

Pollination Biology of *Cremastra appendiculata* var. *variabilis* (Orchidaceae)

NAOTO SUGIURA¹⁾

Graduate School of Science and Technology, Kobe University, Kobe 657, Japan

¹⁾ Division of Environmental Biology, Faculty of Life and Environmental Science, Shimane University, Matsue 690, Japan

Abstract Anthecological observations on an orchid *Cremastra appendiculata* var. *variabilis* were carried out during May and June, 1994, in Kobe, Japan. The pendulous, tube-shaped flowers were visited by three species of bees and two of syrphid flies. Only queens of a long-tongued bumble bee *Bombus diversus diversus* received the pollinarium on one of their fore-femora. The frequencies of *Bombus* flower visits were extremely low. A carpenter bee, *Xylocopa appendiculata circumvolans*, consistently robbed nectar by making a perforation at the flower base.

Key words: *Cremastra*, orchid, pollination, *Bombus*.

The genus *Cremastra* Lindley is distributed in eastern Asia, while its allied genus *Aplectrum* Nuttall is found in eastern North America (Lund, 1987). The total number of species recognized in the genus *Cremastra* varies from 2 (Hawkes, 1965; Dressler, 1993) to 7 (Summerhayes and Hunt, 1973). In Japan, *C. appendiculata* (D. Don) and *C. unguiculata* (Finet) are found (Satomi, 1982), and Lund (1987) distinguished a variety in the former as *C. appendiculata* var. *variabilis* (Blume). Nothing is known concerning pollination of the genus (van der Pijl and Dodson, 1966; Lund, 1987; Dressler, 1993). According to Hogan (1983), nectarless flowers of *A. hyemale* (Muhl. ex. Willd.) are regularly autogamous and probably agamospermic though they are visited by a sweat bee *Lasioglossum (Dialictus) oblongus*.

Here I report on insects visited flowers of *C. appendiculata* var. *variabilis* together with their intrafloral behavior.

Materials and Methods

Observations on pollination of the orchid were carried out for 7 days between 17 May and 3 June 1994 at a secondary forest in Kobe, Hyogo Prefecture, Japan. The canopy layer of the forest was dominated by *Celtis sinensis* var. *japonica* (Planch.). Its understory was dominated by shrubs (*Aucuba japonica* Thunb. and *Deutzia crenata* Sieb. et Zucc.) or low herbs. *Cremastra appendiculata* var. *variabilis* abundantly grew among the shrubs and herbs and frequently formed colonies

presumably by vegetative propagation. Many colonies included dozens of inflorescences with open flowers. The orchids among the herbs (largely or moderately sunny sites) usually bloomed earlier than those among the shrubs (semishady or shady sites). In order to confirm species of pollinators and their intrafloral behavior, a total of 22.75 hours and some additional observations were carried out for one to several neighboring colonies of the orchid which included at least 20 inflorescences.

The number of flower scars and the number of fruits on each rachis were counted on 24 September 1994 to estimate the proportion of the flowers that received pollinia.

Flower Features

The inflorescence of *C. appendiculata* var. *variabilis* is an erect raceme with 3–47 flowers (Lund, 1987; Sugiura, unpubl.) which open acropetally. The pendulous flowers with a strong unique perfume are more or less tubular, not widely spreading. The sepals and petals are long (3–3.5 cm length and 4–5 mm width, Satomi, 1982) and variable in color, e.g. pink or brown in luminosity 3. The labellum is linear-oblongate (about 3 cm length and 1.8 mm width, Kitamura et al., 1964; Satomi, 1982) with a saccate base where ample nectar is found, and its anterior part is dilated and 3-lobed. The labellum except for the 3-lobed parts, tightly embraces the ventral side of the column forming the long tube which leads to the saccate base of the labellum. The entrance of the tube is closed by the callus on the mid lobe of the labellum and the wing of the column. The distance from the closed entrance to the bottom is 19–22 mm (n=8, Sugiura, unpubl.). The anterior part of the lateral lobes and the margin of the

mid lobe are usually deep purplish pink, while the other parts are whitish. The slender column (about 2.5 cm length, Kitamura et al., 1964; Satomi, 1982) enlarges at the apex and has a wing of deep purplish pink on the ventral side in the upper part. This wing is absent in *C. appendiculata* var. *appendiculata* (Lund, 1987). The pollinarium consists of 4 laterally flattened pollinia and a viscidium. The stigma is cupular. Judging from low fruit set (see Results) and spatial separation of the anther and the stigma, the flowers should probably not be regularly autogamous and should need pollinating agents to bear fruits.

