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Floral Visitors and Nectar Secretion of the Japanese Camellia, *Camellia Japonica* L.

Jeong Rae Rho and Jae Chun Choe*

School of Biological Sciences, Seoul National University, Seoul 151-742, Korea

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We studied the nectar secretion of the Japanese Camellia (*Camellia japonica* L.), an evergreen tree and observed its floral visitors during the day. The mean volume of nectar secreted, during daylight (08:31 to 16:30 h) was 30.26 ± 18.29 ml (SD) (n = 27). During the late afternoon and overnight (16:31 to 08:30 following day), 100.54 ± 54.85 ml (n = 27) of nectar was secreted. Total volume measured when flowers were sampled once every two hours for an eight-hour period was approximately one-half the volume which was measured when the flowers were sampled only once after eight hours. The mean nectar volume secreted was 8.55 ± 8.3 ml (n = 30) between 08:31 to 10:30, 4.38 ± 6.1 ml (n = 30) between 10:31 to 12:30, 4.6 ± 5.4 ml (n = 30) between 12:31 to 14:30, and 4.02 ± 3.5 ml (n = 30) between 14:31 to 16:30 hours. During the day, Japanese Camellia flowers were principally visited by the Japanese white-eye (*Zosterops erythropleura erythropleura* S.), a native bird, although insects and squirrels also visited to a lesser degree.

Morphological features of flowers and their floral rewards influence kinds of pollinators and the behavior of pollinators. One reward for pollinators is nectar. Nectar amounts are associated with the attraction of different kinds of pollinators (Proctor et al., 1996; Varassin et al., 2001). The frequency of foraging bouts is associated with the amount of secreted nectar volume and the patterns of nectar secretion (Rathcke, 1992). It has been reported that secretion of nectar is specific to plant species in volume and patterns (Cruden et al., 1983; Pettersson and Knudsen, 2001). Flowers that produce copious nectar are pollinated by birds, bats, non-flying mammals, and insects, which are undoubtedly the most important animal pollinators (Stiles, 1975; Sutherland and Gass, 1995; Law and Lean, 1999).

The Japanese Camellia (*Camellia japonica* L.) is a tree that grows approximately 1-15 m high. In Korea, it is sparsely distributed on the hillsides of the southern region of the peninsula. Yumoto (1987) reported that in Japan the Japanese Camellia is visited by a bird called Japanese white-eye (*Zosterops erythropleura erythropleura* S.). However, the pattern of nectar secretion in *Camellia japonica* L. has not been reported in Korea. The objective of this study was to document the pattern of nectar secretion and floral visitors of the Japanese Camellia in Korea.

*Corresponding author: Jae C. Choe
Tel: 82-2-880-8157; Fax; 82-2-882-7195
jcchoe@snu.ac.kr

Methods

Study site and subject

This study was conducted on a Japanese Camellia population near Sun-woon Temple, Go-chang Gun (35° 30' N, 126° 30' E), Jeollabuk-do, Korea from April 10 to 16 and from April 18 to 23, 2002. The color of the Japanese Camellia flower is bright red. The animals present during the study period were birds including the Japanese white-eye (*Zosterops erythropleura erythropleura* S.), the squirrel (*Tamias sibiricus asiaticus* G.), bats (*Rhinolophus ferrumequinum korai* K. and *Myotis macrodactylus* T.), and various insects.

Climate data were recorded hourly by a government-established automatic weather station located near the study site. The average air temperature was 11.4°C during the study period, while the average wind speed was 1.8 m/s. The average rainfall was 16.5 mm for the month of April, 2002.

Data collection

All of the nectar was removed at 08:30 h from one or two flowers of each of 19 trees using microcapillary tubes (n = 30 flowers). The flowers were bagged with bridal veil to exclude visitors. The volume of nectar secreted by each flower was measured at 10:30 h, 12:30 h, 14:30 h, and 16:30 h for three consecutive days when the flower and

anthers were open.

