Chromosome Science 7: 55-60, 2003

Brief Report

A comparative chromosomal study of three *Rhodiola* species (Crassulaceae) collected in central Tianshan Mountains, Xinjiang, China

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Received November 6, 2003/Accepted December 26, 2003

Abstract. Chromosomal characters of three *Rhodiola* species (*R. gelida*, *R. quadrifida* and *R.* aff. *litwinowii*) collected in central Tianshan Mountains in Xinjiang, China, had commonly the simple chromocenter type in the resting chromosomes and the proximal type in the mitotic prophase chromosomes. *Rhodiola gelida* and *R. quadrifida* showed the chromosome number of 2n=20 and *R.* aff. *litwinowii* showed the chromosome number of 2n=16. The chromosome numbers of *R. gelida* and *R.* aff. *litwinowii* were reported here for the first time, and the chromosome number of *R. quadrifida* verified the previous report. *Rhodiola gelida* and *R. quadrifida* had monomodal (gradual) decrease in chromosome length from the largest to the smallest chromosomes in alignment and *R.* aff. *litwinowii* had bimodal decrease in chromosome length.

Keywords: China, Crassualceae, Karyomorphology, *Rhodiola*, Xinjiang

Introduction

Rhodiloa L., the Crassulaceae, consists of approximately 90 species, is perennial, herbaceous, dioecious or hermaphrodite (monoecious) and has thick rhizomes. The members of the genus are distributed in the alpine to the arctic regions of the Northern Hemisphere mainly from Himalaya to West China and the Central Asia. Ohba (1975) recognized 21 species in the genus in the eastern Himalaya from Nepal, Sikkim, Tibet to Bhutan, while Fu (1984) described 73 species in China. Fu and Ohba (2001) revised Chinese *Rhodiloa* consisted of 55 species, of which 16 species were endemic to China and 13 species were distributed in Xinjiang Uygur Zizhiqu.

Chromosome numbers of nine species of *Rhodiola* have been studied; 2n=22 in *R. atropurpurea* (Zhukova, 1965, 1967) and *R. rosea* (*eg.*, Löve and Löve, 1956; Zhukova, 1966, 1980, 1982; Gadella and Kliphuis, 1970; Lavrenko and Serditov, 1987; Kochjarova and Bernatova, 1995), 2n=36 in *R. integrifolia* (Löve *et al.*, 1971), 2n=42 in *R. linearifolia* (Zhukova, 1967), 2n=34 in *R. stephanii* (Zhukova, 1967), 2n=20, 22, 44, 66, 88 and 110 in *R. bupleuroides* (Wakabayashi, 1992; Ohba and Wakabayashi, 1993). Amano *et al.* (1995) studied cytotaxonomically *Rhodiola* in Altai Mountains, and reported 2n=14 in *R. algida*, 2n=24 in *R. elongata*, 2n=20 in *R. quadrifida* and 2n=22 in *R.* aff. *quadrifida* and *R. rosea*. Since only 10% members of *Rhodiloa* species have been counted their chromosome numbers, many more cytological data are needed to justify the cytotaxonomical relationship of *Rhodiola*.

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Materials and methods

Seven samples of three *Rhodiola* species were collected in three sites of two localities in central Tianshan Mountains, Xinjiang Uygur Zizhiqu, The People's Republic of China (Figs. 1 and 2; Table 1). Those three species were dioecious and seven samples collected were all female plants. They were brought back to Japan, and cultivated in pots in the shaded place in the experimental garden of Showa Pharmaceutical Univer-

