

# Japanese Cedar Airborne Pollen Monitoring by Durham's and Burkard Samplers in Japan —Estimation of the Usefulness of Durham's Sampler on Japanese Cedar Pollinosis—

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## Abstract

An attempt was made to compare pollen counts determined by the volumetric method (Burkard sampler) with the gravitational method (Durham's sampler) during the flowering seasons of evergreen coniferous trees such as (1) Japanese cedar, *Cryptomeria japonica* (abbreviation in this article: JC) and (2) *Cupressaceae* family, mainly hinoki cypress, *Chamaecyparis obtusa* (abbreviation: Cup). Observations were carried out in the cities of Fukuoka, Sagami-hara and Funabashi over five consecutive years. The pollen counts obtained by Durham's method correlated very well to the counts obtained by the Burkard technique. Intensity of airborne pollen dispersion varied regionally and from year to year. Very low pollen counts were observed in Fukuoka in 2004 and excessively high pollen counts in Sagami-hara in 2005.

Comparison of the results derived from Durham's sampling method with those derived from Burkard's sampling method revealed that these two methods are equally suitable for monitoring exposure to airborne JC and Cup pollen. To determine the starting days of JC and Cup pollen dispersion, Durham's technique is not inferior to Burkard's technique, but rather defines the start of pollen dispersion more distinctly. A long-term record of pollen counts obtained by Durham's technique from 1986 to 2008 in Fukuoka, revealed that the predictive values showed very low pollen counts in the case of particularly low July temperatures in the year before. As a conclusion, continuation of airborne pollen monitoring by the volumetric method (Burkard's sampling technique) in comparison with the gravitational method (Durham's sampling technique) will be required to evaluate the validity of the two methods for the climatic conditions of Japan. On the other hand, potential advantages of pollen data obtained by Durham's sampler deserve international re-evaluation.

**Key words:** Burkard's sampler, *Cryptomeria japonica*, *Chamaecyparis obtusa*, Durham's sampler, pollen monitoring, pollinosis

## 1. Introduction

Planting of Japanese cedar, *Cryptomeria japonica* D. Don (*sugi* in Japanese, abbreviated to JC in this article) trees was promoted throughout broad areas of Japan (Yokohama & Kanazashi, 1990). It prevails as the main harvest timber on the Japanese islands except Okinawa and most of Hokkaido. On the other hand, planting of trees of the *Cupressaceae* family, mainly hinoki cypress, *Chamaecyparis obtusa* (*hinoki* in Japanese, abbreviated

to Cup in this article) has been less extensive, prevailing from Fukushima Prefecture in the north to the western part of Honshu and in the several parts of Shikoku and Kyushu islands.

Systematic forestation with coniferous trees began in the middle of the Meiji Era (at the end of the 19th century) and the extent of coniferous woodlands has increased since that time. Forestation was promoted even further after World War II with continuous support from the Japanese government, which provided supplies

to improve Japan's forest resources. The total area of JC forestation's in particular, has increased to 4,510,000 hectares (ha) in 1986, *i.e.*, to about twice the area forested in 1956.

Because, the flowering and seed bearing of JC starts about 30 years after planting, the production of JC pollen is generally proportional to the area of JC forests exceeding an age of 31 years. Artificial JC forests older than 31 years occupied 610,000 ha in 1970, 730,000 ha in 1980 and 1.26 million ha in 1986. Considering the allergenic potency of JC pollen, the almost two-fold increase in area of JC forests capable of dispersing pollen means that an increasing fraction of the Japanese population is becoming exposed (Yokoyama & Kanazashi, 1990).

In the majority of JC forests, wild trees were planted and, consequently, there is remarkable regional genetic variation. Moreover, male flower formation and dispersal of pollen depend on weather conditions and geographic features. Accordingly, the amount of pollen in the air to which humans are exposed is strongly regional. Furthermore, pollen production of JC forests varies markedly from year to year, and so does the exposure of the population to airborne pollen.

In Japan the prevalence of AR (allergic rhinitis and/or rhino-conjunctivitis) began to increase in the late 1960s, growing more rapidly in the 1970s, with JC pollinosis as a major causative factor. In 1998 the general prevalence of JC pollinosis was 16% (2,800/17,000), with regional differences due to the reasons mentioned above (Committee of PG-MARJ, 2005).

