Review of the Pollen Front of *Cryptomeria japonica* over Japan

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The present study analyzes the correlation between the average date of the beginning of Japanese cedar (*Cryptomeria japonica*) pollen-scattering, the mean daily maximum temperature and the latitude on the basis of data obtained for the past 9 years at 17 observational sites distributed from low latitudes (Kyushu) to high latitudes (Tohoku).

The results showed that the integrated mean daily maximum temperature in January had a close negative correlation with the time interval between the first day of the year and the beginning of pollen scattering, and that the relation between the number of days until the beginning of pollen scattering and the integrated daily maximum temperature for this period was not specific to a particular site, but a general feature. In addition, the integrated daily maximum temperature in January could be estimated from the latitude of the site. This suggests that the day of the beginning of pollen-scattering can be predicted from the latitude even for areas where no accurate meteorological data are available. Through this analysis, the average Japanese cedar pollen fronts over Japan were obtained.

Key words : Japanese cedar (*Cryptomeria japonica*), Maximum temperature, Latitude, Pollen front.

Introduction

The sharp annual fluctuations in airborne Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obtusa*) pollen counts over the past ten years have resulted in an increased number of patients who suffer from pollinosis or aggravation of its symptoms in early spring.

In order to prevent and treat this disease, it is very important to carry out a nationwide survey each year to clarify when Japanese cedar pollen begins to be scattered (Japanese cedar pollen front). In this regard, we have surveyed how the Japanese cedar pollen front travels over Japan every year since 1986[(1)] in cooperation with many individual researchers and research institutes dealing with airborne pollen. Our preliminary report[(2)] covered only 6 years of data (1986-1991). In this study we attempted to draw up a map of the average Japanese cedar pollen front, from which the beginning of pollen dispersal could be predicted. However, our preliminary report lacked sufficient data for both the weather and the pollen front to predict the accurate average pollen front or when pollen-scattering begins.

Our annual surveys until 1994[3] revealed a certain relationship between meteorological factors and the beginning of dispersal of Japanese cedar pollen, allowing us to draw the average pollen front travelling over Japan. This also enabled us to predict when Japanese cedar pollen begins to scatter at any particular spot where few or no observational data are available.

Materials and Methods

The number of observation sites used to establish the first day of pollen-scattering increased year by year from 28 in 1986 to 46 in 1987[4], 48 in 1988[5], 61 in 1989[6], 70 in 1990[7], 80 in 1991[8], 102 in 1992[9], 104 in 1993[10] and 110 in 1994, eventually covering almost the whole of Japan. The study included 17 sites located at the same place as a meteorological observatory and for which there are 9 years of continuous data, apart from 2 sites for which there are only 6 years data (Fig. 1).

Japanese cedar pollen was sampled generally by the gravitational method using Durham's sampler[11], and in some facilities by the IS-rotary sampler[12] as well. The white petrolatum-applied slide was renewed every day, stained with Carverla solution and stored in gentian violet-glycerin jelly[13] as occasion demanded. The day of the beginning of pollen-scattering was defined as the first day the pollen count became 1 or more per cm^2 of slide. (In many facilities, the number of pollen grains was determined in an area of 3.24㎠ on slides, and the results are expressed as number of grains per ㎠.) Pollen counts during the week following this day were also analyzed for more accurate determination of the beginning of pollen-scattering. Weather data (daily maximum temperature,℃) were obtained (AMeDAS data) from the 17 meteorological observatories (Fig.1).

Results and Discussion

The northward transfer of the pollen front of Japanese cedar varies markedly according to locality and year. For example, Fig. 1 in the journal (p.30) shows changes in the Japanese cedar pollen front in 1986, and Fig. 2 of the same volume (p.31) shows the sampling sites in that year[2]. The pollen front reached the southern part of the Kanto district, the Pacific seaboard of Shikoku and Kyushu by mid-February, and came north to the line linking the southern part of Tohoku and Hokuriku districts one month later i.e. by mid-March. On the other hand, Fig. 1 of the journal (p.62) shows the major Japanese cedar pollen front in 1993, and Fig. 2 of the same volume (p.64) shows the more than one hundred sampling sites in that year[10], permitting a more precise pollen front to be drawn. The pollen front reached Shikoku, the whole of Kyushu, and Kanto and Tokai districts in early February, and came north to the southern part of Tohoku as early as late February.

