(Original paper)

Relationship between Combined Pollen Count of *Cryptomeria japonica* and Cupressaceae and Precipitation in July of the Previous Year

Hiroyuki NAMBA[1], Katsuyoshi SAITOU[2] and Norio SAHASHI[3]

[1] *Pharmacy, and* [2] *Department of Internal Medicine, Kurashiki Municipal Kojima Shimin Hospital, 2 - 39 Ekimae, Kojima, Kurashiki, Okayama, 711- 0921 Japan*
[3] *School of Pharmaceutical Sciences, Toho University, Funabashi, Chiba, 274- 8510 Japan*

(Received Sep. 29, 2000, Accepted Aug. 30, 2000)

There have been relatively few reports showing that the pollen count of *Cryptomeria japonica* and the combined pollen count of *C. japonica* and Cupressaceae are correlated with precipitation in July of the previous year. In Okayama Prefecture, we found high correlations between the pollen counts in the southern area and precipitation in July of the previous year at the weather stations in the northern area, but not with precipitation at weather stations in the southern area. The pollen counts correlated well with the mean value of maximum temperature in July of the previous year at all observation sites.

About 85.7% of the *C. japonica* and *Chamaecyparis obtusa* in Okayama Prefecture are located in the northern area of the prefecture. We therefore assumed that the source of the pollen in the southern area was in the northern area. The results of this study indicate that the annual variations in the mean value of maximum temperature in July in the northern area are very similar to that in the southern area, but that the variations in precipitation are not very similar. As a result, the mean value of maximum temperature at all weather stations correlates significantly with each of the pollen counts in the southern area, but only precipitation in the northern area correlates with the pollen counts.

Thus, it is possible to characterize the areas where the pollens originated and to adequately estimate the annual pollen counts of *C. japonica* and Cupressaceae on the basis of meteorological conditions in the area of the pollens' origin.

Key Words : Okayama Prefectrure, *Cryptomeria japonica*, Cupressaceae, precipitaion

Introduction

Cryptomeria japonica pollinosis was first reported in Japan by Horiguchi *et al.*,[1] and it has recently

become a considerable social concern because of seasonal allergic epidemics. Since the fluctuations in numbers of pollinosis patients have been correlated with the combined pollen count of *C. japonica* and Cupressaceae [2, 3], it is very important to predict the yearly pollen counts of *C. japonica* and Cupressaceae and provide the information to pollinosis patients.

A positive correlation has been found between annual total pollen counts and meteorological factors, especially the mean value of maximum temperature in July of the previous year [2, 3, 4, 5]. However, there have been relatively few studies showing that pollen counts are correlated with precipitation in July of the previous year [3, 5]. Precipitation is generally greatly influenced by geographical features [6], and the amount of precipitation in the northern area of Okayama Prefecture near the Chugoku Mountainous District is greater than in the southern area of the prefecture.

The present study was undertaken to investigate the annual variations of *C. japonica* and Cupressaceae pollen counts at three observation sites (Kojima, Okayama, Wake) in the southern area of Okayama Prefecture and their relation to weather conditions (precipitation and the mean value of maximum temperature) at the seven weather stations in Okayama Prefecture. The data obtained allowed us to derive pollen-forecasting formulas.

Materials and methods

We used Durham [7] standard pollen samplers to sample the pollens and used Calberla liquid to stain pollen

