Pak.J.Bot., 28(1): 9-19, 1996.

A NUMERICAL TAXONOMIC STUDY OF *SIBBALDIA* L. (ROSACEAE)-IV.

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Abstract

Numerical technique has been used to construct the cladogram to depict the natural relationships among the species of the genus *Sibbaldia*. The cladistic analysis of the genus is presented with a discussion of characters used and the result suggest the exclusion of *S. micropetala* from the genus *Sibbaldia*. The transfer of *S.adpressa* by Juzepczuk (1941) to the monotypic genus *Sibbaldianthae* is rejected.

Introduction

The genus *Sibbaldia* of the family Rosaceae, was established by Linnaeaus (Linnaeus, 1753), honoring the Scot botanist and Professor at Edinburgh University, Robert Sibbald (1643-1720), who was instrumental in establishing of the Royal Botanic Garden at Edinburgh in 1670. Hooker (1878) did not recognize *Sibbaldia* as an independent genus of Rosaceae, but described it as a section of the genus *Potentilla* and described 7 species from the British India. Seringe (1825) recognized *Sibbaldia* and *Potentilla* as distinct genera of Rosaceae and included both genera in the Tribe Dryadeae. Rajput *et al.*, (1994b) recognized 10 species, predominantly distributed in South East Asia, but with one species in Europe and North America.

There has been a considerable development of numerical methods which provided numerous new concepts and techniques to systematists. During the monographic review of the genus *Sibbaldia* at world level, much difficulties have been experienced in giving the species a natural sequence considering the significance of numerical techniques in plant taxonomy, an attempt has been made to investigate the systematic structure of *Sibbaldia* by using Reading Taxonomy ASF4 Program.

Material and Methods

The cladistic analysis was started with the study of about 5000 herbarium specimens of genus *Sibbaldia*, collected mainly from South East Asia, one species from Europe and North America which were burrowed on loan from the herbaria: A, B, BM, E, GH, K, KUH, KYO, PE, RAW, RGN and US.

Preparation of the data was performed by Reading Taxonomy package ASF4 developed by J.Roger, of the Department of Applied statistics and converted to MS-

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DOS version by Dr. R.M. Wadsworth of the Department of Botany, University of Reading, England.

The morphological and micromorphological data of 10 species of the genus *Sibbaldia* (Rosaceae) was obtained from the examination of herbarium specimens. For each species (O.T.U.) 38 attributes were scored. The multistate attributes were arranged in possible logical transformation series. The data includes binary, ordered multistate and unordered multistate attributes.

Attributes

In this numerical study, the attributes are not usually weighted. The method adopted here was to generate cladograms from the attributes/characters which are considered to be important in discriminating between the species using the Reading University Taxonomy computer program ASF4. In this numerical analysis two types of attributes were used viz., Multistate attributes and binary attributes or Qualitative attributes. Multistate attributes can be ordered multistate or disordered multistate. The attributes and their states which were used in this study are listed together with brief discussion:

Details of the attributes used in this study

Morphological characters

The species of *Sibbaldia* vary from prostrate to small erect herbs, while a few species are cushion like or moss like in habit.

1. Habit : prostrate-0; Prostrate to erect- 1; erect-2.
2. Nature of the plant: Cushion-like-0; non-cushion-like-1.

Trichomes: The trichomes on the leaves are present in all the species of *Sibbaldia* and four attributes of trichomes were taken into consideration. Basically the hairs are uniseriate and unicellular hair colour is quite constant, and can be used as distingnishing characters.

3. Kind: stiff-0; soft and stiff-1.
4. Density: sparsely distributed-0; mediumly distributed-1, densely distributed-2.
5. Nature: straight-0; straight and curly -1; straight and interlaced-2.
6. Colour: silvery-0; gray-1; brown-gray-2; brown-3; yellow-4, snow-white-5.

Stipule: Stipules are present in all the species of *Sibbaldia* and consists of a basal portion "the body" that is adnate to the base of the petiole, and upper free portion, "the auricle". The size of the stipule body, and size, shape and venation of auricle can be used as a distinguishing attribute.