Differences in the velocity of northward travel of the pollen front seems to be caused mainly by differences in air temperature in winter. For instance, in 1993 there was a warm winter − which was record-breaking − and the first storm in spring was considerably earlier than usual. Thus the flowering was accelerated everywhere, with pollen-scattering occurring earlier than in an average year.

In general the integrated temperature is considered to be closely related to the flowering and growth of plants. For analysis of this type, various parameters such as the integrated days with a temperature of 0℃ or 5℃, integrated daily mean temperature and integrated daily maximum temperature are used. Although there is controversy as to the starting point of integration, we set it at 1 January, and examined the relationship between the number of days from 1 January to the day when pollen-scattering began (Y) and three factors, the daily maximum temperature integrated up to the day of beginning of

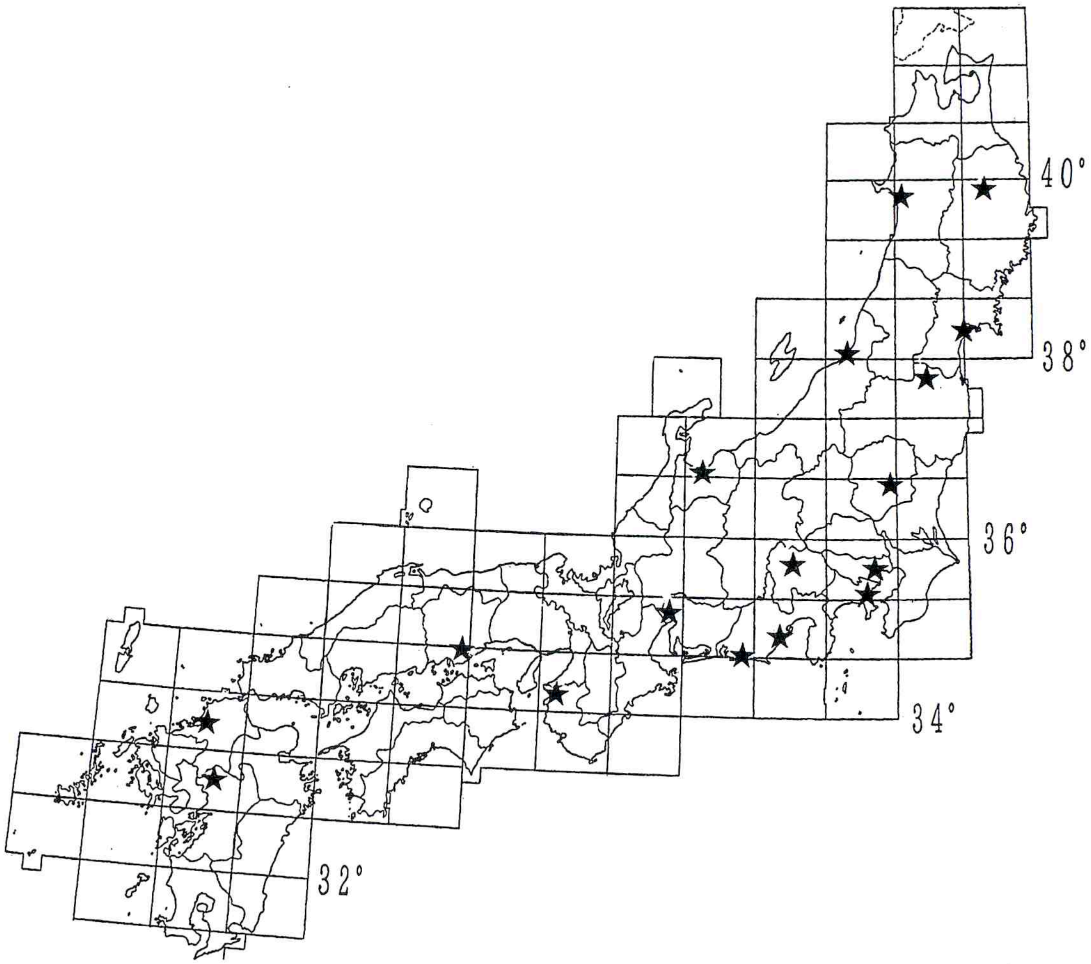

Fig.1. Location of 17 observational sites for airborne pollen during 1986-1994.