Subjects susceptible to *Cryptomeria* pollinosis often exhibit cross allergenicity to *Cupressaceae* pollens. For this reason, Cup pollen has to be considered as an allergenic antigen causing pollinosis. It is important to note that the pollination season of Cup generally starts later than the pollination season of JC. Therefore, the start of exposure to airborne Cup pollen usually overlaps every year with the exposure to JC pollen late in the season of JC flowering. As the consequence, pollinosis caused by JC flowering may be worsened and prolonged by subsequent Cup flowering. Similar to JC pollination, the start and intensity of Cup pollination fluctuate annually and are affected by climatic and geographical conditions similarly to JC pollination.

Because JC generally flowers first, it is of particular clinical importance to monitor its onset as the point of time at which exposure to airborne conifer pollens becomes relevant to susceptible humans as the beginning of the pollinosis season. JC pollen grains can be recognized by a finger-like projection (papilla) which is slightly bent at the top on the distal face and by the appearance of its intine layer (inner layer) in optical sections. These morphological properties clearly distinguish JC pollen grains from *Cupressaceae* pollen grains.

The external morphology of Cup pollen grains differs only slightly between different Cup species or even genera. Therefore, it would be difficult to distinguish between pollen grains of various Cup species and those of *Chamaecyparis obtusa*. However, pollen of the latter

as the most widely distributed species prevails and is clinically most relevant as the cause of pollinosis. Therefore, we did not distinguish among species when counting Cup pollen. As mentioned above, airborne pollen from *Chamaecyparis obtusa* is clinically relevant mainly as an agent prolonging or aggravating pollinosis started by JC pollen. For this reason, the first appearance of Cup pollen in general is sufficient to indicate the start of its airborne dispersion, and it is more important for surveillance of susceptible patients to monitor the intensity and duration of exposure to airborne Cup pollen after the start of Cup flowering.

## 2. Aim

The authors used two methods to estimate density of airborne pollen grains during the flowering seasons of JC and Cup: a) the gravitational method according to Durham which is frequently used for pollen monitoring in Japan and b) the volumetric method according to Burkard which prevails internationally as a standard method. Standardized devices (Durham's sampler, Burkard sampler) were available for pollen monitoring. The authors' aim was to compare the usefulness of the two methods by using them simultaneously in Japan. For this purpose, airborne pollen grains were sampled in the cities of Fukuoka (A: 130°24'E 33°35'N), Sagami-hara (B: 139°23'E 35°34'N) and Funabashi (C: 139°59'E 35°41'N) for five consecutive years, starting in 2002 or, respectively, in 2003, as shown in Fig. 1.

## 3. Materials and Methods

### 3.1 Pollen monitoring by the gravitational method

This method of monitoring airborne pollen in Japan has been used since the 1970s when JC pollinosis was recognized as an important allergic disease. We collected pollen adhering to vaseline coated glass slides which were fixed in the Durham sampler and exchanged every morning, as a rule. After staining the samples with saturated basic fuchsin (Carberla's stain) we identified the pollen grains at 400x magnification and counted them at 100x magnification.

For the Durham method, pollen counts were standardized by expressing them as the number of pollen grains per cm<sup>2</sup>.

### 3.2 Pollen monitoring by the volumetric method

Burkard spore traps were located in each one of the selected cities on the rooftop of the involved institute building. The principle of pollen grain trapping consists of passing 10 liters of air per minute through the Burkard sampler in which the grains adhere to a collection drum which is prepared with adhesive Melinex® tape. Counts are evaluated internationally by three different methods. One each was used at each of the sampling sites.

In Fukuoka City located on Kyushu island (130°24'E 33°35'N, Fig. 1), we have monitored atmospheric aller-

genic conifer pollen since 2003 by evaluation according to the Pan-American Aerobiology Association, Standardized Protocols (PAAA protocols) following their comprehensive guidelines for the operation of Hirst-type suction, bioaerosol seven-day record samplers by Christine Rogers, Michael Mulilenberg and Estelle Levetin, Tulsa University, Oklahoma (Copyright 2001 by The Pan American Aerobiology Association). The drum which is prepared with adhesive Melinex® tape in the device is exchanged once a week, during which airborne pollen is collected. After seven days of collecting airborne pollen, the Melinex® tape, to which the pollen grains have become attached in the device, is cut in 48 mm sections corresponding to 24 hours (one day) with a width of 14 mm. Melted glycerin jelly with saturated basic fuchsin or gentiana violet is placed on each tape section for staining and each is subsequently mounted between a slide glass and a cover glass for counting under the microscope. According to the PAAA protocol counting technique, grains are counted along a longitudinal traverse near the middle of the trace ( $0.23 \text{ cm}^2$ ) at 400x magnification (Rogers & Mulilenberg, 2001).