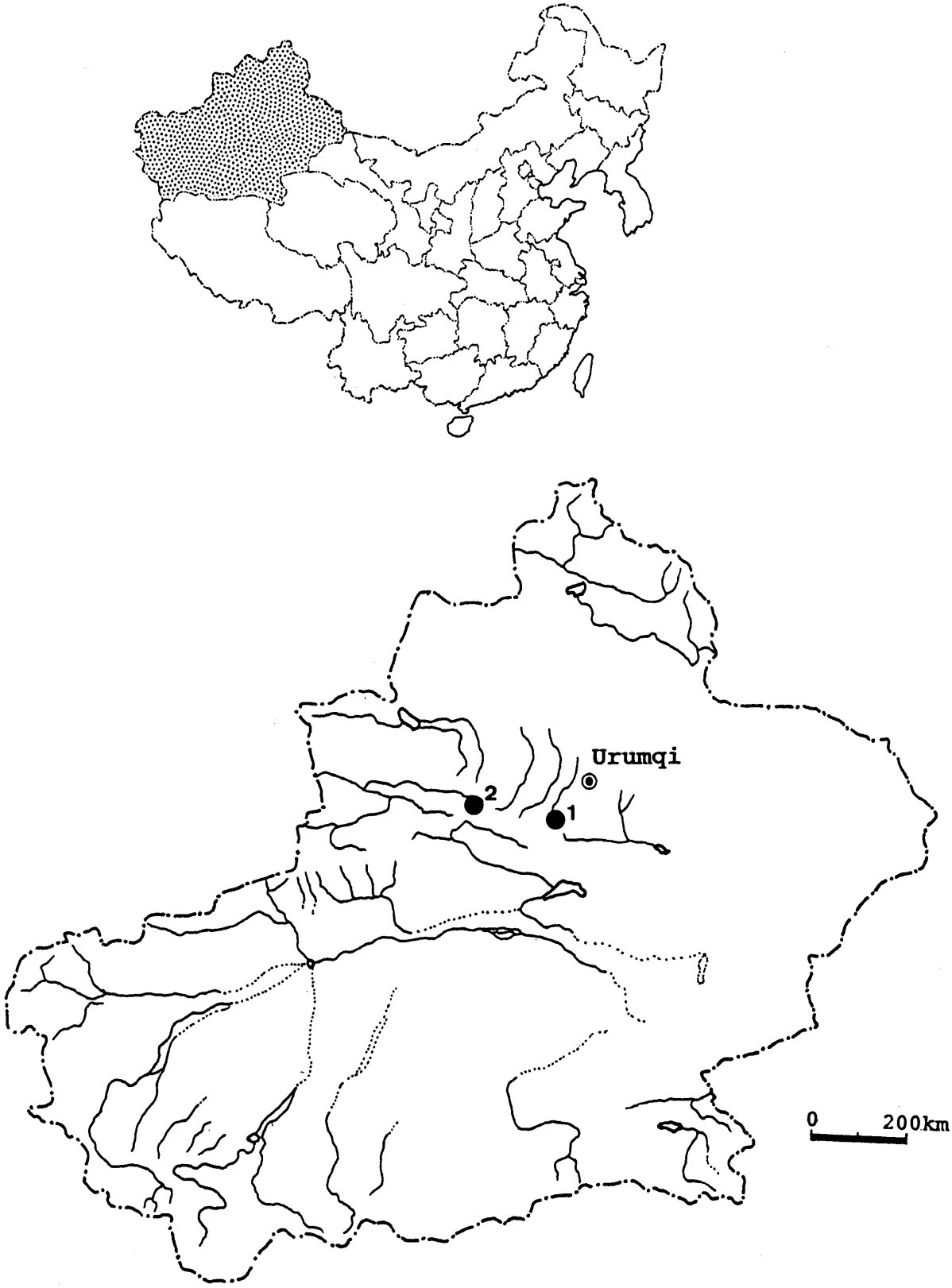

Figure 1. Maps of collection sites in the central part of the Tianshan Mountains, Xinjiang, China. 1: No. 1 glacier of Tianshan Mountains. 2: Qiaoerma Daban.

