A NUMERICAL TAXONOMY OF THE GENUS *ROSULARIA* (DC.) STAPF FROM PAKISTAN AND KASHMIR

GHULAM RASOOL SARWAR[*] AND MUHAMMAD QAISER

Centre for Plant Conservation, University of Karachi, Karachi-75270, Pakistan
Federal Urdu University of Arts, Science and Technology, Gulshan-e-Iqbal, Karachi, Pakistan

Abstract

Numerical analysis of the taxa belonging to the genus *Rosularia* (DC.) Stapf was carried out to find out their phenetic relationship. Data from different disciplines viz. general, pollen and seed morphology, chemistry and distribution pattern were used. As a result of cluster analysis two distinct groups are formed. Out of which one group consists of *R. sedoides* (Decne.) H. Ohba and *R. alpestris* A. Boriss. while other group comprises *R. adenotricha* (Wall. ex Edgew.) Jansson ssp. *adenotricha* , *R. adenotricha* ssp. *chitralica,* G.R. Sarwar, *R. rosulata* (Edgew.) H. Ohba and *R. viguieri* (Raym.-Hamet ex Frod.) G.R. Sarwar. Distribution maps of all the taxa, along with key to the taxa are also presented.

Introduction

Rosularia is a small genus composed of 28 species, distributed in arid or semiarid regions ranging from N. Africa to C. Asia through E. Mediterranean (Mabberley, 2008). Some of the taxa of *Rosularia* are in general cultivation and several have great appeal due to their extraordinarily regular rosettes on the leaf colouring in various seasons. Thus, *Rosularia* are not only an ideal subject for the alpine grown but are also well suited for cultivation among other succulents. Apart from their apparent value as horticultural subjects, some taxa of the genus have a moderate importance in folklore pharmacy. Decoction of dried flowers and fruits of *R. sempervivum* ssp. *persica* is used as a cure for rheumatism in Iraq. Leaves of *R. platyphylla* and *R. radicosa* are used against a skin diseases. Root decoction of *R. platyphylla* is used in fracture for relieve pain and rapid healing in Kirgizistan (Krasnov *et al.*, 1979).

Taxonomy of *Rosularia* is problematic, as demonstrated by differences among classifications and disagreement about generic boundaries. De Candolle (1828) established the section *Rosularia* of the genus *Umbilicus*. The section *Rosularia* was raised to generic level by Stapf (1923). Berger, (1930) was the first who divided the genus into sections. Ohba (1978) merged genera *Afrovivella* and *Sempervivella* with *Rosularia* while *Hypagophytum* was reduced to *Sempervivum*. Borissova (1939) divided the genus *Rosularia* into sections and series and transferred *Sedum pilosum* and *Sedum sempervivoides* to *Rosularia*. These 2 species were placed in *Sedum* by Berger (1930). Chamberlain & Muirhead (1972) excluded these 2 species from *Rosularia* and treated them under *Sedum*. Ohba (1978) erected a new genus *Prometheum* to accommodate these 2 species. *Prometheum* is distinguished from *Rosularia* by rosette leaves and free petals. He treated *Afrovivella* and *Monanthella* as synonyms of *Rosularia*. Eggli (1988) shifted *Sedum wilczekianum* to *Rosularia* as *R. wilczekiana* and reduced *Cotyledon libanotica* to *R. sempervivum* ssp. *libanotica.*

Little work has been done on numerical analysis of the genus *Rosularia.* Hart (1982) studied the relationship within the genus *Rosularia.* Ham & Hart (1998) also studied the genus *Rosularia* and indicated that the genus is polyphyletic. Mayuzumi & Ohba (2004) analyzed the relationships within the genus *Rosularia*. According to different workers *Rosularia* is polyphyletic.

There are no reports on numerical studies of Crassulaceae except the genus *Sedum* from Pakistan (Sarwar & Qaiser, 2011). The primary aim of this study is to analyze diagnostic value of morphological characters in distinguishing different taxa of the genus *Rosularia* as well as identifying the most useful characters which provide taxonomic clarity in the genus and also to trace the close relationships between the taxa.