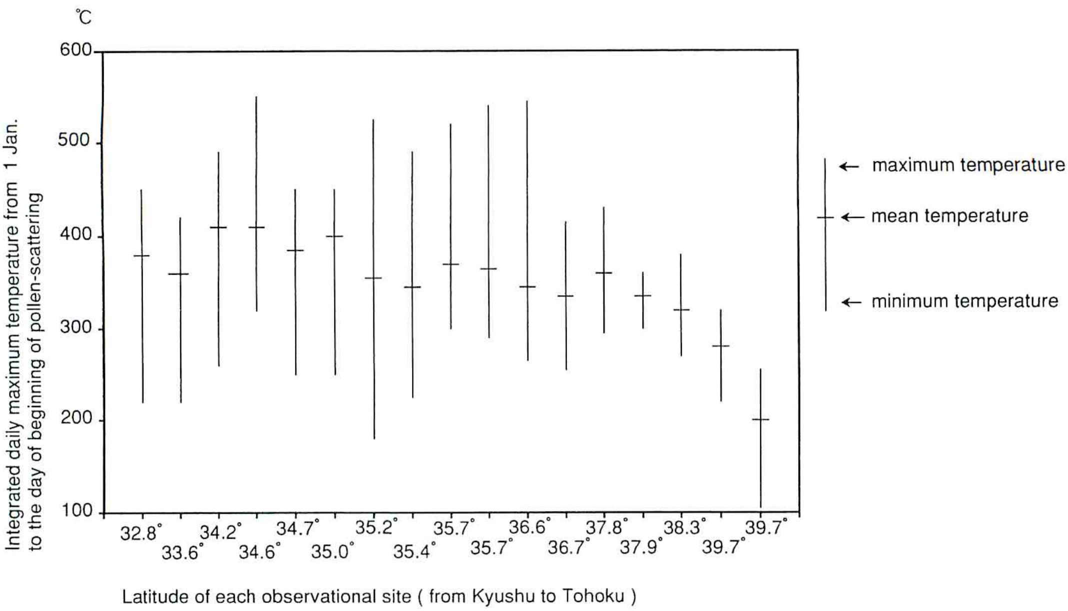

Fig.2. Variation in the integrated daily maximum temperature up to the day of the beginning of pollen-scattering at 17 sites.

pollen-scattering (TX1), integrated daily maximum temperature in January (TX2) and latitude of observational site (LAT).

Figure 2 shows the variation in the integrated daily maximum temperature (TX1) up to the day when pollen-scattering began at these 17 sites. Latitudes were plotted on the X-axis in ascending order to the right. Although the variation in integrated maximum temperature was generally large, it was particularly conspicuous at low latitudes. The correlation coefficient was calculated for TX1 and TX2 at each site. The correlation coefficient for TX2 was 0.5-0.9, demonstrating that the relationship between the integrated maximum temperature and the time interval until the beginning of pollen-scattering is not characteristic of the site, but a general feature. However, with TX1, a lower correlation coefficient was obtained for a number of observational sites. This may represent the influence of cold weather directly preceding the flowering.

The relationship between the beginning of pollen-scattering and the mean value for each factor calculated for the 17 sites was also determined. The correlation coefficient for TX1 and the time interval until the beginning of pollen-scattering (Y) was −0.76, and the primary regression equation was:

$$Y = -0.18 \times TX1 + 113.87 \text{ ----------(1).}$$

As shown in Fig.3, there is a large deviation from the regression line at some observational sites. These are basins or mountainous areas where the air temperature is high during daytime, but very cold in the mornings and evenings. The low value for the correlation coefficient can probably be attributed to the influence of the geographic features of these sites.

The correlation between Y and TX2 was closer than that between Y and TX1, showing a correlation coefficient of −0.96, and the primary regression equation was:

