Tsunehiko NISHIKAWA* & Koji ITO**: **An experimental hybridization of the *Adonis amurensis* group and morphological comparisons of cultivars*****

西川恒彦*・伊藤浩司**: フクジュソウの雑種形成と園芸品種の形態比較

In 1978 and 1979 Nishikawa and Ito showed three different chromosome numbers (2n=16, 32 and 24) in northern Japanese *Adonis* plants including one cultivar Fukujukai. Then, it was pointed out that the occurrence of 2n=24 chromosome number was limitedly found in the cultivar Fukujukai and that its origin was presumably a hybridization between a 2n=16 plant and a 2n=32 plant. Thus Nishikawa, one of the authors, made an attempt to cross between *Adonis* plants with 2n=16 and those with 2n=32 obtained from wild habitats in 1978 and 1979.

Materials and methods The parent materials were collected from the following: Towada, Aomori Pref. in N. Honshu (A-1), Utanobori, Abashiri Pref. in N. Hokkaido (A-2), Ohmagoshi, Aomori Pref. in N. Honshu (B-1), and Kuromatsunai, Shiribeshi Pref. in SW. Hokkaido (B-2).

Crossing experiments were carried out with potted plants indoor in March 1980 in Asahikawa. The emasculation of flowers was performed before blooming. Before blooming and therafter, female flowers were isolated with parafine bags. Seeds were obtained at about 5 weeks after post-pollination. For the purpose of the effective raising, seeds were sown after the harvesting in April 1980.

Determination of the somatic chromosome number was made by using root tips and ovules. These materials were initially treated with 0.1% aqueous solution of colchicine for 1 to 2 hours. The following procedures were the same as those of the previous paper (Nishikawa & Ito 1979).

Pollen fertility was estimated by Tateoka's method (Tateoka 1973). Pollen grains from the mature anthers were stained by cottonblue-lactophenol solution.

* Biological Laboratory, Asahikawa College, Hokkaido University of Education, Asahikawa 070. 北海道教育大学 旭川分校生物学教室.

** Graduate School of Environmental Science, Hokkaido University, Sapporo 060. 北海道大学 大学院環境科学研究科.

*** Contribution from the Herbarium of SAPT.

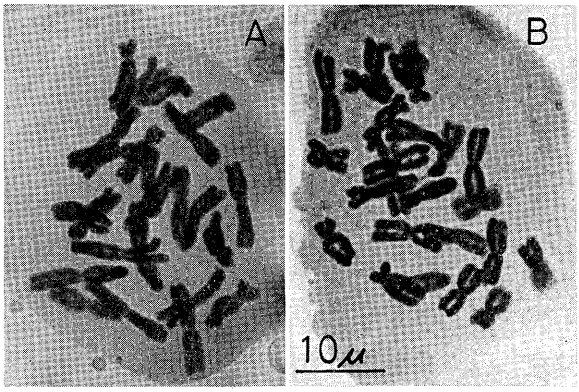

Fig. 1. Somatic chromosomes of hybrids between tne 2n=16 plants and the 2n=32 plants. A: 2n=24 (*A. ramosa* with 2n=16 × *A. amurensis* with 2n=32). B: 2n=24 (*A. amurensis* with 2n=32 × *A. amurensis* with 2n=16).

Crossing experiments In the crossing, *A. ramosa* (A-1, 2n=16) × *A. amurensis* (B-1, 2n=32), 34 seeds were obtained in 1980, and 6 seedlings were raised from them in April 1981. The chromosome numbers of them were 2n=24 as shown in Fig. 1-A.

The reciprocal crossing was also attempted. 16 seeds were obtained in 1980, but no seedlings were raised in 1981. In 1981 the repeated reciprocal crossing was made and many seedlings were raised in 1982, and they showed 2n=24 chromosome number.

In the crossing, *A. amurensis* (B-2, 2n=32) × *A. amurensis* var. *puberula* (A-2, 2n=16; cf. Nishikawa & Ito 1978), 54 seeds were obtained and 15 seedlings were raised in April 1981. The chromosome numbers were 2n=24 as seen in Fig. 1-B. The reciprocal crossing was not successful partly because of difference of the flowering time from each other, and partly of the lack of sufficient numbers of plants in the experiment.

