(Original Paper)

Pollen Production of Mature *Quercus gilva* in Southern Kyoto

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To clarify the differences in pollen yield among various tree species, we measured annual pollen production rates in pure and mixed stands of mature and aged trees of *Quercus gilva* in the vicinity of central Japan. Pollen production was determined on an areal basis from the number of fallen male catkins and the mean number and dry weight of pollen grains contained in male catkins before pollen release. Ten trees were sampled to estimate production rates for 1998 and 1999. In addition, the mean amount of pollen contained in catkins before flowering was measured in 2001 for a *Q. gilva* tree on the Kyoto Prefectural University campus. The production rate for the five trees of the pure stand was 31.3×10^{12} grains/ha/yr in 1998 and 55.9×10^{12} grains/ha/yr in 1999; estimated pollen dry weights were 330 and 590 kg/ha/yr, respectively. These values for *Q. gilva* were higher than those of four other *Quercus* species in Japan. The high rate of pollen production was probably a function of the high forest ecosystem productivity due to the warm-temperate climate, in addition to the fact that the trees studied were generally fully mature. Further, the year-to-year variation in pollen production was low, in common with other *Quercus* species, although our data relate to only two years of study.

Key Words : male flower, pollen, *Quercus gilva*, production rates, warm-temperate zone

Introduction

Understanding the annual production rates of pollen grains (by number) in forest stands is important for analyzing pollen diagrams for cores and for evaluating airborne pollen levels. In addition, such understanding is essential for studies on the sexual reproduction of higher plants. However, there is not enough information about pollen production rates per unit land area of forest ecosystems (e.g., Hashizume *et al.*, 1992 ; Kiyonaga, 1991 ; 1994 ; Kunitomo and Saito, 1996 ; Saito, 1994a, b ; 1995 ; Saito *et al.*, 1987a, b ; 1989 ; 1991a, b ; 1996). Observations of pollen production by dry weight are also important for studies on primary production in forest ecosystems. Pollen production rates by dry weight are high when considered in relation to above-ground net production rates of 10-20 t/ha/yr (Kira, 1977b). For example, pollen production rates of 0.6 t/ha/yr were reported for stands of *Castanopsis cuspidata* (Saito *et al.*, 1987a) and *Alnus japonica* (Saito *et al.* 1996), while rates of 1 t/ha/yr or more have been measured for *Cryptomeria japonica*.

Rates of pollen production for a wide range of species are needed for studies on pollen analysis, pollinosis, sexual reproduction and primary productivity. The objective of our study was to measure production rates of the number and dry weight of pollen grains per hectare of stand of mature and aged trees of *Quercus gilva* Blume (*Cyclobalanopsis gilva* (Blume) Oerst.) (Fagaceae)

Table 1. General description of the study site.

Location:	In the precinct of Wakidenomiya Shrine (Yamashiro-cho, Souraku-gun, Kyoto Prefecture) Longitude, 135°49'16" E; Latitude, 34°46'18" N Altitude, ca. 30 m
Climate:	Mean temperature, 14.6℃ (13.8 - 15.4℃) Annual precipitation, 1,416.6 mm (1,125 - 1,747 mm) Warmth index, 117.5℃ month; Coldness index, −2.4℃ month
Quercus gilva sampled:	DBH, 47 cm (Tree# 7) to 79 cm (Tree# 6) Tree height, 17 m (Tree# 3) to 25 m (Tree# 6)
Vegetation:	(listed in order of dominance) Canopy stratum: (south side) *Quercus gilva* (north side) *Quercus gilva, Cinnamomum camphora, Quercus glauca, Ilex chinensis* Sub-tree stratum: *Quercus gilva, Quercus glauca, Ilex chinensis, Cleyera japonica, Cinnamomum japonicum, Camellia japonica, Ilex intergra, Ligustrum japonicum, Podocarpus macrophylla, Acer palmatum* subsp. *palmatum, Actinodaphne lancifolia, Photinia glabra*

Meteorological data: cited from the Normals for the period 1971 - 2000 at Kyotanabe Meteorological Station (Log. 135°46.5' E; Lat. 34°48.5' N; Alt. 50 m) (Japan Meteorological Agency, 2001).

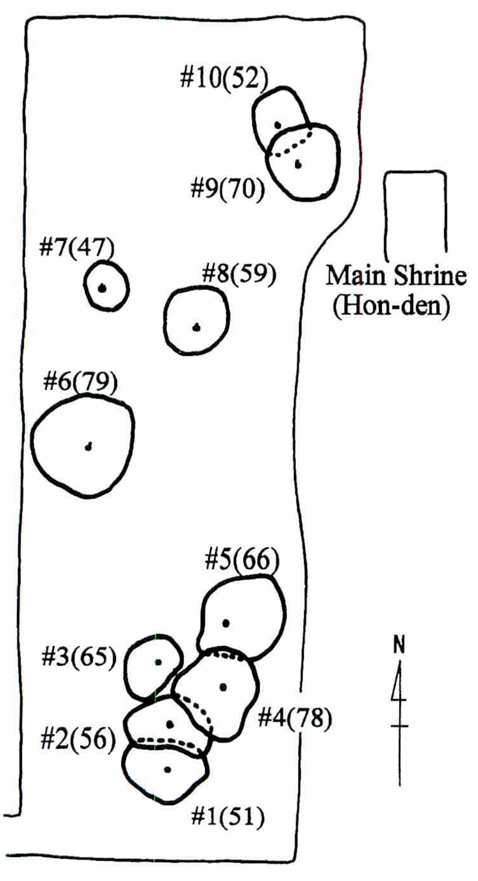

Fig. 1. Map of 10 *Quercus gilva* studied in the precinct of Wakidenomiya Shrine (34°46'18"N, 135°49'16"E; alt. ca.30 m).

