

## A Revision of *Cardamine loxostemonoides* O. E. Schulz (Cruciferae)

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### *Cardamine loxostemonoides* (アブラナ科) の分類学的研究

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*Cardamine loxostemonoides* O. E. Schulz is revised. Based on the discussion on gross morphology, it is clarified that the so called *C. loxostemonoides* can be distinguished into three species; *C. loxostemonoides* sensu stricto, *C. luxurians* and *C. tibetana*. Chromosome number for *C. luxurians* and *C. loxostemonoides* is reported for the first time. *Cardamine tibetana*, from S. E. Tibet is described in this paper; a new combination *C. luxurians* is proposed.

Schulz (1927) described *Cardamine loxostemonoides* in the section *Macrocarpous* based on Duthie's collection in the 1880's from N. W. India and W. Nepal. Jafri (1973), Hara (1979) and Polunin and Stainton (1989) consider this as a distinct species ranging from Pakistan to Bhutan in elevations 3000 to 5000 m (Fig. 1). Lan and Cheo (1981) transferred it to the genus *Loxostemon*.

Regarding our study of the genus *Cardamine* and other allied genera recently we have realized that *C. loxostemonoides* has not been critically examined. The present study aims to clarify vegetative and reproductive features and to provide chromosome numbers for the taxonomic revision.

#### Materials and methods

Herbarium specimens preserved in BM, E, K,

RAW and TI were used for the study. Fifteen quantitative characters were measured in each individual in addition to the qualitative characters (Table 1). The number of leaflets were counted in the second cauline leaves from the base of each individual for the character 3 and terminal leaflet of the same leaf was measured for the characters 5 and 6. Minimum, maximum, average and standard deviation for each variable was calculated. For the qualitative characters some terms such as coral bulbils, globular bulbils, reduced leafy bulbils, digitate appendages and crescent scaly leaves were used based on morphological appearances.

Chromosome counts were made from the root tips. The materials were collected from Pakistan and Nepal and treated in 0.1% colchicine for 2 hours; fixed in Newcomer's solution; macerated in 1 N HCl for 10

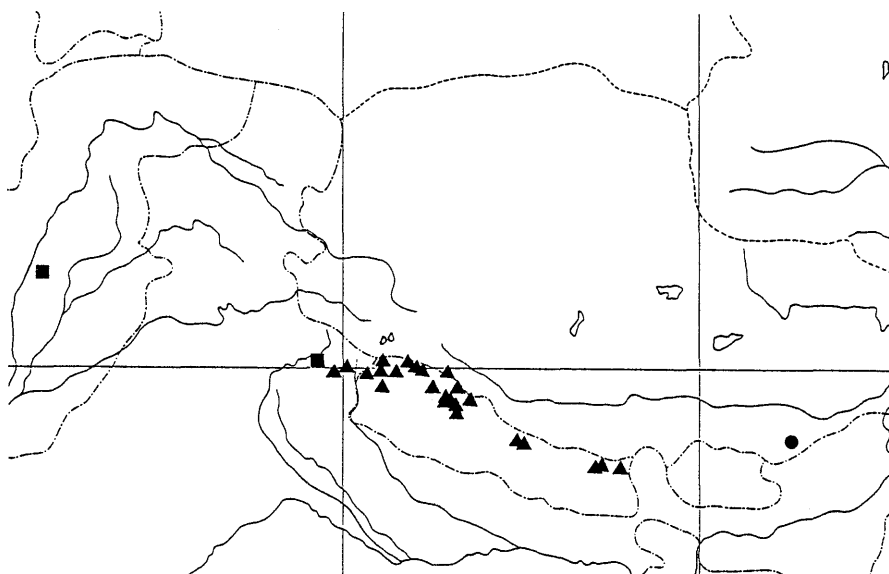


Fig. 1. Distribution map of *C. luxurians* (■), *C. loxostemonoides* (▲) and *C. tibetana* (●).

minutes at 60°C and squashed after staining for 2 hours in 2% aceto-orcein. The voucher specimens (Ohba et al. no. 393 and Miyamoto et al. no. 147) were deposited in TI and PUH.

### Observations

#### 1. Morphology

*Cardamine loxostemonoides*, growing in moist habitats among the loose boulders, rock crevices and screes, shows great variations in rhizome morphology, plant height, number of cauline leaves, number of leaflets, leaflet size, pubescence, number of flowers per raceme, and shape of petals among different localities (Table 1).

a. Rhizome: The plants from Pakistan show vigorous growth of stolons but without any bulbils. The stolons produce secondary stolons from the axils of the membranous scaly and the radical leaves. The scaly leaves are papery with wide base and tapering into acute to acuminate apex.