From the results of these two experiments, it was shown that the chromosome number of 2n=24 can be derived from the hybridization between 2n=16 and 2n=32 plants, or between 2n=32 and 2n=16 plants.

Fig. 2 shows that somatic chromosome numbers of *Adonis* cultivars are 2n=16, 24, 32 and 40, and Tab. 1 lists the chromosome numbers of twenty-four Japanese *Adonis* cultivars and their pollen fertility. It is noteworthy that pollen fertility of 2n=24 and 2n=40 cultivars was extremely low, less than 10%; that of 2n=16 and 32 cultivars was almost normal, from 79 to 98%, although very few are exceptional.

The present situation is somewhat problematic, because the authors' discussion on the hybrid origin has been based on the belief in X=8 as the basic

Tab. 1. Chromosome number and pollen fertility of *Adonis* cultivars.

Name of cultivars		Number of stocks	Chromosome number (2n)	Pollen fertility (%)
Kotobuki	寿	2	16	—*
Hinomotoko	日の本紅	1	16	96.5
Hinodeko	日の出紅	2	16	98.6**
Tamatebako	玉手箱	1	16	71.6
Sandanzaki	三段咲	1	16	—*
Shichifukujin	七福神	1	16	20.0
Jitsugetsusei	日月星	2	24	3.0**
Nadeshiko	撫子	1	24	0.8
Kinsekai	金世界	2	24	2.5**
Fukujukai	福寿海	2	24	5.3**
Kinshi	金鵄	2	24	5.1**
Shiun	紫雲	2	24	5.5**
Beninadeshiko	紅撫子	2	24	1.6**
Garaku	雅楽	2	32	94.4**
Henge	変化	1	32	87.4
Benten	弁天	1	32	86.8
Kogiku	小菊	2	32	84.1**
Kinsai	金采	1	32	38.5
Tsumaoregasa	爪折笠	1	32	34.1
Gosho	御所	1	32	91.5
Chichibuko	秩父紅	1	32	90.0
Sado	佐渡	1	32	80.9
Fukurokuju	福禄寿	1	40	1.8
Taiho	大鳳	1	40	5.6

* All stamens and pistils are transformed into petals.
** Average values.

number of the genus *Adonis*. In Japanese materials of *A. amurensis* s. l., the chromosome numbers hitherto reported are n=12 (Ishikawa 1916, Takamine 1916), n=20 (Sugiura 1931) and 2n=24 (Kurita 1955). These chromosome counts suggest that all the chromosome numbers of 2n=24 might not be derived from a simple hybridization among *Adonis* plants which are attributed to the basic number of X=8, if the materials used by them were not obtained from