In Sagami-hara City, Kanagawa Prefecture, in the central part of Honshu Island ( $139^\circ 23' \text{E}$   $35^\circ 34' \text{N}$ , Fig. 1), we have sampled pollen grains also during every seven-day period since 2003. We count pollen grains using the routine monitoring methodology for airborne pollen which is recommended by the European representatives of the International Association for Aerobiology (IAA) and determines pollen density by counting along three longitudinal bands "sweeps," although a minor modification was introduced in 2002 (Saito *et al.*, 2005). We switched from counting along three longitudinal bands to counting along two longitudinal traverse bands, one along the middle of tape and the second one along a line 3 mm vertically distant from the middle. Counting is done at 100x magnitude and the counted area is  $0.96 \text{ cm}^2$  for each 24 hour section of the 48 mm adhesive tape (Saito *et al.*, 2005; Kishikawa *et al.*, 2007).

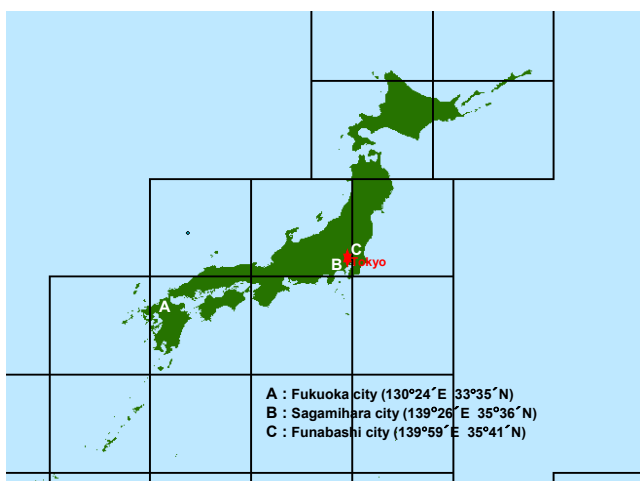


Fig. 1 Locations of observation points where JC pollen was identified.

For pollen counting performed since 2002 in Funabashi City, located on Honshu Island ( $139^\circ 59' \text{E}$   $35^\circ 41' \text{N}$ , Fig. 1) east of the Tokyo metropolitan area, we determined the entire number of pollen grains on a piece of adhesive tape corresponding to a quarter of the entire 24 hr Merinex® tape section, *i.e.*, grains adhering to a piece 24 mm long by 7 mm wide cut from the  $48 \text{ mm} \times 14 \text{ mm}$  tape section representing the particular day ( $1.68 \text{ cm}^2$ ).

For the Burkard method, the pollen counts were converted to grains/ $\text{m}^3$  of air. Basic data were daily mean concentration values.

### 3.3 Comparison of counting methods

Pollen counts in their respective dimension obtained by the gravitational method (standardized as counts per  $\text{cm}^2$ ) were compared with the counts obtained by the volumetric method (standardized as counts per  $\text{m}^3$ ). The results obtained by each of the two methods are compared for each sampling site in Fukuoka, Sagami-hara and Funabashi. For each site the counts obtained by the two methods were correlated and correlation coefficients were tested for significance using the student test for the total pollen count per season and for daily pollen counts throughout the season of airborne pollen dispersion.

Determination of the starting day of pollen dispersion was based on the Durham's sampling technique and defined, according to the Palynological Society of Japan, as the first day on which more than 1 grain/ $\text{cm}^2$ /day is sampled on two consecutive days. The end of airborne pollen exposure was defined as the first of three consecutive days during which no pollen grains are monitored by Durham's sampler. This is also coincided with the definition by the Japanese Palynological Society.

## 4. Results

### 4.1 Comparison of total pollen counts using Burkard and Durham sampling techniques

Table 1 shows the total pollen counts of JC and Cup obtained by Burkard and Durham samplers in Fukuoka, Sagami-hara and Funabashi. The average pollen numbers in each city were 3,391-11,886/ $\text{m}^3$ /season (JC: Burkard) and 1,419-7,585/ $\text{cm}^2$ /season (JC: Durham) for JC pollen. Cup pollen numbers, ranged from 1,628-8,950/ $\text{m}^3$ /season (Cup: Burkard) and from 716-2,904/ $\text{cm}^2$ /season (Cup: Durham).

Year-to-year changes were marked. They were smallest in Funabashi (not exceeding a factor of 18) but could be very large (exceeding factors of 30) in Fukuoka and Sagami-hara. Degrees of year-to-year variations were similar for JC and Cup pollen counts, and are similarly apparent in the results obtained by the Burkard and Durham sampling techniques.