The plants from Nepal have slender rhizomes and delicate aerial stem. The rhizome bears globular bulbils

composed of fleshy scaly leaves (Figs. 2, 3). The scaly leaves are somewhat whitish in colour and fleshy at the base tapering into apical digitate appendages. The specimens collected in S. E. Tibet have delicate rhizome and both coral and reduced leafy bulbils at the axils of stolons (Figs. 3–6). The coral bulbils are composed of crescent shaped scaly leaves which are arranged on the reduced axis ending into apical bud. Some of the crescent scaly leaves also bear axillary bulbils. Reduced leafy bulbils are composed of reduced leaves. They are close to the soil surface and usually terminating into aerial shoots.

b. Cauline Leaves: The Pakistan plants have 5–11 petiolulate, suborbicular-oblong, lobulate and glabrous leaflets. Those from Nepal have 7–13, petiolulate or sessile, obovate, suborbicular or linear oblong, lobulate and glabrous to hairy leaflets. Those from S. E. Tibet are 7–9 sessile, obovate leaflets with hairy margins.

c. Flowers: The ovules are anatropous, valves veinless, placentae uniform, funicles filiform and septa nerveless. Generally *C. loxostemonoides* has a

Table 1. Mean, standard deviation and range for quantitative characters in the three species.

	<i>C. luxurians</i>	<i>C. tibetana</i>	<i>C. loxostemonoides</i>
1. Plant height (cm)	11–25 (17.2±4.07)	8–12 (9.8±1.63)	5–17 (10.3±3.48)
2. Number of cauline leaves	3–5 (4±0.77)	2–4 (3±0.89)	1–3 (2.25±0.62)
3. Number of leaflets	5–11 (8.4±1.90)	7–9 (8.2±0.97)	7–13 (9.2±1.66)
4. Number of flowers	6–20 (11.6±3.89)	2–6 (4.4±1.35)	1–12 (5.9±3.16)
5. Length of terminal leaflet of 2nd cauline leaf (mm)	13–16 (15.07±0.92)	5–8 (6.3±1.07)	5–11 (8.4±2.45)
6. Width of terminal leaflet of 2nd cauline leaf (mm)	7–12 (8.68±1.23)	3–6 (4±1.09)	1.5–5 (2.93±0.94)
7. Length of sepals (mm)	3–3.6 (3.29±0.17)	3.4–3.6 (3.48±0.07)	2.5–3.5 (2.94±0.28)
8. Width of sepals (mm)	1.5–2.1 (1.87±0.17)	1.5–1.8 (1.68±0.11)	1.5–2 (1.76±0.18)
9. Length of petals (mm)	10–12.2 (11.51±0.68)	10–12.1 (10.82±0.78)	10–12 (10.82±0.66)
10. Width of petals (mm)	5–6.1 (5.78±0.38)	8.3–8.5 (8.4±0.06)	5–6.6 (5.87±0.43)
11. Length of short stamens (mm)	5–5.5 (5.24±0.15)	6.0–6.2 (6.08±0.07)	5–5.4 (5.21±0.12)
12. Length of short stamen's anther (mm)	0.9–1.2 (1.02±0.07)	1.1–1.2 (1.16±0.04)	1–1.2 (1.12±0.07)
13. Length of long stamen (mm)	6.8–7 (6.93±0.07)	6.0–6.3 (6.16±0.10)	6–6.5 (6.18±0.19)
14. Length of long stamen's anther (mm)	0.9–1.2 (1.01±0.07)	1.0–1.2 (1.12±0.07)	0.9–1.2 (1.06±0.10)
15. Length of pistil (mm)	5.2–6.2 (5.9±0.27)	6.3–6.5 (6.42±0.07)	5.8–6.1 (5.95±0.09)

racemose inflorescence. The number of flowers per inflorescence is different among localities (Table 1). The flowers from Pakistan have ovate sepals with visible veins, spatulate petals, and 16–20 ovules (Fig. 8). Those from Nepal have ovate sepals with prominent veins, obovate petals and with 14–20 ovules (Fig. 9). Those from Tibet are ovate sepals with obscure veins; widely obovate petals and 14–18 ovules (Fig. 10).

