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Species Diversification of Genus *Cirsium* (Asteraceae) in Japan

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Genus *Cirsium* (Asteraceae) from Japan is revised based on both field and herbarium examinations. As a result it is clarified that the *Cirsium* flora of Japan is consisted of more than 120 species and that several groups are considerably diversified in the Japanese Archipelagoes. Here two instances will be shown for the diversification. The northern maritime group (sect. *Onotrophe* subsect. *Littoralicola*), a recently recognized group, is differentiated in the maritime regions of Honshu and Hokkaido. The *Cirsium kagamontanum* group (sect. *Onotrophe* subsect. *Reflexae*), the most diversified group in Japan, is differentiated mainly in the cool temperate zone of Honshu and Shikoku.

Key words: Asteraceae, *Cirsium*, *Cirsium kagamontanum* group, Japan, subsect. *Littoralicola*, subsect. *Reflexae*,

The Flora of Japan is currently believed to be thoroughly clarified. However, not a little taxa still remain to be solved. Genus *Cirsium* (Asteraceae), which is the object of this study, is one of the taxa including a great deal of taxonomic issues. Studying the genus *Cirsium* of Japan based on fieldexplorations of natural populations as well as herbarium examinations, more than twenty years have passed and I have published several papers (Kadota and Nagase, 1988; Kadota, 1989 - 2007). The aim of this study is to publish a monograph of the genus *Cirsium*in Japan according to results of the researches.

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In Japan thistles are very common, grow from the summit areas of high mountains in the alpine zone to the seashore and extend from Hokkaido (northern island) to the Ryukyus (southern islands) stretching over 3000 km. At present more than 120 species are recognized inside of Japan (Kadota, in prep.). The number 120 is much larger than that of Korea (11 spp., Y. N. Lee 1996; 12 spp., W. T. Lee 1996), that of China including Taiwan (52 spp., Shih 1987) and that of Russian Far East (11 spp., Barkalov et al. 1992) and is equivalent to one third of the species number of the genus occurring throughout the world (Kadota, unpubl.).

Why so many species of *Cirsium* are distributed in Japan? In the Eurasian Continent there are several genera similarly armed with strong spines to the genus *Cirsium* (e. g., *Alfredia*, *Carduus*, *Centaurea*, *Cousinia*, and so on; Asteraceae - Cynareae). The spines are clearly considered to be protection against herbivorous animals. The *Cirsium*-like genera prefer similar habitats and compete with each other. On the other hand, in Japan, the genus *Cirsium* is the only native asteraceous genus armed with spines. In this way the genus *Cirsium* has no rivals within the family Asteraceae inside Japan. This may be one of reasons why the genus *Cirsium* is diversified in the Japanese Archipelagoes.

The genus *Cirsium* is notorious for its taxonomic difficulty. The difficulty must be due to the occurrence of natural hybridization (introgressive hybridization). Natural hybridization is observed usually among the species of the same ploidy level. But actual conditions of natural hybridization are insufficiently studied still now. Phenotypic plasticity also plays an important role in the taxonomic difficulty of the genus. For example *Cirsium kamtschaticum*, the northernmost representative in the Japanese *Cirsium*, shows a remarkably wide range of morphological variation: in the montane zone its stem attains to 3 m or higher, on the contrary, around the summit areas of high mountains and in windy sites near the seashore it reaches less than 0.1 m.

Many species of Japanese *Cirsium* have robust plant bodies armed with sharp, strong spines. Collectors may hesitate to prepare herbarium specimens of the genus because they are provided of dangerous spines. As a result materials of the genus may be less accumulated in herbaria. In this way less accumulation of herbarium materials may cause the taxonomic difficulties of the genus *Cirsium*.

As stated below the direction of involucral phyllaries (especially middle and outer phyllaries) is regarded as an important diagnostic character in the classification of the genus *Cirsium*. However, this attribute may become unclear after the press for specimen preparation because involucres are three dimensional. This is also a cause of the taxonomic difficulties of the genus *Cirsium* like the flowers of orchids and aconites.