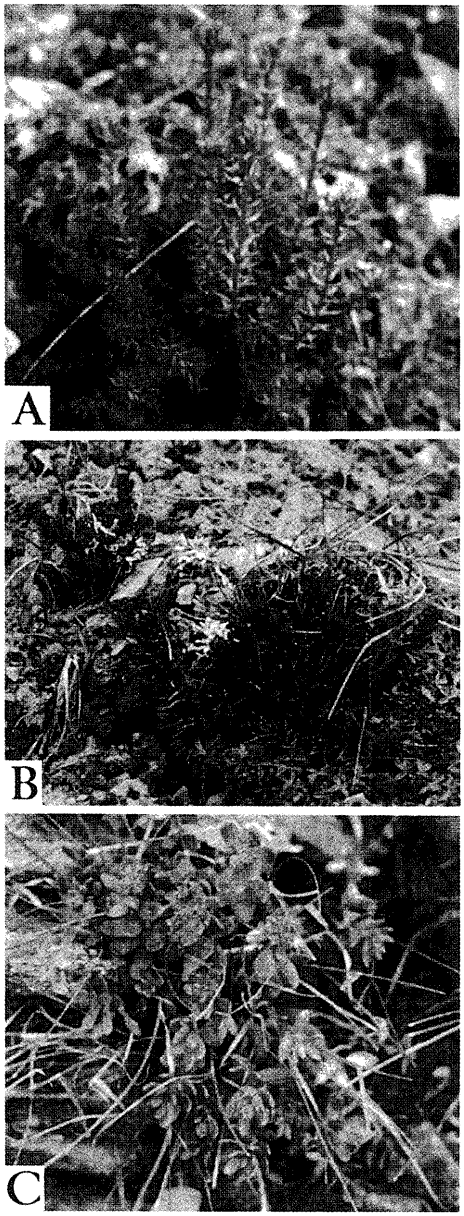

Figure 2. Plants of three *Rhodiola* species collected. A: *R. gelida*. B: *R. quadrifida*. C. *R.* aff. *litwinowii*.

sity. Chromosome observation were made in meristematic cells of root tips, which were cut off in 5–10 mm long and pretreated in 2 mM 8-hydroxyquinoline for 4 h at 20°C, and were then fixed in 45% acetic acid for 10 min at ca 2°C. Then, they were macerated in a mixture of 45% acetic acid and 1N hydrochloric acid (1 : 1) for 20–23 sec at ca 60°C, and were stained in 2% aceto-orcein for 30 min at room temperature in a chamber moistered with 45% acetic acid and were squashed by the conventional squash method. Measurements of somatic metaphase chromosomes of three *Rhodiola* species were made in several good metaphase cells.

Karyomorphological types of the resting and the mitotic prophase chromosomes were classified according to Tanaka (1971, 1977), and grouping of the mitotic metaphase chromosomes by the centromeric positions due to Levan *et al.* (1964). Taxonomical treatment followed the system of Fu and Ohba (2001) in Chinese *Rhodiola*. The voucher specimens were housed in Funamoto's personal herbarium in Showa Pharmaceutical University.

Results and discussion

Seven samples of *Rhodiola gelida* Schrenk, *R. quadrifida* (Pallas) Schrenk, *R.* aff. *litwinowii* Brissova collected in the central part of the Tianshan Mountains in Xinjiang had the common karyomorphological characters in their resting and mitotic prophase chromosomes; the resting chromosomes of the simple chromocenter type, that had several small heteropycnotic bodies per nucleus (Fig. 3A, D, G); and the mitotic prophase chromosomes of the proximal type, of which the early condensed segments were confined to the proximal regions of both short arms or only to the short arm, showing to the distal regions (Fig. 3B, E, H). *Rhodiola gelida* and *R. quadrifida* had the chromosome number of 2n=20 (Fig. 3C, F) and *R.* aff. *litwinowii* had the chromosome number of 2n=16 (Fig. 3I). Intraspecific aneuploid or polyploid were not observed

Table 1. Collection sites, sample and chromosome numbers of three *Rhodiola* species collected in the central part of the Tianshan Mountains in Xinjiang, China

Species	Collection site	Sample number	Chromosome number (2n)
Section Chamaerhodiola			
Series Quadrifida			
R. gelida Schrenk	Xinyuan County, Qiaoerma Daban, alt. 3,420 m	2	20
R. quadrifida (Pallas) Schrenk	Urumqi County, No. 1 glacier of Tianshan Mountains, alt. 3,750 m	3	20
Series Fastigiatae			
R. aff. *litwinowii* Brissova	Urumqi County, No. 1 glacier of Tianshan Mountains, alt. 3,539 m	2	16