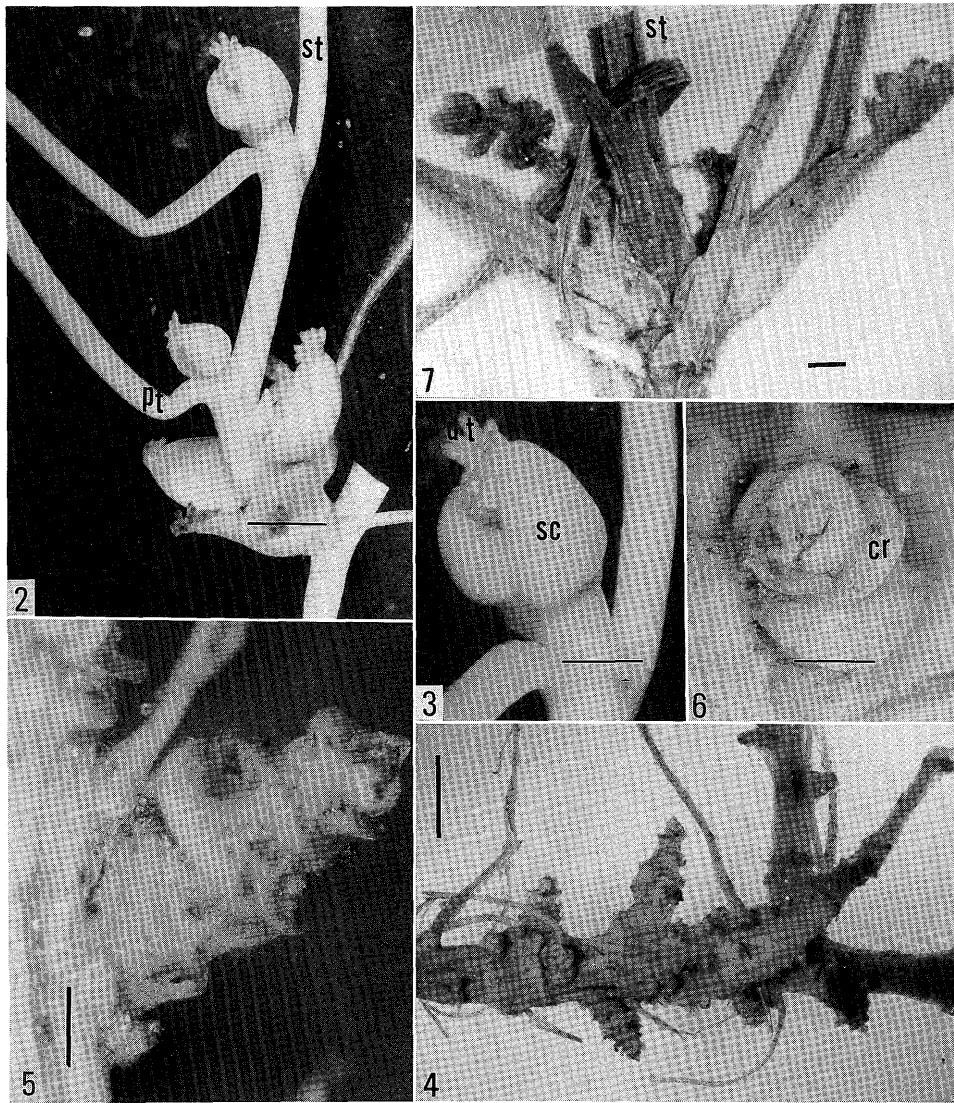
## 2. Chromosome number

Thirty two ( $2n=32$ ) somatic chromosome number was observed in 10 individuals from two populations in N. Pakistan and 6 individuals from one population

in central Nepal (Figs. 11, 12).

## Taxonomic comments and discussion

Schulz (1903) defined one monotypic section *Macrocarpus* from Estrecho de Magallanes, S. Chile based on *C. geraniifolia* (Poir) DC. Schulz (1927) described *C. loxostemonoides* from Himalaya and then placed it in the section *Macrocarpus* (Schulz 1936). Both the species are geographically quite far from one another in addition to different morphological characters. The present study does not support the homogenous nature of the section *Macrocarpus* and is difficult to consider them as a monophyletic one.



Figs. 2–3. *C. loxostemonoides*, 2. rhizome, Bar: 1 mm, 3. globular bulbil, Bar: 0.5 mm. Figs. 4–7. *C. tibetana*, 4. rhizome, Bar: 1 mm, 5. young coral bulbil, Bar: 0.5 mm, 6. coral bulbil, Bar: 0.5 mm, 7. reduced leaves at the base of stem, Bar: 1 mm, st: stem, pt: petiole of radical leaf, sc: fleshy scaly leaf, dt: digitate apex of the fleshy scaly leaf, cr: crecent shaped scaly leaf.