Materials and Methods

Specimens kept in the following herbaria are employed in this study: KAG, KUN, KYO, LE, MHA, MKB, MW, PE, SAPT, TI, TNS, TPM, TUS, VLA, etc. Field works have been done throughout Japan (Kadota and Nagase, 1988; Kadota, 1989 - 2007). Comparative field works were also executed in Korea, China [Heilongjian, Jirin, Qinghai, Sichuan, Yunnan and Xixang (Tibet) Provinces], Kazakhstan, Khirghistan, Russia, Uzbekhistan, etc. In the field variation of morphological attributes were examined. Chromosome number for each species was counted as basic information.

Results and Discussion

Diagnostic characters of the genus *Cirsium*: Based on both herbarium and field examinations the following attributes are considered to be diagnostic in the classification of the genus *Cirsium*.

1. Presence vs. absence of radical leaves at anthesis (this character has a strong relationships to habitat preference of each species)
2. Direction of heads (erect to oblique vs. nodding)
3. Involucres (shape and size) and involucral phyllaries (shape, size and row number)
4. Glandular bodies (presence vs. absence; glandular bodies are the source of involucre adhesiveness)
5. Florets (relative length of the tube to the throat)
6. Achenes (shape, size, texture and coloring) and pappi (length)
7. Chromosome number [2=2x=34 (diploid), 2n=4x=68 (tetraploid), 2n=6x=102 (hexaploid)]

Tentative infrageneric classification of Japanese *Cirsium*: Of the Japanese 120 species five species (*C. japonicum* DC., *C. kamtschaticum* Ledeb. ex DC., *C. lineare* (Thunb.) Sch.-Bip., *C. maackii* Maxim. and *C. pendulum* Fisch. ex DC.) are also distributed in the surrounding regions of Japan. However, the remainder 115 species are endemic to Japan. Furthermore various groups are recognized within the 115 species. A tentative systematic treatment of Japanese *Cirsium* is as follows:

Genus *Cirsium* Mill., Gard. Dict. Abringd. ed. 4, 1 (1754), emend. Scop., Fl. Carn. 355 (1760).

Sect. 1. *Pseudoeriolepis* (Nakai) Kitam. in Acta Phytotax. Geobot. 3: 2 (1934). [1]*

Sect. 2. *Spanioptilon* (Less.) Shih in Acta Phytotax. Sin. 22: 448 (1984). [1]

Sect. 3. *Megacephala* Kitam. in Acta Phytotax. Geobot. 3: 1 (1934). [1]

Sect. 4. *Onotrophe* (Cass.) DC., Prodr. 6: 644 (1837).

Subsect. 1. *Sieboldii* (Kitam.) Kitam., Compos. Jap. 1: 48 (1937). [3]

Subsect. 2. *Odontolepis* Kitam. in Acta Phytotax. Geobot. 3: 6 (1934). [1]

Subsect. 3. *Intermedia* Kitam. in Acta Phytotax. Geobot. 3: 7 (1934). [1]

Subsect. 4. *Praticola* Kadota, Fl. Jap. IIIb: 125 (1995). [1]

Subsect. 5. *Suffulta* Kadota in Bull. Natn. Sci. Mus., Tokyo, Ser. B 32: 86 (2006). [10]

Subsect. 6. *Nutantia* (Kitam.) Kadota, Fl. Jap. IIIb: 128 (1995). [2]

Subsect. 7. *Nipponensia* Kadota in Bull. Natn. Sci. Mus., Tokyo, Ser. B 33: 118 (2007). [9]

Subsect. 8. *Arenicola* Kitam. in Acta Phytotax. Geobot. 3: 3 (1934). [5]

Subsect. 9. *Sinocirsium* Kitam. in Acta Phytotax. Geobot. 3: 3 (1934). [6]

Subsect. 10. *Angustiinvolucrae* Kadota, Fl. Jap. IIIb: 135 (1995). [1]