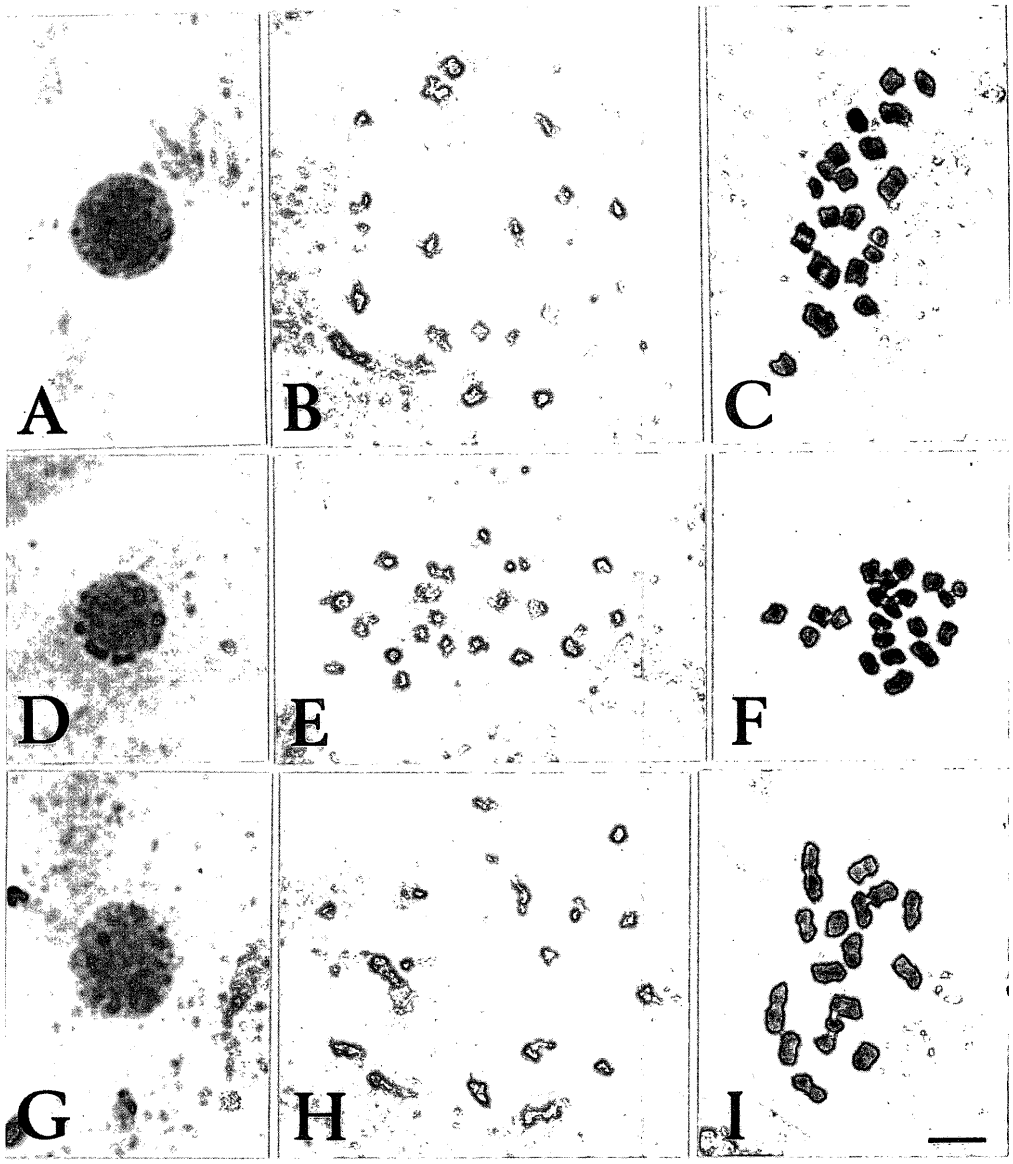

Figure 3. Comparative karyomorphology of three *Rhodiola* species observed. A-C: *R. gelida* (2n=20). D-F: *R. quadrifida* (2n=20). G-I: *R.* aff. *litwinowii* (2n=16). A, D and G: Resting chromosomes. B, E and H: Mitotic prophase chromosomes. C, F and I: Mitotic metaphase chromosomes. Scale bar represents 3 μm for A to I.

in those three *Rhodiola* species in this study. Thus, the chromosome number of 2n=20 in *R. gelida* and 2n=16 in *R.* aff. *litwinowii* were reported here for the first time, and the chromosome number of 2n=20 in *R. quadrifida* supported the previous count by Amano *et al.* (1995).

Rhodiola gelida and *R. quadrifida* showed very similar karyotype characters such as the same chromosome number (2n=20), the same sizes of the appropriate chromosomes, all meidan-centromeric chromosomes of the respective chromosome complement, and monomodal (gradual) decrease in length from the longest to the shortest chromosomes in the respective chromosome alignment (Fig. 4A, B; Table 2). The two species are taxonomically placed in the same series Quadrifida (Fu, 1984). In contrast, *R.* aff. *litwinowii* had different karyotype from the former two species and placed in different series Fastigiatae (Fu, 1984); the chromosome number of 2n=16, and the bimodal decrease in length from the longest to the shortest chromosomes in the chromosome alignment. With distinct two largest chromosomes (Fig. 4C; Table 2), a little larger average chromosome length (2.47 μm) than that of the former two species (1.72 μm and 1.48 μm). The largest size chromosome and the second largest size chromosome had 1.4 to 1.6 times as long as in the third size chromosome. The other 14 chromosomes from the 3rd to the 16th chromosomes showed gradual decrease in length in the chromosome alignment (Fig. 4C).