Materials and Methods

Plant material: Twenty eight macro and micromorphological characters including general, pollen and seed morphology, chemical characters and distribution pattern were used for numerical analysis (Table 1). The data were collected from c. 500 specimens present in the herbaria BM, E, K, KUH, KYO, LINN, RAW and US (abbreviated according to Holmgrem *et al*., 1990). However, in addition to herbarium specimens, living material was also studied in the field.

Numerical analysis: A hierarchical cluster analysis of 6 taxa belonging to the genus *Rosularia* was carried out on the basis of multistate or binary variables (Table 2). For the analysis, macro and micromorphological characters were used (i.e. seed and pollen) along with chemical (flavonoid) and distribution pattern. In most of the cases, the qualitative characters were recorded in binary state and in some cases, multiple state. The binary characters were recorded as 1 and 2. Multiple state characters were recorded as 1, 2 and 3. For quantitative characters their average values were used, while in case of presence or absence, certain characters were coded as 1 or 0 respectively (Sneath & Sokal, 1973). However, weightage was given to those characters which were thought to be more informative than others. The numerical analysis was performed by using the Euclidean distance index and group average strategy with the computer package (SPSS Inc., 1998). Each of the taxon was treated as operational taxonomic unit (OTU).

[*]Corresponding author e-mail: grsarwar05@yahoo.com

Table 1. List of characters scored for cluster analysis for the taxa of
***Rosularia* (DC.) Stapf listed in table 2.**

No.	Characters description
1.	Plant not robust (0) robust (1)
2.	Stolon absent (0) present (2)
3.	Caudex absent (0) present (1)
4.	Shape of rosulate leaves (1) one type (2) two types
5.	Leaf apex mucronate (1) rounded (2)
6.	Inflorescence (1) one type (2) two types
7.	Flowers (1) 5-merous (2) 6-8 merous
8.	Colour of flower (1) one type (2) two types
9.	Length of sepal in (mm)
10.	Breadth of sepal in (mm)
11.	Shape of sepal (1) one type (2) two types
12.	Sepals (1) ½ the length of petals (2) ¼ the length of petals
13.	Length of petal in (mm)
14.	Shape of petals (1) elliptic to broadly elliptic (2) oblong (3) oblong-lanceolate
15.	Length of stamens in (mm)
16.	Length of nectar scale in (mm)
17.	Breadth of nectar scale in (mm)
18.	Nectar scales larger than broad (1) broader than large (2)
19.	Shape of nectar scale (1) oblong (2) square (3) obovate
20.	Breadth of carpel in (mm)
21.	Length of style in (mm)
22.	Breadth of fruit in (mm
23.	Seed length in (mm)
24.	Seed breadth in (mm)
25.	Kaempferol 3-rutinoside-7-glucoside (0) absent (1) present (2) NC
26.	Quercetin 3-glucoside (0) absent (1) present (2) NC
27.	Pollen (1) oblate-spheroidal (2) suboblate (3) Not comparable NC
28.	Phytogeographical regions (1) Irano-Turanian region (2) Sino-Japanese region

Table 2. Data matrix of *Rosularia* scored for 28 characters presented in table 1.

No.	Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	*R. viguieri*	2	0	0	1	2	1	1	6.5	3.6	1	3	7.8	1	5
2.	*R.sedoides*	2	0	0	1	2	2	2	6	2	2	1	10	1	7
3.	*R. alpestris*	2	0	1	1	1	2	2	4.5	1.2	1	1	9	3	5.5
4.	*R. rosulata*	1	1	0	2	2	1	1	5	1.8	1	3	6.5	1	5
5.	*R. adenotricha* ssp. *adenotricha*	2	0	0	1	2	1	2	5	1.5	2	1	7	2	5
6.	*R.adenotricha* ssp. *chitralica*	2	0	0	1	2	1	2	5	1.8	2	2	7	2	5

Table 2. (Cont'd.).

No.	Taxa	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1.	*R. viguieri*	1.5	1	0.4	1	1.5	0.8	0.3	1	1	1	0	0	1	1
2.	*R.sedoides*	1.5	1	0.8	3	3	1	0.3	0	0	0	1	1	1	0
3.	*R. alpestris*	2	2	2.2	2	2	1	0.2	2	2	1	1	1	1	1
4.	*R. rosulata*	1	1	0.3	1	1	0.6	0.2	2	2	0	1	0	0	1
5.	*R. adenotricha* ssp. *adenotricha*	1	1	0.4	1	1	1	0.3	1	0	1	1	1	1	0
6.	*R.adenotricha* ssp. *chitralica*	0.8	1	0.2	1	1	1	0.3	1	0	1	0	1	0	1

Results and Discussion

The cluster analysis of the genus *Rosularia* indicates the presence of two distinct groups largely based on flower, number of stamens and types of inflorescence (Fig. 1). Detail of characters is given in Table 1.