$$Y = -0.141 \times TX2 + 81.92 \text{ ----------(2).}$$

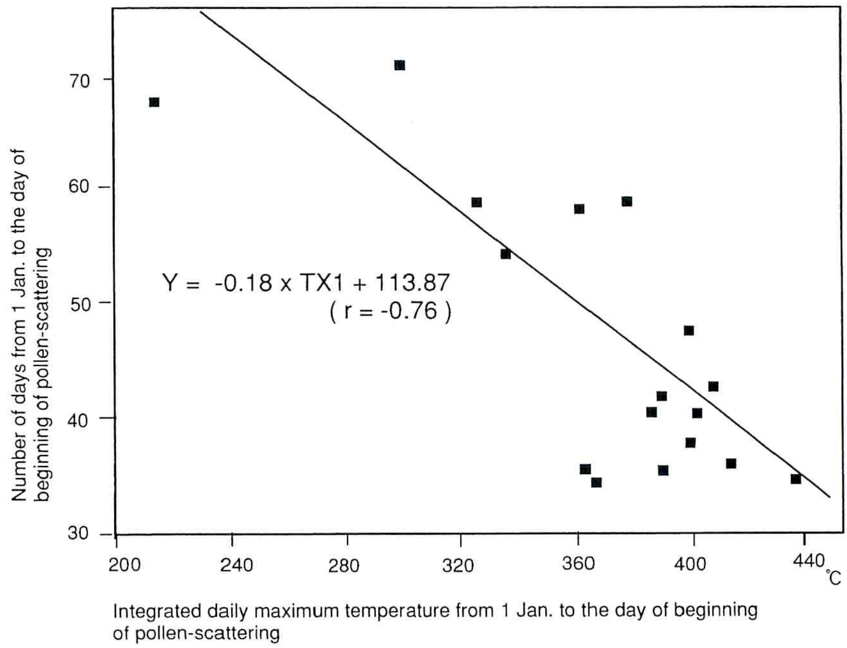

Fig.3. Correlation between the integrated daily maximum temperature from 1 Jan. to the day of the beginning of pollen-scattering and number of days from 1 Jan. to the day of the beginning of pollen-scattering.

Figure 4 shows that there is almost no deviation from the regression line. However, it is not understood why the latter equation (2) shows a better correlation than the former (1). Kawashima et al.[14] demonstrated that a multiple regression equation for altitude and mean January temperature shows the most likely day for Japanese cedar to flower. Although there are no firm grounds for our setting the period for integration of the temperature, this may cause no problem in predicting the day of flowering.

As shown in Fig. 2, the higher the latitude, the lower the integrated temperatures tended to be. Therefore, the relationship between the latitude (LAT) of a site and Y, TX1 or TX2 was examined. Figure 5 shows the correlation between the latitude and TX1: the correlation coefficient was −0.71, and the primary regression equation obtained as follows:

$Y = -18.3 \times LAT + 1117.4$ ----------(3).

There was however, a deviation from the regression line at two sites at low latitudes and one site at a high latitude. Figure 6 shows the correlation between the latitude and TX2, with a correlation coefficient of −0.91, and the primary regression equation was:

$Y = -37.42 \times LAT + 1599.24$ ----------(4).

It can be seen that the relation between the latitude and TX1 or TX2 is similar to that between Y and these factors. It is apparent that the integrated daily maximum temperature in January practically depends on the latitude of the site, and the possibility that latitude can be used as an alternative factor for sites where no accurate meteorological data are available is suggested.

The actual correlation between the latitude and Y is shown in Fig. 7. Although there was a rather wide variation at about 35° north latitude, the correlation coefficient was 0.94, and the primary

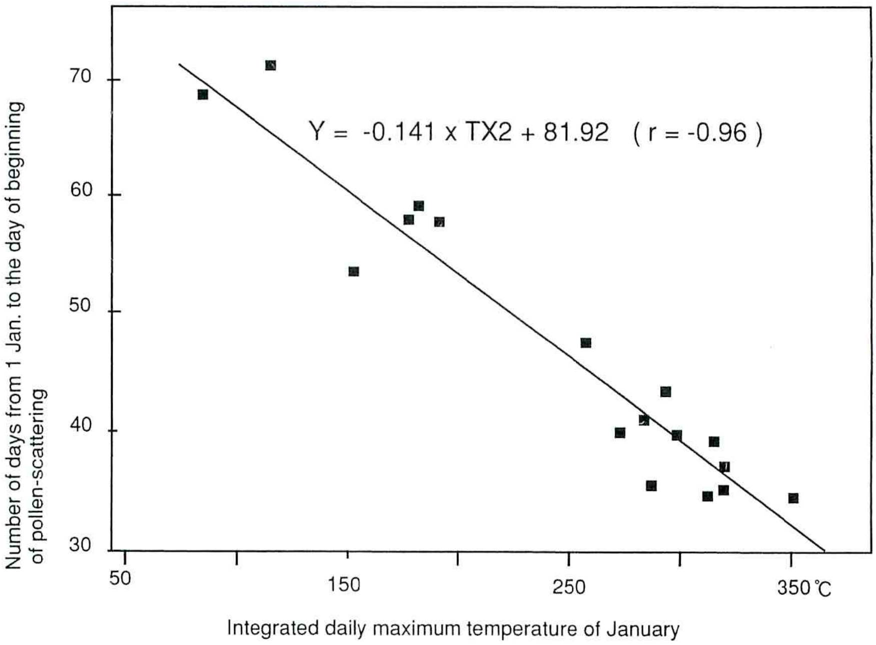

Fig.4. Correlation between the integrated daily maximum January temperature and the day of the beginning of pollen-scattering.

