece graticule precise to 0.1 mm. The pubescence and the degree of reticulation were assessed at a magnification of X10.

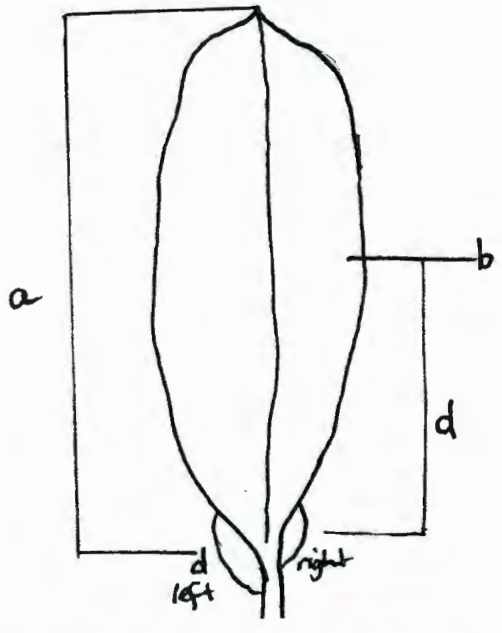


Fig. 2: Measuring the leaf length (a), leaf width (b), the distance from the widest point to the leaf base (c) and the angles at the base (d).

Data

The data matrix used for phenetic analysis consisted on continuous, meristic and binary variables. Data were entered into Microsoft Excel version 5.0a and then transposed and converted to produce a data set that can be imported into NTSYS version 2.02i (Rohlf, 1998).

Phenetic analysis

Multivariate analysis

Phenetic variation patterns among the specimens were analysed using NTSYS version 2.02i (Rohlf, 1998). Numerical phenetics can be used to define groups on the basis of the greatest number of shared characters. It employs multivariate statistical methods for the study of joint relationships of variables in data that contain intercorrelations and is suitable for metric and ordered multistate data (Abbot et al., 1985).

The data were first standardized using the STAND program in NTSYS. The standardization of the character states makes all the character means equal to zero and character variance equal to unity (Sneath and Sokal, 1973), therefore reducing the effects of different scales of measurement in different characters.

Clustering is the classification of the objects into hierarchical categories on the basis of shared similarities. The similarity matrix was calculated in the SIMINT module, using the taxonomic Distance coefficient. The distance coefficient is best suited for continuous data and is the easiest similarity to

visualize (Sneath and Sokal, 1973). Missing values are also taken into account. A triangular matrix is produced, which lists the level of similarity or dissimilarity between OTU's. In order to visualize the similarity or dissimilarity between the OTU's, they were clustered together using the clustering program in NTSYS.

Clustering of the OTU's was done in the sequential agglomerative hierarchical nested (SAHN) clustering module (Sneath and Sokal, 1973). The FIND option was used to find all the possible trees, and the maximum number of tied trees were 25.The phenogram was produced using UPGMA (unweighted paired-group method using arithmetic averages). This method involves equal weighting of OTU's and examines the dissimilarity matrix for most mutually similar pairs (Sneath and Sokal, 1973). UPGMA is generally preferred to other methods, because it minimizes distortion of inter-OTU distances during clustering (Rohlf, 1998). The dendogram reflects the maximum phenetic differentiation, if any, (as computed by the Distance coefficient) between taxa. The cluster analysis also implies to what degree a group of taxa are phenetically different by the distance values calculated on the dendogram.

Principal component analysis (PCA) was performed to determine which of the characters are predominantly responsible for the groupings of the clusters. PCA is widely used as a dimension-reducing technique, to summarize as much of the information (variation) in the data as possible in few dimensions (Thorpe, 1983) so that the data can be displayed effectively on a two- or

three-dimensional graphs. While clustering methods tend to artificially superimpose clusters on the data, ordination methods may clearly show up the groupings. Ordination is particularly good at showing how distinct the groups really are and whether there are intermediate specimens that the clustering method is forcing into one of the groups.

The results are reflected in the eigenvalues and eigenvectors. Eigenvectors determine the characters that contribute most to the variation between OTU's. The higher the values, the more the character contributes to the variation. Usually the first few components account for most of the variation (Sneath and Sokal, 1973).

Univariate and bivariate analysis

Univariate and bivariate methods were used to complement the results from multivariate analysis. Multivariate methods can be criticized for being subjective in the way similarity or dissimilarity between objects is analysed. This is primarily because different clustering methods may show different clustering results for the same data set. Univariate techniques examine the patterns of variation between groups by investigating a single character at a time. Bivariate techniques examine the variation combinations of two characters, especially those related to the size of a structure i.e. length and width measurements. For 10 characters the variation was plotted as a histogram in STATISTICA , to see if this would group the OTU's, and if so, to see if the groups correspond to the ones identified by multivariate analysis. A two dimensional scatterplot was produced in STATISTICA for leaf length and

leaf width. The aim of this was to show whether these two characters can separate the OTU's into two groups.