Group-A: It is represented by *R. viguieri*, *R. rosulata*, *R. adenotricha* ssp. *adenotricha*, *R. adenotricha* ssp. *chitralica*. The delimiting characters are 5-merous flowers, 10 stamens, lax thyrse inflorescence. This group is further divided into two subgroups.

Subgroup I: It comprises 3 taxa viz. *R. rosulata*, *R. adenotricha* ssp. *adenotricha*, and *R. adenotricha* ssp. *chitralica*. The latter two taxa are evolved from same point due to the similarity in characters except size of sepals i.e. half the length of petals in *R. adenotricha* ssp. *adenotricha* whereas 1/4th the length of petals in *R. adenotricha* ssp. *chitralica*. Isorhamnetin, azaleatin and apigenin are present in the type subspecies but absent from subspecies *chitralica*. The type subspecies is a basically W & C Himalayan element but extending to Balochistan through Afghanistan. Whereas subspecies *chitralica* is endemic to Pakistan and occurs in Chitral, Kohat, Hazara and Kashmir (Fig. 2).

However, *R. rosulata* falls in between these two taxa and is characterized by ovate sepals and elliptic petals. Stolons are present in *R. rosulata* but absent in other taxa. This species resembles with two subspecies of *R. adenotricha* on the basis of shape of rosulate leaves, lax inflorescence and 5-merous flower. *R. rosulata* is a Sino-Japanese element and does not extend beyond Pakistan in the west and Nepal in the east. It is distributed in Nepal, Sikkim, N. India and Pakistan (Himalayas) (Fig. 3).

