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ORIGINAL PAPER

Global warming and the earlier start of the Japanese-cedar (*Cryptomeria japonica*) pollen season in Toyama, Japan

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Abstract Atmospheric pollen surveys were conducted in Toyama City, Japan over a 21-year period (1983–2003). Airborne pollen was collected by two methods, the gravimetric method and the volumetric method. The gravimetric method indicated that the start of the *Cryptomeria japonica* pollen season, as indicated by pollen dispersion, has advanced from day 73 (from January 1) in 1983 to day 47 in 2003. Measurements taken using the volumetric method confirmed this trend. There was a significant correlation between the start dates obtained by both methods. Meteorological data indicated that the most noticeable elevation in temperature during the experimental period occurred in February – an increase of 2.1°C. Significant correlations existed between the mean temperatures and the start dates of the pollen season. These results support the steadily increasing number of reports indicating a global warming trend. The temperature change in February in affecting the start dates of the *C. japonica* pollen season is particularly relevant in the context of human health. Further studies will be needed to clarify the effects of the global warming trend on the pollen season and human health in more detail.

Keywords Climate change · Cryptomeria japonica · Pollen season

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Introduction

Global warming and its effects are the foci of increasing concern worldwide. While there is some evidence suggesting a significant correlation between global warming and human health, specific effects of the former on airborne pollen and subsequent allergic diseases have not been sufficiently confirmed. Recent evidence from studies carried out in London, Brussels, Zurich and Vienna indicates a trend towards earlier start dates of the birch (*Betula*) pollen season. Emberlin et al. (2002) predicted – based on temperature changes in the spring – that the mean start dates in the birch pollen season in these cities will advance by about 6 days over the next 10 years. In Japan, however, comparable studies for the Japanese cedar (*Cryptomeria japonica* D. Don) pollen season have not been carried out with any precision.

We report here on our investigation of the relationships between ongoing changes in the start date of the *C. japonica* pollen season and meteorological data, in Toyama, Japan. We also analyzed the correlation between data collected by the gravimetric method and by volumetric method.

Materials and methods

Atmospheric pollen surveys were conducted at the University of Toyama, Sugitani Campus, Toyama City, Japan (36°40′ N, 137°07′ E). Samples of airborne pollen grains were collected daily during a 21-year period, from 1983 to 2003, by the gravimetric method, using a Durham sampler (Durham, 1946). The slides, coated with white Vaseline, were collected each day at 9:00 a.m. and prepared using glycerine jelly containing 0.002% methyl violet (Merck, Germany). Pollen grains on the slide were counted under a light microscope. The start date of the Japanese cedar pollen season was defined as the day on which three or more pollen grains per square centimeter were counted for the first time, or the first day that one grain per square centimeter was counted on 3 or more consecutive days after January 1.

In this same experimental period, airborne pollen grains were also collected using a Hirst-type volumetric spore trap (Hirst, 1952). In the application of the volumetric method, the start date was defined as the day when the accumulated pollen count was recorded as being 1% or more of the total pollen counts for the season (Emberlin et al., 2002). The start date of the pollen season was expressed as the number of the days from January 1. Meteorological data were obtained from the Toyama Meteorological Station.

Results

The start dates of the *C. japonica* pollen season in the period 1983–2003 as determined using the gravimetric method are shown in Fig. 1. In 1983 and 1984 the pollen season started on March 14 and March 20, respectively, while in 2002 and 2003, it started earlier, on February 21 and February 16, respectively. These measurements clearly indicate that the first date of the pollen season advanced approximately 25 days from 1983 to 2003.

Figure 2 presents a comparison of the start dates of the *C. japonica* pollen season for the period 1997–2003 calculated from results obtained using both the gravimetric and volumetric methods. Based on pollen counts obtained by the gravimetric method, the start day of the *C. japonica* pollen season has advanced by 10 days in the period from February 26, 1997 to February 16, 2003, although other fluctuations were also observed in this period. A similar trend was found using the volumetric method, with the start date of the pollen season showing a similar curve from February 28, 1997 to March 12, 2000 to February 26, 2003. We found that there was a significant correlation between the start dates obtained by the gravimetric and volumetric methods (Pearson correlation coefficient $r = 0.87$, $p<0.05$) (Fig. 3).