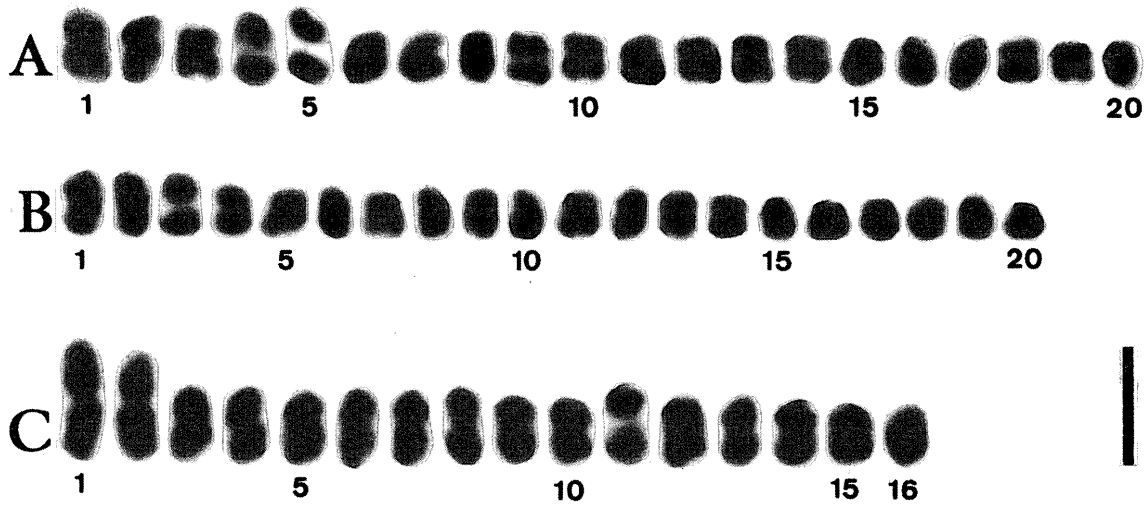

Figure 4. Karyotype comparisons of three *Rhodiola* species observed. A : *R. gelida.* B : *R. quadrifida.* C : *R.* aff. *litwinowii.* Scale bar represent 3 μm.

Table 2. Karyotype comparisons of three *Rhodiola* species collected in the central part of the Tianshan Mountains in Xinjiang, China

Species	Chromosome number (2n)	Chromosome alignment in length	Chromosome length (μm)				Form
			Longest mean±SD (Extremes)	Shortest mean±SD (Extremes)	Total mean±SD (Extremes)	Average mean±SD (Extremes)	m
R. gelida	20	monomodal (gradual)	1.8±0.19 (2.0-1.6)	1.0±0.05 (1.1-1.0)	25.2±1.05 (26.4-24.2)	1.25±0.05 (1.32-1.21)	20
R. quadrifida	20	monomodal (gradual)	1.5±0.06 (1.5-1.4)	0.9±0.11 (1.0-0.7)	22.7±0.33 (23.0-22.2)	1.14±0.02 (1.15-1.11)	20
R. aff. *litwinowii*	16	bimodal	2.6±0.32 (3.0-2.2)	1.3±0.05 (1.4-1.3)	28.2±1.15 (29.8-26.8)	1.76±0.07 (1.87-1.68)	16

SD : standard deviation ; m : median-centromeric chromosome

Among the genera of the Crassulaceae, *Sedum* (*Hylotelephium*) and *Echeveria* had bimodal karyotypes (Funamoto and Yuasa, 1986, 1989).

Many more chromosomal investigations are necessary to clarify and justify the systematic relationships and chromosome phylogeny of *Rhodiola*.

Acknowledgments

We gratefully thank Professor Dun-yan Tan, Xinjiang Agricultural University, for arrangement and guiding our field trip to the Tianshan Mountains, Xinjiang, China and identifying plant materials. This study was supported by the Grant-in-Aid for Scientific Research Program (A) (1) No. 14255014 (the representative: Katsuhiko Kondo) of the Japan Society for the Promotion of Science.