Moreover, the present finding reveals some more reliable characters such as types of bulbils, texture and apex of scaly leaves which can easily be observed even in the dry herbarium specimens.

Eighty five percent species of *Cardamine*, and the species of *Loxostemon* are perennial and reproduce vegetatively from rhizome. *Cardamine pratensis* reproduces from foliage leaves (Lovkvist 1956). In *C.*

*appendiculata* we have observed growth of plantlets from the leaflets and petioles. Lifeform accompanied by rhizomes, stolons and bulbils are found widely throughout in the genus *Cardamine* for regeneration.

Hooker and Thomson (1861) established the genus *Loxostemon* by the winged long filaments bent outside (reflexed) in the upper part. *Cardamine loxostemonoides* differs from *Loxostemon* in having

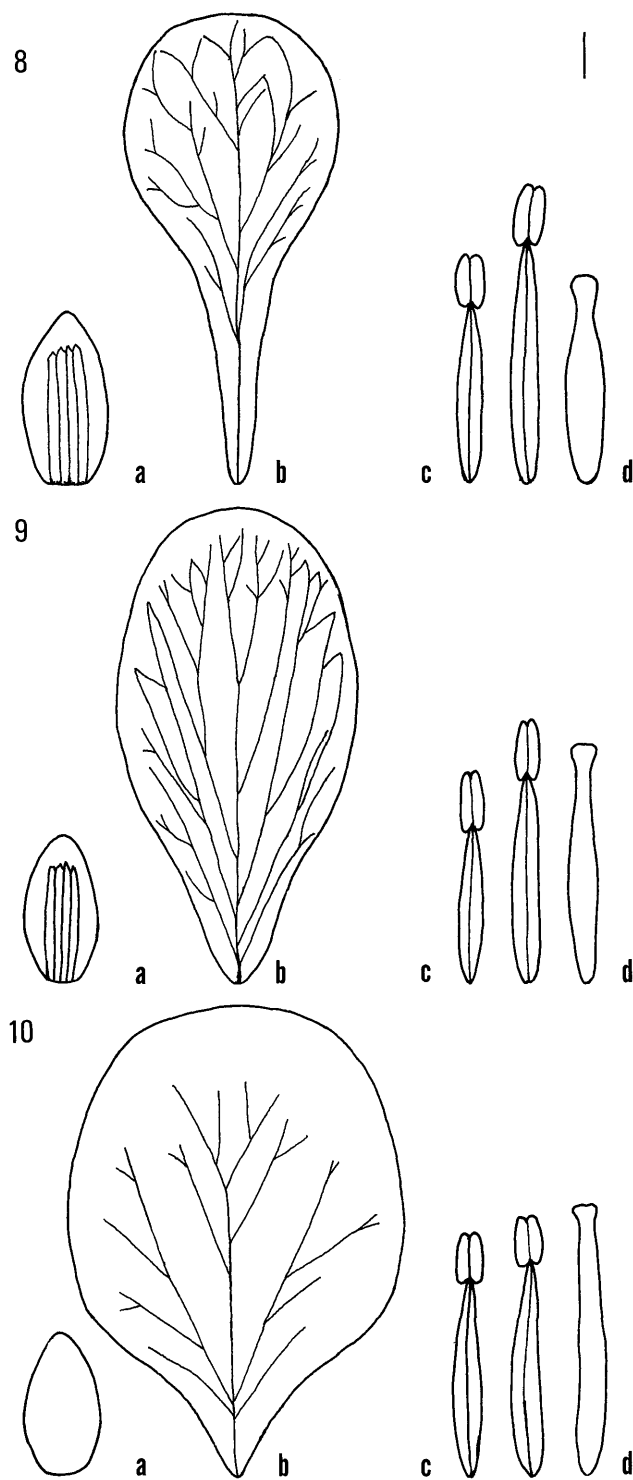


Fig. 8. *Cardamine luxurians*, Fig. 9. *C. loxostemonoides*, Fig. 10. *C. tibetana*, a: sepal, b: petal, c: short and long stamens, d: pistil. Bar: 1 mm.