Results

1. Flower Visitors and their Intrafloral Behavior

Flowers of *C. appendiculata* var. *variabilis* were visited by three species of bees and two of syrphid flies (Table 1). Frequencies of flower visits were extremely low, except for those of carpenter bees (*Xylocopa appendiculata circumvolans* Smith).

Queens of a bumble bee, *Bombus diversus diversus* Smith, were observed at least twice receiving the pollinaria of the orchid on the femur of either or both forelegs (Fig. 1). One queen received 16 pollinia and many viscidia on the right femur and one pollinarium on the left femur. The bumble bees visited more than one flower per inflorescence and usually lower flowers first. Unfortunately, I could not clarify how the bumble bees actually received the pollinarium from the flowers since they immediately escaped from the close observation.

A flower of the orchid receiving a large clump of pollinaria on the stigma was found during the present survey. The clump presumably came from 12 flowers, and was very likely deposited by a queen of *B. d. diver-*



Fig. 1. A queen of *Bombus diversus diversus* visiting the flower of *Cremastra appendiculata* var. *variabilis*. Note pollinaria (with anther caps) on the forelegs.

sus because the clump was very similar to those found on the foreleg of the bumble bee.

Two visits of queen *B. d. diversus* to inflorescences of the orchid were further observed in Kobe Municipal Arboretum on 31 May and 1 June 1992. In both cases, the bumble bee received the pollinaria on the femur of the forelegs. An examination of 43 preserved queens of *B. d. diversus* collected from various localities in Honshu and one queen of *B. diversus tersatus* Smith from Hokkaido in Dr. Y. Maeta's private collection included one individual of *B. d. diversus* collected from Nagano Pref. on 12 June 1980 with 2 pollinaria and at least 3 viscidia on the right fore-femur and 3 viscidia on the left. These pollinaria were very likely those of *C. appendiculata*, judging from the shape and size of pollinia.

The pollinaria were never observed on the other insects that visited the orchid flowers in the present survey. The flower-visiting carpenter bees (mostly females) always made a perforation at the base of flowers with their maxillae to suck nectar. The number of

Table 1. Flower visitors and their effectiveness as pollinator of *Cremastra appendiculata* var. *variabilis*.

Species	Sex (caste)	Frequency of flower visits	Pollinia uptake
Hymenoptera:			
Halictidae			
<i>Lasioglossum japonicum</i> (Dalla Torre)	♀	2	no
Anthophoridae			
<i>Xylocopa appendiculata circumvolans</i> Smith	♀ ♂	uncounted but commonly seen	no
Apidae			
<i>Bombus diversus diversus</i> Smith	♀ (queen)	4	yes
Diptera:			
Syrphidae			
<i>Baccha elongata</i> (Fabricius)	♂	1	no
<i>Volucella jeddona</i> Bigot	♂	1	no

flowers visited by the carpenter bee per minute varied from 7.3 to 10.8 ($n=9$ observations), and the mean duration on each flower was 2.7 sec ($n=38$ flowers). A sweat bee, *Lasioglossum (Evylaeus) japonicum* (Dalla Torre), and two species of syrphid flies, *Baccha elongata* (Fabricius) and *Volucella jeddona* Bigot, landed on the anterior part of the labellum and then briefly walked on the flower presumably to seek nectar.

2. Fruit Set

The number of flower scars per rachis ranged from 9 to 47; the mean was 23.5 ($n=98$). The mean number of fruits per rachis was only 0.4 (range 0–9, $n=213$). Of the 26 rachises which bore at least one fruit, 19 were collected from a single colony. The mean fruit set per rachis was 1.8% (range 0.0–34.6, $n=185$).