An analysis of the meteorological data for this 21-year period revealed that the most noticeable elevation in temperature occurred in February, with the monthly mean temperature changing from 1.3°C in 1983 to 3.4°C in 2003. Average temperatures rose by 2.1°C in February and by 0.8°C in March during the 21-year span of this investigation (Fig. 4).

Although significant correlations were obtained among the mean temperatures in January, February and March, the highest significant correlation coefficient ($r = 0.88$) was obtained between the mean temperature in February and the start dates of the pollen season ($p < 0.01$) (Fig. 5).

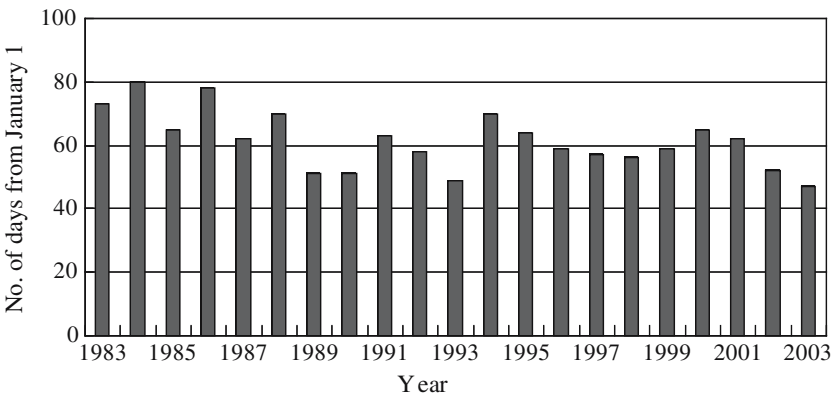


Fig. 1 Yearly change in the start date of the pollen season of *Cryptomeria japonica* D. Don from 1983 to 2003 as determined by the gravimetric method

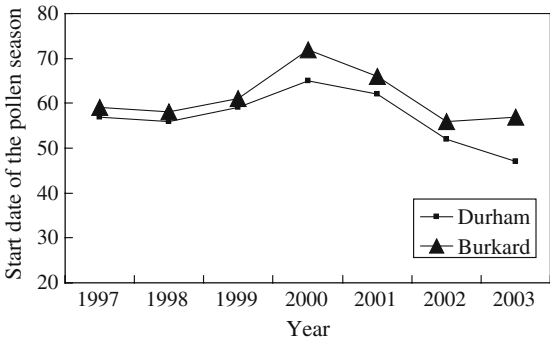


Fig. 2 Yearly changes in the pollen season start dates of *C. japonica* from 1997 to 2003 as determined by the gravimetric method and volumetric method

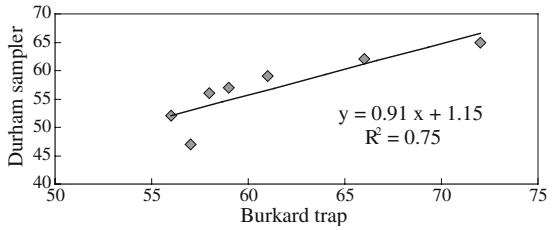
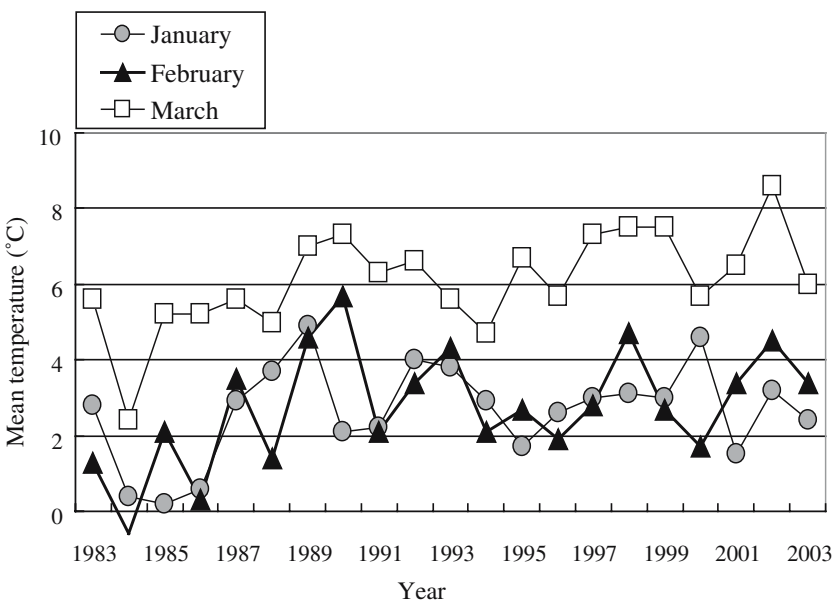