Subsect. 11. *Dipsacolepis* Kitam. in Acta Phytotax. Geobot. 3: 4 (1934). [1]

Subsect. 12. *Erecta* (Kitam.) Kadota, Fl. Jap. IIIb: 136 (1995). [2]

Subsect. 13. *Amplexifolia* Kadota, Fl. Jap. IIIb: 137 (1995). [2]

Subsect. 14. *Inundata* Kitam. in Acta Phytotax. Geobot. 3: 6 (1934). [5]

Subsect. 15. *Borealicola* Kitam. in Acta Phytotax. Geobot. 3: 7 (1934). [4]

Subsect. 16. *Nipponocirsium* Kitam. in Acta Phytotax. Geobot. 3: 4 (1934). [12]

Subsect. 17. *Tubelosae* Kitam. in Acta Phytotax. Geobot. 3: 5 (1934), p. p. [13]

Subsect. 18. *Reflexae* (Kitam.) Kadota, Fl. Jap. IIIb: 148 (1995). [26]

Subsect. 19. *Stolonifera* Kadota, Fl. Jap. IIIb: 150 (1995). [1]

Subsect. 20. *Littoralicola* Kadota in Bull. Natn. Sci. Mus., Tokyo, Ser. B 33: 30 (2007). [7]

Subsect. 21. *Ogapeninsulae* Kadota in Bull. Natn. Sci. Mus., Tokyo, Ser. B 31: 42 (2005). [1]

Subsect. 22. *Ramosa* Kadota in Bull. Natn. Sci. Mus., Tokyo, Ser. B 30: 64 (2004). [2]

Subsect. 23. *Izuinsulicola* Kadota in Mem. Natn. Sci. Mus., Tokyo (42): 30 (2007). [1]

Subsect. 23. *Tenuisquamata,* nom. prov. [3]

Subsect. 24. *Calcicola,* nom. prov. [2]

*[Numbers in brackets indicate the numbers of component species]

Among the Japanese *Cirsium* species two infrageneric taxa will be discussed here.

The northern maritime group: The northern maritime group (Sect. *Onotrophe* Subsect. *Littoralicola,* Type: *C. umezawannum* Kadota) is characterized by having robust habit, the absence of radical leaves at anthesis, erect heads, campanulate to broadly cylindrical involucres and the chromosome number of 2n=4x=68. This group is endemic to Japan and is distributed in Honshu (Tohoku District) and Hokkaido (Rishiri Island). First it was considered that species of this group exclusively grew near the seashore and in maritime mountains. *Cirsium umezawanum* is distributed in the Rishiri Island and grows chiefly in maritime grassland dominated by *Sasa kurilensis.*

In 2007 two new species were added to this subsection: *C. togaense* Kadota and *C. domonii* Kadota. *Cirsium togaense* (Fig. 1; Kadota, 2007) was described from the Oga Peninsula (Fig. 3, star), Akita Pref., northern Honshu and is different from *C. umezawanum* by having robust stem branched in the upper part (Fig. 1A), 12 - 13-seriate, strongly recurved involucral phyllaries, non-amplexicaul cauline leaves and narrowly elliptic glandular bodies on the midribs of the inner involucral phyllaries (Fig. 1B, arrowhead). *Cirsium togaense* usually grows in maritime herb stands also facing the Japan Sea. The habitats are frequently damaged severely by seawater in windy time. Actually most plants of this species were dead in 2004 due to typhoon attacks. The distribution range is restricted to the narrow area, however, this thistle grows abundantly in the localities.

Cirsium domonii Kadota (Fig. 2; Kadota, 2007) was described from Tsuruoka (Fig. 3, square), Yamagata Pref., Honshu and is distinguished from *C. umezawanum* by 10 - 11-seriate involucral phyllaries and elliptic, subentire, cauline leaves and from *C. togaense* by also 10-11-seriate involucral phyllaries and elliptic, subentire, cauline leaves, stem branched from the lower part (Fig. 2A) and the alosence of glandular bodies on phyllaries (Fig. 2B). *Cirsium domonii* also grows in maritime grassland facing the Japan Sea. As shown in Fig. 3, the distribution range is divided into two regions. The two subdivided areas are separated by a sandy beach which is not suitable for this thistle species.