The highest quantities of pollen counts were found in Sagami-hara both for JC and Cup pollens. The high average obtained for Sagami-hara strongly depends on the counts in a particular year (2005). Statistical evaluation

does not confirm, however, that average pollen counts for both JC and Cup were consistently higher in Sagamihara than in Fukuoka or Funabashi. Thus, the exceptional counts found in Sagamihara in 2005 illustrate a particularly favorable year for flowering of both JC and Cup male trees.

As far as the numerical values obtained by the Burkard and Durham methods are concerned, the generally lower numbers obtained by the Durham method would suggest a difference in sensitivity between the two methods. However, Table 2 shows that the Durham and Burkard data obtained at each sampling site during the five consecutive years (Table 1) were closely correlated for each pollen type. Correlation coefficients listed in Table 2 are generally high ( $>0.9$ ) and range between 0.917 and 0.998. All correlation coefficients are significant ( $<0.05$  to  $<0.001$ ) at each location. Thus, there is no

**Table 1** Annual total pollen counts using Burkard and Durham's samplers obtained for five consecutive years in Fukuoka, Sagamihara and Funabashi.

| Fukuoka | Japanese Cedar |        | Cupressaceae |        |
|---------|----------------|--------|--------------|--------|
|         | Burkard        | Durham | Burkard      | Durham |
| 2003    | 5,104          | 1,709  | 9,386        | 3,345  |
| 2004    | 543            | 113    | 288          | 74     |
| 2005    | 8,033          | 2,289  | 26,068       | 4,866  |
| 2006    | 4,421          | 1,385  | 7,588        | 2,950  |
| 2007    | 7,769          | 1,601  | 1,419        | 652    |
| average | 5,174          | 1,419  | 8,950        | 2,377  |
| SD      | 3,038          | 803    | 10,330       | 1,984  |

| Sagamihara | Japanese Cedar |        | Cupressaceae |        |
|------------|----------------|--------|--------------|--------|
|            | Burkard        | Durham | Burkard      | Durham |
| 2003       | 7,715          | 8,214  | 2,342        | 983    |
| 2004       | 1,259          | 705    | 1,515        | 163    |
| 2005       | 42,345         | 22,832 | 30,545       | 11,525 |
| 2006       | 2,660          | 2,074  | 985          | 558    |
| 2007       | 5,451          | 4,100  | 2,024        | 1,293  |
| average    | 11,886         | 7,585  | 7,482        | 2,904  |
| SD         | 17,209         | 8,982  | 12,903       | 4,838  |

| Funabashi | Japanese Cedar |        | Cupressaceae |        |
|-----------|----------------|--------|--------------|--------|
|           | Burkard        | Durham | Burkard      | Durham |
| 2002      | 4,231          | 3,498  | 2,157        | 866    |
| 2003      | 2,411          | 1,771  | 1,922        | 409    |
| 2004      | 1,297          | 336    | 463          | 157    |
| 2005      | 7,069          | 5,872  | 3,404        | 2,038  |
| 2006      | 1,947          | 786    | 196          | 112    |
| average   | 3,391          | 2,453  | 1,628        | 716    |
| SD        | 2,327          | 2,264  | 1,316        | 797    |

**Table 2** Correlation between total pollen counts obtained by the Durham and the Burkard pollen sampling techniques during five consecutive years for JC pollen and Cup pollen in Fukuoka, Sagamihara and Funabashi.

|            | r (JC) | p      | r (Cup) | p      | counting technique |
|------------|--------|--------|---------|--------|--------------------|
| Fukuoka    | 0.923  | 0.025  | 0.917   | 0.0282 | PAAA               |
| Sagamihara | 0.984  | 0.0025 | 0.998   | 0.0001 | IAA (modified)     |
| Funabashi  | 0.994  | 0.0005 | 0.918   | 0.0277 | Direct             |

indication of differences in reliability between the different counting methods used for evaluation of the Burkard sampling technique in the three cities, and with regard to total pollen counts, the two different pollen sampling techniques (Durham and Burkard) seem to be equivalent.

#### 4.2 Onset of pollen dispersion – Comparison of Burkard and Durham sampling techniques

The onset of pollinosis due to pollen from coniferous trees depends on the start of dispersion of pollen from JC as the conifer usually starts flowering first after winter. To elucidate the start of JC pollen dispersion we monitored pollen counts daily using Durham's and Burkard's sampling techniques simultaneously starting on January 1st. Studies were done for the same five consecutive years (2003 to 2007) in Fukuoka and Sagamihara. The most important problem from the clinical point of view was to determine the starting day of pollen dispersion based on the Durham sampling technique, as explained above.