Subgroup II: It includes only one species viz. *R. viguieri* which is characterized by robust plants, all parts are densely hairy, presence of subprolate pollen and quercetin 3-glucoside. It differs from *R. rosulata* in petal colour and type of roots i.e., white petals and slender to filiform roots in latter taxa while petals pink and tap root in former taxa. These two taxa resemble on the shape of rosulate leaves, sepals ovate and petals shape elliptic. *R. viguieri* differs from two subspecies of *R. adenotricha* by shape of sepals and petals i.e. sepals ovate and petals elliptic in *R. viguieri* while sepals lanceolate and petals oblong in latter taxa. It resembles with two subspecies on inflorescence type and shape of rosulate leaves i.e. lax thyrse and spathulate. It is an Eastern Irano-Turanian element (Central Asian) and is distributed from Pakistan to Tadzhikstan through Afghanistan.
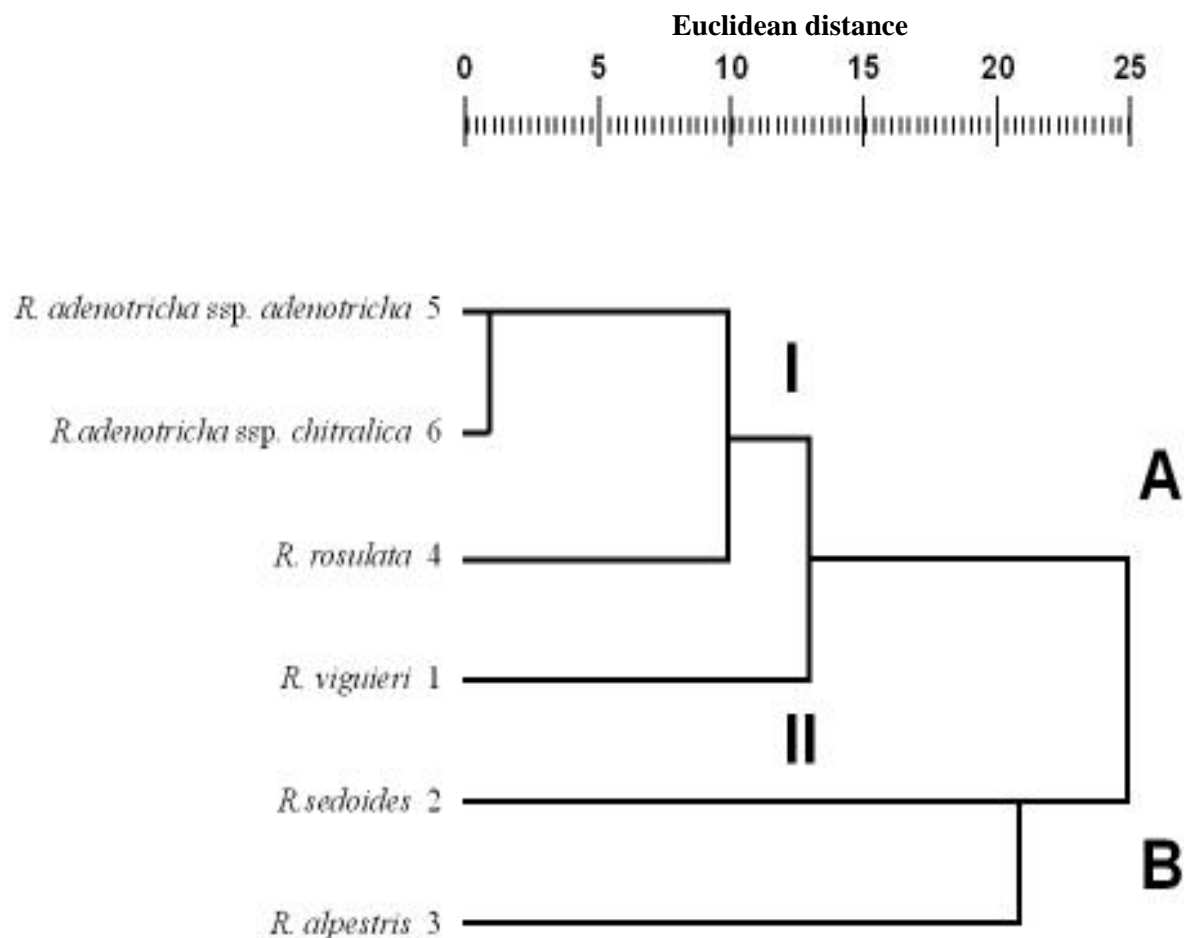

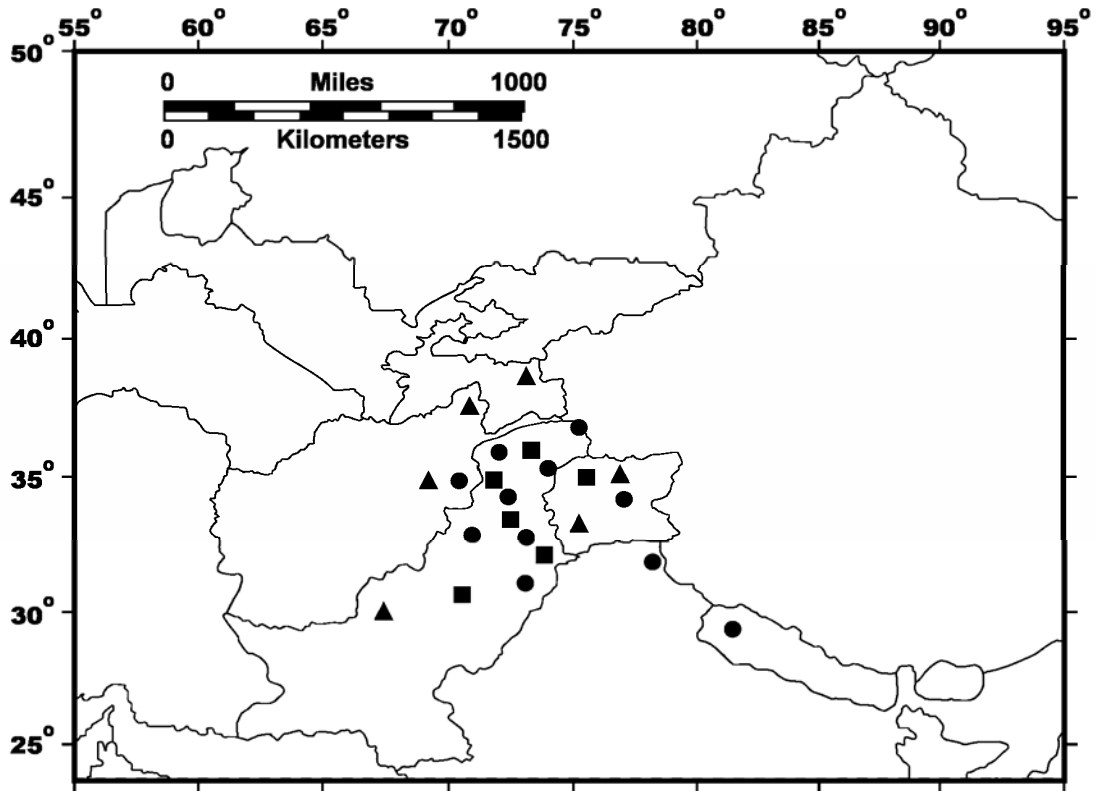Fig. 1. Dendrogram showing the relationships of the taxa of the genus *Rosularia*.