As stated above, this group (Sect. *Onotrophe* Subsect. *Littoralicola*) was recognized to be consisted of the three species at first. The three species (*C. umezawanum, C. togaense*

Fig. 1. *Cirsium togaense* Kadota (Oga Peninsula, Oga-shi, Akita Pref.). A. Habit. B. Capitulum. Arrowhead indicates glandular body.

Fig. 2. *Cirsium domonii* Kadota (Kobato, Tsuruoka shi, Yamagata Pref.). A. Habit. B. Capitulum. Arrowhead indicates glandular body.

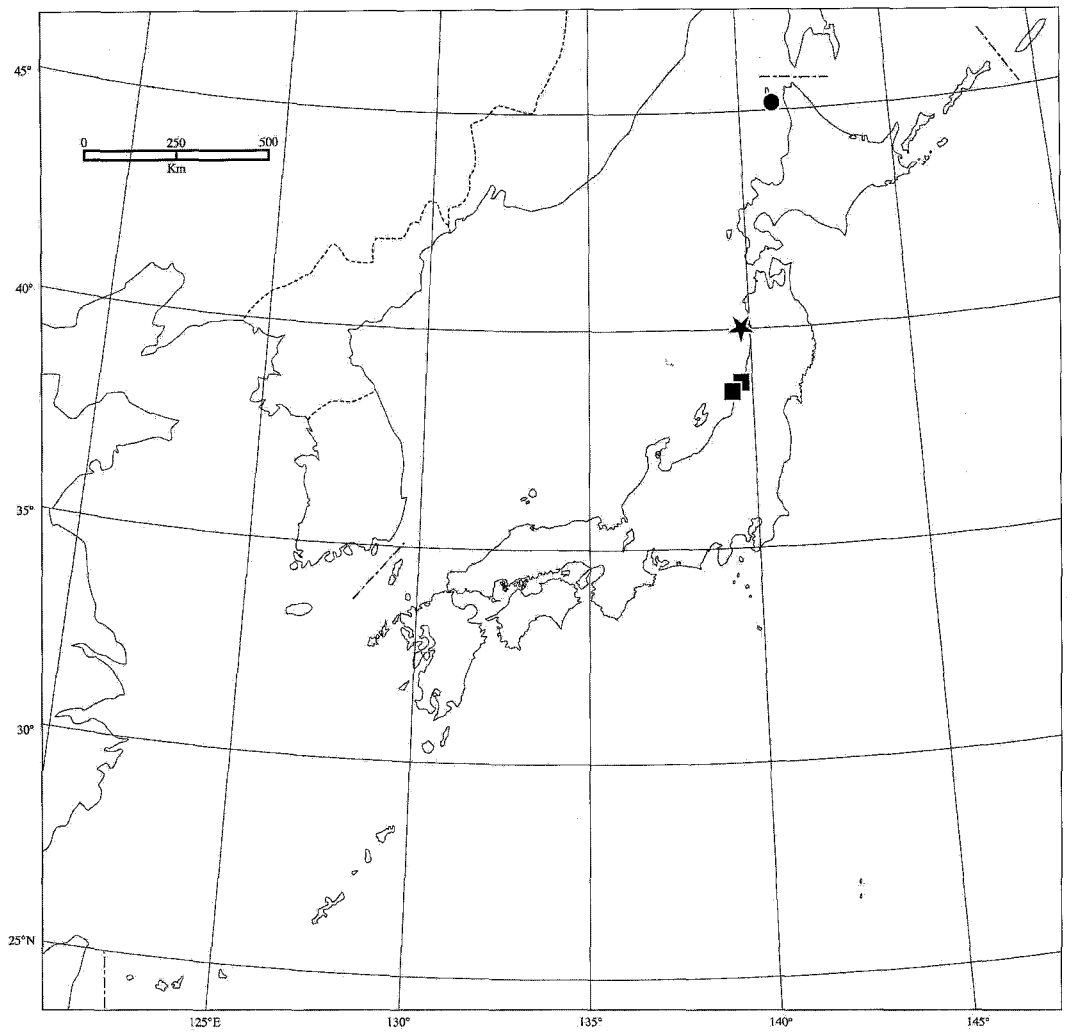

Fig. 3. Distribution of *Cirsium togaense* and its allied species. Disc. *C. umezawanum* Kadota. Star. *C. togaense* Kadota. Square. *C. domonii* Kadota.

