PRODUCTION RATE OF
QUERCUS SERRATA POLLEN GRAINS IN A
SECONDARY *QUERCUS SERRATA* FOREST

Jota KIYONAGA

Abstract The production rate of *Quercus serrata* pollen grains from a secondary forest near Tokyo was estimated by measuring annual fall rates of male catkins and number of pollen in a male catkin. The estimated production rate ranges from 4.6×10^{11} to 2.2×10^{12} no. $ha^{-1}y^{-1}$ during 1988-1991. The mean value for the four years is 1.4×10^{12} no. $ha^{-1}y^{-1}$.

Key words: pollen grains production rate, *Quercus serrata*, secondary forest, Metropolis of Tokyo

1. Introduction

Results of pollen analysis are usually demonstrated by a pollen diagram based on the component percentage of fossil pollen grains of each taxon in certain horizon. However, the processes through which pollen grains are first released from anthers of parent plants, and finally fossilized within sediments are very complex. Thus component percentage in the pollen diagram does not directly represent the dominance of each taxon in the communities at that time. For this reason the dominance of each taxon might have been overestimated or underestimated. Therefore, detailed and quantitative studies of the processes from pollen release to their fossilization are required.

The investigation of production rates of pollen grains in a forest stand dominated by one species may offer fundamental information for palynological studies. Such studies were conducted about some arboreal species growing in Japan, as exemplified by *Pinus densiflora* (Saito *et al.*, 1984; Saito and Takeoka, 1985; Sekiguchi *et al.*, 1986), *Cryptomeria japonica* (Saito and Takeoka, 1987), *Chamaecyparis obtusa* (Saito and Takeoka, 1983), *Juglans mandshurica* subsp. *sieboldiana*, (Saito, 1986), *Castanopsis cuspidata* (Saito *et al.*, 1987a), *Quercus serrata* (Saito *et al.*, 1987b), *Quercus mongolica* var. *grosseserrata* (Saito *et al.*, 1988, 1989) and *Aesculus turbinata* (Saito *et al.*, 1990).

This study follows the same line above about *Quercus serrata* in human-impacted secondary forest. *Quercus serrata* belongs to *Quercus* subgenus *Lepidobalanus*, an important taxon for pollen analysis of the Holocene sediments in Japan.

2. Methods

This investigation consists of two steps: 1) the measurement of number of pollen grains contained in a male catkin just before the pollen release, and 2) the measurement of annual fall rates of male catkins. Multiplication of results of the above two measurements gives the production rate of pollen grains per unit area of the forest.

Step 1: Number of pollen grains on a catkin

Branches from four *Quercus serrata* sample trees (Table 1) with male catkins were collected in April 1988, 1989 and 1991, just before the anthers opened. Sample tree E grows in the study forest near Hachioji City, mentioned below, while other three sample trees A, B and D grow in secondary *Quercus serrata* forests in the western suburbs of Yokohama City, about 30 km southeast from the study forest (Fig. 1).

First, the number of male flowers per male catkin was counted for all catkins on the branches collected. Secondly, the number of anthers per male flowers was counted with a stereoscopic microscope for all male flowers on the male catkins selected arbitrarily from all of the catkins counted. Thirdly, the number of pollen grains per anther was counted for all or a part of anthers on the male flowers selected arbitrarily from all the male flowers counted. At this treatment an anther was torn by a needle, and pollen grains in the anther were washed out with a water drop on a slide glass. Then the water drop on the slide glass was evaporated in a desiccator, and pollen grains left on the slide glass were enclosed with glycerin and a cover glass. The number of pollen grains observed in the whole extent of the cover glass was counted
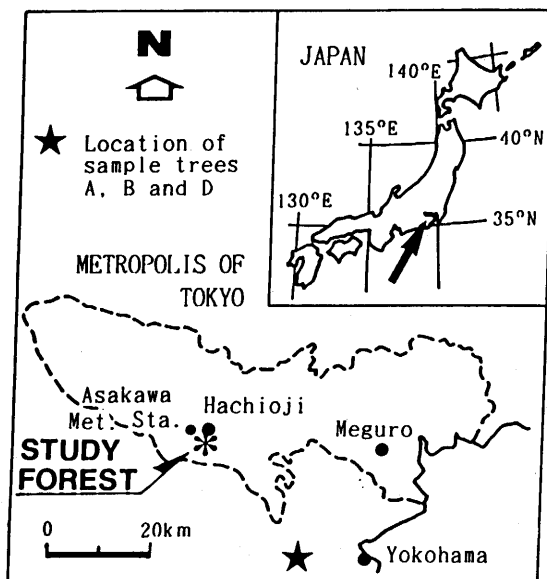

Fig. 1 Location of the study forest

Table 1 Dimensions of *Quercus serrata* sample trees

Sample trees	Location	DBH (cm)	Height (m)	Age (years)
A	Western suburbs of Yokohama	30	6	—
B	Western suburbs of Yokohama	20	4	—
D	Western suburbs of Yokohama	16	4	—
E	Near Hachioji	15	8	25

under ×100 magnification, using a biological microscope.