Fig. 3 Relationship between the start dates of the *C. japonica* pollen season obtained by the gravimetric and volumetric methods

pollen dispersal in the atmosphere (Taira, Teranishi, & Kenda, 1997; Yamazaki, Mizuno, Shida, & Shimizu, 1979) following the first description of an airborne pollen map and a pollen calendar in the Japanese archipelago (Nagano, Katsuta, & Shida, 1978). Kishikawa and Nagano (1988) reported that the start dates of the *C. japonica* pollen season correlated with the mean temperature in January in Fukuoka City (33°33′N, 130°27′E), Kyushu.

In a previous study in which we used the gravimetric method to measure atmospheric *C. japonica* pollen, we pointed out several correlations between trends in increasing temperatures and the changing pattern of *C. japonica* pollen dispersion (Teranishi et al., 2000). In Japan, the gravimetric method is the most commonly used method for measuring atmospheric pollen, while the volumetric method is employed for more specific studies (Sakaguchi, Inoue, Takahashi, Katagiri, & Yasueda, 1995). As the gravimetric method has several limitations (D'Amato, Spieksma, & Bonini, 1991), it may be well advisable to consider the application of the volumetric method for the evaluation of airborne particles, especially from the point of view of aerobiology.

Fig. 4 Yearly changes in the mean temperatures of January, February and March from 1983 to 2003



Discussion

Several types of studies have been carried out in Japan on the effects of meteorological conditions on

In the present study we employed two different methods to define the start date of the *C. japonica* pollen season, the gravimetric method and the volumetric method. The gravimetric method revealed

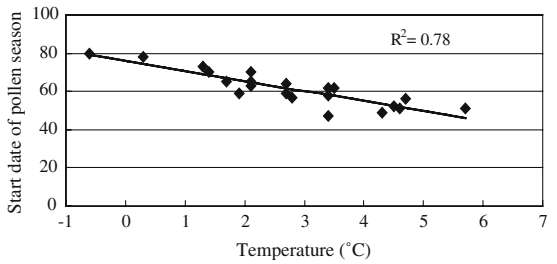


Fig. 5 Correlation between mean temperature in February and the start date of the *C. japonica* pollen season

that the start date of the pollen season had advanced in the period 1983–2003. Similar trends were confirmed using the volumetric method for the period 1997–2003. A significant correlation was obtained between the data collected by both methods. Consequently, we speculate that these results indicate rather strongly that the data obtained by each method reasonably reflect the phenological phenomenon of *C. japonica*.

Although further studies are necessary to confirm long-term trends in more detail, the results of our investigation strongly suggest that temperature changes have a direct impact on the start date of the *C. japonica* pollen season.

We also found that the start date of pollen dispersal was closely correlated with the mean temperature of February. Although the start day of the pollen season has been reported to correlate with the mean temperature in January in Fukuoka, Kyushu, the difference between January and February can be explained by the difference in latitudes between Toyama (36°N) and Fukuoka (33°N). The pollen season of *C. japonica* begins earlier in the more southern latitudes, and as the mean temperature increases, the pollen front moves northward to Toyama, Honshu (Sahashi & Murayama, 1993).

A tendency to increasing pollen counts has also been observed in recent years, although yearly fluctuations have also been found (Ishizaki et al., 1987; Taira, Teranishi, & Kenda, 1998). Based on the results of a simulation study in Yamagata City, Takahashi, Kawashima, and Aikawa (1996) reported that this significant increase in total pollen counts may be caused by global warming.

In Japan, a significant relationship between the atmospheric pollen count of *C. japonica* and the number of outpatients presenting with pollen allergy has been reported (Sahashi et al., 1990; Teranishi & Fujisaki, 2003). More precautions are recommended as the effect of global warming on the atmospheric pollens begins to have an effect on the general population and on public health.