For Fukuoka City, Fig. 2 shows that the starting day of JC pollen dispersion is quite distinctly definable every year. Further, pollen counts obtained by Durham and Burkard sampling coincide quite well. The correlation coefficients between the two methods were highly significant ( $p<0.001$ ) for the annual pollen counts in 2003, 2005, 2006 and 2007. In 2004, the levels of airborne pollen dispersion were unusually low and, consequently, the correlation coefficient of the counts obtained by Durham and Burkard sampling was low, but still significant ( $p<0.05$ ) for the combined JC and Cup pollen counts.

For Sagamihara City, Fig. 3 shows that the start of JC pollen dispersion was more difficult to determine. The Burkard sampling technique, in particular, provided counts from the beginning of the observation period during phases in which no or sub-threshold counts were obtained by the Durham technique. Nevertheless, the correlation coefficients for the results obtained by the Durham and Burkard counting techniques were high in 2003, 2006 and 2007 and significant ( $p<0.001$ ). In 2004, pollen counts were at low levels, although not as low as in Fukuoka, and Durham and Burkard pollen counts were significantly correlated ( $p<0.01$ ). In contrast, in 2005 the quantities of both JC and Cup pollen were exceptionally large in Sagamihara as documented in Table 1. Further, JC pollen dispersion started unusually early in that year on January 3rd as defined by Durham counting, and was already present on January 1st when counting by the Burkard technique, so we did not evaluate them in 2005.

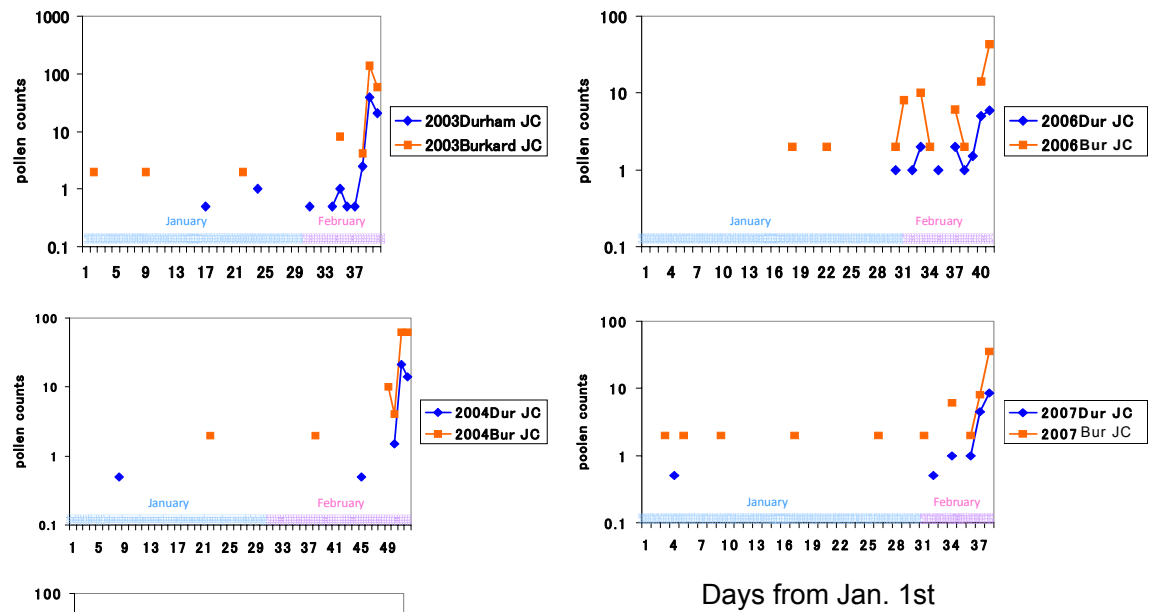


Fig. 2 Start of JC pollen dispersion during the five consecutive years in Fukuoka from 2003 to 2007, using gravitational (Dur) and volumetric (Bur) methods in parallel. The inserted table lists the starting day of airborne JC pollen dispersion.