The number of pollen grains on a catkin is given by the multiplication of these three numbers counted.

Step 2: Fall rates of male catkins

Study forest

The study forest is situated on a north-facing terrace scarp at Kobiki-machi,

☐ Quadrat	⬤ A crown and the position of stem base of *Quercus serrata*
⬤ Litter trap	◯ A crown and the position of stem base of trees except *Quercus serrata*

O 20cm ≦ DBH
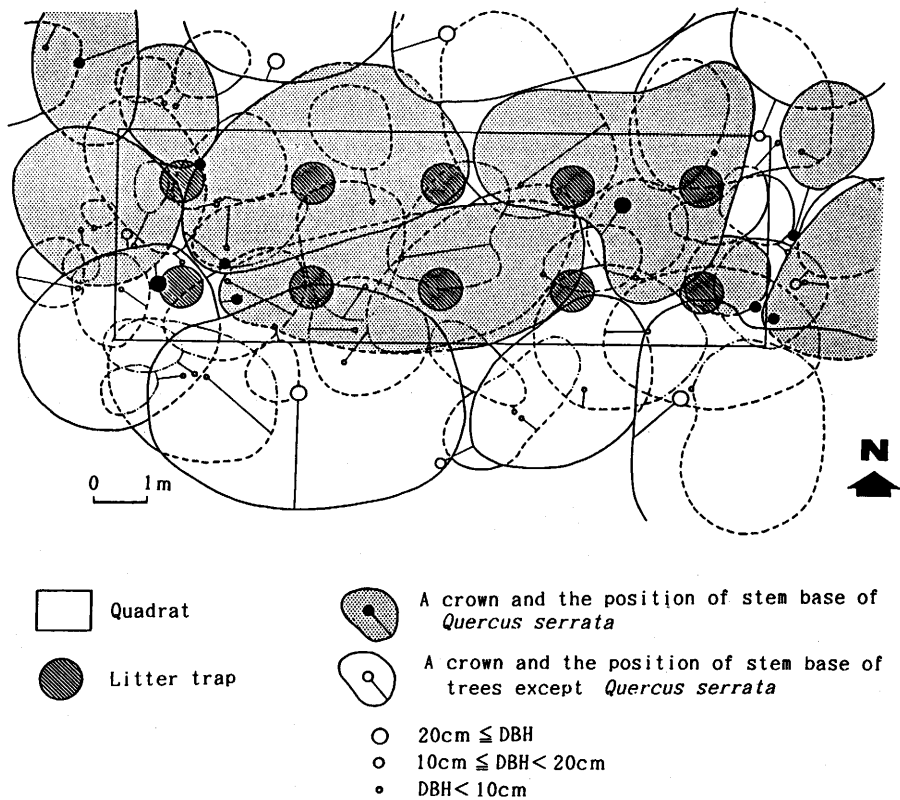o 10cm ≦ DBH< 20cm
o DBH< 10cm

Fig. 2 Crown projection diagram of the quadrat in the study forest

Hachioji City, Metropolis of Tokyo (Fig. 1). The forest is dominated by *Quercus serrata* and *Carpinus laxiflora* in a tree layer. A quadrat, 48 m² (12 m × 4 m) in area was set in a *Quercus serrata*-dominating stand located on a very gentle slope at a foot of the terrace scarp (Fig. 2). General description of the study stand is given in Table 2 with environmental data. The age of the biggest *Quercus serrata* tree is ca. 35 years. The study forest is a typical human-impacted secondary forest.

Measurement of fall rates of male catkins

Ten litter traps were installed in the quadrat during one month and a half in every spring from 1988 to 1991. The periods during which traps were installed are as follows: April 16, 1988-May 18, 1988; April 9, 1989-May 28, 1989; April 10, 1990-May 27, 1990; and April 16, 1991-May 26, 1991.

The litter trap used in this study is made of cotton cloth bag attached to a wire frame with a 80 cm diameter. The mouth area of a litter trap is 0.5 m². The height of the frame was 90 cm above the ground (Fig. 3). The number of male catkins of *Quercus serrata* trapped during the above period was counted.