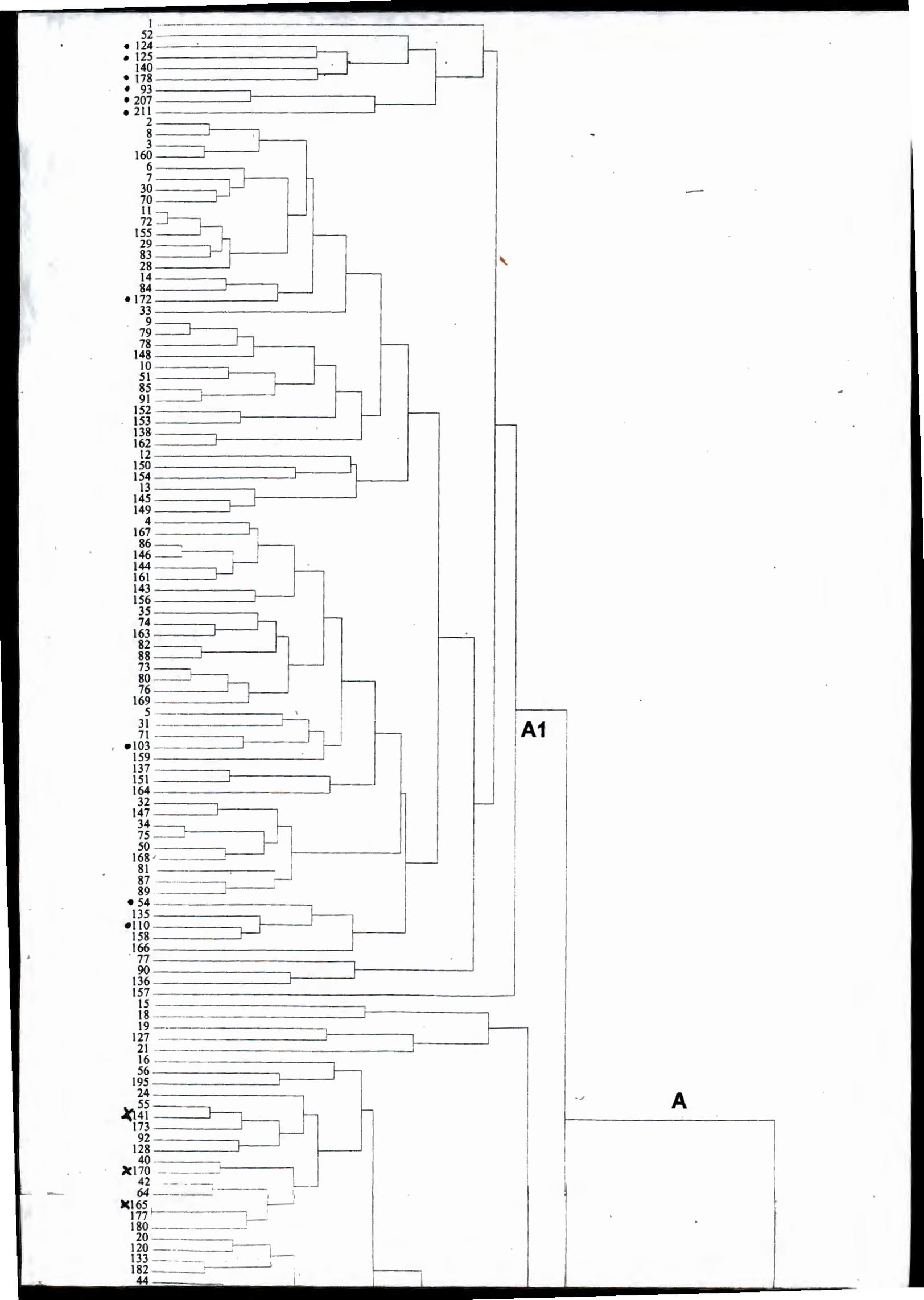
Results

Cluster analysis

A hierarchical cluster analysis grouped the OTU's into two major clusters (Fig. 3). Cluster A consists of 2 subclusters: cluster A1, which includes the majority of specimens that have preliminary been identified as *G. flava*, and ten *G. bicolor's* (marked •), and cluster A2, which includes mainly *G. bicolor*, except for 5 specimens (marked **x**). Cluster B includes 13 *G. bicolor* specimens from northern Namibia, which all have noticeably large leaves. The first two subclusters do not reflect any geographic variation pattern, neither a trend in character variation. The branches on the phenogram are short, and indicate that there is no significant difference between the OTU's from cluster A and B and the various subclusters.

Ordination

The first three principal components accounted for 71.96% of the variation (Table 1). The associated eigenvectors for the first three components are represented in table 2. The first component shows, that the strongest influencing factor is leaf width valued at 8.81and leaf length at 8.51. The larger the value, the stronger it is. The second component is strongly influenced by the size of the serrations on the leaf margin, with a value of 7.80.


1
52
• 124
• 125
140
• 178
• 93
• 207
• 211
2
8
3
160
6
7
30
70
11
72
155
29
83
28
14
84
• 172
33
9
79
78
148
10
51
85
91
152
153
138
162
12
150
154
13
145
149
4
167
86
146
144
161
143
156
35
74
163
82
88
73
80
76
169
5
31
71
• 103
159
137
151
164
32
147
34
75
50
168
81
87
89
• 54
135
• 110
158
166
77
90
136
157
15
18
19
127
21
16
56
195
24
55
141
173
92
128
40
170
42
64
165
177
180
20
120
133
182
44
A1
A

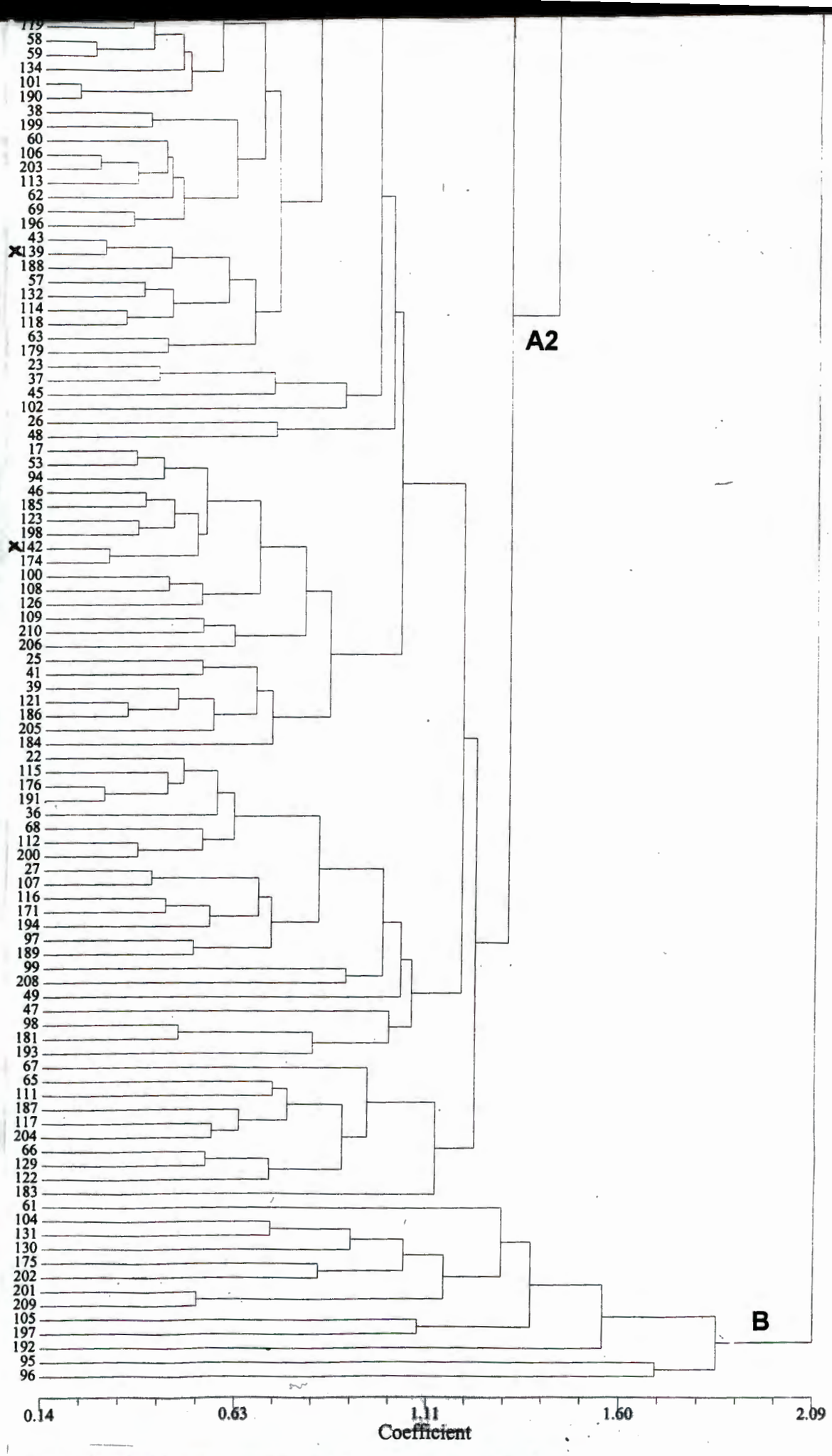


Fig. 3: UPGMA phenogram of G. bicolor and G. flava

Table 1: Character variation on the first three components

	Eigenvalue	Percent	Cumulative
1	4.585918	41.6902	41.6902
2	2.230070	20.2734	61.9635
3	1.014953	9.2268	71.1904

Table 2: Eigenvectors for each principal component, indicating the most meaningful characters

	PC1	PC2	PC3
Leaf width	8.81	3.36	-2.85
Leaf length	8.51	4.38	1.64
No of serrations on margin	7.51	-1.50	4.13
Pubescence on adaxial surface	-7.35	1.97	3.06
Distance widest pt to base	6.99	5.01	3.07
Reticulation of tertiary veins	-6.53	5.68	4.30
No of flower stalks on peduncle	5.62	-6.20	-1.07
Left angle at leaf base	-5.49	5.62	3.65
Right angle at leaf base	-5.04	1.65	4.45
Pubescence on abaxial surface	3.14	-5.13	4.96
Size of serrations	2.99	7.80	-1.87

When the first two principal components were plotted against each other, there was no distinct separation of groups (Fig. 4). Although ordination does group the OTU's into *G. bicolor* and *G. flava*, corresponding to the groups