7. Average stipule body size: small (2-5 mm.)-0; medium (6-10 mm.); large (11-18 mm.)-2.
8. Average auricle size: small (1-2 mm.)-0; medium (3-4 mm.)-1; large (7-8 mm.)-2.
9. Auricle venation: unveined-0; slightly veined-1; distinctly veined-2.
10. Auricle apex: obtuse-0; obtuse-round-1; round-2;acuminate-3; sharply acute-4.

Leaves: All the species of *Sibbaldia* have compound leaves, except *S. trullifolia*. The number of leaflets varies between species, but it is quite constant within species. Only one species have lobed margin, while all the remaining species have either dentate leaflet margin or dentate leaflet apices with two to nine usually glandular teeth. The number of apical teeth is variable within species consequently tooth number are not used a a key character. In some species of *Sibbaldia* an articulation is present at the base of the leaflets, which is a significant character in the identification of species.

11. Kind of leaf: simple-0; compound-1.
12. Dentation: apical-0; present on entire leaflets-1.
13. Average no of teeth/lobes three-0; four-1; five-2; six-3; ten-4; thirteen-5.
14. Leaf articulation present-0; absent-1.

Inflorescence: The inflorescence in the species of *Sibbaldia* is basically a cyme. In a few species loose umbel-like cyme and dichasia is also found.

15. Type of infloresence: Solitary-0; solitary-cyme-1; dichasia-2; umbel-like cyme-3.

Flowers: All the species of *Sibbaldia* have actinomorphic flowers, which are mostly perfect and 5-merous expect *S. tetrandra* which have both perfect and staminate flowers.

16. Pedicel length: short (1.2-2.5 mm)-0; medium (3-19 mm)-1.
17. Bract on pedicel: present-0; absent-1.
18. Shape of sepal lobes: Linear-oblong-0; oblong-lanceolate-1; lanceolate-2; narrow-deltoid-3; deltoid-4; broad-deltoid-5.
19. Sepal lobes hairy: On outside-0; on both side-1.
20. Corolla Colour: cream-white-0; pale-yellow-1; yellow-2; pinkish-3; purple-red-4; purple-5.

Stamens: Mostly the species of *Sibbaldia* have 5 stamens, except, *S. tetrandra* (4 stamens) *S. adpressa* and *S. perpusilloides* (10 stamens). Stamens number is an important taxonomic characters, and it is used in separating *Sibbaldia* from *Potentilla*.

21. Number of stamen: four to five-0; ten-1;
22. Filament length:Small (0.2-1.5 mm)-0; medium (1.6-2.9 mm)-1.

Receptacle: Present in all the species of this genus, mostly hairy except two species. This characters has been used in separating the species.

23. Receptacle dise:Circular-0; Circular-lobed-1; lobed-2. Carpel: In perfect flowers 4-22 carpels are present. The position of style is an important characters and it has been used in distinguishing *Sibbaldia* from *Potentilla*.
24. Average number of carpels: Six-eleven-0, twelve-sixteen-1; seventeen - twenty two-2.
25. Position of style: lateral-0; sub-terminal-1.

Fruit: Fruits in all the species are achenes, which are mostly smooth and glabrous. Colour of fruit is quite constant, within the species.

26. Achenes colour: light brown-0; greenish-brown-1; brown-2; purple-brown-3; blackish-brown-4.

Micromorphological characters

The micromorphological characters of leaf, petal and achene surfaces of all the species of *Sibbaldia* was carried out by Scanning Electron Microscope. The micromorphological characters observed and their reliability as taxonomic markers is discussed in a separate contribution (Syeda *et al.*, 1996).