Discussion

The finding of pollinia-bearing queens of *B. d. diversus* strongly suggests that flowers of *C. appendiculata* var. *variabilis* are pollinated by long-tongued bumble bees. Morphological features of the orchid flowers support this opinion. Because ample nectar of the flower is concealed at the innermost part of the tube with a closed entrance, nectar-sucking is impossible for small insects with a short tongue (e.g. sweat bees). Except for the obligate nectar robber *X. a. circumvolans*, only long-tongued bumble bees should be able to utilize such concealed nectar. The malar space of *B. d. diversus* is elongated, and the length of the proboscis (the total of prementum and glossa) in the queens is reported to be 15.0–17.5 mm (Inoue and Kato, 1992), it seems that the proboscis length is adequate to obtain nectar deposited in the bottom if the mouthparts are inserted as deeply as possible into the tube. Although intrafloral behavior of the bumble bee is unknown, the deep insertion of the proboscis might allow the pollinaria to attach exactly on the femur of forelegs.

The bumble bee-pollinated flowers that bloom under cool and dark conditions, i.e. understory of forest, have to provide a sufficient nectar reward to their pollinators, which are capable of regulation of body temperature but require a high cost of energy (Heinrich and Raven, 1972; Heinrich, 1979). This might be a reason why flowers of *C. appendiculata* var. *variabilis* produce abundant nectar and conceal it at the bottom of the tube.

The fruit set was quite low. A probable reason is that pollination of the flowers completely depends on only

queens of *B. d. diversus* which visit the flowers with low frequency. Low efficiency in pollinia transfer from body surface of the pollinator to the stigma might be also important because large clumps of pollinaria were found both on the body surface and on the stigma.

In conclusion, flowers of *C. appendiculata* var. *variabilis* are probably pollinated only by long-tongued bumble bees even though the efficiency of the probable pollinator would be quite low.

Acknowledgments I wish to thank to Mr. Y. Ikezaki and Mr. M. Goubara for identifying a syrphid fly and a sweat bee, respectively, and Dr. K. Hoshikawa for reading the manuscript and making a number of helpful suggestions. My cordial thanks are also due to Dr. Y. Maeta for permission to examine bumble bee specimens in his private collection, Mr. Y. Hamanishi for permission to use the photograph, Mr. S. Miyake for identifying the study site of the orchid, and Mr. Y. Okajima for help in preparing the photograph.

References

- Dressler, R.L. 1993. Phylogeny and Classification of the Orchid Family. Dioscorides Press, Portland, Oregon.
- Hawkes, A.D. 1965. Encyclopaedia of Cultivated Orchids. Faber, London. (indirectly cited from Lund 1987).
- Heinrich, B. 1979. Bumble Bee Economics. Harvard University Press, Cambridge.
- and Raven, P.H. 1972. Energetics and pollination. *Science* **176**: 597–602.
- Hogan, K.P. 1983. The pollination biology and breeding system of *Aplectrum hyemale* (Orchidaceae). *Can. J. Bot.* **61**: 1906–1910.
- Inoue, T. and Kato, M. 1992. Inter- and intraspecific morphological variation in bumble bee species, and competition in flower utilization. In: Hunter, M.D., Ohgushi, T. and Price, P.W. (eds.), *Resource Distribution and Animal-Plant Interactions*, 393–427. Academic Press, San Diego.
- Kitamura, S., Murata, G. and Koyama, T. 1964. *Coloured Illustrations of Herbaceous Plants of Japan (Monocotyledoneae)*. Hoikusha, Osaka (in Japanese).
- Lund, I.D. 1987. The genus *Cremastra* (Orchidaceae), a taxonomic revision. *Nordic J. Bot.* **8**: 197–203.
- Pijl, L. van der and Dodson, C.H. 1966. *Orchid Flowers: Their Pollination and Evolution*. University of Miami Press, Coral Gables.
- Satomi, N. 1982. Orchidaceae. In: Satake, Y., Ohwi, J., Kitamura, S., Watari, S. and Tominari, T. (eds.), *Wild Flowers of Japan: Herbaceous Plants (including Dwarf Subshrubs)* Vol. I, 187–235. Hokuryukan, Tokyo (in Japanese).
- Summerhayes, V.S. and Hunt, P.F. 1973. Orchids. In: Willis, J.C. (ed.), *A Dictionary of the Flowering Plants and Ferns*. Cambridge (indirectly cited from Lund 1987).

Received April 24, 1996. Accepted October 10, 1996.