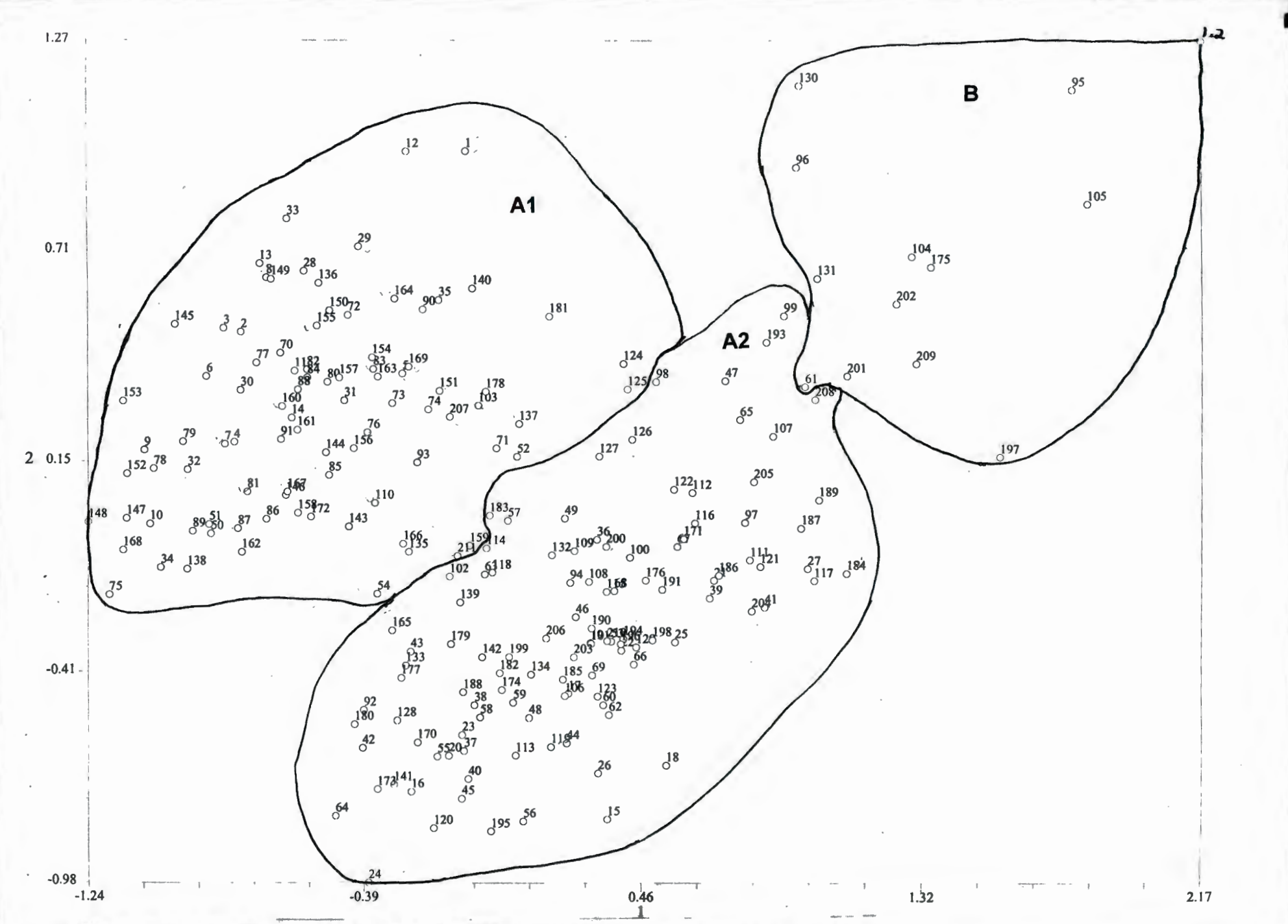
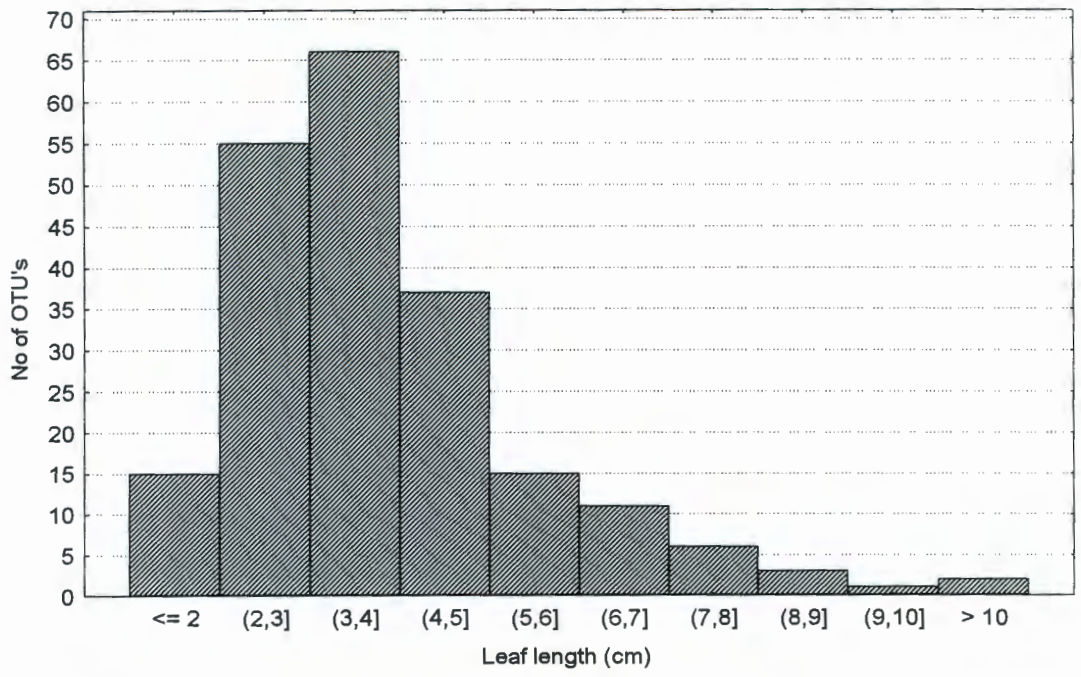


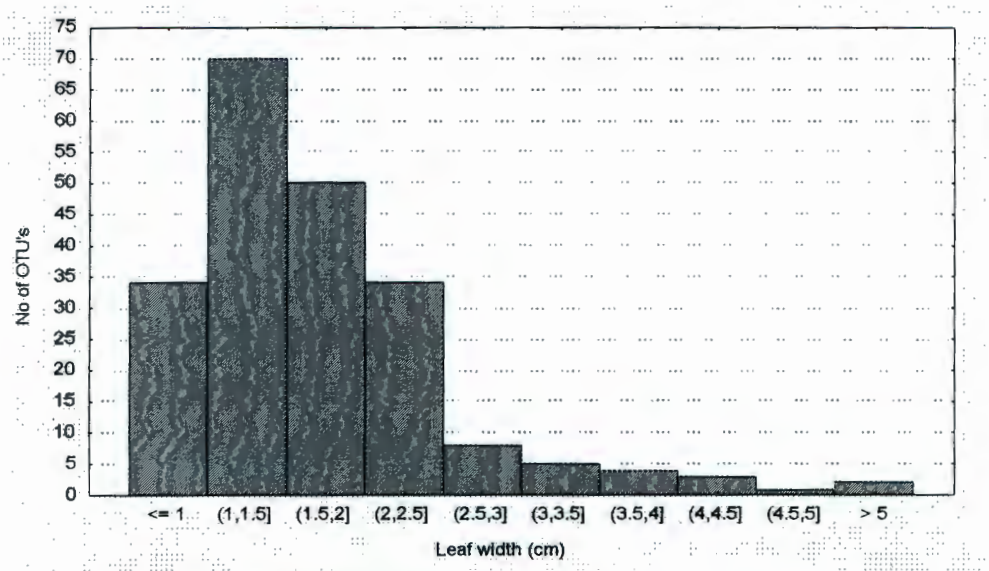
Fig. 4: Plot of the first two principal components based on 11 characters for 211 OTU's