In some species leaf epidermis is covered with wax, which is considered as an important taxonomic character in *Sibbaldia* taxonomy. Stomata anomocytic, occurring on both the sides of leaves, with variable degree of elevation and sunkeness. Leaf indumentum consists of non-glandular, unicellular soft and stiff trichome, present on both leaf surfaces. Petal epidermis cells exhibit definite geometrical patterns, where cell boundaries are usually raised. Achene surface shows more or less similar pattern in the

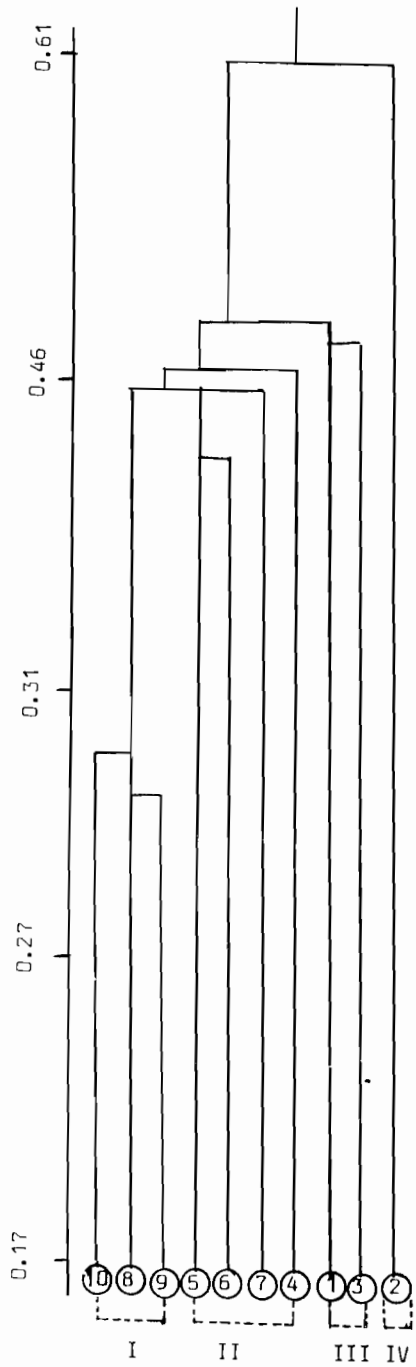

Fig:1. Cladogram developed by using ASF4 Reading Taxonomy computer program with Nearest neighbour strategy.

species of *Sibbaldia* except *S. micropetala* which has 3-4 ribs or folds with strong colliculate pattern.

27. Epidermal wax: present-O; absent-1.
28. Stomatal opening: elongated-0; circular-1.
29. Stomata elevation: elevated-0; non-elevated or at the level of epidermis-1;sunken-2.
30. Stomatal aperture: narrow long-0; oblong-1; elliptical-2; elliptical-3; circular-4.
31. Neighbouring cell:with striate pattern-0; without pattern-1.
32. Petal epidermal cell arrangement: closely packed-0; loosely packed-1.
33. Petal epidermal cell shape: irregular-0; irregular to circular-1; ± circular-2; circular-polygonal-3; polygonal-4.
34. Boundary walls of petal epidermis cell: elevated-0; non-elevated-1.
35. Pattern on the boundary walls of petal epidermal cell: present-0; absent-1.
36. Petal epidermal cell elevation: not raised-0; raised into rugose-1; forming an umberella-like structure-2,
37. Achene: folds or ribs: present-0; absent-1.
38. Surface pattern on achene: no prominent pattern-0; smooth to finally reticulate 1; irregular-reticulate-2; pustieculate colliculate-3; light wavy-4; undulate-5; strongly colliculate-6.

Results and Discussion

The result of cladistic analysis are depicted in the cladograms, developed with nearest neighbour, furthest neighhour and group average linkage strategy (Fig.1-3). In all the three analyses 4 major groups are produced for the species of *Sibbaldia*.

I. Nearest neighbour strategy

In the cladogram generated by nearest neighbour strategy (Fig-1) four major clusters are developed.

Cluster-I: Three species viz., *S. unguiculata, S. trullifolia* and *S. tetrandra* are included in this cluster and all species included in this cluster have common cushion-like habit.