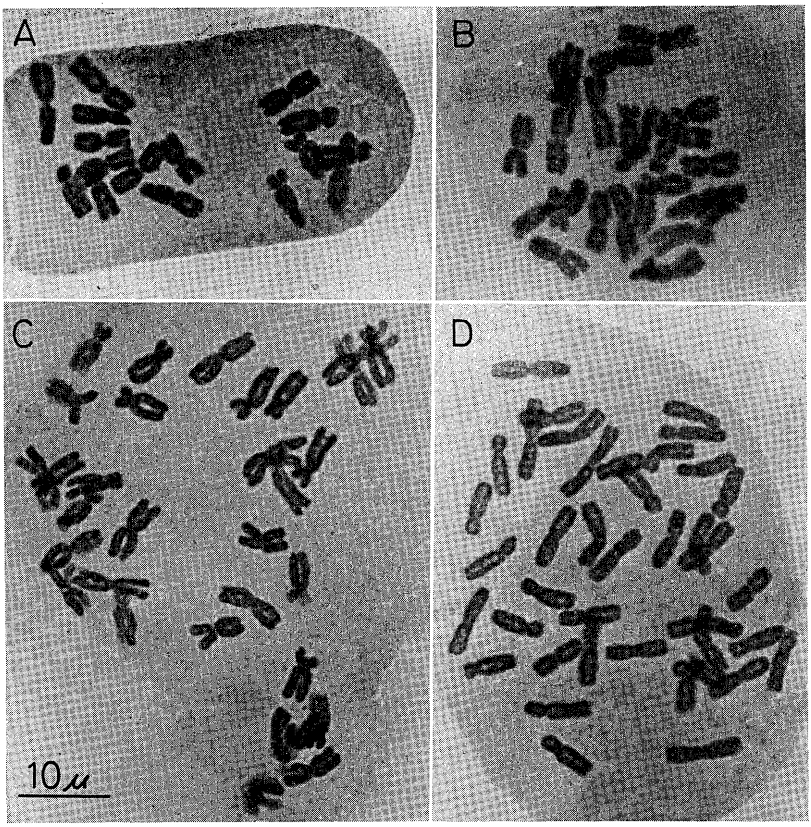

Fig. 2. Somatic chromosomes of *Adonis* cultivars. A: 2n=16 (Hinomotoko). B: 2n=24 (Beni-nadeshiko). C: 2n=32 (Garaku). D: 2n=40 (Fukurokuju).

commercial sources but obtained certainly from wild habitats or their derives. In addition, the suggestion means that there is a possibility of the X=4 as the basic number (Kurita 1963), although the present experimental results are not in accordance with the latter.

Comparison of some morphological characters Shape of petals and of sepals. All cultivars show that the shape of petals is usually elliptic to obovate. The shape of sepals is usually elliptic, or often obovate except for 2n=16 individuals which show usually obovate and not elliptic.

Petal color. On the basis of the color of petals on the inside, the cultivars

are grouped into three. The 1st group is reddish orange in the color, including Hinodeko (2n=16), Hinomotoko (2n=16), Beninadeshiko (2n=24), and Chichibuko (2n=32). The 2nd group is pale yellow, including Shiun (2n=24) and Benten (2n=32). The 3rd group is bright yellow to golden yellow, including Kotobuki (2n=16), Tamatebako (2n=16), Sandanzaki (2n=16), Shichifukujin (2n=16), Fukujukai (2n=24), Kinsekai (2n=24), Jitsugetsusei (2n=24), Nadeshiko (2n=24), Kinshi (2n=24), Garaku (2n=32), Sado (2n=32), Henge (2n=32), Gosho (2n=32), Kogiku (2n=32), Kinsai (2n=32), Tsumaoregasa (2n=32), Fukurokuju (2n=40) and Taiho (2n=40). However, the specific relation of the color to the chromosome number is not clearly recognizable.

On the contrary, the color of petals on the outside shows a good correlation with the ploidy. The cultivars with 2n=24, 32 and 40 are commonly yellow tinged with purple or dark purple as a whole, whereas those with 2n=16 are reddish brown on the upper margin of the petals.

Sepal color. Except for the cultivars with 2n=16, in which sepals are pale green inside and pale green or dark green outside, sepals are commonly yellow to pale yellow inside

Tab. 2. Comparison of shape and color of petals and sepals among 4 polyploid groups.

Chromosome number (2n)	Shape of petals	Shape of sepals	Color of petals		Color of sepals	
			inside	outside	inside	outside
16	elliptic to obovate	obovate	usually yellow, not fixed	yellow with reddish brown on the upper margin	pale green	pale green to dark green
24		elliptic, often obovate		usually yellow, sometimes purple to dark purple	yellow to pale yellow	purple to dark purple
32						
40						

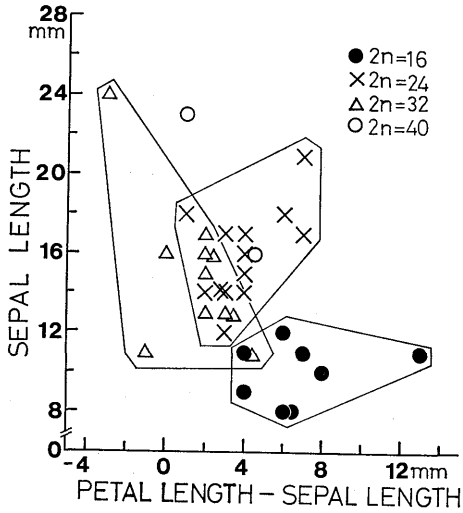

Fig. 3. Scatter diagram showing the relationship of "petal length minus sepal length" to "sepal length" of *Adonis* cultivars.

and dark purple to purple outside.

Relation of sepal length to petal length. Nishikawa & Ito (1979) showed the relation of sepal length to petal length was applicable to the classification of *Adonis*. As seen in Fig. 3, this application was considered to be valid in this case, too. The diploid and triploid cultivars were characterized by having petals longer than sepals : the tetraploid was characterized by having petals which are nearly as long as sepals. Among them, the diploid cultivars have the shortest sepals.