For a second group of flowers, one or two flowers of each of 19 trees were selected (n = 27 flowers). The nectar was removed, and the flowers bagged as above. Nectar volume was subsequently measured at 16:30 h the same day and again at 08:30 h the following day.

Nectar volume secreted was measured by extraction of nectar with 1 ml capillary tubes from intact flower of the Japanese Camellia. The capillary tubes were inserted into the nectar. The collected volume was calculated based on the proportion of the capillary tube filled (accurate to ± 0.05 ml) using scale.

In order to compare nectar secretion in each two-hour period, generalized linear model statistics (GLM, Statistical Analysis Software) were applied to the mean volume at each observation time. A GLM was also used to compare the nectar volume secreted during daylight (between 08:31 h to 16:30 h) and during the late afternoon and overnight (16:31 h to 08:30 h the following day).

Floral visitors

The species and numbers of birds and mammals that visited the Japanese Camellia inflorescences were recorded between 08:00 h and 12:00 h and between 13:00 h and 17:00 h from April 18 to 23, 2002. Insect species were also recorded but the number of insect visitors was not counted. When necessary, floral visitors were photographed for identification. When pos-sible, we also noted the placement of pollen on the visitors bodies.

Results

Nectar secretion

Diurnal changes of nectar secretion of the Japanese Camellia are shown in Fig. 1. Nectar secretion varied significantly across the day (GLM, $F = 4.88$, $P < 0.01$). The mean nectar volume between 08:31 and 10:30 h was approximately double the volumes measured in the other daylight time periods. The mean nectar volume secreted was 8.55 ± 6.51 ml (n = 30) between 08:31 and 10:30 h, 4.38 ± 5.2 ml (n = 30) between 10:31 and 12:30 h, 4.6 ± 4.49 ml (n = 30) between 12:31 and 14:30 h, and 4.02 ± 4.26 ml (n = 30) at between 14:31 and 16:30 h.

Total nectar volume measured when flowers were sampled once every two hours for an eight-hour period was approximately one-half the volume which was measured when the flowers were sampled only once after eight hours. The mean nectar volume secreted between 08:31 and 16:30 was 30.26 ± 18.29 ml (n = 27). Active nectar secretion continued during the night. In fact, the nectar volume secreted in the late afternoon and through the night was greater than that secreted during the day (GLM, $F = 39.89$, $P < 0.001$). Between 16:31 and 08:30 the following day, 100.54 ± 54.85 ml (n = 27) of nectar was secreted.

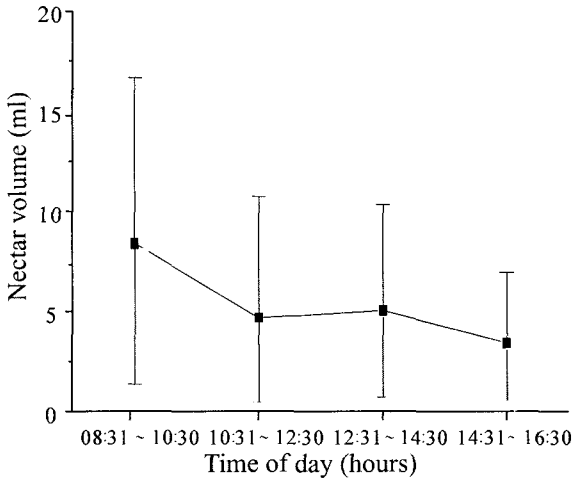

Fig. 1. Mean nectar volume ±S.D. secreted between 08:31 and 16:30 h (sample size=30).