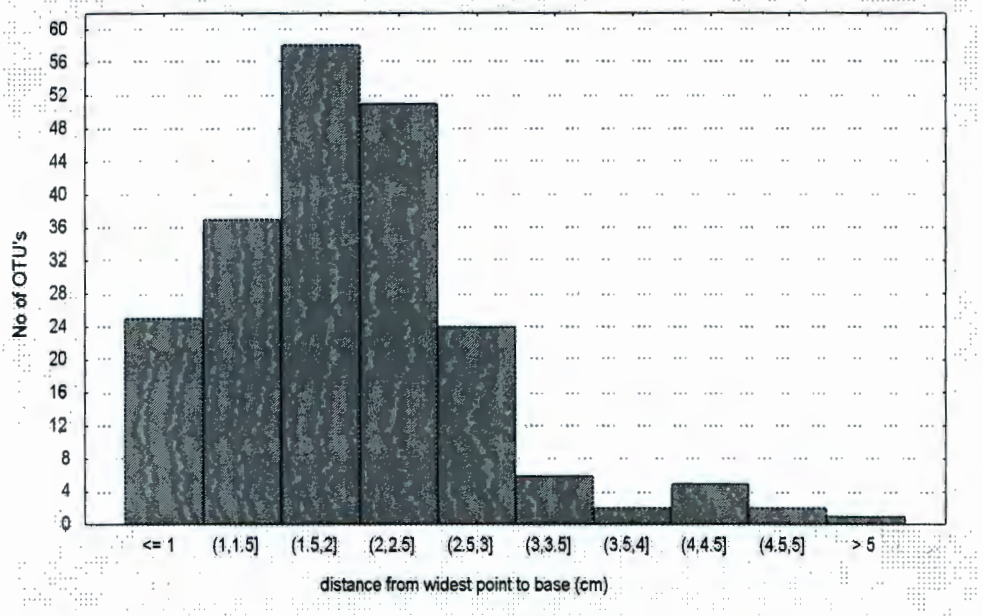
obtained from cluster analysis, there are no distinct boundaries between these two. Thus they cannot be recognized as two species.

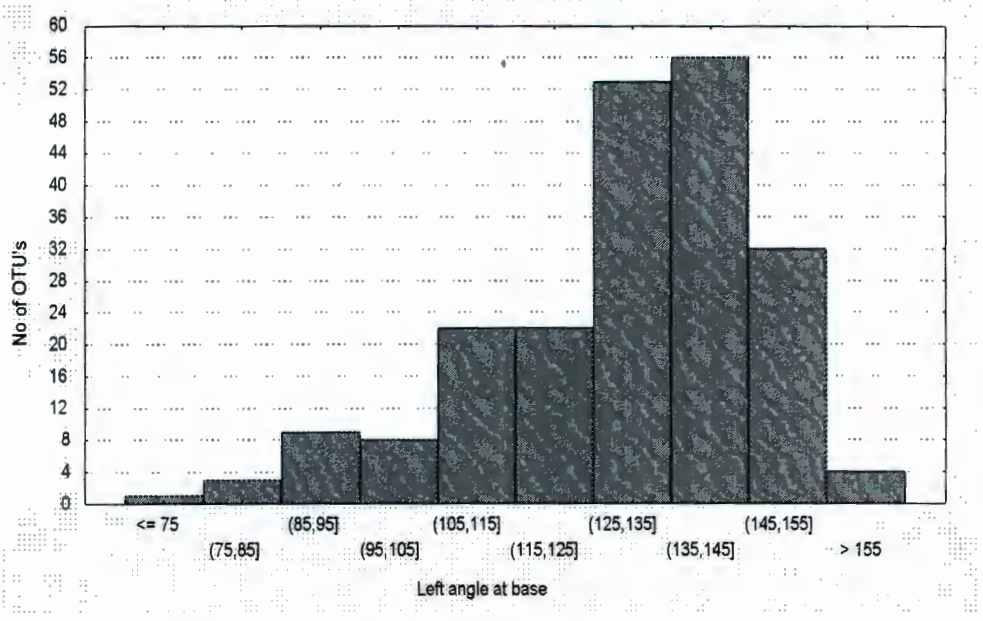
Univariate and bivariate analysis

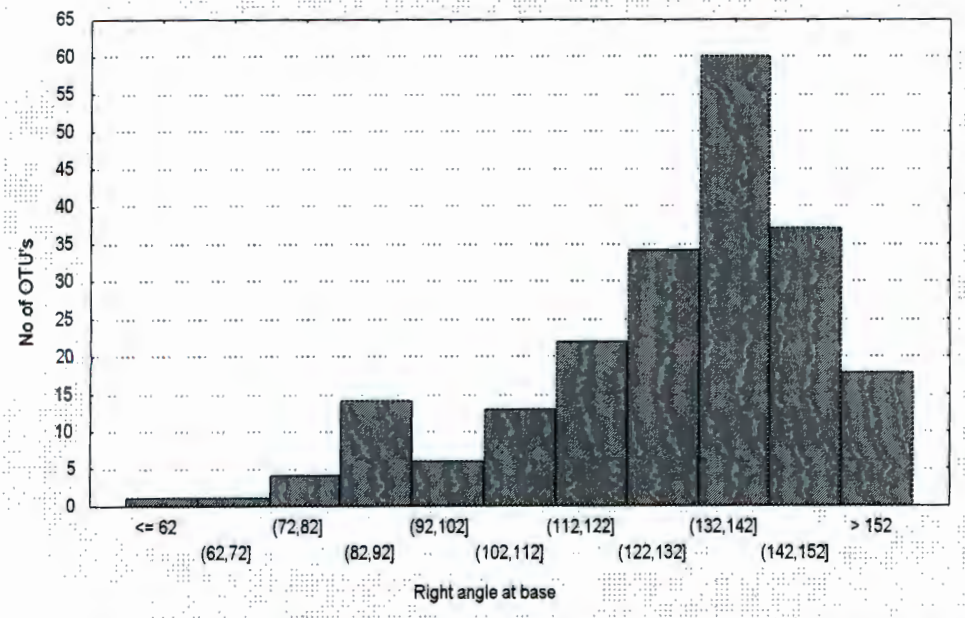
Univariate analysis of 10 of the 11 characters did not separate the OTU's into different groups. Most histograms are unimodal, which means that only one group is recognized. Two distinct groups are only evident in the histogram representing the number of flower stalks, but as this character only has three states, it is biased. This confirms that *G. bicolor* and *G. flava* can not be distinguished on the base of the currently used diagnostic characters.




No of OTU's
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
<= 1
(1,1.5]
(1.5,2]
(2,2.5]
(2.5,3]
(3,3.5]
(3.5,4]
(4,4.5]
(4.5,5]
> 5
Leaf width (cm)


No of OTU's
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
<= 1
(1,1.5]
(1.5,2]
(2,2.5]
(2.5,3]
(3,3.5]
(3.5,4]
(4,4.5]
(4.5,5]
> 5
distance from widest point to base (cm)


No of OTU's
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
<= 75
(75,85]
(85,95]
(95,105]
(105,115]
(115,125]
(125,135]
(135,145]
(145,155]
> 155
Left angle at base