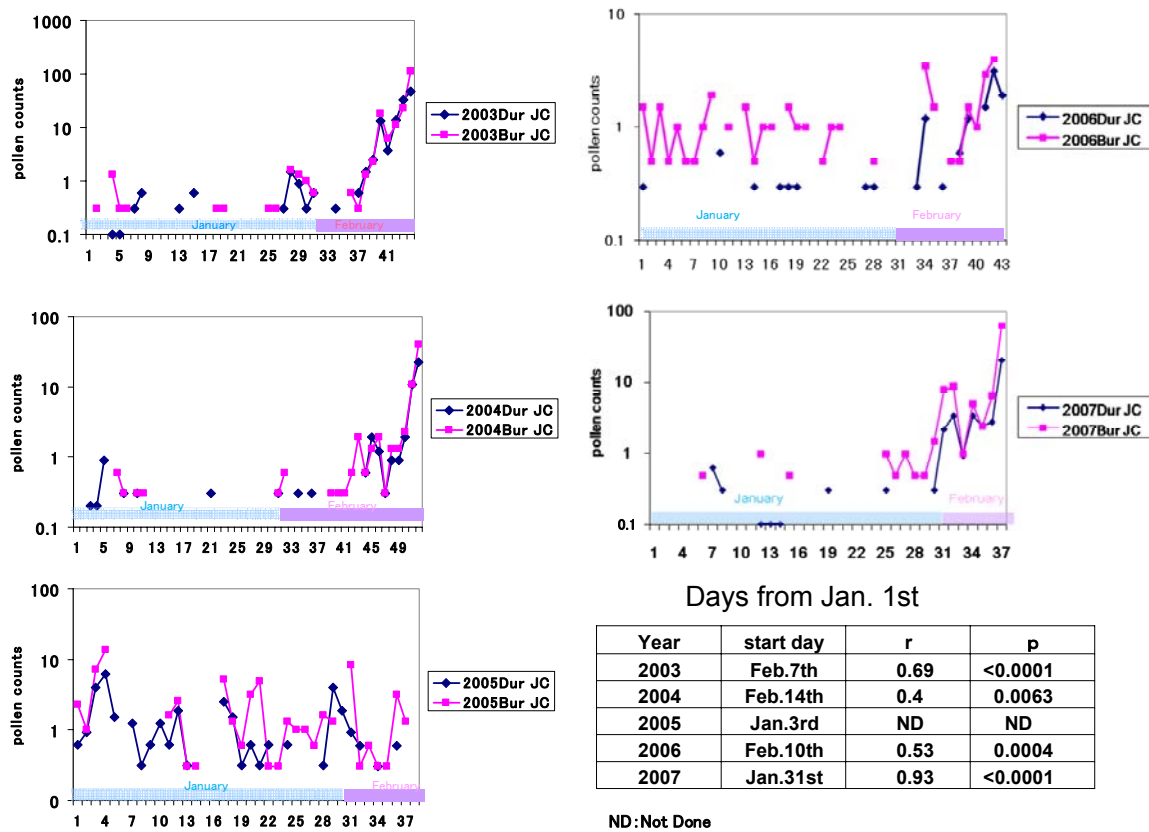


Fig. 3 Start of JC pollen dispersion during the five consecutive years in Sagami-hara from 2003 to 2007, using gravitational (Dur) and volumetric (Bur) methods in parallel. The inserted table lists the starting day of airborne JC pollen dispersion.

### 4.3 Summary of parameters of clinical relevance for conifer pollinosis

In Fukuoka, the following evidence was found. Every Saturday, Sunday and holiday we collected pollen automatically using Durham's sampler prepared on the day before and the Burkard sampler, with records every seven days. Pollen counts obtained by each method were arranged and examined: In Fukuoka, the correlation between Burkard daily pollen counts and Durham's data was high and highly significant for both JC and Cup pollen counts from the start to the end of the pollen dispersion periods in 2003, 2005, 2006 and 2007. An exception was the pollen counts obtained in 2004, because of unusually low levels of airborne pollen.

In Sagamihara, the following facts were observed. Every Saturday and Sunday we collected daily pollen samples automatically using an automatic four-day modified Durham's sampler and, in parallel, pollen was collected using a Burkard sampler. Correlation between the Burkard daily pollen counts and Durham's data was always high and highly significant for both JC and Cup pollen counts from the start to the end of the pollen dispersion period in Sagamihara during each of the five years from 2003 to 2007.

Shown are the start and end of pollen dispersion for each year and each conifer type and the number of days with supra-threshold airborne pollen levels. In addition, the correlation coefficients between the annual pollen counts obtained by the Durham and Burkard method and their levels of significance are presented. Correlation coefficients and significance levels were generally high, except for JC pollen in Fukuoka in 2004, because of

very low levels of airborne pollen collected throughout the flowering season in this area (also see Table 1). Definitions of the start and end of pollen dispersion are based on the counts obtained by the Durham method as explained above.