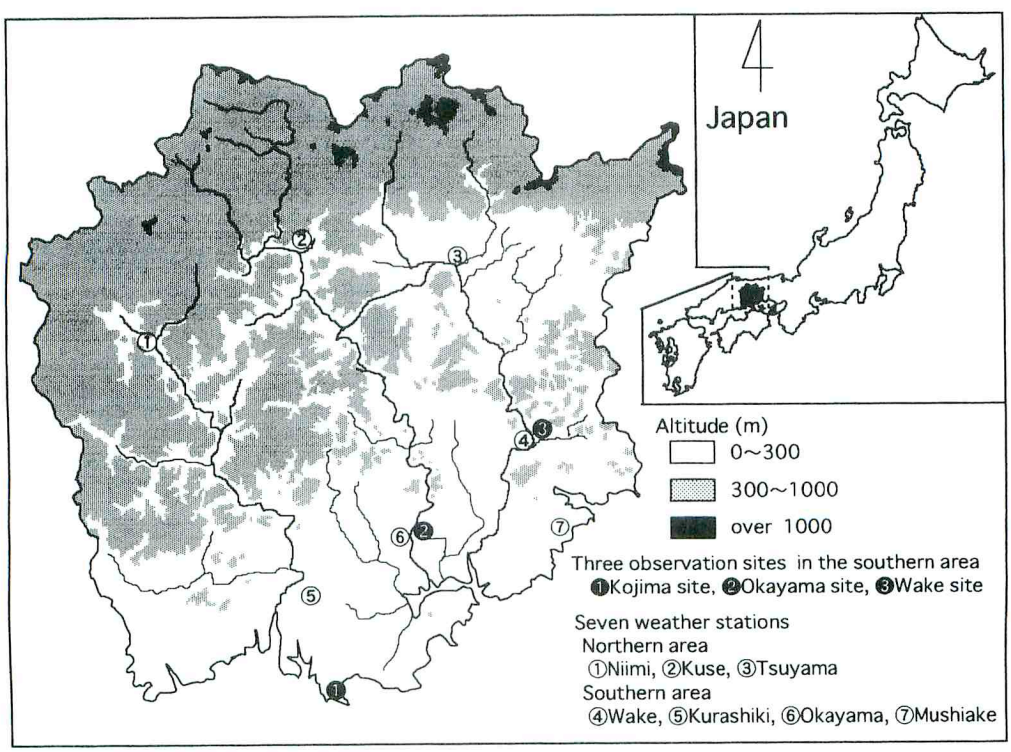

Fig. 1. Three observation sites, seven weather stations, and the topographical map of Okayama Prefecture, in Japan.

grains that had fallen naturally onto glass slides and been trapped in a thin layer of white Vaseline during the 24-h period from 8 : 30 a. m. to 8 : 30 a. m. the next day. Grains in a 3.24-cm^2 area (1.8×1.8cm) were counted under a light microscope, and the results were expressed as pollen grains / cm^2. The observation period was from the beginning of February until the beginning of May.

Regression analysis was employed for statistical evaluation. Differences were considered to be significant when p was < 0.05.

1) Three observation sites for airborne pollen grains and seven weather stations [8]

Fig. 1 shows the locations of the three observation sites in the southern area, the seven weather stations, and a topographical map of Okayama Prefecture with a line drawn at the 300 m level [9].

Three observation sites in the southern area of Okayama Prefecture :

❶ Kojima site : Kojima, Kurashiki City (Kurashiki Municipal Kojima Shimin Hospital, Kurashiki Shitei Hospital)

❷ Okayama site : Ridai-cho, Okayama City (Okayama University of Science)

❸ Wake site : Wake-cho, Wake-gun (Kitagawa Hospital)

Seven weather stations in Okayama Prefecture :