No of OTU's
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55
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45
40
35
30
25
20
15
10
5
0
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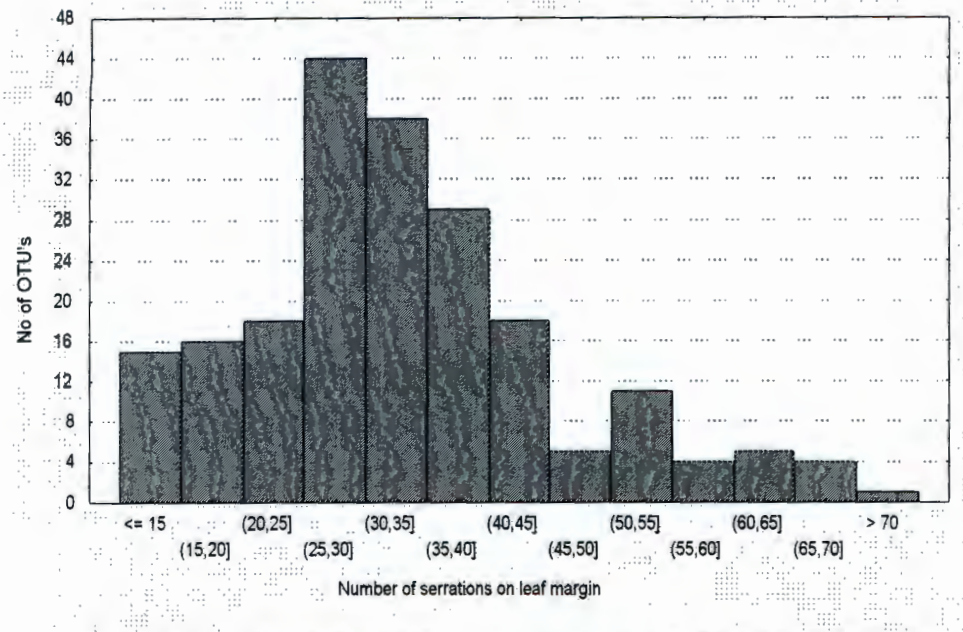
(62,72]
(72,82]
(82,92]
(92,102]
(102,112]
(112,122]
(122,132]
(132,142]
(142,152]
> 152
Right angle at base


No of OTU's
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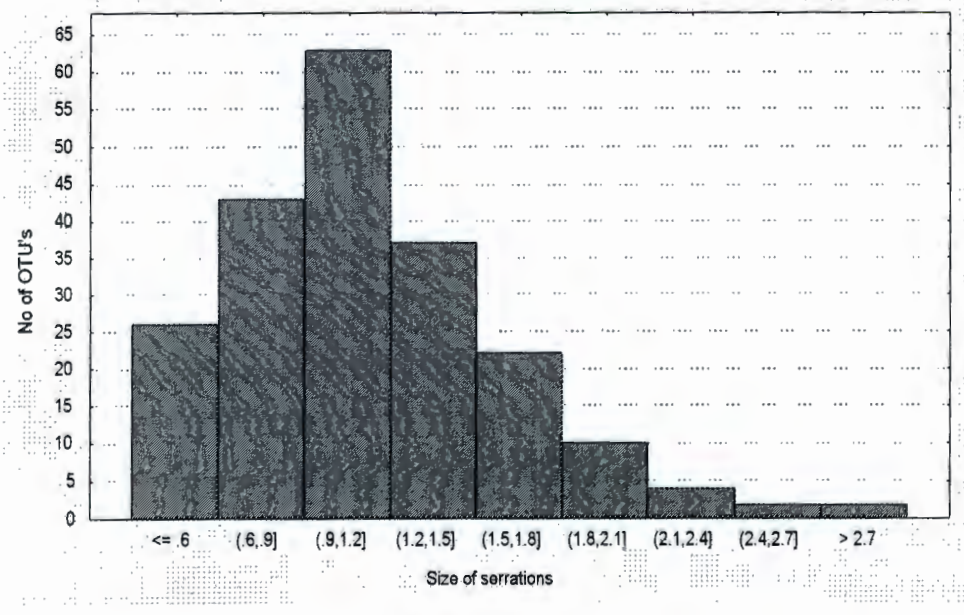
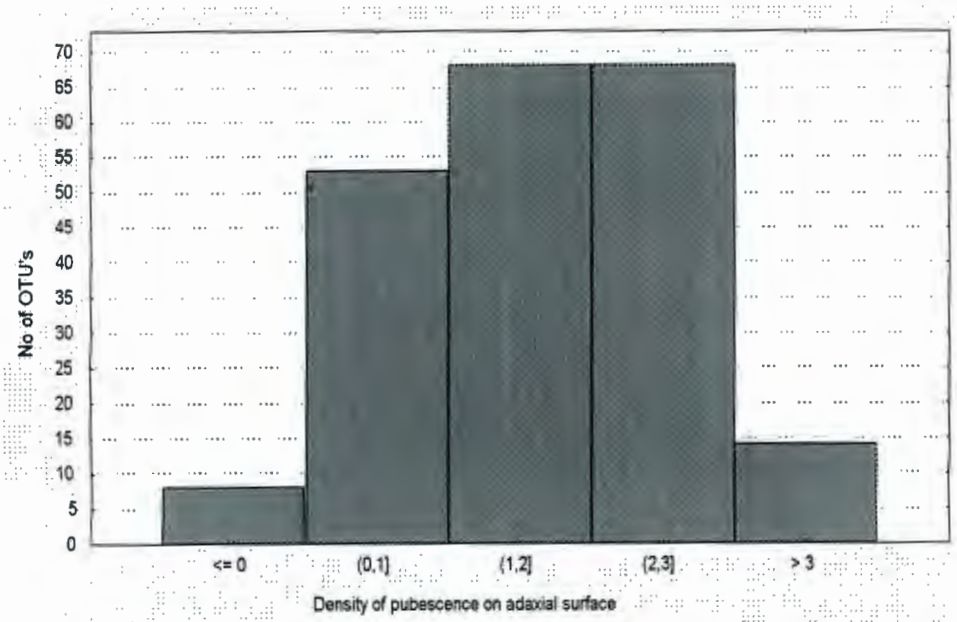
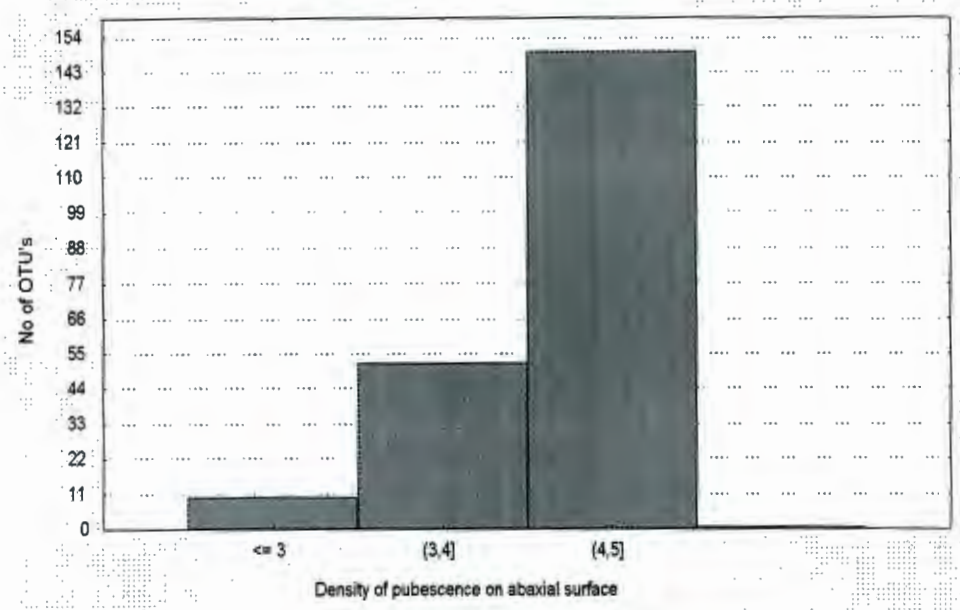
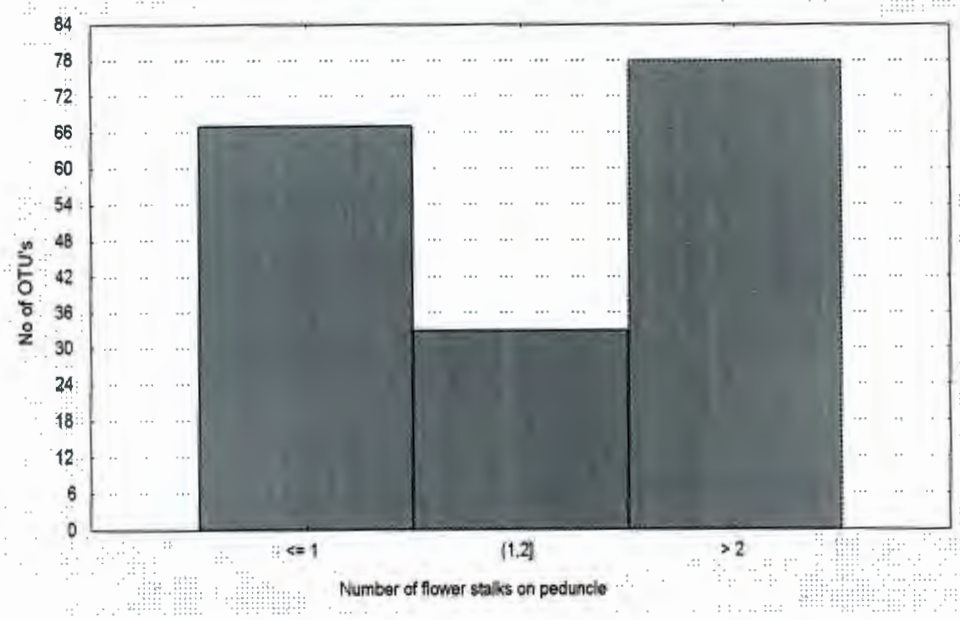
44
40
36
32
28
24
20
16
12
8
4
0
<= 15
(15,20]
(20,25]
(25,30]
(30,35]
(35,40]
(40,45]
(45,50]
(50,55]
(55,60]
(60,65]
(65,70]
> 70
Number of serrations on leaf margin