In Table 3, the starting and final days of airborne pollen dispersion, as defined by the counts obtained by the Durham method, and the number of days with supra-threshold pollen density are presented for the towns of Fukuoka and Sagamihara for the five consecutive years from 2003 to 2007. The start and end of dispersion of both JC and Cup pollen are presented separately. It is obvious that the flowering season of JC consistently starts earlier than flowering of Cup and that the Cup flowering period overlaps with the JC flowering period. For patients who suffer from JC pollinosis and who are susceptible to Cup pollen, it means a prolonged period of allergenic exposure. The parameters summarized in Table 3 are useful from the clinical point of view, because they provide information on when and for what duration preventive measures should be taken for persons susceptible to conifer pollinosis in order to avoid or to mitigate conifer pollen allergies (Kishikawa *et al.*, 2004a, 2004b).

As additional information, Table 3 shows that the results obtained by the Durham and Burkard counting techniques are highly correlated in general for both JC and Cup pollen counts. The single exception was the year 2004 in Fukuoka, which stands out for the very low pollen counts found for JC as indicated before in Table 1.

**Table 3** Seasons of JC and Cup pollen dispersion determined for Fukuoka and Sagamihara during five consecutive years (2003 – 2007).

| Fukuoka    | JC  | Year | start of pollen | end of pollen | days of pollen | r     | p       |         |
|------------|-----|------|-----------------|---------------|----------------|-------|---------|---------|
|            |     |      | dispersion      | dispersion    | dispersion     |       |         |         |
|            |     | 2003 | 7-Feb           | 2-Apr         | 54             | 0.853 | <0.0001 |         |
|            |     | 2004 | 19-Feb          | 16-Mar        | 27             | 0.362 | <0.1    |         |
|            |     | 2005 | 19-Feb          | 14-Apr        | 54             | 0.942 | <0.0001 |         |
|            |     | 2006 | 1-Feb           | 26-Mar        | 54             | 0.927 | <0.0001 |         |
|            |     | 2007 | 5-Feb           | 26-Mar        | 50             | 0.806 | <0.0001 |         |
|            | Cup | Year | 2003            | 14-Mar        | 22-Apr         | 40    | 0.976   | <0.0001 |
|            |     | 2004 | 14-Mar          | 18-Apr        | 36             | 0.675 | <0.0001 |         |
|            |     | 2005 | 27-Mar          | 29-Apr        | 34             | 0.963 | <0.0001 |         |
|            |     | 2006 | 5-Mar           | 19-Apr        | 39             | 0.967 | <0.0001 |         |
|            |     | 2007 | 14-Mar          | 28-Apr        | 46             | 0.578 | <0.0001 |         |
|            |     |      |                 |               |                |       |         |         |
| Sagamihara | JC  | Year | start of pollen | end of pollen | days of pollen | r     | p       |         |
|            |     |      | dispersion      | dispersion    | dispersion     |       |         |         |
|            |     | 2003 | 7-Feb           | 30-Apr        | 83             | 0.88  | <0.0001 |         |
|            |     | 2004 | 14-Feb          | 27-Apr        | 73             | 0.824 | <0.0001 |         |
|            |     | 2005 | 3-Jan           | 7-Jun         | 156            | 0.828 | <0.0001 |         |
|            |     | 2006 | 10-Feb          | 26-Apr        | 76             | 0.861 | <0.0001 |         |
|            |     | 2007 | 30-Jan          | 30-Apr        | 91             | 0.868 | <0.0001 |         |
|            | Cup | Year | 2003            | 8-Mar         | 5-May          | 49    | 0.666   | <0.0001 |
|            |     | 2004 | 12-Mar          | 24-Apr        | 44             | 0.479 | <0.001  |         |
|            |     | 2005 | 11-Mar          | 12-Jun        | 63             | 0.807 | <0.0001 |         |
|            |     | 2006 | 11-Mar          | 12-Jun        | 94             | 0.807 | <0.0001 |         |
|            |     | 2007 | 27-Feb          | 30-Apr        | 63             | 0.734 | <0.0001 |         |

## 5. Discussion

Before World War II, Japanese people had little conception on the occurrence of hay fever (pollinosis). Since the 1960s increasing numbers of patients have been reported suffering from hay fever due to ragweed, grass, Japanese hops, mugwort and occupational pollen allergies. Hypersensitivity to JC pollen was recognized first as an allergic disease peculiar to the Nikko area, near Tokyo, and reported as a cause of pollinosis in 1963 by Saitoh & Horiguchi (1964). Thereafter, increasing numbers of patients suffering from JC pollinosis have been identified since the 1980s and it is recognized as an increasingly serious nationwide social problem which requires countermeasures to be taken by the Japanese government.