Figures in parentheses represent DBH in cm.

growing in the warm-temperate zone. We were able to clarify some interspecific differences among *Quercus* species, particularly with respect to dry-matter production.

Materials

Quercus gilva (*ichiigashi* in Japanese) is an evergreen broadleaf tree. Male flowers are minute, arranged singly on thread-like stems, and hang down in tassel-like clusters from buds on current-year shoots. The pollen is dispersed by wind. This species is an abundant tree in the lucidophyllous forest zone, where it is restricted to Kyushu, Shikoku and the Pacific coast of Honshu southwest of Mt. Kiyosumi-yama (Chiba Prefecture) and Hachioji (Tokyo) (Hayashi, 1969). *Q. gilva* is rare on Honshu north of 35° N (Hayashi, 1969). Hatiya (1977) stated that "a [forest] type dominated by *Cyclobalanopsis gilva* (*Q. gilva*) seems to have once occupied well-drained lowlands and foothills, but has been almost completely destroyed as it gives way to agricultural fields and settlements."

The study site is located in the precinct of Wakide-no-Miya Shrine, Yamashiro-cho, Kyoto Prefecture, central Japan (see Table 1). The topography is flat. The site is situated in the lucidophyllous or evergreen broadleaf forest zone, judging from Kira's Warmth and Coldness Indices (Table 1), which delimit the various forest zones in Japan (Kira, 1977a). The study site is located near the northern limit of the natural distribution of *Q. gilva* (Suganuma, 1993; Hayashi, 1969).

Ten mature and aged trees of *Q. gilva* were sampled at the site to measure the annual production rates of male flowers and pollen. Samples were taken from a rectangular plot (30 m by 150 m: see Fig. 1). The southern part of the plot, where Trees #1 to #5 were sampled, contained a pure stand of *Q. gilva*. The overstorey of the northern portion of the plot, where Trees#6 to #10 were sampled, was a mixed stand of *Q. gilva* with other evergreen broadleaf trees, *Cinnamomum camphora*, *Q. glauca* and *Ilex chinensis*.

Stem diameters at breast height (DBH) of the sampled trees were within the range of 47 - 79 cm (see Table 1 and Fig. 1). No attempts were made to determine tree age or whether the study trees were natural or planted.

Methods

The male catkins of *Q. gilva* make an abscission layer between the catkins and the twig after flowering. The catkins then separate from the twig at the abscission layer and fall without breaking. This makes collection of fallen catkins a reliable method of determining pollen production. The annual pollen production rate per ha (P) was obtained from the product of the number of open male catkins per ha (C) and the mean amount of pollen (p) contained in catkins just before pollen release.

$$P = p\,C \qquad (1)$$

Male flower/catkin production

The annual production rates of male catkins of *Q. gilva* per hectare of stand were measured with litter traps. The traps had a 50 × 50-cm mouth and contained a water-permeable Terylene gauze (0.2-mm mesh) bag (45 cm deep). Four traps were set under the crown of a sample tree to the north, south, east and west of the trunk, as shown in Fig. 2. The mouth was about 0.7 m above the ground.

The litterfall survey was conducted from 13 March 1998 to 24 December 1999.

The contents of the litter traps were collected at the beginning of each month. After collection, fallen litter in each trap was sorted into open (pollen released) and unopen catkins. The number and dry weight of each component was recorded for each trap. After drying at 85℃ for 48 h, catkins were weighed to ± 1 mg .

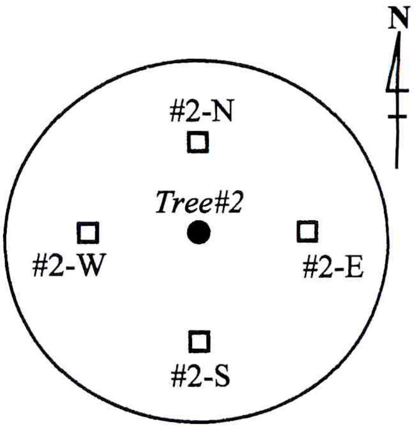

Fig. 2. Layout of four litter traps (each with a mouth 0.5 m by 0.5 m) in relation to tree trunk and crown.

Estimation of pollen production

The amount of pollen contained in catkins before flowering was measured as follows. The mean amount (by both number and dry weight) of pollen per stamen (p'') and mean numbers of stamens per flower (s') and flowers per catkin (f) were measured. From the products of these figures, the mean amount of pollen per flower (p') and per catkin (p) were:

$$p = f\,p' \qquad (2)$$

where $p' = s'\,p''$ (3).