References

Amano, M., Wakabayashi, M. and Ohba, H. (1995). Cytotaxonomical Studies of Siberian Sedoideae (Crassulaceae) I. Chromosomes of *Rhodiola* in the Altai Mountains. J. Jpn. Bot. **70** : 334-338.

Fu, S.-H. (1984). *Rhodiola* L. *In* Flora Reipublicae Popularis Scinicae **34** (1) (eds. Fu, S.-H. and Fu, K.-T.), pp. 159-220, Science Press, Beijing. (*in Chinese*)

Fu, K.-T. and Ohba, H. (2001). *Rhodiola* Linnaeus. *In* Flora of China, Vol. 8 (eds. Wu, Z.-Y. and Raven, P.H.), pp. 251-268, Science Press (Beijing) and Missouri Botanical Garden, St. Louis.

Funamoto, T. and Yuasa, H. (1986). Karyological studies on diploid species of the section Telephium of *Sedum* in Japan. J. Jpn. Bot. **61** : 365-371.

Funamoto, T. and Yuasa, H. (1989). Chromosome Studiers of the Genus *Echeveria* (Crassulaceae), Part II. Somatic Chromosome Numbers of the Remaining Taxa. Res. Inst. Evolut. Biol. Sci. Rep. **6** : 16-29.

Gadella, Th. W.J. and Kliphuis, E. (1970). Chromosome

studies in some flowering plants collected in the French Alps (Hante Savoie). Rev. Gen. Bot. **77**: 487-497.

Kochjarova, J. and Bernatova, D. (1995). Chromosome numbers of several rare, endangered and endemic species of the flora of Slovakia. Biologia (Bratislava) **50**: 27-31.

Lavrenko, A.N. and Serditov, N.P. (1987). Chromosome numbers in some members of the Urals flora (the Komi Autonomous Soviet Socialist Republic). Bot. Zhurn. **72**: 846-847.

Levan, A., Fredga, K. and Sandberg, A.A. (1964). Nomenclature of centromeric position on chromosomes. Hereditas **52**: 201-220.

Löve, A. and Löve, D. (1956). Cytotaxonomical conspectus of the Icelandic flora. Acta Horti Gothoburgensis **20**: 65-291.

Löve, A., Löve, D. and Kapoor, B.M. (1971). Cytotaxonomy of a century of Rocky Mountain orophytes. Arctic and Alpine Res. **3**: 139-165.

Ohba, H. (1975). A revision of the eastern Himalayan species of the subgenus Rhodiola of the genus *Sedum* (Crassulaceae). Univ. Mus. Univ. Tokyo, Bull. **8**: 283-362.

Ohba, H. and Wakabayashi, M. (1993). Cytotaxonomic study of *Rhodiola bupleuroides* in the Himalaya and Yunnan, China (Crassulaceae). P. 208. In XV International Botanical Congress, Abstracts.

Tanaka, R. (1971). Types of resting nuclei in Orchidaceae. Bot. Mag. Tokyo **84**: 118-122.

Tanaka, R. (1977). Recent karyotype studies. *In* Plant cytology (eds. Ogawa, K., Kurozumi, K., Koike, S. and Sato, S.), pp. 293-326, Asakura Book, Tokyo. (*in Japanese*)

Wakabayashi, M. (1992). Kozansyokubutsu no Sensyokutai no Tokusei. Iden **46**: 36-42. (*in Japanese*)

Zhukova, P.G. (1965). Kariologicheskaya kharakteristika nekotorykh rasteniy Chukotskogo poluostrova. Bot. Zhurn. **50**: 1001-1004.

Zhukova, P.G. (1966). Chromosome numbers in some species of plants of the northeastern part of the U.S.S.R. Bot. Zhurn. **51**: 1511-1516. (*in Russian*)

Zhukova, P.G. (1967). Karyology of some plants, cultivated in the Arctic-Alpine Botanical Garden. *In* Plantarum in Zonam Polarem Transportatio. II. (ed. Avrorin, N.A.), pp. 139-149, Leningrad. (*in Russian*)

Zhukova, P.G. (1980). Chromosome numbers of some Southern Chukotka plant species. Bot. Zhurn. **65**: 51-59. (*in Russian*)

Zhukova, P.G. (1982). Chromosome numbers of some plant species of north-eastern Asia. Bot. Zhurn. **67**: 360-365. (*in Russian*)