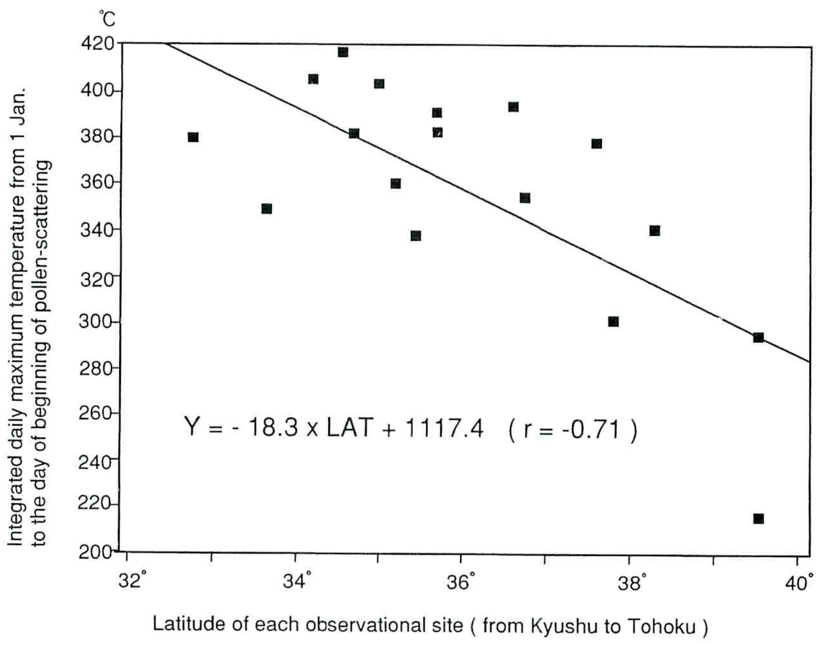

Fig.5. Correlation between the integrated daily maximum temperature from 1 Jan. to the day of the beginning of pollen-scattering and the latitude of each observational site.

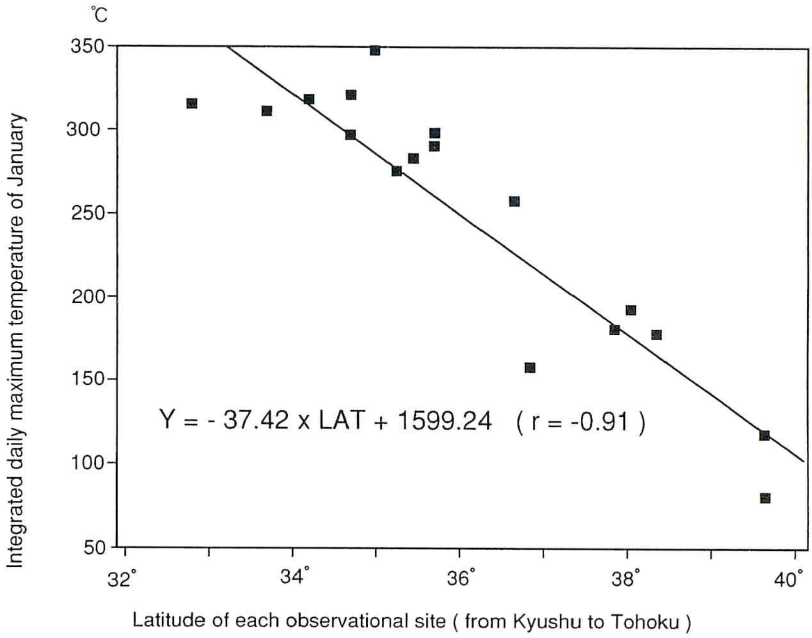

Fig.6. Correlation between the integrated daily maximum January temperature and the latitude of each observational site.