and *C. domonii*) are distributed in the maritime region stretching from the middle part of Tohoku District, Honshu, to Hokkaido on the Japan Sea side (Fig. 3). However, later examinations show that this subsection must be composed of additional four species including *C. sendaicum* Nakai (= *C. matsushimense* Kitam.). The additional four species are distributed in the inland region of Tohoku District as well as the maritime region facing the Pacific Ocean. Further investigation is necessary for the remaining four species

Fig. 4. *Cirsium kagamontanum* Nakai (Okoya, Komatsu-shi, Ishikawa Pref.). A. Habit. B. Capitulum. Arrowhead indicates glandular body. Courtesy of Mr. S. Miya.

Fig. 5. *Cirsium uzenense* Kadota (Aosawa-goe, Sakata-shi, Yamagata Pref.). A. Capitulum. B. Habit. Arrowhead indicates glandular body. Courtesy of Mr. S. Miya (photo A).

distributed chiefly in the northern part of Tohoku District.

The *Cirsium kagamontanum* group: The *Cirsium kagamontanum* group (Sect. *Onotrophe* Subsect. *Reflexae*) is characterized by having robust habit, absence of radical leaves at anthesis, nodding heads, narrowly cylindrical involucres and the chromosome number of 2n=2x=34. This group is endemic to Japan and is greatly diversified in Honshu and Shikoku Islands. Species of this group exclusively grows along and/or in summer-green forests (predominantly *Fagus crenata* forests) of the cool temperate zone.

Cirsium kagamontanum Nakai (Fig. 4; Nakai, 1912), a representative of this group, is characterized by having adpressed involucral phyllaries and well-developed, oblong glandular bodies on all the phyllaries (Fig. 4B, arrowhead) and is now recognized to be distributed in Fukui, Ishikawa, Toyama and Niigata Prefectures, on the Japan Sea side of Honshu Island (Fig. 10, A). However, *C. kagamontanum*was formerly believed to be also distributed in Yamagata Prefecture, which is located in the north of Niigata Prefecture. After the examination plants from Yamagata Prefecture (Figs. 5B, 10, B) are significantly different from *C. kagamontanum*; plants from Yamagata Prefecture have patent to slightly recurved involucral phyllaries and oblanceolate glandular bodies (Fig. 5A). Based on the results plants from Yamagata Prefecture have been ascribed to a distinct species, *C. uzenense* Kadota (Fig. 5; Kadota, 2005).

Cirsium horiianum Kadota (Fig. 6; Kadota, 2005) is distributed in the Oga Peninsula, Akita Prefecture, Tohoku District, in the north of Honshu Island (Fig. 10, C) and is characterized by having relatively deeply pinnatilobate cauline leaves, strongly recurved involucral phyllaries and the absence of glandular bodies. *Cirsium pseudogyojanum* [nom. prov.; Fig. 7] is characterized by having subcoriaceous, large, deeply pinnatilobate, cauline leaves and slightly developed, narrowly obovate glandular bodies (Fig. 7B, arrowhead). The involucres of this species are scarcely glutinous. The distribution range of *C. pseudogyojanum* covers Honshu (the Kii Peninsula) and Shikoku and is relatively wider than the other species in the *Cirsium kagamontanum* group. *Cirsium nagisoense* [nom. prov.; Fig. 8] is characterized by having coriaceous, finely pinnatisect, cauline leaves and well developed, oblanceolate glandular bodies (Fig. 8B, arrowhead). In fact the involucres of this species are heavily glutinous. The distribution area of *C. nagisoense* is quite narrow and restricted to the southern foot of Mt. Nagisodake, Nagano Prefecture, central Honshu. *Cirsium aidzuense* Nakai ex Kitam. (Fig. 9; Kitamura, 1937) densely hirsute stem well branched in the middle part, clearly amplexicaul, cauline leaves and linear glandular bodies (Fig. 9B, arrowhead) and is distributed in the south of Tohoku District (Fig. 10, F).