Cluster-II: This cluster includes 4 species viz., *S. purpurea, S. sikkimensis, S. tenuis* and *S. procumbens*. These species are mainly grouped together by having stiff trichomes.

Cluster-III: Contains only 2 species viz., *S. adpressa* and *S. perpusilloides*, which are held together by having 10 stamens.

Cluster-IV: This cluster has only 1 species viz., *S. micropetala*, which have two type of trichome and have unique achene characters, the details of which are given in discussion.

II. Furtherst neighbour strategy

In the cladogram (Fig.2) developed by furthest neighbour strategy the following four clusters are developed:-

Cluster-I: The cluster include 2 species viz, *S. adpressa* and *S. perpusilloides*, which were placed in cluster-III in nearest neighbour strategy.

Cluster-II: This cluster includes 4 species viz, *S.tenuis, S.tetrandra, S.trullifolia*, and *S.unguiculata*. The composition of this cluster is same as cluster-I in the nearest neigh-

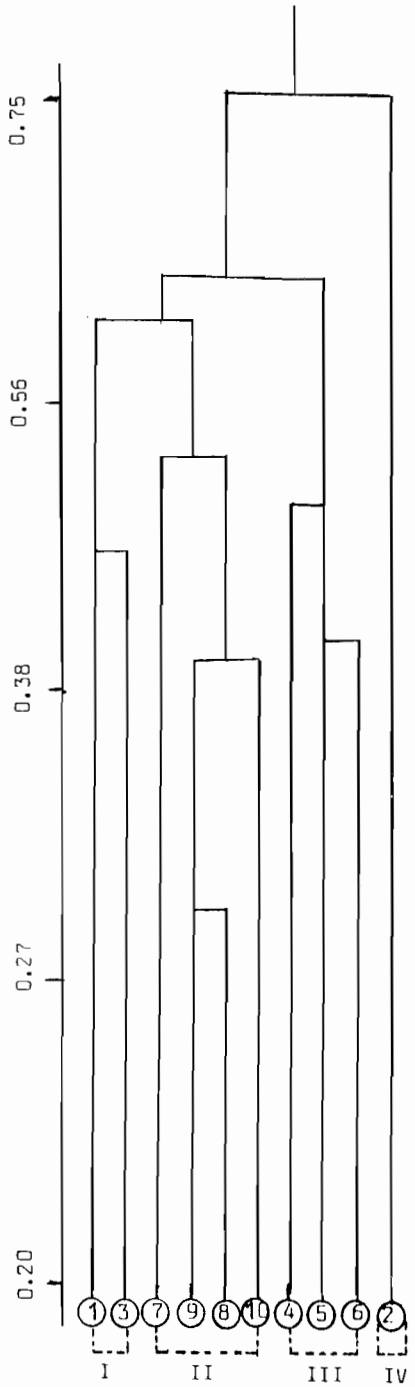

Fig:2. Cladogram developed by using ASF4 Reading Taxonomy computer program with furthest neighbour strategy.

bour strategy, except one species (*S. tetrandra*) is added to this cluster.

Cluster-III: This cluster includes 3 species viz., *S. procumbens, S. purpurea* and *S. sikkimensis*. The composition of this cluster is the same as in cluster-II in the nearest neighbour strategy except *S. tenuis* has been shifted to cluster-II.

Cluster-IV: This cluster includes only *S. micropetala*. The composition of this cluster is same as in cluster -IV in the nearest neighbour strategy.

III-Group average strategy

In this analysis 4 clusters were produced (Fig.3) which included the following clusters.

Cluster-I: The composition of this cluster is same as in the cluster-I in furtherst neighbour and cluster-III is nearest neighbour strategy, only its position has changed.

Cluster-II: This includes 3 species viz., *S. procumbens, S. purpurea, S. sikkimensis* and its composition is same as in the cluster-III in the furtherst neighbour strategy.

Cluster-III(A): Contains only *S. tenuis*. which is separated from the group of species held in cluster IIIB because of its leaf-margin, which is entirely dentate and unveined auricles.