Male flowers of *Quercus serrata* form a catkin. After flowering, the male catkins fall to the ground without destruction. Thus the number of fallen male catkins in a year must equal the number of male catkins produced per year. Some catkin, however, do not fall to the ground but hang on branches. In this study such catkins were ignored. Therefore the estimated fall rates of male catkins in this study may be underestimated.

Installation of litter traps all the year round is necessary to know the exact fall rates of male catkins. The period during which the litter traps were installed in this study is, however, limited to one month and a half. In order to confirm this period is not too short, one litter trap was exchanged on May 28, 1989, and was left till July 22, 1989. However, no male catkins fell during that period. This suggests most of male catkins produced fall during one month and a half after flowering in mid-April.

Table 2 General description of the study forest

Arboreal species in the quadrat (Tree height > 2m)	Number of trees	DBH (cm) Mean (Range)		Height (m) Mean (Range)	
Carpinus laxiflora	17	5.2	(2-17)	4.7	(2-12)
Quercus serrata	6	18.0	(13-23)	10.0	(9-11)
Styrax japonica	1	6.0	(—)	5.0	(—)
Altitude		132 m			
Soil type		Ando soil			
Annual mean temperature*		13.9℃			
Warmth Index**		109.8℃·month			
Coldness Index**		−2.9℃·month			
Annual mean precipitation*		1783 mm			

  * Climatic data at Asakawa Met. Sta., 5 km away from the study
    forest (Japan Meteorological Agency, 1982).
 ** Warmth and Coldness Index (Kira, 1977) derived from climatic
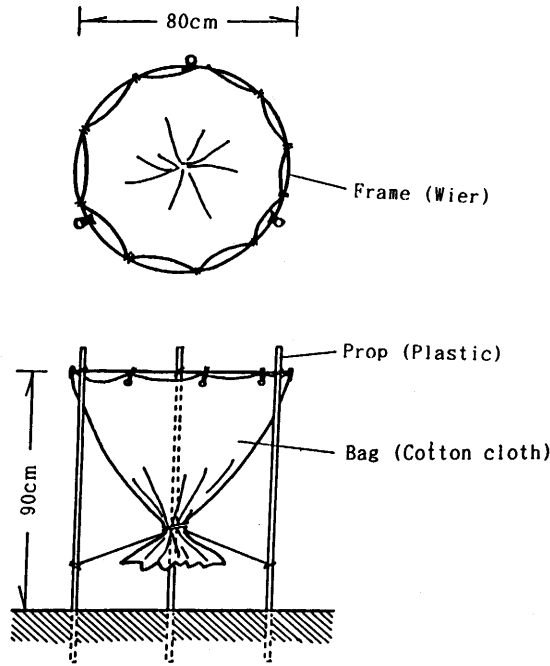   data at Asakawa Met. Sta.

Fig. 3 Litter trap used in this study

3. Results and Discussion

Number of pollen grains on a male catkin

The number of pollen grains per anther (p), the number of anthers per male flower (a), and the number of male flowers per male catkin (f) measured with the method mentioned above are shown in Table 3, by the mean value for every year and every sample tree.

The variation of a is small among years or sample trees, while p and f show considerable annual fluctuation. p and f in 1991 are larger than those in 1989 for the sample trees A and E. p is large in the years 1988 and 1991, when f is also large. On the other hand, p is small in the year 1989, when f is also small.

The number of pollen grains on a male catkin (P_c) is obtained from following equation:

$$P_c = p \cdot a \cdot f. \tag{1}$$

Fall rates of male catkins

The fall rates of male catkins per unit area of the study forest (c) show considerable year-to-year fluctuation during the four years (Table 4). The ratio of the maximum to minimum value is 2.2.

From the comparison between Tables 3 and 4, it is revealed that p and f are large in the year when c is large and vice versa.