Since the late 1980s the Japanese government has initiated studies with the aim of making provisions for preventing or mitigating the occurrence of JC pollinosis in the Japanese population. As a successful approach to the problem we have investigated airborne pollen dispersion by monitoring its start, intensity and duration. Gravitational sampling by Durham's sampler as a technically simple method used already by our predecessors was immediately available and easily applicable by clinicians, who have had little knowledge, so far, on aerobiology. For this reason the gravitational method using Durham's sampler has become the most popular monitoring technique used in Japan. Currently, we have about 400 JC pollen monitoring sites in our country.

The relationship is apparent between unusually low annual pollen counts and low July temperatures of the preceding year. Several meteorological parameters during July of the preceding year and total annual counts of JC pollen and combined JC+Cup pollen counts during the subsequent years are correlated, as given in the tables, showing correlation coefficients and statistically reliable levels of significance.

Figure 4 documents the predictive value of this relationship in providing information for clinicians

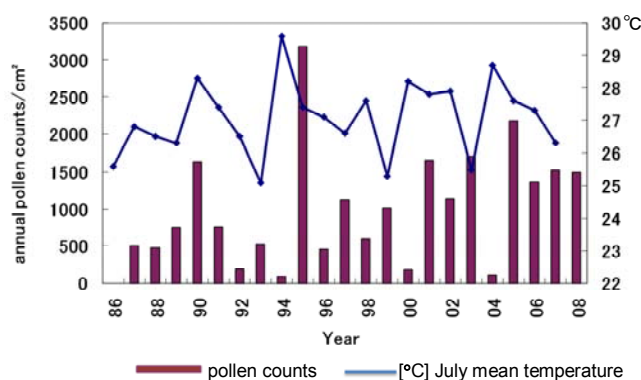


**Fig. 4** Long-term (1986-2008) monitoring of annual pollen counts by gravitational method. Diagram: Total annual JC pollen counts (left hand abscissa and columns) and July temperature (right hand abscissa and solid line).

about the severity of seasonal pollinosis in the following year and, thus, helping to make provisions for prevention and treatment. Data gathered by monitoring airborne pollen dispersion have also been shown to be useful as short-term information about the onset, intensity and duration of potential exposures to JC and Cup pollen for persons that may become afflicted by JC and Cup pollinosis. Based on these data we have distributed pollen information and medical recommendations for patients susceptible to pollinosis. This information has been broadcasted in Fukuoka City from February 1st to April 15th every year since 1988 in collaboration with the Fukuoka Prefecture Medical Association.

According to our own experience we consider pollen data obtained by Durham's sampling technique a reliable and predictive basis for transmitting medically useful information to persons in Japan who are susceptible to JC pollinosis. Because its predictive value is well documented in Japan, it is suggested that the gravitational method, which is widely used in Japan, should be re-evaluated internationally.

More frequently used as an international standard method has been the volumetric Burkard method using Hirst-Type suction for bioaerosol sampling. In line with the history of pollen monitoring outside of Japan, the volumetric method has become the standard technique in Europe and USA.

Reviewing the results of monitoring conifer pollen dispersion using the gravitational and the volumetric methods simultaneously in parallel in Fukuoka, Sagami-hara and Funabashi, we found that the data obtained by each method were, in general, closely correlated. According to our comparative analysis of volumetric and gravitational sampling techniques, the data obtained by each method are equally valid in the climatic conditions of Japan. This result is encouraging for further efforts to compare volumetric and gravitational methods in Japan on a nationwide basis. For this purpose, the new volumetric method should be used nationwide and, if possible, in parallel with the gravitational method established in Japan.

At the international level (Kishikawa *et al.*, 2004a, 2004b, 2007), it would also be desirable to compare worldwide data obtained by the two methods used in the present study. Currently, however, sufficient data are available outside of Japan from parallel applications of volumetric and gravitational methods.

## 6. Perspectives and Conclusions

We intend to continue investigations, aiming at improving the methods of monitoring the occurrence and distribution of allergenic pollens to promote preventive and therapeutic measures enhancing the quality of life of persons susceptible to airborne pollinosis. Adjusting pollen monitoring in Japan to international standards will require more frequent application of the volumetric sampling technique in Japan. Applying the Burkard sampling technique in parallel with the well-established

Durham's sampling technique in Japan will reveal the advantages or shortcomings of either method. International use of the gravitational method would be encouraged if potential advantages of Durham's technique in predicting exposure to airborne pollen could be documented.

We also want to continue monitoring the remarkable annual fluctuations in airborne JC and Cup pollen and compare them with recent annual changes in meteorological conditions in Japan to give the useful information for human health and the medical care of patients with hypersensitivity to conifer pollen antigens.

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