No of OTU's
65
60
55
50
45
40
35
30
25
20
15
10
5
0
<= .6
(.6,.9]
(.9,1.2]
(1.2,1.5]
(1.5,1.8]
(1.8,2.1]
(2.1,2.4]
(2.4,2.7]
> 2.7
Size of serrations


No of OTU's
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
<= 0
(0,1]
(1,2]
(2,3]
> 3
Density of pubescence on adaxial surface


No of OTU's
154
143
132
121
110
99
88
77
66
55
44
33
22
11
0
<= 3
(3,4]
(4,5]
Density of pubescence on abaxial surface


No of OTU's
84
78
72
66
60
54
48
42
36
30
24
18
12
6
0
<= 1
(1,2]
> 2
Number of flower stalks on peduncle

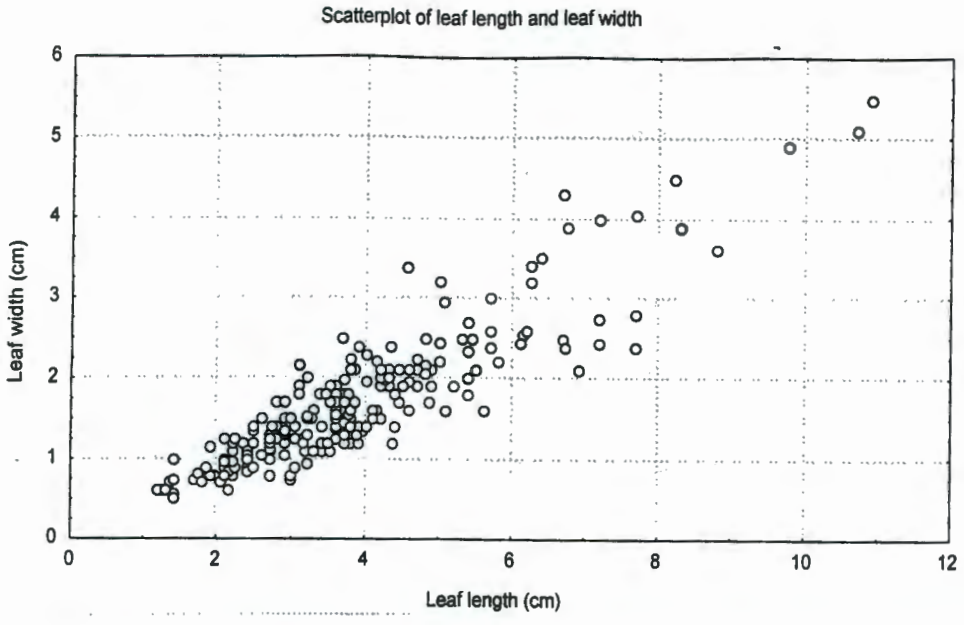


Fig. 6: Two-dimensional scatter plot of leaf length and leaf width

The two dimensional scatter of leaf length and width (Fig. 6) did also not show a distinct grouping of the OTU's.

Discussion

The results obtained from this study do not support the distinction of *Grewia bicolor* from *Grewia flava*. Although specimens that have preliminary been identified as *G. bicolor* and *G. flava* form two groups in cluster analysis, they are subclusters to each other. This implies that *G. bicolor* and *G. flava* are one species and are more closely related to each other than to *G. bicolor* in cluster B. Specimens that have been identified as *G. bicolor* form two groups, rather than one. The G. *bicolor* specimens in cluster B deviate from the ones in cluster A only by having exceptionally large leaves, all being longer than seven centimeters, thus exceeding the upper limit as defined by Wild (1984) However, this deviation would probably not have caused a separation, if the other characters (leaf texture, shape of leaf base, number of peduncles on

flower stalks, reticulation of tertiary veins etc.) would contribute more significantly to the variation. Clustering methods are often criticized, because they superficially impose the grouping of specimens. This might explain why the groups that were formed by clustering were not supported by the results of ordination and bivariate/ univariate analysis. Ordination did not show a distinct separation between *G. bicolor* and *G. flava*.

This study also reveals that the characters that have been used so far to delimit the species are not very useful, because they do not contribute significantly to the variation, and do not separate the OTU's into two groups (Fig. 5). PCA showed, that the characters that account for most variation in this study are leaf length and leaf width, but when these two characters were plotted against each other (Fig. 6), no distinct clusters were formed. In that sense these leaf length and width do not provide an alternative to the currently used ones. Leaf width and length have not been used before as diagnostic characters, possibly because in a taxonomic sense, it is not a good character. It is very variable and is influenced by environmental factors, such as rainfall, temperature, soil type etc.

When leaf width and length are ignored, characters that have been used previously contribute most to the variation. In PC 1 the number of serrations, pubescence on the adaxial surface and distance from the widest point to the base become most important. In PC 2 the size of the serrations, number of flower stalks on peduncle and reticulation of tertiary veins contribute most to the variation. The number of flower stalks is used by Merxmüller (1967), Wild