Further, the total number of stamens per catkin (s) was

$$s = f\,s' \qquad (4).$$

The crowns of trees at the study site were too high to collect sample twigs for measuring p'', s' and f. These measurements were therefore obtained from a *Q. gilva* tree (DBH, 36 cm; tree age > 50 yr) on the campus of Kyoto Prefectural University. Several twigs bearing male catkins were obtained during the flowering period on 29 May 2001. Male catkins before pollen release were sampled from the twigs and the amount of pollen was measured immediately.

The number of pollen grains per stamen (anther) on a sample slide was counted at ×100 magnification using an optical microscope equipped with a mechanical stage and an ocular micrometer (10 mm long). One stamen was removed randomly from each of 30 catkins (i.e. 30 stamens in total), and a mean value of *p*" (number of pollen grains) obtained. To measure the weight of pollen, the pollen contained in 10 to 16 stamens from two flowers in a catkin was washed into water (0.3-0.5 cm^3) held in 3 hollows on a glass slide. The weight of these slides at room temperature was measured to ± 0.01 mg with a balance (Sartorius 2024MP6) after drying at 85℃ for 48 h. The dry weight of pollen grains per stamen was determined as the difference between the weight of a slide with pollen and its initial weight. The total sample size for assessing the weight of pollen was 183 stamens or 15 slides, collected from 42 catkins.

The mean number of stamens per flower (*s*') was averaged for 200 flowers sampled from 40 catkins. Flowers were sampled from catkins by dividing the catkin into five segments of equal length and selecting one flowers per segment.

One hundred and forty six current-shoots were taken to count the number of flowers borne on catkins. The mean number of flowers per catkin (*f*) was averaged for all 413 catkins borne on these 146 shoots.

In 1999, Hayashi (2000) used the same method to measure the amount of pollen on the same tree of our university campus (Kyoto Prefectural University). Several twigs were collected on 28 May 1999 before flowering had commenced, put into vases with plastic bags, and left for a few days in the laboratory. These catkins were subsequently used to measure the amount of pollen per stamen. In addition, sound catkins were sampled randomly to measure the number of flowers per catkin.

The values in 2001 were used to estimate pollen production rates per hectare of stand at the study site, although we did not measure the catkin production rates in this year.

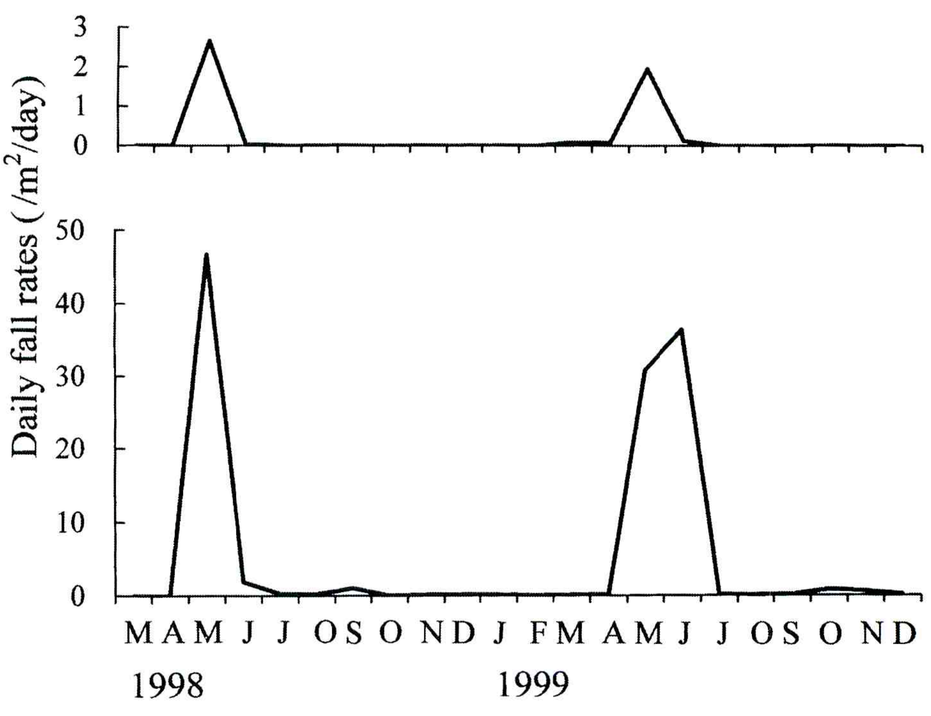

Fig. 3. Seasonal fluctuations in the daily fall rate of closed catkins (upper) and open catkins (lower) of *Quercus gilva*.

Daily fall rate: mean for the 40 litter traps under the ten sample trees averaged by the number of days in the collection period.

Results and Discussion

Seasonal rhythm of catkin fall

Figure 3 shows the seasonal rhythm in daily fall rate (by number) of open and closed catkins during the study period. The daily fall rate represents the average daily rate for the month of collection calculated from the average litter trap yields of the 10 sampled trees.

The fall of both open and closed catkins showed a conspicuous seasonal peak (Fig. 3). The fall rate of open catkins in May 1998 amounted to 93% of the annual total, with the value for June decreasing to only 3.4%. In 1999, the peak was distributed over two months, May and June. The combined fall for the two months was 97% of the annual total.