References

D'Amato, G., Spieksma. F. T. M., & Bonini, S. (1991). *Allergenic pollen and pollinosis in Europe*. Oxford: Blackwell.

Durham, O. C. (1946). A proposed standard method gravity sampling, counting and volumetric interpolation of results. *Journal of Allergy*, *17*, 79–86.

Hirst, J. M. (1952). An automatic volumetric spore trap. *The Annals of Applied Biology*, *39*, 257–265.

Horiguchi, S., & Saito, Y. (1964). Japanese cedar pollinosis in Nikko (in Japanese with English summary). *The Japanese Journal of Allergology*, *13*, 16–18.

Emberlin, J., Detandt, M., Gehrig, R., Jaeger, S., Nolard, N., & Rantio-Lehtimäki, A. (2002). Responses in the start of *Betula* (birch) pollen seasons to recent changes in spring temperatures across Europe. *International Journal of Biometeorology*, *46*, 159–170.

Ishizaki, T., Koizumi, K., Ikemori, R., Ishiyama, Y., & Kushibiki, E. (1987). Studies of prevalence of Japanese cedar pollinosis among the residents in a densely cultivated area. *Annals of Allergy*, *58*, 265–270.

Kishikawa, R., & Nagano, H. (1988). The annual variations in airborne *Cryptomeria japonica* and Cupressaceae pollen counts and meteorological conditions in Fukuoka City (in Japanese with English summary). *The Japanese Journal of Allergology*, *37*, 355–363.

Nagano, H., Katsuta, M., & Shida, T. (1978). *Airborne pollen grains in Japanese archipelago* (in Japanese). Tokyo: Hokuryukan.

Sahashi, M., Ikuse, M., Ohmoto, T., Saito, Y., Takahashi, Y., & Takeda, H. (1990). Relationship between seasonal and annual total pollen counts of *Cryptomeria japonica* and Cupressaceae and number of outpatients with Sugi pollinosis in central Japan. *Review of Palaeobotany and Palynology*, *64*, 79–86.

Sahashi, N., Murayama, K. (1993). Change in the northward movement of the pollen front of *Cryptomeria japonica* in Japan, during 1986–1991. *Allergie et Immunologie*, *25*, 150–153.

Sakaguchi, M., Inoue, S., Takahashi, Y., Katagiri, S., & Yasueda, Y. (1995). Immunoblotting of mite aeroallergens collected with an indoor Burkard air sampler. *Aerobiologia*, *11*, 265–268.

Taira, H., Teranishi, H., & Kenda, Y. (1997) Comparison of predictive methods of Sugi (*Cryptomeria*) atmospheric pollen counts using mean temperture, solar radiation and male flower index-An example of Toyama Prefecture (in Japanese with English summary). *The Japanese Journal of Allergology*, *46*, 489–495.

Taira, H., Teranishi, H., & Kenda, Y. (1998). The formation of pollen in male flowers and yearly atmospheric pollen counts of *Cryptomeria japonica* in the following year. *Allergology Int*, *47*, 297–302.

Takahashi, Y., Kawashima, S., & Aikawa, S. (1996). Effect of global climate change of Japanese cedar pollen concentration in air (in Japanese with English summary). *The Japanese Journal of Allergology*, *45*, 1270–1276.

Teranishi, H., Kenda, Y., Katoh, T., Kasuya, M., Oura, E., & Taira, H. (2000). Possible role of climate change in the pollen scatter of Japanese cedar *Cryptomeria japonica* in Japan. *Climate Research*, *14*, 65–70.

Teranishi, H., & Fujisaki, Y. (2003). Environment aspect of the countermeasures against the Sugi (*Cryptomeria japonica*) polinosis in Japan (in Japanese with English summary). *The Japanese Journal of Palynology*, *49*, 79–84.

Yamazaki, F., Mizuno, M., Shida, T., & Shimizu, T. (1979). Studies of pollen grains causative of pollinosis. II. On earlier prediction of pollen dispersion number of *Cryptomeria japonica* (in Japanese with English summary). *The Japanese Journal of Allergology*, *28*, 732–737.