Table 3 The results of the measurement of number of pollen grains per anther, anthers per male flower and male flowers per male catkin

Year	Sample trees	Number of pollen per anther (p)	Number of anthers per male flower (a)	Number of flowers per male catkin (f)
1988	A	2969.4 (51, 642-4613, 880.4)	6.1 (286, 1-17, 2.3)	37.3 (26, 23-52, 6.7)
	B	2524.0 (8, 1173-4525, 1013.4)	6.2 (121, 2-12, 1.7)	37.6 (22, 21-50, 8.3)
1989	A	1100.7 (41, 173-3753, 687.4)	6.0 (115, 2-10, 3.0)	27.1 (88, 6-43, 7.5)
	D	1296.5 (6, 168-2161, 759.7)	6.5 (143, 3-11, 1.5)	25.6 (79, 12-39, 6.3)
	E	1874.7 (54, 339-3852, 726.6)	5.8 (153, 2-12, 1.7)	33.9 (18, 17-49, 9.2)
1991	A	2671.6 (17, 1238-3515, 485.8)	5.7 (47, 2-8, 1.4)	36.5 (73, 8-60, 10.8)
	E	2492.9 (20, 1054-3497, 746.0)	5.8 (46, 2-8, 1.3)	37.5 (24, 10-54, 10.5)

Figures in a parenthesis show the number of samples, range and standard deviation.

Production rates of pollen grains

The annual production rates of *Quercus serrata* pollen grains per unit area of the study forest (P) are calculated as follows:

$$P = P_c \cdot c = p \cdot a \cdot f \cdot c. \tag{2}$$

The mean values of p, a and f of all sample trees treated in every year were used in the multiplication. In 1990, p, a and f were not counted. Therefore, the mean values of these numbers in 1988, 1989, and 1991 were used for the values of p, a and f in 1990.

Annual production rate of pollen grains in the stand varies year by year and ranges from 1.1×10^{11} to 2.2×10^{12} no. ha^{-1}y^{-1} (Table 5). The ratio of the maximum to minimum value amounts to 4.8. This year-to-year fluctuation may be caused by year-to-year fluctuation of temperature during the preceding summer. In order to make clear this relation, however, it is necessary to measure production rates of pollen grains for longer periods.

A mean value for four years (1988-1991) is 1.4×10^{12} no. ha^{-1}y^{-1}. This value is one order smaller than that (1.4×10^{13} no. ha^{-1}y^{-1}) obtained from the mature, intact *Quercus serrata* forest by Saito *et al.* (1987b). This difference is caused by the difference in the fall rates of male catkins in the both studied stands. The cause of this may be that the tree age, the DBH (diameter at breast height) and the height of *Quercus serrata* trees

Table 4 Annual fall rates of male catkins of *Quercus serrata* in the study forest

Year	Number of male catkins trapped	Fall rates of male catkins per m² [no. m^{-2}y^{-1}]	Fall rates of male catkins per ha (c) [no. ha^{-1}y^{-1}]
1988	1572	314.4	3.144×10^6
1989	907	181.7	1.817×10^6
1990	1129	225.8	2.238×10^6
1991	2004	400.8	4.008×10^6

Table 5 Estimated annual production rates of *Quercus serrata* pollen grains in the study forest

Year	Production rates of pollen grains per m² $(no. m^{-2}y^{-1})$	Production rates of pollen grains per ha (P) $(no. ha^{-1}y^{-1})$
1988	2.0×10^8	2.0×10^{12}
1989	4.6×10^7	4.6×10^{11}
1990	1.1×10^8	1.1×10^{12}
1991	2.2×10^8	2.2×10^{12}
Mean	1.4×10^8	1.4×10^{12}

observed in this study are smaller than those in the stand investigated by Saito *et al.* (1987b). This suggests that the production rates may relate with the age and tree size.

The effect of tree size

Following measurement was conducted to assure the above-mentioned consideration. Two litter traps were installed during April 20-May 20, 1991, under the crown of a *Quercus serrata* tree which is situated in Meguro Ward, about 30 km east from the study forest. The DBH and the height of this tree are 52 m and 14 m, respectively, and are larger than those of *Quercus serrata* trees in the study forest near Hachioji. The number of male catkins produced during the observed period was estimated as 1.927×10^7 no. ha^{-1}, which corresponds to the values ($2.0464 \times 10^7 \sim 2.9528 \times 10^7$ no. ha^{-1} y^{-1}) reported by Saito *et al.* (1987b).

Hashizume (1987) reported fall rates of *Quercus serrata* male catkins in secondary *Quercus serrata* forests in Okayama Prefecture, Southwest Japan. The size of the *Quercus serrata* trees studied by him are close to that of the present study forest. The measured fall rates of male catkins are reported as $6.25 \times 10^5 \sim 7.096 \times 10^6$ no. ha^{-1}y^{-1}. These rates are close to the result obtained from the study forest. From this, it can be concluded that the production rate of *Quercus serrata* pollen grains in a *Quercus serrata* forest is increasing with the increase of tree size.

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(*: in Japanese,   **: in Japanese with English abstract)