Slight peaks of open catkin fall were found in September 1998 and October 1999 (Fig. 3). These peaks in autumn seemed to be caused by out-of-season flowering, as evidenced by the freshness of fallen catkins and the fact that they occurred in only two trees (Trees#6 and #9). Apart from this fall in autumn, and the two much larger peaks in May and/or June, falls of open catkins at other times were negligible. Closed catkins fell during the flowering time, and before and after that (from April to June), but no falls were observed in other months.

Annual fall rates of catkins per unit land area

The number (Table 2-1) and dry weight (Table 2-2) of male catkins collected from litter traps for 1988 and 1999 were collected over the periods May 1977 - April 1998 and May 1998 - December 1999 respectively. These periods corresponded to annual production for each sample tree because the fall of open catkins had finished within a year of flowering (Fig. 3).

Large differences among the 10 sample trees were recorded within the range 240.0 /m^2/yr (Tree#7) to 3,006.3 /m^2/yr (Tree#5) in 1998 and 202.7 /m^2/yr (Tree#7) to 3,970.0 /m^2/yr (Tree#5) in 1999 (see Table 2). The low producing trees (Trees#7 to #10) grew in the mixed stand in the north of the study plot. The most unproductive tree (Tree#7) had the smallest DBH (see Fig. 1); however there was too much variation to see anything other than a general trend between DBH and production rate.

The mean values for Trees#1 to #5 and for Trees#6 to #10 (Table 2) show that there was a difference in catkin production between the trees of the southern (pure stand) and northern (mixed stand) parts of the study site. The mean production rate of open catkins for Trees#1 to #5 was higher than that of Trees#6 to #10 in both 1998 and 1999, there being a 2-fold difference in 1999. The catkin production rates for individual trees were higher in 1999 than in 1998 for all five trees in the pure stand, the difference ranging from 1.3 times for Tree#5 to 3.0 times for Tree#1. In the mixed stand, Tree#6 also had a higher catkin production rate in 1999, but for Trees#7 to #10 the difference was very slight or even the reverse.

The annual variation in the production of male flowers of *Q. gilva* appears to be relatively low, as has also been reported for evergreen oak *Q. acuta* (Kiyonaga, 1994), deciduous oak *Q. serrata* (Kiyonaga, 1991; Kunitomo, 1997; Saito *et al.* 1987b; 1991b) and *Q. mongolica* var. *grosseserrata* (Kunitomo, 1997; Saito *et al.* 1988; 1989).

The number of closed catkins accounted for 5% of the annual total number of catkins in 1998 and 3% in 1999. Based on dry weight, the closed catkins represented only around 2% in both years. The total production rate (by dry weight) of all male catkins in Trees#1 to #5 amounted to 582.0 kg/ha/yr in 1998 and 974.0 kg/ha/yr in 1999 (Table 2-2). The estimated pollen content of closed catkins was excluded from these values.

Amount of pollen per stamen, flower and catkin

Table 3 shows mean values for i) male flowers per catkin (f), ii) stamens per flower (s'), and iii) number and dry weight of pollen grains per stamen (p''). These data were used to calculate the amount of pollen per flower (p') and per catkin (p), which are also presented in Table 3. The mean number of pollen grains per stamen p'' in 2001 was 5,163 ± 733 (± standard deviation), with 93% of sampled stamens having 4,000 - 6,500 grains. The mean dry weight of pollen per stamen was 0.0548 mg, giving a mean dry weight per pollen grain of 10.6×10^{-6} mg.

Seventy-eight percent of sampled flowers had 9 to 11 stamens (Fig. 4). The number of stamens per flower tended to decrease slightly from the base to the tip of catkins. Figure 5 shows a histogram of the number of flowers borne on male catkins.

Table 2. Annual fall rates of male catkins measured with litter traps set under the crowns of 10 *Quercus gilva*.

(1) Mean numbers (/m²/yr) of catkins for four litter traps

	Flowering in 1998[1]			Flowering in 1999[2]		
Trees	Open	Closed	Total	Open	Closed	Total
#1	1,009.0	68.0 (6.3)[3]	1,077.0	3,058.0	52.0 (1.7)[3]	3,110.0
#2	1,182.0	38.0 (3.1)	1,220.0	2,654.0	248.0 (3.1)	2,902.0
#3	2,174.0	52.0 (2.3)	2,226.0	3,066.0	160.0 (5.0)	3,226.0
#4	1,458.3	21.0 (1.4)	1,479.3	3,037.0	32.0 (1.0)	3,069.0
#5	3,006.3	81.3 (2.6)	3,087.7	3,970.0	125.0 (3.1)	4,095.0
#6	2,720.0	312.0 (10.3)	3,032.0	3,524.0	83.0 (2.3)	3,607.0
#7	240.0	13.0 (5.1)	253.0	202.7	10.0 (4.7)	212.7
#8	910.0	45.0 (4.7)	955.0	1,178.0	23.0 (1.9)	1,201.0
#9	1,585.0	122.0 (7.1)	1,707.0	637.0	14.0 (2.2)	651.0
#10	1,859.7	115.0 (5.8)	1,974.7	537.0	10.0 (1.8)	547.0
Mean	1,614.4	86.7 (4.9)	1,701.2	2,186.4	75.7 (3.2)	2,262.1
Mean for Trees#1 to #5	1,765.9	52.1 (3.2)	1,818.0	3,157.0	123.4 (3.9)	3,280.4
Mean for Trees#6 to #10	1,462.9	121.4 (6.6)	1,584.3	1,215.7	28.0 (2.6)	1,243.7

1: Flowering in 1998: measured from 30 April 1998 to 28 April 1999 (recalculated from Mori, 1999).
2: Flowering in 1999: measured from 28 April 1999 to 24 December 1999.
3: Numbers in brackets are percent of total.