The *Cirsium kagamontanum* group is turned out to be consisted of at least 26 species.

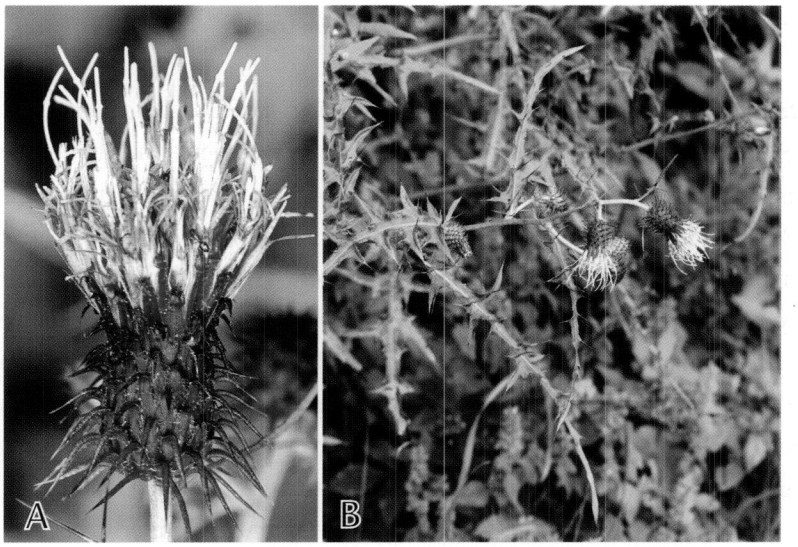

Fig. 6. *Cirsium horiianum* Kadota (Mt. Kenashiyama, Oga Peninsula, Oga-shi, Akita Pref.). A. Habit. B. Capitulum. Arrowhead indicates glandular body.

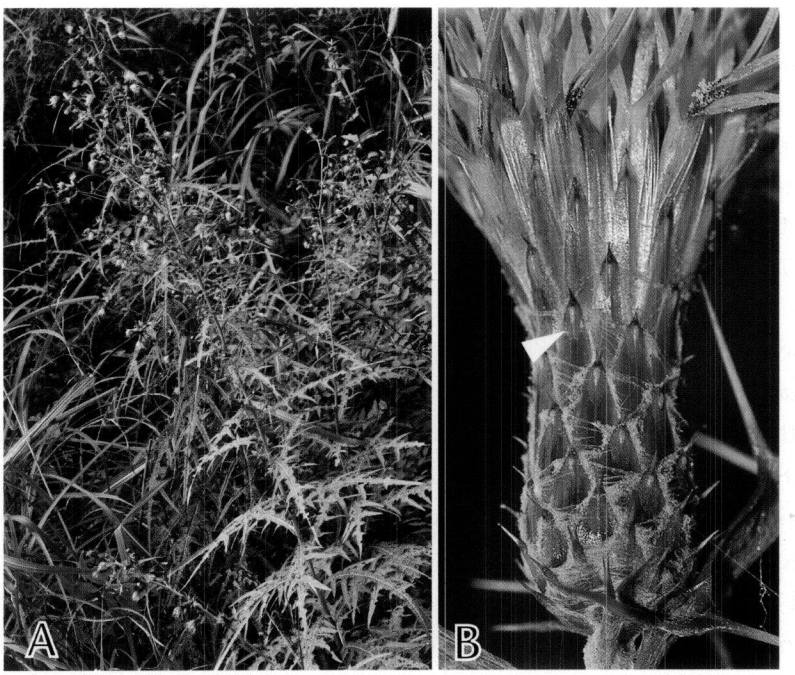

Fig. 7. *Cirsium pseudogyojanum,* nom. prov. (Gyôja-gaeri Tunnel, Kami-Kitayama-mura, Nara Pref.). A.Habit. B. Capitulum. Arrowhead indicates glandular body.