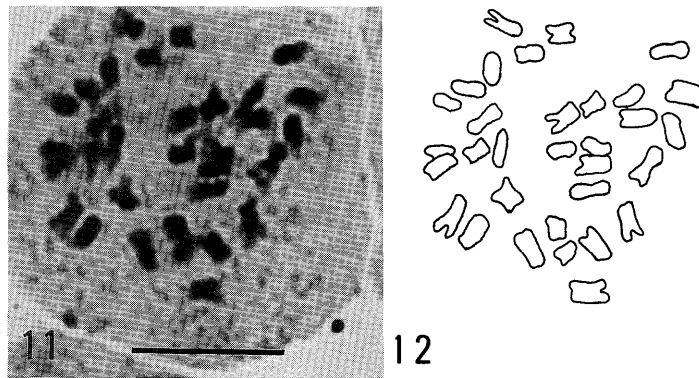


Fig. 11. Somatic chromosome number in *C. loxostemonoides* ( $2n=32$ ). Bar: 10  $\mu$ m; Fig. 12. Illustration of fig. 11.

wingless erect long filaments but possessing the filaments slightly curved towards the stigma, which are in coincidence with the genus *Cardamine*.

Other characters used for the delimitation of genus *Loxostemon* such as few flowers, few leaves, few leaflets and weak stem (Hooker and Thomson 1861) are not reliable and inconsistent. For example, *C. loxostemonoides*, is 5–25 cm tall and has 1–5 cauline leaves, 5–13 leaflets and 1–20 flowers. Therefore, it must be treated under the genus *Cardamine* as no evidence exists to put it under the genus *Loxostemon*.

*Cardamine* and *Loxostemon* are unique in the Cruciferae in having the characters of explosive fruit with marginate narrow replum and elastic dehiscence by spiral coiling of the valves. However, *Loxostemon* is distinguished from *Cardamine* by the triangular obovate filaments of the long stamens.

*Cardamine loxostemonoides* varies in rhizome bulbils morphology. Reduction in the main axis of rhizome and change in the texture and shape of scaly leaves have resulted in variation of morphology.

*Cardamine loxostemonoides* in the Himalayan region exhibits different characters and can be divided into three species. The Pakistan species (*C. luxurians*) is characterised by vigorous stoloniferous rhizome without bulbils; the Nepal one (*C.*

*loxostemonoides*) is characteristic in globular bulbils and the Tibetan one (*C. tibetana*) is delimited by possessing coral and leafy bulbils. The later two have small leaflets.

Usually the genus *Cardamine* possesses the basic number 8, therefore *C. luxurians* ( $2n=32$ ) and *C. loxostemonoides* ( $2n=32$ ) are considered as tetraploid. This is also the first record of chromosome counts from Himalayan region in the genus *Cardamine*.

### Taxonomic treatment

#### Key to the species

1. Bulbils absent; scaly leaves membranous with acute to acuminate apex; leaflets suborbicular, glabrous, large; petals spatulate ..... 1. *C. luxurians*
1. Bulbils present; scaly leaves, fleshy, crescent shaped or fleshy with digitate apex; leaflets suborbicular-obovate, linear-oblong, glabrous to hairy; petals wide obovate, obovate-oblong
2. Globular bulbils present and leafy bulbils absent; scaly leaves digitate at the apex; reduced leaves absent at the base of the stem, petals obovate oblong ..... 2. *C. loxostemonoides*
2. Coral and leafy bulbils present; scaly leaves crescent shaped; reduced leaves present at the

base of stem; petals widely obovate .....

..... 3. *C. tibetana*

1. ***Cardamine luxurians*** (O. E. Schulz) Rashid et H. Ohba, comb. et stat. nov.

*Cardamine loxostemonoides* O. E. Schulz var. *luxurians* O. E. Schulz in Notizbl. Bot. Gard. Berlin **9**: 1070 (1927).

Plants perennial with branched stoloniferous rhizome, bulbils absent, scaly leaves membranaceous, apex acute to acuminate somewhat greyish in colour. Stem suberect to procumbent, 11–25 cm long, glabrous. Radical leaves present; cauline leaves 3–5, long petiolate, pinnatisect, usually leaflets 5–11; leaflets petiolulate, suborbicular, margins entire to trilobulate, 13–16 mm long, 7–12 mm broad; terminal one slightly bigger than the lateral leaflets. Raceme 6–20 flowered. Flowers 9–14 mm across, showy, purple; pedicels 11–19 mm long; sepals 3–3.6 mm long, 1.5–2.1 mm broad; petals 4 times longer than sepals, 10–12.2 mm long, 5–6.1 mm broad, venation dark violet; glands 4 i.e. 2 ring shaped at the bases of short stamens, 2 lateral glands at the dorsal side of long stamens; long stamens 6.8–7 mm long, short stamens 0.9–1.2 mm long. Anther dehiscence introrse, along the longitudinal slits. Siliques linear compressed 2.5–3.3 mm long, 1.5 mm broad, straight, glabrous, septum and valves veinless; ovules 16–20, placenta uniform, funicle filiform. Pollen grains mostly elliptic to spherical, 15.6–30  $\mu\text{m}$  long, 15–17.5  $\mu\text{m}$  broad, isopolar, radiosymmetrical, tricolpate, surface sculpturing reticulate. Somatic chromosome number  $2n=32$ .