Fig. 2. Distribution pattern of *R. viguieri* (▲); *R. adenotricha* subsp. *Adentricha* (●); and *R. adenotricha* subsp. *Chitralica* (■).
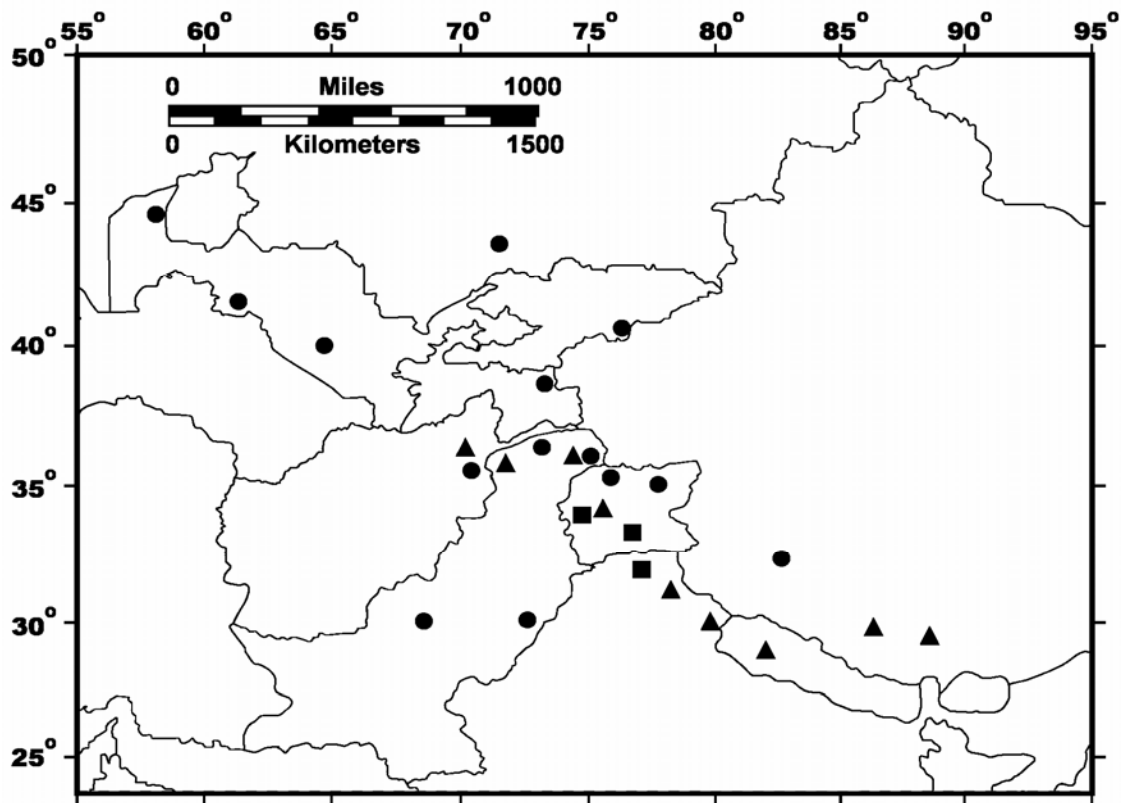

Fig. 3. Distribution pattern of *R. rosulata* (▲); *R. alpestris* (●); and *R. sedoides* (■).