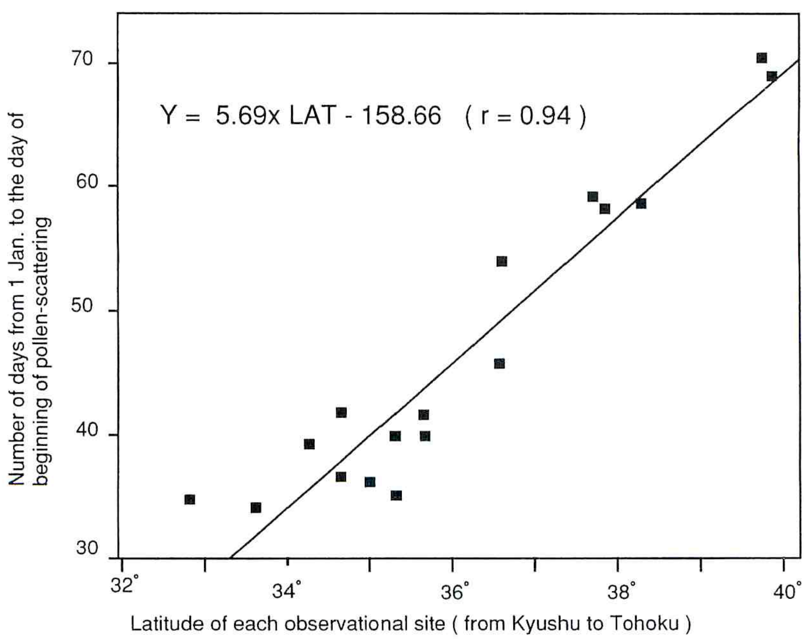

Fig.7. Correlation between the day of the beginning of pollen-scattering and the latitude of each observational site.

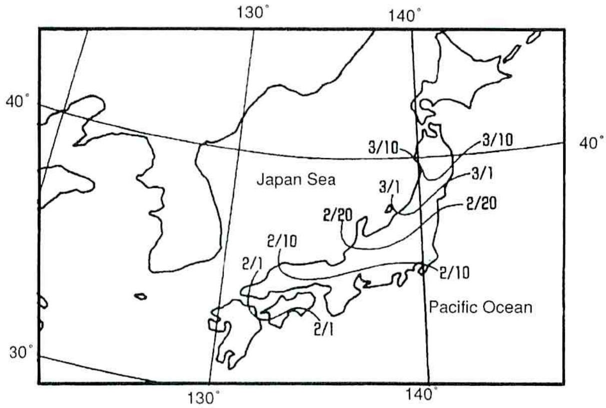

Fig.8. Average Japanese cedar pollen front, drawing mainly from the correlation between latitude and integrated maximum January temperature at each observational site. The front is drawn up in every 10-day period.

regression equation was:

$$Y = 5.69 \times LAT - 158.66 \text{ ----------(5).}$$

Although the correlation was weaker than with the direct use of TX2, it suffices for predicting the average date of the beginning of scattering.

From the above primary regression equations (1) to (5), we obtained the multiple regression equation for the latitude (LAT) and the integrated maximum temperature in January (TX2) to diminish errors in prediction. The multiple regression equation was:

$$Y = -0.091 \times TX2 + 2.3 \times LAT - 13.55 \text{ ----------(6).}$$

The multiple correlation coefficient was 0.97. Thus, using the multiple regression equation, (6), a map of the location of the average Japanese cedar pollen front (Fig. 8) was prepared.

Our present study was originally aimed at predicting the time Japanese cedar pollen begins to scatter and did not cover the issue of flowering of Japanese cedar male blossoms. It is possible that other factors are involved in the flowering.

Although there are some remaining problems in the setting of the period for integration, the close correlation with each factor in question seems to justify its practical use from the viewpoint of methodology. Our method allows the prediction of the time Japanese cedar pollen begins to scatter, even in sites where no or insufficient observational data on pollen-scattering are available. Further investigations are planned.

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日本列島のスギ花粉前線の考察

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筆者らはこの研究で9年間の平均飛散開始日，9年間の最高気温の平均値および緯度の間の相関を，緯度の低い九州から高い東北地方にまたがる17地点で解析した．その結果1月の最高気温の積算値は1月1日から飛散開始日迄の日数と高い負の相関があり，また1月1日から飛散開始日迄の最高気温の積算値と同日数との関係は地域に特有のものではなく一般的なものであることが確認された．さらに少なくとも1月の最高気温の積算値は各地の緯度によってほぼ決定できることがわかった．このことから花粉の飛散開始日は正確な気象データがない地域においても，緯度を代替データとして用いることができる可能性が示唆された．以上のことから日本列島のスギ花粉前線の平均値が求められた．