(2) Mean dry weight (g/m²/yr) of catkins for four litter traps

	Flowering in 1998[1]			Flowering in 1999[2]		
Trees	Open	Closed	Total	Open	Closed	Total
#1	33.42	0.97 (2.8)[3]	34.39	85.92	0.78 (0.9)[3]	86.70
#2	37.52	0.67 (1.7)	38.18	74.16	3.02 (3.9)	77.18
#3	67.62	0.78 (1.1)	68.41	89.65	2.12 (2.3)	91.78
#4	45.03	0.42 (0.9)	45.47	90.00	0.71 (0.8)	90.71
#5	103.01	1.54 (1.5)	104.55	138.45	2.20 (1.6)	140.64
#6	83.17	3.70 (4.3)	86.87	89.79	1.49 (1.6)	91.28
#7	11.99	0.20 (1.6)	12.18	6.54	0.31 (4.5)	6.85
#8	29.34	0.93 (3.1)	30.27	36.01	0.47 (1.3)	36.48
#9	50.54	1.53 (2.9)	52.08	15.67	0.14 (0.9)	15.81
#10	48.51	1.69 (3.4)	50.20	14.70	0.12 (0.8)	14.83
Mean	51.02	1.24 (2.3)	52.26	64.09	1.14 (1.9)	65.23
Mean for Trees#1 to #5	57.32	0.88 (1.6)	58.20	95.64	1.77 (1.9)	97.40
Mean for Trees#6 to #10	44.71	1.61 (3.0)	46.32	32.54	0.50 (1.8)	33.05

1: Flowering in 1998: measured from 30 April 1998 to 28 April 1999 (recalculated from Mori, 1999).
2: Flowering in 1999: measured from 28 April 1999 to 24 December 1999.
3: Numbers in brackets are percent of total.

Table 3. Mean numbers of flowers and stamens of *Quercus gilva* male catkins, and the mean pollen amount per stamen, flower and catkin.

(1) In 2001

	M±SD	Range	Sample size (n) etc.
Number of			
Flowers per catkin (f)	34.7±7.7	3-52	n= 413 catkins, all ones borne on 146 current shoots
Stamens per flower (s')	9.85±1.28	7-13	n= 200 flowers, taken from 40 catkins
Pollen per stamen (p'')			
Number	5,163±788	3,790-6,490	n= 30 stamens, one from a catkin
Dry weight	0.0548 mg		n= 183 stamens, total 10-16 stamens from 2 flowers
Pollen per flower (p')			
Number	50.9×10^{3}		= 9.85×5,163
Dry weight	0.539 mg		= 9.85×0.0548 mg
Pollen per catkin (p)			
Number	1.77×10^{6}		= 9.85×5,163×34.7
Dry weight	18.7 mg		= 9.85×0.0548 mg×34.7
Mean dry weight of grains	10.6×10^{-6} mg per grain		= 0.0548 mg÷5,163

M±SD: mean±standard deviation.

Sample twigs were taken on 29 May 2001 from a *Q. gilva* tree (DBH = 36 cm, tree age >50 yr) during flowering on the campus of Kyoto Prefectural University.

(2) In 1999 (Hayashi, 1999)

	M±SD	Range	Sample size (n) etc.
Number of			
Flowers per catkin (f)	40.7±6.8	24-51	n= 45 catkins, taken randomly
Stamens per flower (s')	10.1±1.17	8-12	n= 30 flowers, from 10 catkins taken randomly
Pollen per stamen (p'')			
Number	4,532±823	3,530-5,860	n= 10 stamens, two from each catkin
Dry weight	0.0546 mg		n= 50 stamens, total 10 stamens from a catkin
Pollen per flower (p')			
Number	45.9×10^{3}		= 10.1×4,532
Dry weight	0.553 mg		= 10.1×0.0553 mg
Pollen per catkin (p)			
Number	1.87×10^{6}		= 10.1×4,532×40.7
Dry weight	22.5 mg		= 10.1×0.0553 mg×40.7
Mean dry weight of grains	12.0×10^{-6} mg per grain		= 0.0546 mg÷4,532

M±SD: mean±standard deviation.

Sample twigs were taken on 28 May 1999, before flowering had commenced, from the *Quercus gilva* tree (see the footnote of Table 3-1), put into vases with plastic bags, and left for a few days in the laboratory.

One-third of the catkins had 36-40 flowers, and 81.3% of catkins had 26 to 45 flowers. There were a few small/short catkins with only two flowers and large/long catkins with 53 flowers. The means and standard deviations of flower counts are shown in Table 3.