Floral visitors

A total of 84 flower visits was recorded over 20 hours between April 18 to 23, 2002. The Japanese Camellia was visited by Japanese white-eye (n = 56, 66.7%) and squirrels (n = 28, 33.3%). The Japanese white-eye tended to visit more frequently in the morning (n = 34, 60.7%) than in the afternoon (n = 22, 39.3%). Between 08:00 h and 10:00 h, the Japanese white-eye (n = 16) visited more frequently than the squirrels (n = 3). In some instances, insects, including honeybees (*Apis mellifera* L. *and A. cerana* F.), visited. Other bird species were observed on the study site (e.g., the Eurasian tree sparrow, *Passer montanus dybowskii* D.; Great tit, *Parus major minor* T.; Chestnut-eared bunting, *Emberiza fucata fucata* P.; Yellow-throated bunting, *Emberiza elegans elegans* T.; Long-tailed tit, *Aegithalos caudatus caudatus* L. and Black-billed magpies, *Pica pica sericea* G.). These birds did not visit the flowers of the Japanese Camellia during the observation period.

The Japanese white-eye and the squirrels went to the open flowers of the Japanese Camellia and moved among them. Pollen was deposited on the bill, forehead and body of the Japanese white-eye and on the ventral sides and forehead of the squirrels.

Discussion

In Korean Japanese Camellia, nectar volume secreted in the early morning (08:31-10:30 h) was nearly double that secreted during the other daytime periods between 10:31-16:30 h. Moreover, nectar secreted at night was nearly four times that produced during the day. We observed the Japanese white-eye to be the most frequent visitor during the day, and their activity peaked

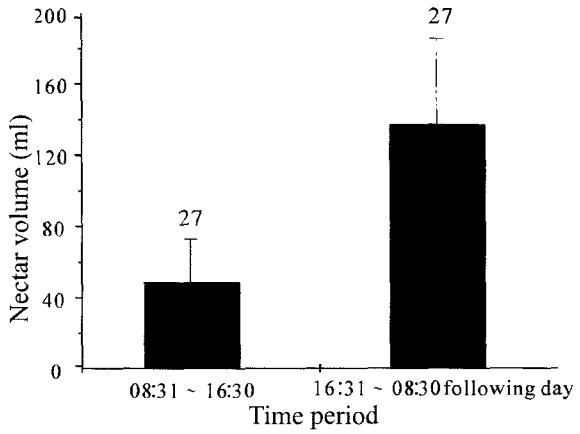

Fig. 2. Mean nectar secretion during the day (08:31-16:30 h) and during the late afternoon and overnight (16:31-08:30 h). Mean ± S.D and the sample size is given above each bar.

during the morning hours when nectar secretion also peaked. However, we did not make observations in the period between late afternoon the following early morning when nectar production was most pronounced. Because nectar secretion at night correlates with pollinator activities in many other plant families, it is highly probable that nocturnal animals such as bats or moths visit the Japanese Camellia inflorescences during the night. Many bat pollinated flowers have similar floral color (Proctor et al., 1996).

We also observed squirrels frequently visiting Japanese Camellia. Proctor et al. (1996) and Kwok and Corlett (2000) reported that the Japanese white-eye suckled the juices of fruits as well as the nectar of flowers. Yumoto (1987) reported that the Japanese Camellia was visited by the Japanese white eye in a forest on Yaku Island in Japan. Squirrels as floral visitors of the Japanese Camellia had not been noted previously, and this report is the first for floral visitation by non-flying mammals in Korea.

In this study, nectar secretion varied across the day. For many pollinators, floral-visitation patterns are correlated with seasonal and daily variations in nectar volume (Rathcke, 1992). For example, the nectar secretion of *Cayratia japonica* (Vitaceae) had two diurnal peaks; one at 1100 and a second at 1500 h. The visitation of the insect pollinators is correlated with nectar secretion (Kakutani et al., 1989). In another example, nectar secretion in *Durio* sp. (Bombacaceae) peaked during the early morning and visitation of the bird pollinators also peaked with nectar secretion (Yumoto, 2000).

Japanese Camellia is widely distributed in Japan and adjacent islands, and the southern Korean peninsula. This report is the first description of diurnal nectar secretion pattern, and total secretion over the day and night for the Japanese Camellia. Future studies that evaluate the interaction between the Japanese Camellia and its visitors and concentration and contents of nectar are encouraged.

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