Holotype: N. W. India (Tihri-Garwal): Nila Valley, 16 August, 1883 (Duthie 912, probably DD, not seen, photo in K; isotype in K).

Other specimens examined: Pakistan: Northern Areas, District Gilgit, Astore, Above Rama Lake, (Webster & Nasir 6450, 12 August 1955, RAW); Rama Lake, (H. Ohba et al., 393, 20 August 1992, TI, PUH).

2. ***Cardamine loxostemonoides*** O. E. Schulz in Notizbl. Bot. Gard. Berlin **9**: 1069 (1927); Jafri in Fl. Pak. **55**: 168 (1973); Hara in Enum. Flow. Pl. Nepal **2**: 40 (1979); Polunin and Stainton, Flow. Himal. **41** (1989).

*Loxostemon loxostemonoides* (O. E. Schulz) Y. C. Lan et T. Y. Cheo in Bull. Bot. Res. N. E. Forest. Inst. **1**: 54 (1981); T. Y. Cheo in Fl. Reip. Pop. Sin. **33**: 233 (1987).

Plants perennial with stoloniferous branched rhizome, bulbils present, scaly leaves fleshy with apical digitate appendages somewhat white in colour; stem suberect or procumbent, 5 to 17 cm long, glabrous, sometimes hairy in the upper portion. Radical leaves present; cauline leaves 1–3, leaves long petiolate, pinnatisect, usually leaflets 7–13, variable in size and shape; leaflets petiolulate or expetiolulate, suborbicular to linear oblong, 5–11 mm long, 1.5–5 mm broad, terminal lobe scarcely differentiated from the lateral ones, entire to lobulate, margins hairy. Raceme 1–12 flowered. Flowers 8–14 mm across, showy, pink or purple; pedicels 10–20 mm long; sepals 2.5–3.5 mm long, 1.5–2 mm broad; petals 4 times as many as sepals; 10–12 mm long, 5–6.6 mm broad, ascending, obovate-oblong, hardly clawed, dark violetly veined; long stamens 5–5.4 mm long, short stamens 6–6.5 mm long; anther dehiscence introrse along the longitudinal slits; Pistil 5.8–6.1 mm, ovules 16–20, septum and valves veinless, placenta uniform, funicle filiform. Siliques linear compressed 2.4–3.2 mm long, 1.4 mm broad, straight, glabrous. Pollens 17.5–39.4  $\mu\text{m}$  long, 16.9–21.9  $\mu\text{m}$  broad, mostly elliptic, isopolar, radiosymmetrical, tricolpate, surface sculpturing reticulate. Somatic chromosome number  $2n=32$ .

Lectotype: N. W. India (Kunawer): Nipchang valley alt. 4300–4600 m (Duthie 2724, 31 August 1884, K, the lectotype is here selected; isotype in ?DD). Syntypes: Lebung Pass (Duthie 5330, 1 August 1886); Tihri-Garwal: Chinal opposite Bandrapunch (Duthie 911, 913, 25 August 1883); West Nepal: Opposite

Budhi village (Duthie 5330, 18 July 1886); Nampha Gadh, (Duthie 5330, 27 July 1886), all probably in DD, not seen.