Cluster-III(B): Contains *S. tetrandra, S. trullifolia* and *S. unguiculata*, which are held together by having leaves, which are apically dentate, and also have distinctly veined auricles.

Cluster-IV: Contains only 1 species i.e., (*S. micropetala*).

In all the above cited strategies under discussion, four clusters are recognized, cluster-IV has come out very clearly in all the analyses. Cluster I and cluster III has also come out with some overlapping and changes in position of a few taxa within the clusters. Cluster-IV includes only *S. micropetala* which has been isolated in all the strategies.

Sojak (1970) recognized three sections in *Sibbaldia* and placed *S. micropetala* under Sect. Piletophyllum Sojak, on the basis of pinnate leaves which are tomentose below, stamen 5, and style sub_basic to lateral. Rajput *et al.*, (1994a) provided taxonomic notes on *S. micropetala* and placed five taxa under its synonymy.

The character used in recognizing sect. Piletophyllum Sojak by Sojak (1970) are also found in other species of *Sibbaldia*. The present study indicates that *S. micropetala* has some unique characters, which are not found in other species of *Sibbaldia*. In *S. micropetala* two kind of trichomes are found on the lower leaf surface, one which are soft, snow-white, thin, curly and interlaced, and others which are few stiff, brown and are sparsely distributed among the snow-white, indumentum whereas on the upper surface at maturty, only one kind of trichome is found, which are stiff, brown and sparsely distributed.

In all the species of *Sibbaldia* fruit is achene. Micromorphological study of *Sibbaldia* by Syeda *et al.*, (1996) indicates that achene surface of all the species of *Sibbaldia* shows similarities excepts *S. micropetala*, which has a distinct surface pattern having strongly colliculate surface pattern with 3-4 prominent transversely arranged folds or wrinkles and with a keel like structure on the stylar side. The micromorphological characters of indumentum and achene are quite useful for *Sibbaldia* species. Keeping in view of above cited unique characters, it is suggested that *S. micropetala* may be excluded from the genus *Sibbaldia*. which needs further investigations.

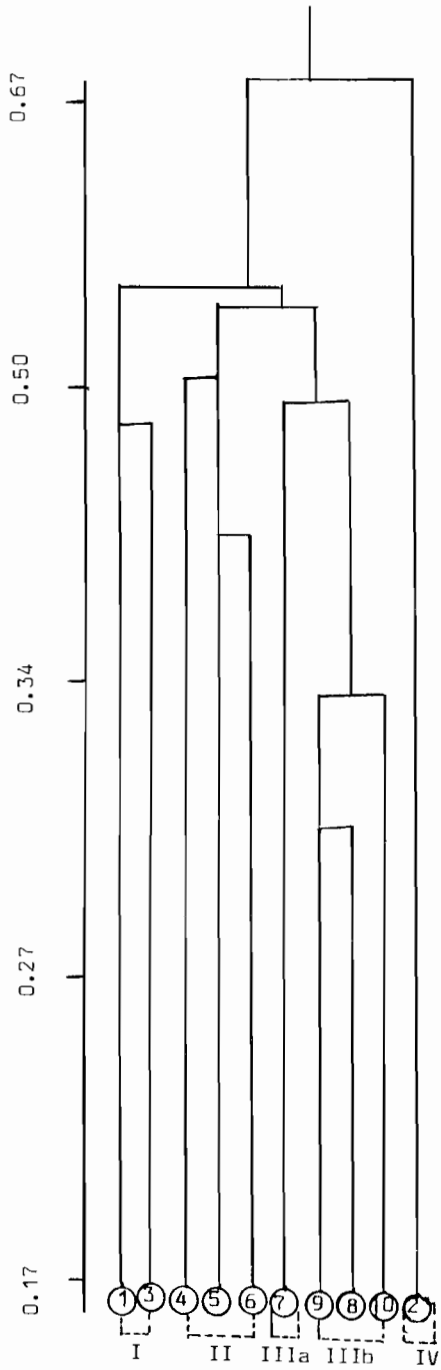

Fig:3. Cladogram developed by using ASF4 Reacing Taxonomy computer program with group average strategy.