① Niimi weather station : Niimi City, Okayama

② Kuse weather station : Kuse-cho, Maniwa-gun, Okayama

③ Tsuyama weather station : Tsuyama City, Okayama

④ Wake weather station : Wake-cho, Wake-gun, Okayama

⑤ Kurashiki weather station : Kurashiki City, Okayama

⑥ Okayama weather station : Okayama City, Okayama

⑦ Mushiake weather station : Mushiake Oku-gun, Okayama

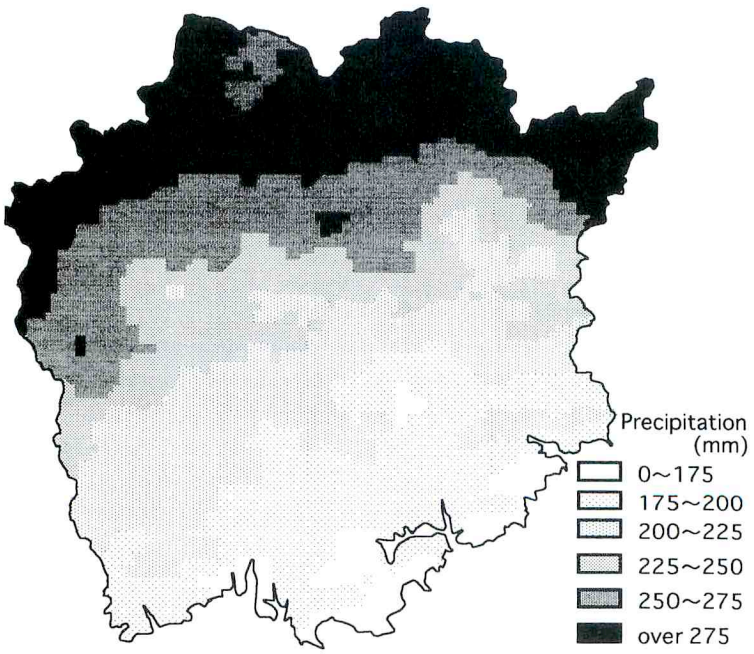

Fig. 2. Distribution map of a climatic diagram of grid data for the annual mean precipitation values in July in Okayama Prefecture for 24 (1953 ~ 1976) years.

Table 1. Pollen counts observed at the three observation sites and meteorological conditions in July at two weather stations in Okayama Prefecture

Year	Observed pollen count (grains / cm^2 / year)					Weather station			
						Tsuyama	Okayama	Tsuyama	Okayama
	Kt	Ot	Wt	Ocr	Ocu	P7 (mm)		T7 (℃)	
1984	–	–	–	–	–	133.0	73.5	30.0	31.1
1985	–	1,886	–	–	–	245.0	113.0	29.7	31.5
1986	–	850	–	–	–	420.0	155.0	28.2	29.7
1987	–	587	–	–	–	342.0	200.0	29.3	30.9
1988	–	1,482	–	729	753	255.0	150.0	28.2	29.6
1989	846	327	1,302	215	112	222.0	120.0	29.0	29.6
1990	1,694	1,494	1,911	885	609	253.0	112.0	30.5	32.2
1991	3,679	3,125	3,729	1,799	1,326	226.0	262.0	29.5	31.0
1992	550	642	648	312	330	168.0	79.0	29.8	30.9
1993	2,179	1,491	3,143	955	536	364.0	383.0	26.8	28.0
1994	207	413	414	149	264	49.0	131.0	33.8	34.1
1995	9,914	8,096	11,941	4,259	3,837	374.0	298.0	29.2	31.1
1996	541	421	361	188	233	176.0	73.0	30.3	31.3
1997	1,387	1,983	1,255	1,173	810	353.0	304.0	28.2	30.0
1998	558	539	467	236	303	294.0	69.0	29.7	31.0
1999	1,741	1,658	1,375	1,193	465	142.0	122.0	28.6	29.5
2000	958	595	740	341	254	–	–	–	–
Mean	2,021	1,732	2,274	975	757	251.0	165.3	29.4	30.7
Range	9,707	7,769	11,580	4,110	3,725	371.0	314.0	7.0	6.1

Abbreviations : Mean and Range, annual pollen counts at the three sites are from 1989 to 2000 and the weather data are from 1984 to 1999 ; Kt, total pollen counts of *Cryptomeria japonica* and Cupressaceae at the Kojima site ; Ocr, *Cryptomeria japonica* pollen counts at the Okayama site ; Ocu, Cupressaceae pollen counts at the Okayama site ; Ot, total pollen counts of *Cryptomeria japonica* and Cupressaceae at the Okayama site ; Wt, total pollen counts of *Cryptomeria japonica* and Cupressaceae at the Wake site ; P7, precipitation in July ; T7, the mean value of maximum temperarure in July.