Specimens examined: W. Nepal: Dozam Khola near Simikot (Polunin, Sykes & Williams 4284, 1 June 1952, BM, TI); near Pudamigaon, near Suli Gola (Polunin, Sykes & Williams 2253, 19 June 1952, TI); Padmara Lagna (Polunin, Sykes & Williams 4372, June 1952, BM, TI); Phoksumdo Tal (Stainton 4296 12 June 1963, BM, TI); Phoksumdo Khola (Stainton 4316, 17 June 1963, E); Porakya Lagna, Karnali (Stainton 4878, 23 May 1965, BM, TI); Tingjegaon (Polunin, Sykes & Williams 1155, 19 June 1952, BM, TI); Balangra Pass (Polunin, Sykes & Williams 1043, 30 May 1952, TI); Sisne Himal (Stainton 6342, 27 June 1968, BM, TI); Sisne Himal (Stainton 6347, 29 June 1968, BM, TI); Tarap-she (Dolpa District) (Yoshida 1035, 9 July 1991, TI); Chaurpni (Dobremez 2301, 17 May 1973, BM); 3.5 miles E of Saipal (Arnold 306, 31 August 1954, BM); 5 miles, N. E. of Saipal (Arnold 233 & 230, 25 August 1954, BM); Chhairogaon, N. of Tukucha (Stainton, Sykes & Williams 859, 1 June 1954, BM); Sialgarki (Polunin, Sykes & Williams 991, 22 May 1952, BM); Jangla Banyang (Einarsson, Skarby & Wetterhall 838, 17 June 1963, BM); C. Nepal: 3 miles S. E. of Thorong pass (Epstein 5, 25 June 1977, BM); Khung Khola (Gray-Wilson & Philips 646, 16 August 1973, K); Langtang (Polunin 188, 8 June 1949, BM); Langtang valley, facing N. across river (Polunin 654, June 1949, BM); Langtang valley (Miyamoto et al. 147, Aug. 1992, TI); Tinkar Khola (Tyson 60, 24 June 1953, BM); Nampa Khola, (Tyson 37, 14 June 1953, BM); N. E. of Chalike Pakar (Stainton Sykes & Williams 3115, 14 June 1954, BM); Jargeng Khola (Lowndes 1045, 21 June & 2 July 1950, BM); E. Nepal: Arum valley, Piling Khola, N. E. of Chyamtang (Stainton 406, 23 May 1956, K); east of lower Sangdah (Grey-Wilson & Philips 411, 27 July 1973, K); north of Chung See (Grey-Wilson & Phillips 613, 12 August

1973, K); Thumu Khola, Khumbu (Bowes Lyon 2211, 20 June 1964, BM); Hongu Khola, left bank near Mera Kharka (Mc Cosh 360, 3 July 1964, BM).

3. *Cardamine tibetana* Rashid et H. Ohba, sp. nov. (Fig. 13)

*Cardamine loxostemonoide* O. E. Schulz similis sed bulbilos coralliforme et illos foliaceos et folia rudimentalia habens.

Plants perennial with stoloniferous rhizome, two types bulbils present i. e. coral bulbils and leafy bulbils; scaly leaves fleshy crescent shaped, spirally arranged, somewhat whitish in colour. Stem suberect to erect, 8–12 cm long, glabrous. Radical leaves present; cauline leaves long petiolate 2–4, leaflets expetiolulate obovate-oblong with entire margins, hairy usually along the margins; 5–8 mm long, 3–6 mm broad, all the leaflets in the same leaf uniform. Raceme panicle, 2–6 flowers. Flowers 8–11 mm across, showy, violet; sepals 3.4–3.6 mm long, 1.5–1.8 mm broad, venation obscure; petals 10–12.1 mm long, 8.3–8.5 mm broad, violet, widely obovate; glands 4, i.e. 2 ring shaped glands at the base of the short stamens, 2 lateral glands on dorsal side of the bases of long stamens; short stamens 2; long stamens 4; short stamens 6–6.2 mm long; long stamens 6–6.3 mm long; anther dehiscence introrse, longitudinally along the slits; pistil 6.3–6.5 mm long, stigma flat, slightly bifid; ovules 14–20, septum and valves veinless, placenta uniform, funicle filiform; siliques linear compressed, glabrous. Pollen grains 19.4–27.5  $\mu\text{m}$  long, 16.3–22.5  $\mu\text{m}$  broad, spherical, isopolar, radio-symmetrical, tricolpate, spherical to elliptical in shape, surface sculpturing reticulate.

Type: S. E. Tibet, Tse La, Langong, 94°00'N. 28°45'E, alt. 14–15000 ft (Ludlow and Sherriff 5618, 21 June 1938, holotype, TI: isotype, BM).