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APPENDICES

Appendix 1: Details of specimens used for this study

Code	Prelim ID	Herbarium	Collector & no.	Country	Area
1	*G. flava*	PRE	Swartz 87/94 EN	SA	Gauteng
2	*G. flava*	PRE	Barker	SA	Gauteng
3	*G. flava*	PRE	Mogg 37241	SA	Gauteng
4	*G. flava*	PRE	Mogg 37153	SA	Gauteng
5	*G. flava*	PRE	Retief 1776	SA	Gauteng
6	*G. flava*	PRE	Germishuizen 3971	SA	Gauteng
7	*G. flava*	PRE	Germishuizen 3368	SA	Gauteng
8	*G. flava*	PRE	Smith 1132	SA	Gauteng
9	*G. flava*	PRE	Verdoorn 1231	SA	Gauteng
10	*G. flava*	PRE	van Wyk 2422	SA	Gauteng
11	*G. flava*	PRE	Smith 1145.1	SA	Gauteng
12	*G. flava*	PRE	Pole Evans 627	SA	Gauteng
13	*G. flava*	PRE	Mogg 14269	SA	Gauteng
14	*G. flava*	PRE	Sutton 917	SA	Gauteng
15	*G. bicolor*	PRE	van Wyk 3030	SA	Gauteng
16	*G. bicolor*	PRE	van Wyk 3024	SA	Gauteng
17	*G. bicolor*	PRE	Fourie E. 2438	SA	Gauteng
18	*G. bicolor*	PRE	Fourie S.P. 5/62	SA	Gauteng
19	*G. bicolor*	PRE	Retief 227A	SA	Gauteng
20	*G. bicolor*	PRE	Plantkunde Hons 140	SA	Gauteng
21	*G. bicolor*	PRE	Codd 8380	SA	Gauteng
22	*G. bicolor*	PRE	Hutchinson 2299	SA	Gauteng
23	*G. bicolor*	PRE	Pole Evans 1925	SA	Gauteng
24	*G. bicolor*	PRE	Fourie E. 2223	SA	Gauteng
25	*G. bicolor*	PRE	Codd & Dyer 3903	SA	Gauteng
26	*G. bicolor*	PRE	Codd & Dyer 3931	SA	Gauteng
27	*G. bicolor*	PRE	Rogers 20841	SA	Gauteng
28	*G. flava*	PRE	Chadwick 240	Botsw	SW
29	*G. flava*	PRE	Hilliard & Robe 511	Botsw	SE
30	*G. flava*	PRE	Skarpe 83	Botsw	SW
31	*G. flava*	PRE	Smith 2141	Botsw	N
32	*G. flava*	PRE	Cole 995	Botsw	SE
33	*G. flava*	PRE	van der Spuy 27	Botsw	N
34	*G. flava*	PRE	Cole 976	Botsw	SE
35	*G. flava*	PRE	Camerik 14	Botsw	SE
36	*G. bicolor*	PRE	Thompson 1661	Botsw	SE
37	*G. bicolor*	PRE	Cole 969	Botsw	SE
38	*G. bicolor*	PRE	Mansergh 25920	Botsw	SE
39	*G. bicolor*	PRE	Leach & Noel 3	Botsw	N
40	*G. bicolor*	PRE	van der Spuy 69	Botsw	N
41	*G. bicolor*	PRE	Kunhardt 21	Botsw	SE
42	*G. bicolor*	PRE	Kerfoot & Falconer 79	Botsw	SE
43	*G. bicolor*	PRE	Robson 813	Zimb	N
44	*G. bicolor*	PRE	Levy 136	Zimb	W
45	*G. bicolor*	PRE	Wild 4689	Zimb	S
46	*G. bicolor*	PRE	Lovemore 180	Zimb	S

47	*G. bicolor*	PRE	Pole Evans & Ere 1418	Kenya	L. Harrington
48	*G. bicolor*	PRE	Tinley 2994	Mozamb	Gaza
49	*G. bicolor*	PRE	Greenway 1976	Amani	E
50	*G. flava*	PRE	Drummond 5919	Zimb	S
51	*G. flava*	PRE	Davies 2319	Zimb	S
52	*G. flava*	PRE	Schoenfelder 25	Zimb	W
53	*G. bicolor*	WIN	Jensen R1/ 862	Nam	WIN
54	*G. bicolor*	WIN	Muller & Kolberg 2066	Nam	WIN
55	*G. bicolor*	WIN	Merxm. & Giess 848	Nam	WIN
56	*G. bicolor*	WIN	von Koenen 408	Nam	WIN
57	*G. bicolor*	WIN	Giess 15043	Nam	WIN
58	*G. bicolor*	WIN	Giess 13909	Nam	OKA
59	*G. bicolor*	WIN	von Koenen 448	Nam	KAR
60	*G. bicolor*	WIN	Curtis 527	Nam	KAR
61	*G. bicolor*	WIN	Schwerdtfeger 4033	Nam	KAR
62	*G. bicolor*	WIN	Meyer 1026	Nam	SW
63	*G. bicolor*	WIN	Hoffmeyer & Jensen 160	Nam	OM
64	*G. bicolor*	WIN	von Koenen 412	Nam	OM
65	*G. bicolor*	WIN	Giess 3696	Nam	OM
66	*G. bicolor*	WIN	Walter & Walter 2716	Nam	OM
67	*G. bicolor*	WIN	von Koenen 441	Nam	OM
68	*G. bicolor*	WIN	Craven 2322	Nam	OM
69	*G. bicolor*	WIN	Craven 2410	Nam	OM
70	*G. flava*	WIN	Muller 163	Nam	WAR
71	*G. flava*	WIN	Craven 3908	Nam	WAR
72	*G. flava*	WIN	Henning A163/ 75	Nam	WAR
73	*G. flava*	WIN	Giess & Muller 11907	Nam	KEE
74	*G. flava*	WIN	Babaletakis 1	Nam	GOB
75	*G. flava*	WIN	Leuenb, Schiers & Raus 3128	Nam	GOB
76	*G. flava*	WIN	Silver 3	Nam	GOB
77	*G. flava*	WIN	Miller 1/ 029	Nam	BET
78	*G. flava*	WIN	le Roux & Coetzee 379	Nam	GIB
79	*G. flava*	WIN	van der Westhuizen 44	Nam	MAL
80	*G. flava*	WIN	Clark Z10	Nam	GIB
81	*G. flava*	WIN	Walter & Walter 161	Nam	REH
82	*G. flava*	WIN	Curtis 1/ 6	Nam	REH
83	*G. flava*	WIN	Scholz 165	Nam	REH
84	*G. flava*	WIN	Muller 1413	Nam	REH
85	*G. flava*	WIN	Codd	Nam	WIN
86	*G. flava*	WIN	von Koenen 404	Nam	WIN
87	*G. flava*	WIN	van Stryk 3	Nam	WIN
88	*G. flava*	WIN	Steyn 8948	Nam	WIN
89	*G. flava*	WIN	Hanekom 127	Nam	WIN
90	*G. flava*	WIN	Hanekom 310	Nam	WIN
91	*G. flava*	WIN	de Winter 2525	Nam	WIN
92	*G. bicolor*	WIN	Giess 9766	Nam	GO
93	*G. bicolor*	WIN	Giess 9749	Nam	GO
94	*G. bicolor*	WIN	Liebenberg 4651	Nam	GO
95	*G. bicolor*	WIN	Giess 11374	Nam	CA
96	*G. bicolor*	WIN	Muller & Irish 3154	Nam	CA
97	*G. bicolor*	WIN	de Winter & Marais 4788	Nam	CA