The mean amount of pollen contained in the male catkins measured in 2001, and calculated using Eqs.(2) and (3), is shown in Table 3-1. The mean number of pollen grains per flower (p') and per catkin (p) was 50.9×10^{3} and 1.77×10^{6}, respectively; by dry weight, the values were p'= 0.539 mg and p = 18.7 mg.

As described in the methods, these pollen measures for individual catkins, flowers and stamens were also measured from the tree at Kyoto

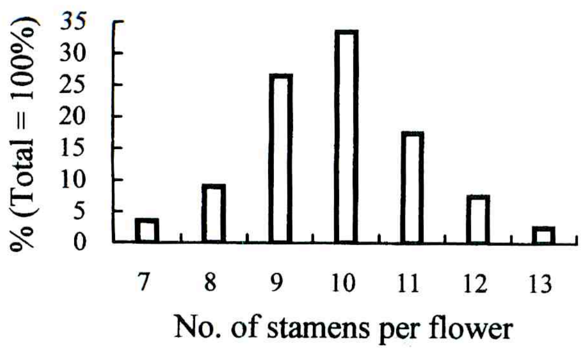

Fig. 4. Histogram of the number of stamens borne on male flowers of an individual *Quercus gilva* on the campus of Kyoto Prefectural University sampled in 29 May 2001 (sample size = 200 flowers, taken from 40 catkins).

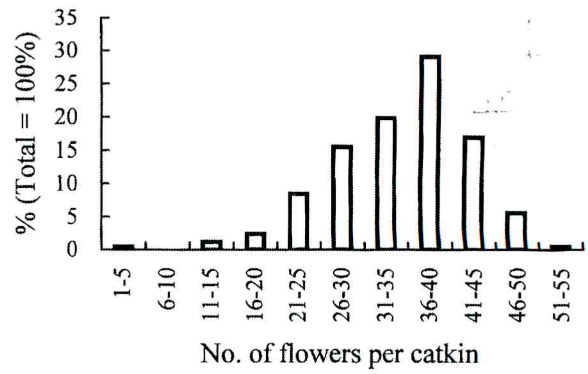

Fig. 5. Number of flowers borne on male catkins of an individual *Quercus gilva* on the campus of Kyoto Prefectural University sampled in 29 May 2001 (sample size = 413 all catkins borne on 146 current shoots).

Prefectural University in 1999 (Table 3-2). The number of pollen grains per stamen and stamens per catkin were greater in 1999 than in 2001 (Table 3-1). However, there were no marked differences in pollen weight per stamen or number of stamens per flower between the two years. The values for the number of pollen grains per catkin (p) were approximately equal in 1999 and 2001, while the dry weight was 1.2 times higher in 1999.

Annual production rate of pollen per unit land area

The annual rate of pollen production per hectare (P) was estimated by number and dry weight with Eq.(1), using the C value for each year (Table 2-1) and the p value in 2001 (Table 3-1); the results are shown in Table 4.

The production rates (by number) for Trees#1 to #5, representing values for a pure stand, were 31.3 $\times 10^{12}$ /ha/yr in 1998 and 55.9$\times 10^{12}$ /ha/yr in 1999. Compared to other trees, pollen production of *Q. gilva* is similar to *Alnus sieboldiana*, 23.1 - 30.3 $\times 10^{12}$ /ha/yr (Saito, 1995), *Alnus pendula*, 23.9 - 40.1$\times 10^{12}$ /ha/yr (Saito, 1994a), *Alnus japonica*, 21.6 - 49.2$\times 10^{12}$ /ha/yr (Saito *et al.*, 1996), *Q. serrata*, 8.92 - 25.3$\times 10^{12}$ /ha/yr (Saito *et al.*, 1991b), *Castanea crenata*, 23.6$\times 10^{12}$ /ha/yr (Saito, 1995) and *Castanopsis cuspidata*, 28.5 - 85.8$\times 10^{12}$ /ha/yr (Saito, 1995).

The ratio of the production rate in 1999 to that in 1998 was 1.8. The year-to-year variation in pollen production rates is closely related to seed production. The Max/Min ratio, representing the ratio of maximum to minimum values of pollen production within a stand, is considered to be an important index of sexual reproduction strategy of trees. Compared to other trees species, the Max/Min ratio of *Q. gilva* is similar to *A. sieboldiana* (1.1 - 2.8), *A. pendula* (1.4 - 2.1) and *Q. serrata* (1.5 - 1.9), but lower than *A. japonica* (4.4 - 5.2), *Castanea crenata* (4.6), and *Castanopsis cuspidate* (1.6 - 12).

On the other hand, the pollen production rates by dry weight for Trees#1 to #5 (Table 4) were higher than *Alnus sieboldiana* (Saito, 1995), *Alnus pendula* (Saito, 1994a), *A. japonica* (Saito *et al.*, 1996), *Quercus serrata* (Saito *et al.*, 1991b), *Castanea crenata* (Saito, 1995) and *Castanopsis cuspidata* (Saito *et al.*, 1987a). We attribute this higher mass of pollen production by *Q. gilva* to differences in the weight of individual pollen grains of each species, since the numbers of grains produced by each species are similar.