Number of flowers per stem. The number of flowers per stem ranged from 1 to 9. However, it was very conspicuous that most of the tetraploid cultivars had only one flower per stem, and that the triploid cultivars had 3 to 6 (average 4.9) as seen in Tab. 3.

Achenes and aggregate fruit. The achenes were observed on 13 fertile stocks. In the diploid cultivars, the achenes were smaller in size, lighter in color, and, in addition, thinner in hairiness than those in the rests.

As seen in Fig. 4 (A-D), the aggregate fruit of the diploid cultivars was different from that of the rests. In the diploid cultivars it was globose and

Tab. 3. Number of flowers per stem.

Chromosome number (2n)	Number of cultivars	Number of stocks	No. of flowers per stem 1	2	3	4	5	6	7	8	9	average
16	6	8	0	1	3	1	1	0	1	0	1	4.5
24	7	13	0	0	2	3	4	3	0	1	0	4.9
32	9	11	8	1	1	1	0	0	0	0	0	1.5
40	2	2	0	1	0	1	0	0	0	0	0	3.0

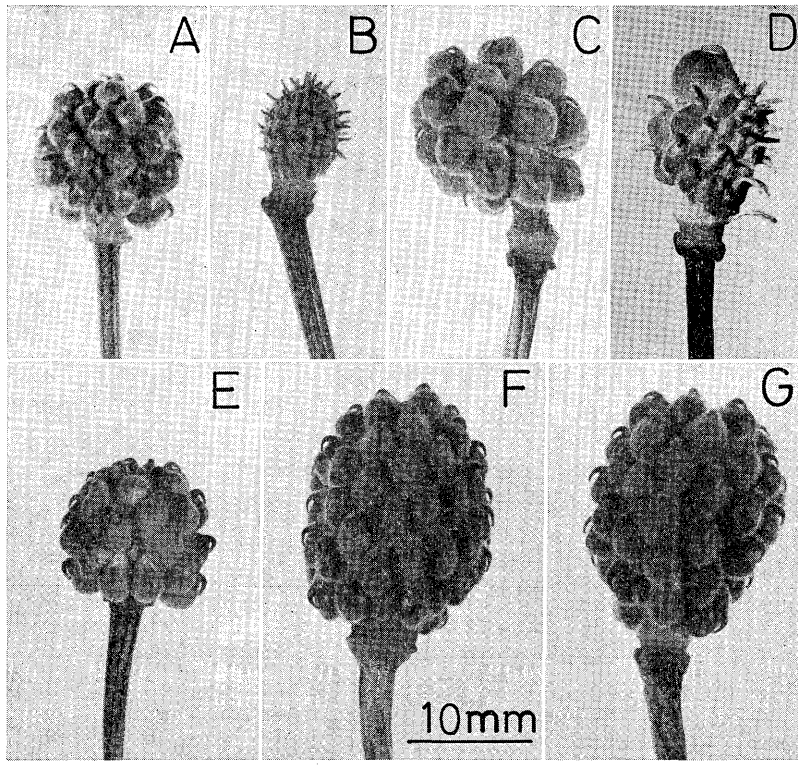

Fig. 4. Aggregate fruits. *Adonis* cultivars (A: 2n=16 Hinomotoko, B: 2n=24 Kinshi, C: 2n=32 Henge, D: 2n=40 Fukurokuju). Wild *Adonis* plants (E: 2n=16 from Towada, F: 2n=16 from Kitami, G: 2n=32 from Hidaka).

smaller than that in the rests. A similar tendency was shown in the aggregate fruit of wild diploid *Adonis* collected at Towada as seen in Fig. 4 (E-G).

Hairiness of leaves. No differences were observed among the cultivars on hairiness of leaves. They were commonly subglabrous to glabrous beneath, and glabrous above.

Flowering time. The flowering time of diploid cultivars was later than that of the rests. Tab. 4 shows the comparison of flower opening date in 1982 in the cultivars under consideration. As seen in the table, the diploid cultivars blossomed from late April to early May; the rest cultivars finished the blossom by late April.

Tab. 4. Date of flower opening in 1982 of *Adonis* cultivars and wild *Adonis* cultivated in Asahikawa.