2) AMeDAS (automated meteorological data acquisition system)

We examined precipitation and the mean value of maximum temperature from June to September (1984 ~ 1999). Meteorological data from the AMeDAS meteorological phenomenon monthly reports at each of the seven weather stations were used. Fig. 2 shows a climatic diagram of the annual mean precipitation values in July modified by the climatic chart of mesh climatic data for 24 years of the Osaka District Meteorological Observatory [10] .

Results

1) Pollen counts of *C. japonica*, combined pollen counts of *C. japonica* and Cupressaceae, the mean value of maximum temperature and precipitation in July

The pollen counts of both *C. japonica* and Cupressaceae and the combined pollen counts of *C. japonica* and Cupressaceae at the three observation sites in the southern area and the mean value of maximum temperature

and precipitation in July at the two weather stations are shown in Table 1.

The annual mean combined pollen count at the three sites in the southern area was 2009 grains / cm^2 / year. The highest peak was observed in 1995 (9984 grains / cm^2 / year), and the lowest peak was observed in 1994 (345 grains / cm^2 / year). The seasonal changes in each pollen count at the three sites were almost same.

The annual mean pollen count of *C. japonica* at the Okayama observation site was 218 grains / cm^2 more than that of the Cupressaceae. There was a significant correlation between counts of *C. japonica* and Cupressaceae ($r = 0.978$, $p < 0.0001$, $n = 13$).

The annual mean value of maximum temperature in July (1984 ~ 1999) was highest at Okayama weather station and lowest at Niimi (Niimi : 27.8℃, Kuse : 30.2℃, Tsuyama : 29.4℃, Wake : 29.5℃, Kurashiki : 29.9 ℃, Okayama : 30.7℃, Mushiake : 29.1℃). The difference was largest at the Kuse station and smallest at the Mushiake station (Niimi : 7.6℃, Kuse : 8.1℃, Tsuyama : 7.0℃, Wake : 5.7℃, Kurashiki : 5.7℃, Okayama : 6.1℃, Mushiake : 5.2℃). Mean precipitation in July (1984 ~ 1999) was greatest at the Tsuyama station and lowest at the Kurashiki station (Niimi : 227.1mm, Kuse : 249.6mm, Tsuyama : 251.0mm, Wake : 177.6mm, Kurashiki : 153.4mm, Okayama : 165.3mm, Mushiake : 158.0mm). The difference in mean precipitation in July was greatest at the Niimi station and smallest at Mushiake (Niimi : 534mm, Kuse : 337mm, Tsuyama : 371mm, Wake : 391mm, Kurashiki : 326mm, Okayama : 314mm, Mushiake : 276mm).

Fig. 2 shows the annual mean precipitation in July for 24 years. As shown in Fig. 1, the distribution of precipitation in July closely conforms to the difference in topography of Okayama Prefecture with a line drawn at the 300m level.

2) Distribution of *C. japonica* and *Chamaecyparis obtusa* plantation areas in Okayama Prefecture [5]