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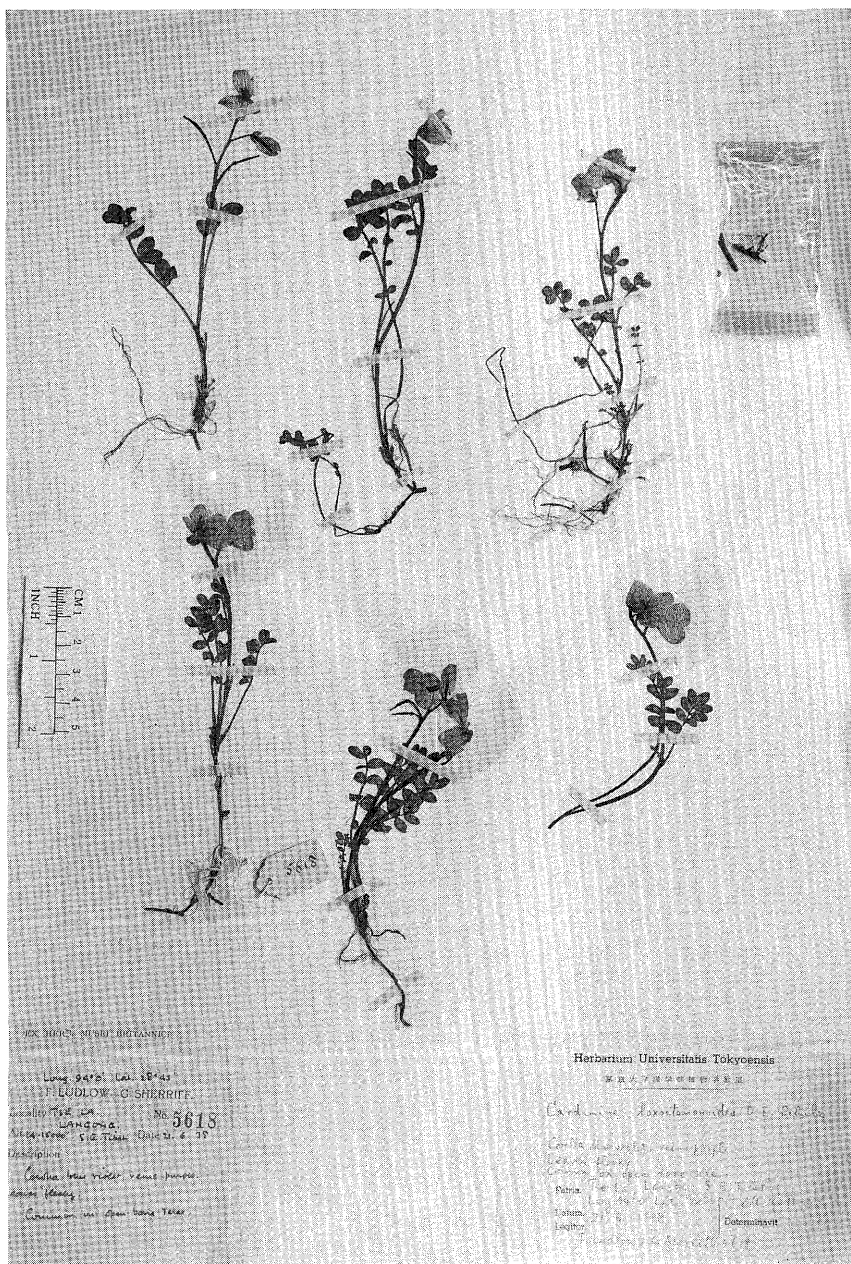


Fig. 13. *Cardamine tibetana* Rashid et H. Ohba (Ludlow and Sherriff 5618, Type).

Tokyo University of Agriculture, for collection of root tips for this study, Dr. A. R. Beg and Dr. F. Hussain, University of Peshawar for help in the field. This study was supported by a grant from the Monbusho International Scientific Research Program

(Field Research), No. 04041038 in 1992 to H. O.

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### 要旨

*Cardamine loxostemonoides* はヒマラヤ高山帯に広く分布するがまれな植物で、これまで標本も少なく、不明の点が多かった。ネパールとパキスタンで現地観察をし、可能な限り標本を借用して、形態学的形質と染色体の観察を行なった。染色体

数はパキスタンとネパール産で  $2n=32$  であった。形態学的形質にはパキスタン～北西インド（クマオン）、ネパール、南東チベットの間に不連続な差異が見いだされた。それらは地理的にもまとまっており、独立の種として認識するのがよい。なお、周太炎と藍永珍（1981）はこの種を *Loxostemon* 属に移した。同属の種と *C. loxostemonoides* は花の構造が違う。*Loxostemon* 属は成熟するとらせん状に巻く果皮をもつことで、タネツケバナ属に類似するが、長雄蕊は逆三角状卵形の花糸をもつことで異なる。