98	*G. bicolor*	WIN	le Roux 44	Nam	GRN
99	*G. bicolor*	WIN	Story 6485	Nam	GRN
100	*G. bicolor*	WIN	Giess, Watt & Snyman 11020	Nam	GRN
101	*G. bicolor*	WIN	Hines 218	Nam	GRN
102	*G. bicolor*	WIN	de Winter 3919	Nam	GRN
103	*G. bicolor*	WIN	Giess & Muller 13951	Nam	GRN
104	*G. bicolor*	WIN	Muller & Giess 414	Nam	GRN
105	*G. bicolor*	WIN	Giess 14902	Nam	GRN
106	*G. bicolor*	WIN	Giess, Watt & Snyman 11167	Nam	GRN
107	*G. bicolor*	WIN	Giess 9836	Nam	GRN
108	*G. bicolor*	WIN	Hines 519	Nam	GRN
109	*G. bicolor*	WIN	Hoffmeyer 112	Nam	GRN
110	*G. bicolor*	WIN	Seely 5	Nam	GRN
111	*G. bicolor*	WIN	Giess 9867	Nam	GRN
112	*G. bicolor*	WIN	le Roux 1056	Nam	GRN
113	*G. bicolor*	WIN	de Winter 3924	Nam	GRN
114	*G. bicolor*	WIN	Oppermann 59	Nam	OVA
115	*G. bicolor*	WIN	Strohbach & Sheuyange 3857	Nam	OVA
116	*G. bicolor*	WIN	du Plessis 9	Nam	OVA
117	*G. bicolor*	WIN	Kolberg & Loots 961	Nam	OVA
118	*G. bicolor*	WIN	Merxmuller & Giess 1380	Nam	KAO
119	*G. bicolor*	WIN	Lukaschik 17	Nam	KAO
120	*G. bicolor*	WIN	Rusch s.n.	Nam	KAO
121	*G. bicolor*	WIN	Craven 39	Nam	KAO
122	*G. bicolor*	WIN	Gibson 192	Nam	KAO
123	*G. bicolor*	WIN	Abner 62	Nam	KAO
124	*G. bicolor*	WIN	de Winter & Leistner 5638	Nam	KAO
125	*G. bicolor*	WIN	Giess 7759	Nam	KAO
126	*G. bicolor*	WIN	Giess 3162	Nam	KAO
127	*G. bicolor*	WIN	Grobbelaar 5	Nam	KAO
128	*G. bicolor*	WIN	Lavranos & Barad 15317	Nam	KAO
129	*G. bicolor*	WIN	Craven 3172	Nam	KAO
130	*G. bicolor*	WIN	de Winter & Leistner 5640	Nam	KAO
131	*G. bicolor*	WIN	Gobbelaar 5a	Nam	KAO
132	*G. bicolor*	WIN	Giess 8147	Nam	KAO
133	*G. bicolor*	WIN	de Winter & Leistner 5507	Nam	KAO
134	*G. bicolor*	WIN	Sullivan 309	Nam	KAO
135	*G. flava*	WIN	Stohbach 2385	Nam	OKA
136	*G. flava*	WIN	Roxin 15	Nam	OKA
137	*G. flava*	WIN	Kolberg 947	Nam	OKA
138	*G. flava*	WIN	von Koenen 392	Nam	OKA
139	*G. flava*	WIN	Schmidt 126	Nam	KAR
140	*G. flava*	WIN	Schwerdtfeger 4034	Nam	KAR
141	*G. flava*	WIN	Jensen 106	Nam	SW
142	*G. flava*	WIN	Craven 724	Nam	OM
143	*G. flava*	WIN	Hoffmann 112	Nam	OTJ
144	*G. flava*	WIN	Craven 304	Nam	OTJ
145	*G. flava*	WIN	Pfeiffer s.n.	Nam	OTJ
146	*G. flava*	WIN	Hoffmann 88	Nam	OTJ
147	*G. flava*	WIN	Muller 186	Nam	OTJ
148	*G. flava*	WIN	Giess 15310	Nam	OU

149	*G. flava*	WIN	Giess 15013	Nam	OU
150	*G. flava*	WIN	Schmidt 300	Nam	ETO
151	*G. flava*	WIN	de Winter & Giess 6809	Nam	ETO
152	*G. flava*	WIN	Abner 22	Nam	KAO
153	*G. flava*	WIN	Owen Smith 261	Nam	KAO
154	*G. flava*	WIN	Viljoen 345	Nam	KAO
155	*G. flava*	WIN	Hilbert 049	Nam	GR
156	*G. flava*	WIN	Burgoyne 3235	Nam	GR
157	*G. flava*	WIN	Walter & Walter 945	Nam	GR
158	*G. flava*	WIN	Walter & Walter 37	Nam	GR
159	*G. flava*	WIN	le Roux 150	Nam	GR
160	*G. flava*	WIN	Walter & Walter 866	Nam	GR
161	*G. flava*	WIN	Giess 11293	Nam	GR
162	*G. flava*	WIN	de Winter 3699	Nam	GR
163	*G. flava*	WIN	le Roux 190	Nam	GRN
164	*G. flava*	WIN	Hines 562	Nam	GRN
165	*G. flava*	WIN	Seely 39	Nam	GRN
166	*G. flava*	WIN	Hines 117	Nam	GRN
167	*G. flava*	WIN	Hines 190	Nam	GRN
168	*G. flava*	WIN	Giess 9490	Nam	GRN
169	*G. flava*	WIN	Giess, Watt & Snyman 11119	Nam	GRN
170	*G. flava*	WIN	Joffe 923	SA	N. Cape
171	*G. bicolor*	WIN	Giess 2028	Nam	OU
172	*G. bicolor*	WIN	Walter & Walter 2/ 218	Nam	OU
173	*G. bicolor*	WIN	Giess & Wiss 3335	Nam	OU
174	*G. bicolor*	WIN	Schwerdtfeger 2/ 223	Nam	OU
175	*G. bicolor*	WIN	Mare 9	Nam	OTJ
176	*G. bicolor*	WIN	Liebenberg 4902	Nam	OTJ
177	*G. bicolor*	WIN	Grobler 31	Nam	OTJ
178	*G. bicolor*	WIN	Craven 295	Nam	OTJ
179	*G. bicolor*	WIN	Hoffmann 95	Nam	OTJ
180	*G. bicolor*	WIN	Hoffmann 83	Nam	OTJ
181	*G. bicolor*	WIN	Craven 616	Nam	OTJ
182	*G. bicolor*	WIN	Walter & Walter 310	Nam	OTJ
183	*G. bicolor*	WIN	de Winter 2818	Nam	OTJ
184	*G. bicolor*	WIN	Craven 365	Nam	OTJ
185	*G. bicolor*	WIN	Pfeiffer s.n.	Nam	OTJ
186	*G. bicolor*	WIN	Strohbach & Sheyange 2648	Nam	GR
187	*G. bicolor*	WIN	Burgoyne 3229	Nam	GR
188	*G. bicolor*	WIN	Basson 1/ 19	Nam	GR
189	*G. bicolor*	WIN	Hobohm 3a	Nam	GR
190	*G. bicolor*	WIN	Walter & Walter 3131	Nam	GR
191	*G. bicolor*	WIN	Burgoyne 3113	Nam	GR
192	*G. bicolor*	WIN	Giess 15197	Nam	GR
193	*G. bicolor*	WIN	Soini 451	Nam	GR
194	*G. bicolor*	WIN	von Koenen 3	Nam	GR
195	*G. bicolor*	WIN	Walter & Walter 838	Nam	GR
196	*G. bicolor*	WIN	Lightfoot 1919	Nam	GR
197	*G. bicolor*	WIN	Giess 15130	Nam	GR
198	*G. bicolor*	WIN	Walter & Walter 345	Nam	GR
199	*G. bicolor*	WIN	le Roux 271	Nam	ETO

200	*G. bicolor*	WIN	Schmidt 274	Nam	ETO
201	*G. bicolor*	WIN	Tinley 1551/ 868	Nam	ETO
202	*G. bicolor*	WIN	Giess & de Villiers 14024	Nam	ETO
203	*G. bicolor*	WIN	Leibnitz 862	Nam	ETO
204	*G. bicolor*	WIN	Giess & Smook 10580	Nam	ETO
205	*G. bicolor*	WIN	Walter & Walter 498	Nam	ETO
206	*G. bicolor*	WIN	Schmidt 256	Nam	ETO
207	*G. bicolor*	WIN	Nott 20	Nam	ETO
208	*G. bicolor*	WIN	Giess 15009	Nam	ETO
209	*G. bicolor*	WIN	Tinley 1164	Nam	ETO
210	*G. bicolor*	WIN	Giess 15438	Nam	ETO
211	*G. bicolor*	WIN	Tinley 1152	Nam	ETO

Appendix 2: Characters used for analysis

1: Leaf length measured from the base to the tip of the leaf

2: Leaf width measured at the widest point of the leaf blade

3: Distance from widest point of leaf blade to base

4: Left angle at leaf base

5: Right angle at leaf base

6: Number of serrations on left side of leaf blade

7: Size of serrations at widest point of leaf (x1.0)

8 & 9: Density of pubescence on adaxial and abaxial surface

0 = no hairs or hairs restricted to main veins

1 = sparsely pubescence

2 = denser, but epidermis still visible

3 = epidermis totally covered

4 = double layer of hairs (very dense lower one and long stellate hairs on upper)

10: Degree of reticulation of tertiary veins

0 = flat

1 = reticulate

11: Number of flower stalks on peduncle