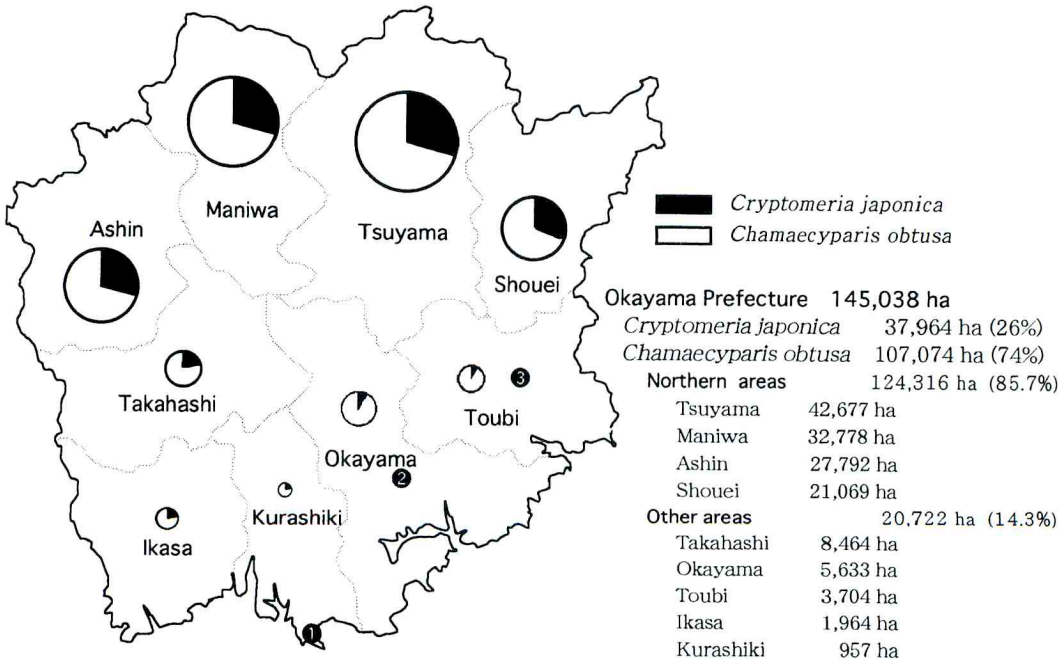

Fig. 3. Three observation sites, and distribution map of the plantation of the area of *Cryptomeria japonica* and *Chamaecyparis obtusa* in Okayama Prefecture. The three observation sites (❶~❸) are described in Fig. 1.

Table 2. Correlation coefficients between each of the pollen counts at the three observation sites and precipitation in each previous month from June to September at the seven weather stations

	Weather station	Month	Observation site				
			Kt	Ot	Wt	Ocr	Ocu
Northern area	Niimi	6	−0.426	−0.446	−0.409	−0.463	−0.461
		7	−0.625 *	−0.629 **	−0.599 *	−0.686 **	−0.573 *
		8	−0.251	−0.181	−0.197	−0.252	−0.253
		9	0.320	0.117	−0.042	0.116	0.041
	Kuse	6	−0.388	−0.428	−0.372	−0.403	−0.411
		7	−0.589 *	−0.569 *	−0.606 *	−0.587 *	−0.527
		8	−0.238	−0.195	−0.161	−0.267	−0.263
		9	−0.230	0.050	−0.085	0.035	−0.030
	Tsuyama	6	−0.337	−0.370	−0.309	−0.359	−0.364
		7	−0.680 *	−0.615 *	−0.691 *	−0.664 *	−0.624 *
		8	−0.270	−0.236	−0.205	−0.301	−0.270
		9	0.038	0.081	−0.017	0.065	0.002
Southern area	Wake	6	−0.426	−0.411	−0.392	−0.423	−0.433
		7	−0.573	−0.512 *	−0.573	−0.607 *	−0.513
		8	−0.176	−0.095	−0.108	−0.147	−0.183
		9	0.067	0.119	0.002	0.138	0.050
	Kurashiki	6	−0.450	−0.344	−0.433	−0.399	−0.414
		7	−0.533	−0.496	−0.515	−0.602 *	−0.466
		8	−0.289	−0.212	−0.239	−0.249	−0.280
		9	0.228	0.261	0.166	0.290	0.210
	Okayama	6	−0.402	−0.350	−0.373	−0.379	−0.403
		7	−0.366	−0.329	−0.335	−0.443	−0.279
		8	−0.198	−0.160	−0.140	−0.166	−0.217
		9	0.181	0.225	0.124	0.247	0.174
	Mushiake	6	−0.335	−0.319	−0.295	−0.325	−0.344
		7	−0.512	−0.442	−0.518	−0.325	−0.455
		8	−0.257	−0.131	−0.205	−0.192	−0.241
		9	0.070	0.129	0.002	0.131	0.064

Abbreviations : Kt, Ocr, Ocu, Ot, and Wt are explained in Table 1.