The comparison of three cladograms showing the numerical relationships among the species of *Sibbaldia*, indicates that the cluster-IV come out clearly in all the cladograms. The position of *S. adpressa, S. perpusilloides* is changing. In group average strategy and furthest neighbour strategy, they are placed in cluster-I, but in nearest neighbour strategy, they are placed in cluster-II. Both *S. adpressa* and *S.perpusilloides* are held together by having 5 stamens, while rest of the *Sibbaldia* species have five stamens.

Juzepczuk (1941) tranfered *S. adpressa* Bunge to his new monotypic genus *Sibbaldianthe* on the basis of 10 stamens, opposite to petals style nearly basal and fusiform. However, Hutchinson (1964), Sojak (1970), Airyshaw (1973) Rajput *et. al.*, (1994b) rejected the circumscription of Sibbaldianthae as the characters at the generic level are variable and are also being found in other species of *Sibbaldia*. The present numerical study does not support the transfer of *S.adpressa* by Juzepczuk (1941) to his monotypic genus Sibbaldianthae.

S. procumbens which is placed on cluster-II in group average and nearest neighbour analysis and is placed in cluster-III in furthest neighbour strategy (Fig. 1,2 and 3) also have some interesting characters e.g., the development of umbel-like cyme inflorescence and trichome shows a tendency of spiral twisting. A great variation in the density of trichomes was found in *S. procumbens* and in the past a few new taxa were recognised from *S. procumbens* primarily on the basis of hair density on leaves.

Juzepczuk (1941) also recognized two series viz., Ser. Procumbentes Juz. and Ser. Cuneatae Juz. for the 5 species described in the flora of the former USSR. *S. procumbens* was placed in Ser. Procumbentes and the species included in Ser. Cuneatae Juz. were not recognized by Rajput (1994b). The characters used in establishing the above two series by Juzepczuk (1941) are misleading and are not based on true facts.

Most of the biologists believe that majority of the taxa have arisen through a sequence of branching events and when a classification is based on only one or a few convenient characters, it is termed as "artificial", and when a classification is based on all the observable characters or on overall similarity it is termed as "natural". Hence a branching tree was developed from the cladogram (Fig.4) generated by the average group strategy with 36 attributes which shows the natural relationship in the species of genus *Sibbaldia*. The possible reason or character for governing the dichotomy of the tree is also provided in the tree diagram (Fig.4). In the construction of this tree polarity of characters was determined that's why an unrooted tree was produced. The cladistic methods in general are likely to provide a reasonable approximation to phylogeny, although it is clear that they have some limitations (Carolin, 1985, Johnson & Brigs, 1985).

Dixit & Panigrahi (1981) while reviewing the Indian species of *Sibbaldia* recognized seven sections including the sections of previous works mainly on leaf, petal colour and style characters. The sections recognized by Muravjova (1963), Sojak (1970), Dixit & Panigrahi (1981) and series recognized by Juzepczuk (1941) are not recognized, due to overlaping of characters used in limiting the sections and series the species ascribed to sections and series by above works are mostly not recognized by Rajput *et. al.*, (1994b). The evidence obtained from this numerical analysis also support the rejection of previous section and series.