Group-B: This group includes *R. alpestris* and *R. sedoides*. It is characterized on the basis of 6-8 merous flowers, 12-16 stamens and corymbose to cyme inflorescence. The former taxon differs from latter on the basis of sepals shapes, inflorescence and rosulate leaves. Rosulate leaves acuminate, membranous, ovate sepal and corymbose inflorescence are found in *R. alpestris* whereas rosulate leaves not membranous, obtuse, sepals oblong and cyme inflorescence in *R. sedoides*. *R. alpestris* is an Eastern Irano-Turanian element (Central Asiatic) and distributed in Afghanistan, Pakistan, India, Kazakstan, Kirghizstan, Usbekistan and China (Xizang). *R. sedoides* is a W. Himalayan element and is distributed from Kashmir and India (Fig. 3).

Taxa having fused petals and number of whorls in androecium were previously placed in *Umbilicus* and *Cotyledon*. Boissier (1872) & Schonland (1890) indicated that both these genera were heterogenous. According to Eggli and Hartmann (2005) *Rosularia* is also heterogenous and both these characters may have evolved several times in Sedoideae. The delimitation of the taxa within the Sedoideae is very complicated due to the convergence of several characters e.g., presence of well developed caudices or (root stock) in number of groups (*Rosularia* some taxa) (Eggli, 1988).

Stapf (1923) raised the section to new genus *Rosularia* . Most of the taxa belonging to the genus *Rosularia* were previously placed in different genera viz. *Umbilicus, Cotyledon, Sedum* etc. There is no doubt the genus is closely related to *Sedum* it can easily be delimited when the several diagnostic characters in combination are considered.

Rosularia alpestris and *R. sedoides* revealed the apomorphic character i.e., flowers 6-8 merous and number of stamens 12-16 while the rest of the taxa showed plesiomorphic character i.e., 5-merous flowers with 10 stamens. *R. rosulata* is the most primitive taxon which showed the primitive charcters i.e., glabrous plants while rest of the taxa are hairy. *R. alpestris* is the most advanced taxon among the rest of the taxa that have advanced character of corymbose inflorescence. *R. rosulata, R. viguieri, R. adenotricha* ssp. *adenotricha* and *R. adenotricha* ssp. *chitralica* showed disjunct distribution and at least partly relict taxa. It is the most primitive group (Taxa) within the genus and has strongest links with a number of taxa of *Sedum* (Eggli, 1988).

According to Eggli (1988), some taxa of the genus create problem during delimiting the taxa and several group of closely related taxa reveals continuous variation. Due to extraordinary variation between the taxa of the genus, she could not construct the key to the taxa in the monograph of the genus *Rosularia*.

Key to the taxa

1 + Flowers 6-8 merous ………………………………………………………………………………….. **2**

 - Flowers 5 merous ………………………………………………………………………………….. **3**

2 + Rosulates leaves sword-shaped, oblong, acuminate, membranous, light green when dry. Sepals glabrous, ovate, 2-4 mm long. Inflorescence corymbose, many flowered ……………………………………… ***R. alpestris***

 - Rosulate leaves oblong, obtuse, thick. Sepals densely hairy, oblong 4-5 mm long. Inflorescence 2-4 flowered cyme …………………………………………………………………………………… ***R. sedoides***

3 + Plants robust with thick tap root. Sepals ovate. All parts densely glandular hairy ..………………… ***R. viguieri***

 - Plants and sepals not as above ……………………………………….…………………………………. **4**

4 + Rosette fully open. Rosulate leaves loosely arranged. Petals elliptic, acute, white. Plants stoloniferous …..……… ………………………………………………………………………………………………... ***R. rosulata***

 - Rosette half open. Rosulate leaves compactly arranged. Petals oblong, acuminate, pink, yellowish pink. Plants not stoloniferous ……………………………………………………………………………………… **5**

5 + Calyx ½ the length of the petals ……………………………….…………………***R. adenotricha* ssp. *adenotricha***

 - Calyx ¼ the length of the petals …………………………………………………***R. adenotricha* ssp. *chitralica***

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