The plantation areas of *C. japonica* and *Chamaecyparis obtusa* in Okayama Prefecture are shown in Fig. 3. The Kurashiki area accounts for only 0.7% of the total plantation areas. The Okayama and Toubi areas account for 6.5% of the total plantation areas (Okayama : 3.9%, Toubi : 2.6%), with 85.7% of all plantations in Okayama Prefecture lying in the northern area, including the Tsuyama area.

3) Relationship between pollen counts in Okayama Prefecture and precipitation from June to September of the previous year

Table 2 shows the correlations between the counts of each type of pollen at the three observation sites and precipitation at the seven weather stations in Okayama Prefecture from June to September of the previous year. There were clear correlations between the counts of each type of pollen at the three sites in the southern

area and precipitation in July of the previous year in the northern area but not in the southern area.

4) Relationship between pollen counts and the mean value of maximum temperature in July of the previous year

The counts of each type of pollen in the southern area correlated significantly with the mean value of maximum temperature in July of the previous year at the all weather stations in Okayama Prefecture. The mean value of maximum temperature at the Tsuyama station correlated best with the counts of all types of pollen at the three observation sites (Kojima : $r = 0.899$, $p < 0.0001$, $n = 12$, Okayama : $r = 0.903$, $p < 0.0001$, $n = 16$, Wake : $r = 0.875$, $p < 0.0001$, $n = 12$), (*C. japonica* at the Okayama : $r = 0.925$, $p < 0.0001$, $n = 13$, Cupressaceae at the Okayama : $r = 0.892$, $p < 0.0001$, $n = 13$).

The correlation coefficient was lowest at the Kurashiki station (Kojima : $r = 0.792$, $p < 0.01$, $n = 12$, Okayama : $r = 0.797$, $p < 0.001$, $n = 16$, Wake : $r = 0.744$, $p < 0.01$, $n = 12$), (*C. japonica* at the Okayama and the Kurashiki station : $r = 0.831$, $p < 0.001$, $n = 13$, Cupressaceae at the Okayama and the Okayama station : $r = 0.805$, $p < 0.001$, $n = 12$). All correlations between the pollen counts and the mean value of maximum temperature were higher in the northern area than in the southern area.

5) Relationship between the meteorological data at Tsuyama and Okayama

Fig. 4 shows the relationship between the precipitation data in July at the Tsuyama and at the Okayama weather stations. Although there was a correlation, the coefficient was very low ($r = 0.593$, $p < 0.05$, $n = 16$).

Fig. 5 shows the correlation between the mean value of maximum temperature in July at the Tsuyama weather station and at the Okayama weather station. The mean value of maximum temperature in July at the Tsuyama station correlated closely with the mean value of maximum temperature at the Okayama station ($r = 0.956$, $p < 0.0001$, $n = 16$).

6) Formulas for estimating the combined pollen count of *C. japonica* and Cupressaceae in the next season

We found correlations between the annual pollen counts of *C. japonica* and Cupressaceae and meteorological factors, such as the mean value of maximum temperature and precipitation in July and propose the following formulas to estimate the total pollen counts in the next season:

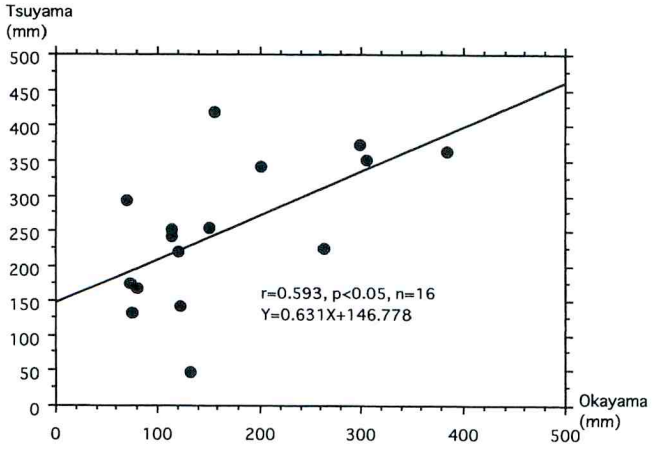

Fig. 4. Correlation between precipitation in July at the Okayama weather station and at the Tsuyama weather station.