The total mass of pollen, open catkins and unopen/closed catkins was estimated at 912.2 kg/ha/yr in 1998 and 1,564.4 kg/ha/yr in 1999, of which, pollen accounted for about 37% and closed catkins about 1%. This total male flower component in 1999 corresponded to 7.6% of the mean above-ground net production of warm-temperate evergreen broadleaf forests (20.65 t/ha/yr; Kira, 1977b); the mean for the two years

Table 4. Estimation of pollen production rates (*P*) of *Quercus gilva*.

Year of flowering	1998	1999	Mean
(1) Mean for 10 trees			
Number (grains/ha/yr)	28.6×10^{12}	38.7×10^{12}	33.6×10^{12}
Dry weight (kg/ha/yr)	302 (36.6%)	409 (38.5%)	355 (37.7%)
(2) Mean for Trees#1 to #5			
Number (grains/ha/yr)	31.3×10^{12}	55.9×10^{12}	43.6×10^{12}
Dry weight (kg/ha/yr)	330 (36.2%)	590 (37.7%)	460 (37.2%)

P, calculated from Equation 1.
(%), percentage of pollen to male catkins including pollen.

(1,238.3 kg/ha/yr) was equal to 6.0%.

Comparison of pollen production among *Quercus* stands

Table 5 provides a summary of the annual rates of pollen production (by number and dry weight) in stands of *Quercus* species in Japan. The various values were obtained by similar methods to this study. The number of open flowers per hectare of stand, the *C* value in this study, was measured with litter traps. The mean amount of pollen per flower, the *p* value, was either measured or cited from references on the same species. There are data for three deciduous species from the subgenus *Quercus* and two evergreen species from the subgenus *Cyclobalanopsis*. The former are *Q. acutissima*, *Q. mongolica* var. *grosseserrta* and *Q. serrata*, which are abundant in the primary stage of succession and secondary forest. The latter are *Q. gilva*, this study, and *Q. acuta*, representative of climax lucidophyllous forest in the warm-temperate zone of Japan. The stands in Table 5 are listed in order of stand age, from old to young.

The pollen production rates by number were in the range of 1 - 10×10^{12} for *Q. acutissima*, *Q. mongolica* var. *grosseserrta*, *Q. serrata* (except aged stands), and *Q. acuta*. Three stands of aged and mature *Q. serrata* were reported to have production rates often exceeding 10×10^{12}. The production rates of evergreen oak *Q. gilva* in this study were larger than those of aged and mature *Q. serrata* stands.

On the other hand, *Q. acuta*, another evergreen oak, showed low pollen production rates. The large difference between *Q. acuta* and *Q. gilva* may be caused by the relatively young age of *Q. acuta* trees sampled, because the *Q. acuta* stand studied by Kiyonaga (1994) was about 50 years old. For *Cryptomeria japonica* stands in a productive year, flower and pollen production rates increase with increasing age of the stand up to 50 years, showing a constant upper limit for several hundred years thereafter (Saito, 1995). It is obvious that the age for this sill in production varies with tree species, and is higher for climax tree species than for pioneer species. Therefore, the trees from the *Q. acuta* study had probably not reached the age of most abundant flower and pollen production.

Between year variation in pollen production rates for the five deciduous species reviewed is low (Table 5). The ratio of maximum to minimum values in a stand, the Max/Min ratio, ranges from 2 to 4, apart from an exceptionally large value of 7.7 from a young *Q. acutissima* stand studied over an 11-year period. The Max/Min ratios of evergreen *Quercus* were small. However, the data are based on only two stands studied over a short period.

With respect to the climate, most stands of deciduous *Quercus* were situated near the boundary between warm and cool temperate zones and the lower part of the cool-temperate zone. Kira (1977b) found that net production rates of forest ecosystems were positively correlated with the Warmth Index. Therefore, low pollen yield in stands of deciduous species of *Quercus* might be caused by the cool climate. However, there have also been reports of low rates for *Q. serrata* in the warm-temperate zone, but these were for a secondary stand of age < 30 yr (Kiyonaga, 1991). It is therefore concluded that the high pollen yield of mature and aged *Q. gilva* trees was probably a results of the high forest productivity, which in turn was a function of the warm-temperate climate.

Table 5. Pollen production rates of *Quercus* forest stands.