	Names of cultivars and localities of wild plants	Chromosome number (2n)	Date of flower opening: April 14	16	18	20	22	24	26	28	30	May 2	4	6	8	10	12
Cultivars	Kotobuki	16															+
	Hinomotoko	16													+		
	Hinodeko	16												+			
	Tamatebako	16												+			
	Sandanzaki	16										+					
	Shichifukujin	16									+						
	Jitsugetsusei	24								+							
	Nadeshiko	24								+							
	Kinsekai	24						+									
	Fukujukai	24					+										
	Kinshi	24				+											
	Shiun	24			+												
	Beninadeshiko	24			+												
	Garaku	32								+							
	Henge	32								+							
	Chichibuko	32							+								
	Sado	32							+								
	Benten	32						+									
	Kogiku	32						+									
	Kinsai	32						+									
	Tsumaoregasa	32					+										
	Gosho	32				+											
	Fukurokuju	40						+									
	Taiho	40			+												
Wild *Adonis*	Nishine (Iwate Pref.)	16												+			
	Towada (Aomori Pref.)	16											+				
	Maruseppu (Hokkaido)	16			+												
	Kitami (Hokkaido)	16		+													
	Shichinohe (Aomori Pref.)	32					+										
	Hirosaki (Aomori Pref.)	32				+											
	Asahikawa (Hokkaido)	32					+										
	Toyoura (Hokkaido)	32			+												

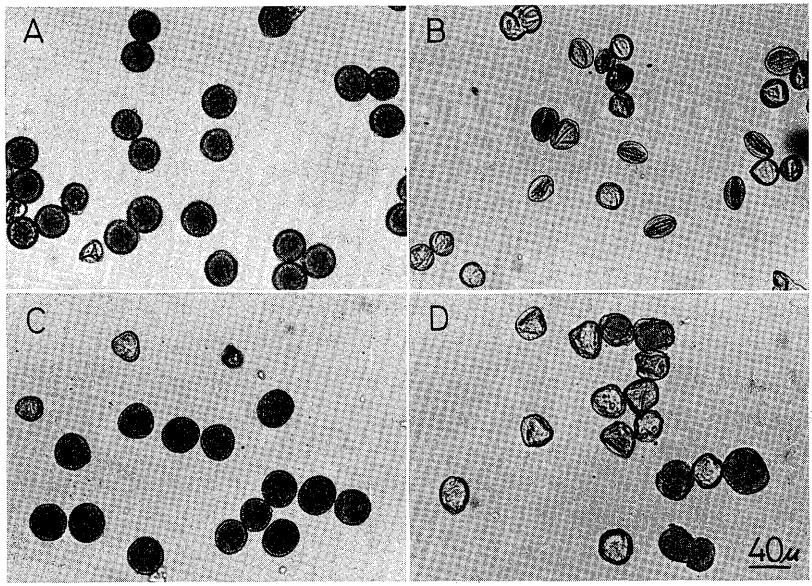

Fig. 5. Pollen grains of *Adonis* cultivars. A: 2n=16 (Hinodeko). B: 2n=24 (Kinsekai). C: 2n=32 (Garaku). D: 2n=40 (Taiho).

Pollen fertility. Tab. 1 and Fig. 5 show the pollen fertility. It was detected without difficulties that the pollen fertility of the even-polyploid cultivars was higher than that of the odd-polyploid cultivars. In the former, the pollen fertility was 75.0% on average and considerably higher than that in the latter (3.5% on average), although in Shichifukujin (2n=16), Tsumaoregasa (2n=32) and Kinsai (2n=32) it was exceptionally low (from 20 to 39%). In some flowers of pentaploid cultivars, solid anthers sometimes contained gigantic pollen grains which were about 3.5 times as large as the normal-sized ones, and empty anthers were often observed in a single flower. The autohrs considered that it resulted from disturbed meiosis.