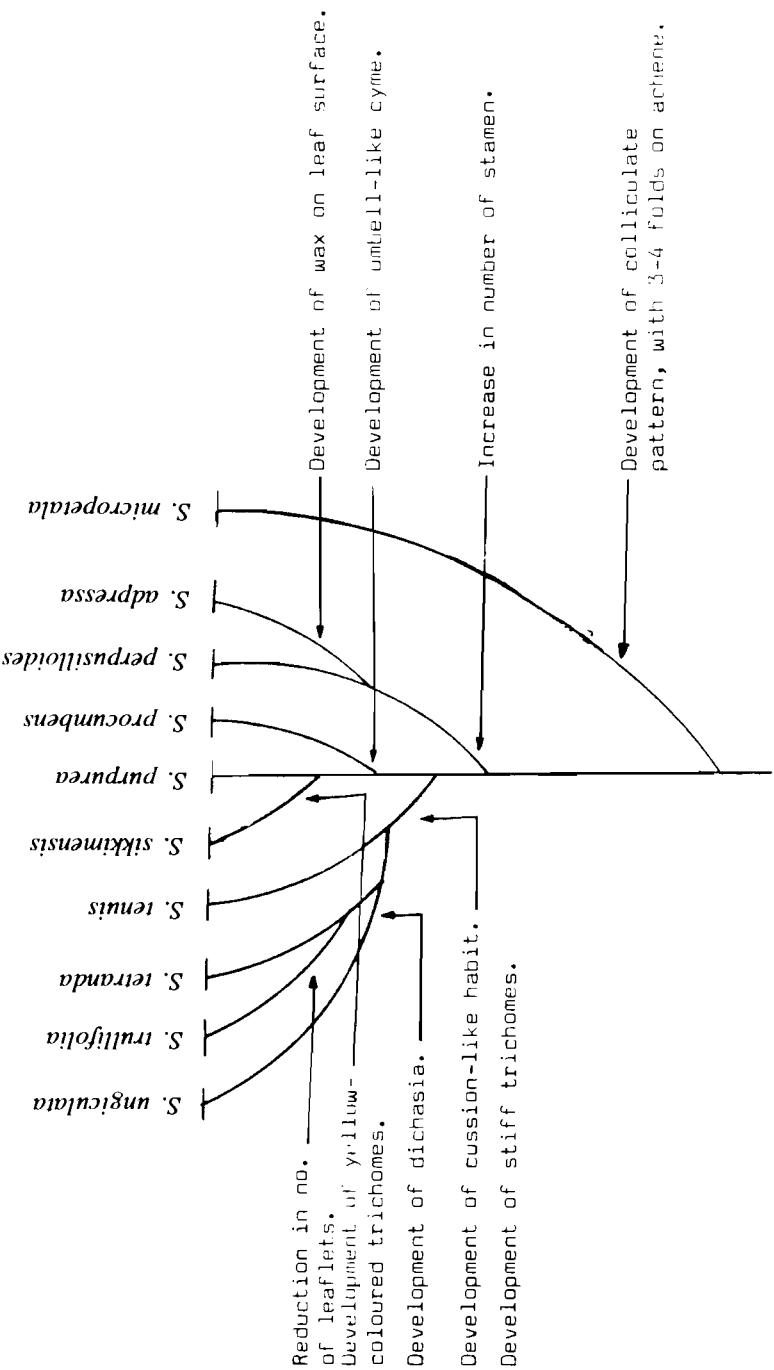

Fig.4. Diagram showing the probable Phylogenetic relationship among the species of genus *Sibbaldia*. This tree-like diagram is based on computer analysis.

Acknowledgements

Authors are grateful to the Director/Curators of the following herberia from which herbarium specimens were borrowed on loan for the study. A, B, BM, E, K, KUH, KYO, LE, PE, RAW, RNG and US. The senior authors are thankful to Dr. Peter Ashton and Dr. S. A. Spongburg for providing facilities and help during their stay at the Arnold Arboretum of Harvard University, U.S.A. We are extremely grateful to Dr. Alastair Culhan for his help in computer analysis and to Dr. J.B.Harborne for providing facilities in the Department of Botany, Reading University, and Dr. Stephen Jury for arranging the loan of specimens. Thanks are also due to Miss. Jayne Brimer and Mr. Basir Ahmed for their assistance with typing of the manuscript.

Financial assistance to (M. T. M. R) from the British Council London, and the Council of International exchange of scholars Washington D.C. is gratefully acknowledged.

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(Received for Publication 21 May, 1996)