Species and stand age	No. years studied	No. of grains ($\times 10^{12}$ /ha/yr) Mean	Min	Max	Dry weight (kg/ha/yr) Mean	Min	Max	Authority
Quercus acutissima, 40-50 yr, secondary and natural	11	1.426	0.358	2.752	14.61	4.31	25.02	Hashizume *et al.* (1992)
Q. acutissima, ca.10 yr, seed orchard	2	3.093	2.880	3.305	36.4	30.74	42.07	Hashizume *et al.* (1992)
Quercus mongolica var. *grosseserrata*, aged (c.250)	5	5.2	2.8	7.9	61	24	78	Saito *et al.* (1989)
Q. mongolica var. *grosseserrata*, aged (c.250), slope facing East	2	4.82	4.18	5.45	72.5	62.4	82.6	Saito *et al.* (1988)
Q. mongolica var. *grosseserrata*, aged (c.250), slope facing West	2	1.97	1.89	2.04	29.6	28.7	30.5	Saito *et al.* (1988)
Q. mongolica var. *grosseserrata*, aged (c.250)	2	8.4	7.2	9.6	96.5	82.8	110.1	Kunitomo (1997)
Q. mongolica var. *grosseserrata*, secondary (c.85 yr)	2	3.9	2.1	5.7	45.2	24.2	66.1	Kunitomo (1997)
Q. mongolica var. *grosseserrata*, secondary (c.75)	3	2.9	1.2	5.3	26	11	43	Saito *et al.* (1989)
Quercus serrata, aged (ca.200 yr)	5	25.3	20.7	31.2	266	141	356	Saito *et al.* (1991)
Q. serrata, aged (ca.200 yr)	2	24.0	23.7	24.3	212	209.3	214.7	Kunitomo and Saito (1996); Kunitomo (1997)
Q. serrata, mature (ca.150 yr)	2	14	12	16	120	100	140	Saito *et al.* (1987)
Q. serrata, secondary (ca.85 yr), on upper slope	2	9.05	7.70	10.4	80.4	68.6	92.2	Kunitomo and Saito (1996); Kumitomo (1997)
Q. serrata, secondary (ca.85 yr), on lower slope	2	7.40	6.90	7.90	65.2	60.9	69.5	Kunitomo and Saito (1996); Kumitomo (1997)
Q. serrata, secondary (ca.75 yr)	3	8.92	5.66	10.7	102	70.4	123	Saito *et al.* (1991)
Q. serrata, secondary (ca.70 yr), mixed with *Q. acutissima* (23% by B.A.)	10	1.66	0.701	2.73	17.9	7.55	29.4	Saito (unpub.)
Q. serrata, secondary (< 35 yr)	4	1.4	0.46	2.2	–			Kiyonaga (1991)
Quercus gilva, mature	2	43.6	31.3	55.9	460	330	590	This study
Quercus acuta, ca.50 yr	5	7.2	5.0	9.7	–			Kiyonaga (1994)

No. of years studied: consecutive years. B.A.: Basal area at breast height.

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Supplementary note

Akira MORI reported the pollen dry weight of *Q. gilva* as 0.11 mg per anther in Journal of Japanese Forestry Society Vol.83, No.2 in 2001. This value, corresponding to the *p*" in this study, was not measured, but estimated from the average 50% pollen content in anthers before opening, which was obtained from the differences between mean anther weight before and after pollen release of *Q. serrata* (Saito *et al.*, 1987b).

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(*, tentatively translated)

京都府南部にあるイチイガシ成熟木の花粉生産

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単位面積当たりの花粉生産量を樹種間で比較研究する一環として，京都府相楽郡山城町の湧出宮境内にあるイチイガシ成熟木を調査した．林分花粉生産量の調査は，リタートラップ法で測定した面積当たり開花雄花序数と開花前の雄花序に含有する平均花粉量との積から行った．調査木を 10 本選び，その樹冠下に 4 個づつリタートラップを設置した．調査木の胸高直径は 47 ～ 79cm，樹高は 14m 前後である．調査は 1998 年と 1999 年に行った．また，雄花序の花粉量は京都府立大学構内の 1 個体で 2001 年に測定した．イチイガシ純林部での林分花粉生産量は 31.3×10^{12} と 55.9×10^{12} grains/ha/yr および 330 と 590kg/ha/yr となった．既報のコナラ属 5 種の値と比べると，今回のイチイガシの値が最も大きかった．これは調査木の樹齢が高いことのほかに暖温帯にあって一次生産力が大きいことに原因があると考えた．また，他のコナラ属の樹種と同様に花粉生産の年次変動は小さいと思われた．

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■用法・用量

通常、成人にはケトチフェンとして1回1mg（1カプセル）を1日2回、朝食後及び就寝前に経口投与する。なお、年齢・症状により適宜増減する。

（ザジテンシロップ・ザジテンドライシロップの用法・用量については添付文書をご参照下さい。）

■使用上の注意

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てんかん等の痙攣性疾患、又はこれらの既往歴のある患者［痙攣閾値を低下させることがある。］

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（1）気管支喘息に用いる場合、本剤はすでに起こっている発作を速やかに軽減する薬剤ではないので、このことを患者に十分説明しておく必要がある。
（2）長期ステロイド療法を受けている患者で、本剤投与によりステロイドの減量をはかる場合は十分な管理下で徐々に行うこと。
（3）眠気を催すことがあるので、本剤投与中の患者には自動車の運転等危険を伴う機械の操作には従事させないよう十分注意すること。

3. 相互作用　併用注意（併用に注意すること）

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4. 副作用（ザジテン）
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主な副作用は眠気（4.4%）、倦怠感（0.3%）、口渇（0.1%）、悪心（0.1%）等であった。
副作用（ザジテンシロップ、ザジテンドライシロップ）
総例11,620例中何らかの副作用が報告されたのは136例（1.2%）であった。
主な副作用は眠気（0.8%）であった。（再審査終了時までの集計）
（1）重大な副作用（頻度不明）
痙攣、興奮があらわれることがあるので、観察を十分に行い慎重に投与すること（乳児、幼児では特に注意すること）。

ザジテン点鼻液

■効能・効果　アレルギー性鼻炎

■用法・用量

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