Discussion In the previous paper (Nishikawa & Ito 1979), the authors pointed out that Japanese cultivars of *Adonis* might comprise three taxa, *A. amurensis* Regel et Radde (2n=16 and 32), *A. ramosa* sensu Gorovoy et Gurzenkov (2n=16) and a cultivar Fukujukai (2n=24), and that the triploid *Adonis* plants were found only in cultivars but not in wild populations. In the present work, a possible origin of the triploid cultivar is shown. Thus Japanese cultivars

of *Adonis* may be grouped into three on the basis of ploidy and origin: 1) diploid cultivars descending from a diploid wild *Adonis, A. ramosa* sensu Gorovoy et Gurzenkov (Kotobuki, Hinodeko, etc.), 2) tetraploid ones descending from the Honshu type of *A. amurensis* (Nishikawa & Ito 1979; Benten, Kogiku etc.), and 3) tri- and pentaploid ones derived from the hybrid between diploid and tetraploid plants. In the last case, judging from the flower opening time, the diploid parent seems to be *A. ramosa* but not *A. amurensi* var. *puberula.*

Each cultivar group is characterized by some morphological features. Diploid cultivars bear some flowers on a stem; sepals are obovate in outline, pale to dark green in color, and shorter than petals; fruits are almost globose. Tetraploid cultivars bear a sole flower on a stem; sepals are tinged with purple to dark purple color outside and similar in length to petals. Triploid and pentaploid ones bear some flowers on a stem; sepals are somewhat shorter than petals. They are similar in gross morphology to *A. amurensis* with 2n=32 and have low pollen fertility.

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染色体数を異にするフクジュソウ（広義）の交雑結果及び園芸品種の染色体数と外部形態の観察結果について報告した。

染色体数 2n=16 の *A. ramosa* と 2n=32 の *A. amurensis*, 及び 2n=16 の *A. amurensis* (=*A. amurensis* var. *puberula*) と 2n=32 の *A. amurensis* との両交雑の結果生じた雑種は，染色体数がいずれも 2n=24 である。

交雑結果と園芸品種の染色体数及び外部形態に基づくと，供試した24種類の品種は次の3群に分けられる。

(1) 染色体数 2n=16 の品種。一茎に多数花をつける。果実は球形，萼片は倒卵形で，緑～黒緑色を呈する。花弁は明らかに萼片より長い。寿・日の本紅・日の出紅・玉手箱・三段咲・七福神が属する。これらは *A. ramosa* Franch. に由来すると考えられる。

(2) 染色体数 2n=32 の品種。通常一茎に一花をつける。果実は楕円形，萼片は紫～濃紫色を呈する。花弁は萼片より長いかまたは短い。雅楽・変化・弁天・小菊・金采・爪折笠・御所・秩父紅・佐渡が属する。これらは 2n=32 の *A. amurensis* に由来すると考えられる。

(3) 染色体数 2n=24, 40 の品種。一茎に多数花をつける。花弁は萼片より長い。外観は 2n=32 の *A. amurensis* に似る。花粉の稔性は低い。日月星・撫子・金世界・福寿海・金鵄・紫雲・紅撫子・福禄寿・大鳳が属する。これらは 2n=16 の *A. ramosa* と 2n=32 の *A. amuensis* の雑種に由来すると考えられる。

□Mirella Levi D'Ancona: **Botticelli's Primavera. A botanical interpretation including astrology, alchemy and the Medici.** 213pp. 1983. Leo S. Olschki Editore, Firenze. ボッチチェリの「春」はルネッサンスの名画として名高い。しかし時の経過による素材の変質や塵埃の堆積で，制作当時の華やかさは失われていた。フィレンツェの国立修復研究所では，1966年の洪水による文化遺産被害修復の一環としてこの絵に手をつけ，1972年その成果を公表した。本書は「春」の中に描かれている多数の植物を一つ一つ同定し，それが選ばれた意義や当時のパトロン・メジチ家との関連を解釈した労作である。ある人の依頼で，私には不似合いなこういう本を見ることになった。植物の日本名を調べてほしいというのがその目的だった。

本書では部分ごとに原画と見取り図を並べ，一つ一つの花を同定している。この際フローレンス大学植物学教室ハーバリウムの協力を得，その結果40種が同定された。典型的な春の花である *Narcissus* がないのはおもしろい。

こういうことをするに当たって基本的なことは，原画が同定に耐えるほど写実的であるかということである。絵画であり，しかも人物中心の絵だから植物の扱いはあまり慎重とは思えない。たとえば殆どの植物は根生葉をもち，茎葉は線状のものが多い。あるパタンのロゼットが異なる花についていたりする。花序の形も画一的である。こういうものを同定するのは，花のみに注目して属レベルでやるとしてもなかなか大変である。