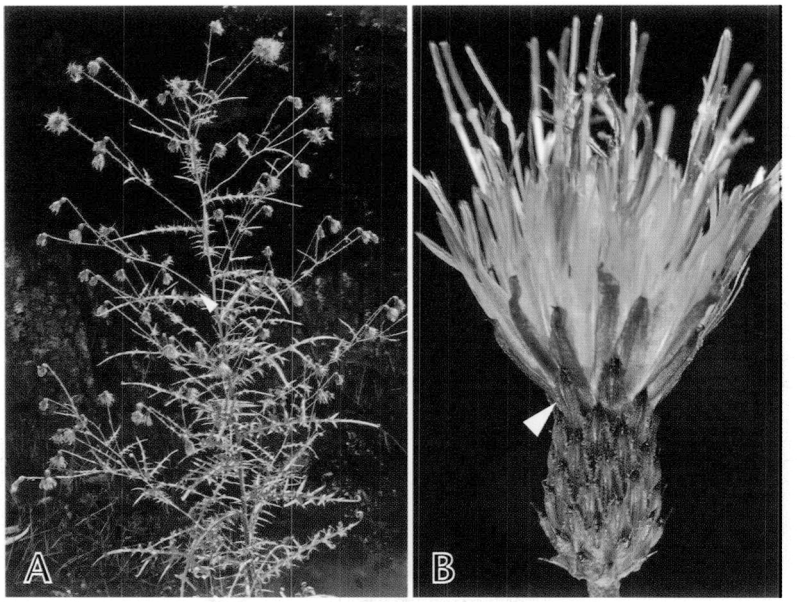

Fig. 8. *Cirsium nagisoense,* nom. prov. (Mt. Nagisodake, Nagiso-machi, Nagano Pref.). A. Habit. B. Capitulum. Arrowhead indicates glandular body.

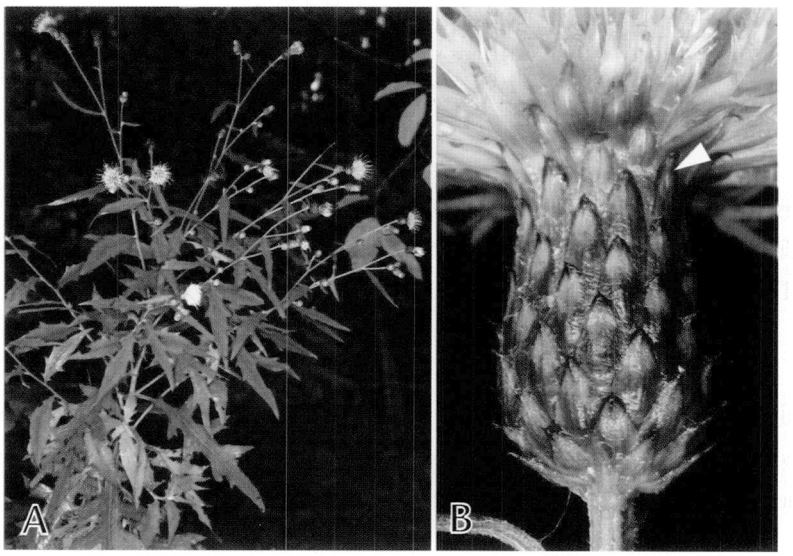

Fig. 9. *Cirsium aidzuense* Nakai ex Kitam. (Nakayama Fûketsu, Aidu-Shimogô-machi, Fukushima Pref.). A. Habit. B. Capitulum. Arrowhead indicates glandular body. Courtesy of Mr. S. Miya.

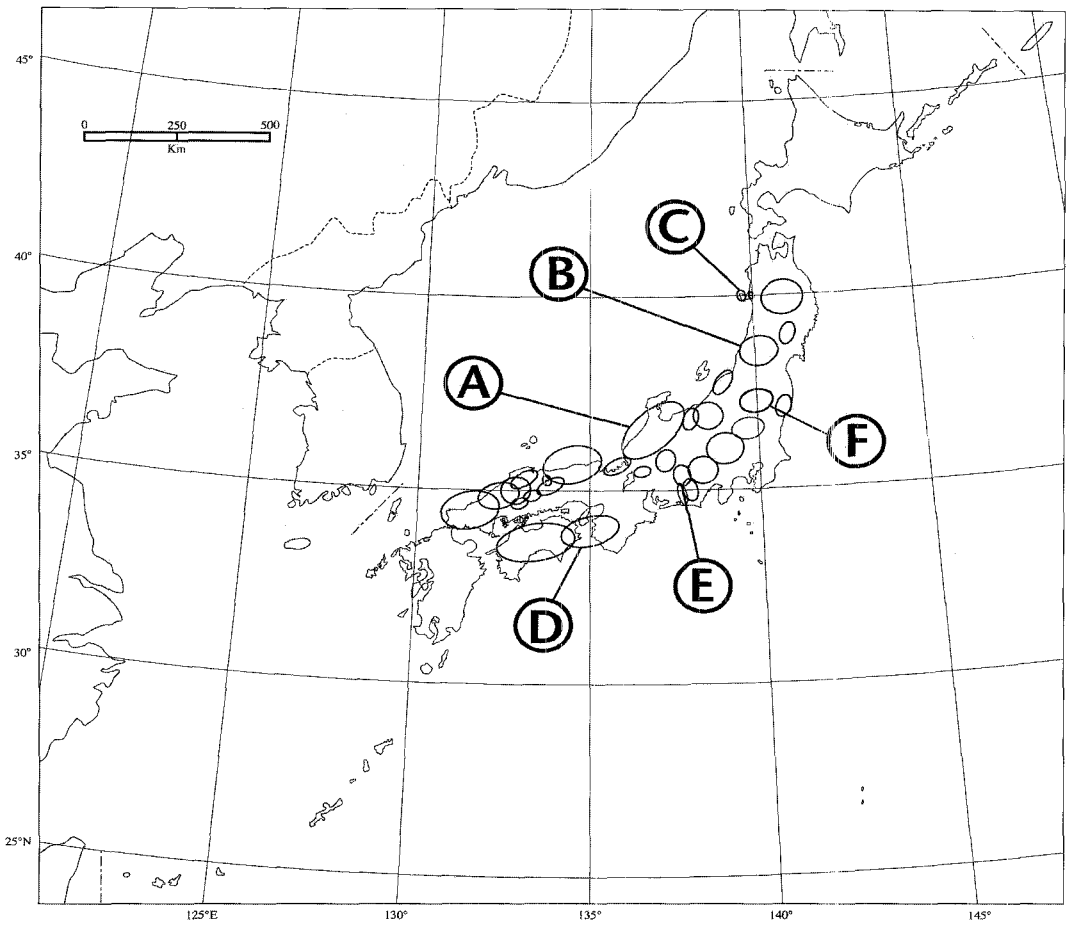

Fig. 10. Distribution of species in the *Cirsium kagamontanum* group. Circle indicates an outline of distribution range of each species. A. *C. kagamontanum*. B. *C. uzenense*. C. *C. horiianum*. D. *C. pseudogyojanum*. E. *C. nagisoense*. F. *C. aidzuense*.

Further analyses lead to a complicated distribution map of this group (Fig. 10). This plant group is most diversified among Japanese *Cirsium*. However, the distribution ranges of the component species are mostly restricted to narrow areas. This group is consequently regarded as paleoendemic due to the extent of distribution ranges and the ploidy level (2n=2x=34). Almost all the species of the *Cirsium kagamontanum* group are also currently endangered.

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