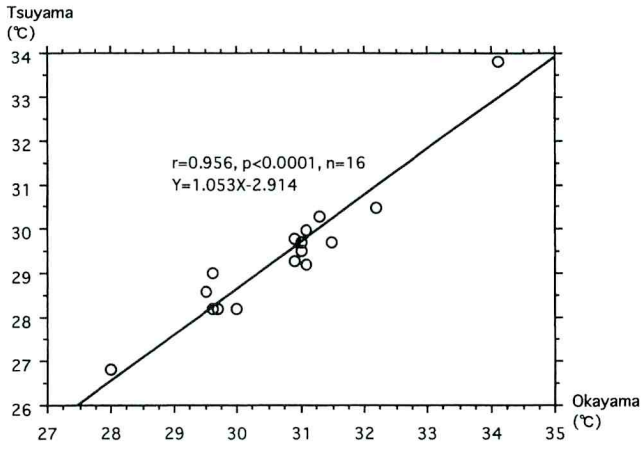

Fig. 5. Correlation between the mean value of maximum temperature in July at the Okayama weather station and at the Tsuyama weather station.

Kojima site : $Y = 1320T - 2.0P - 36384$,

Okayama site : $Y = 1155T - 0.4P - 32484$,

Wake site : $Y = 14776T - 4.4P - 40169$,

where Y is the expected total number of pollen counts per cm^2 / year, T is the mean value of maximum temperature, and P is precipitation in July of the previous year.

Discussion

There have been many reports indicating that the pollen counts of *C. japonica* and combined pollen counts of *C. japonica* and Cupressaceae are closely correlated with meteorological conditions, such as temperature and duration of sunshine in July of the previous year [2, 3, 4, 5]. There is a consensus among experts that the combined pollen counts of *C. japonica* and Cupressaceae correlate significantly with the mean value of maximum temperature [2, 3, 4, 5]. However, there are reports of different findings in regard to precipitation.

In a long-term study in Fukuoka City, Kishikawa *et al.* [2] found that the pollen counts of *C. japonica* and Cupressaceae correlated with precipitation in July of the previous year. *Yamazaki et al.* [11], however, reported that a nationwide investigation showed no correlation between the pollen counts of *C. japonica* and precipitation (Fukuoka City, Kumamoto City, Saga City, Ube City, and Sagamihara City).

The pollen counts in the southern area correlated well with the mean value of maximum temperature in the previous July at all of the weather stations in Okayama Prefecture. We found a good correlation between the counts for each type of pollen at the three observation sites in the southern area and precipitation at the weather stations in the northern area, but not in the southern area.

Because of the strong influence of geographic features in Okayama Prefecture on precipitation, the amount of precipitation in the northern area is greater than in the southern area [6].

Ogasawara *et al.* [12] investigated the area of the *C. japonica* plantations in the Chugoku Mountainous area and Rokko area in Hyogo Prefecture according to altitude, and reported that they were important as pollen sources in the Chugoku District up to the altitude of 500m, especially below 320m.

The results of the present study indicate that a geographic map with a line drawn at the 300m level is consistent with the map of the distribution of precipitation in July. The annual variations in the mean value

of maximum temperature in July at the Tsuyama weather station in the northern area correlates quite well with the variations at the Okayama weather station. The annual variations in precipitation in July at the Tsuyama weather station are not very consistent with the variations at the Okayama weather station. For this reason, the pollen counts in the southern area correlate quite well with the mean value of maximum temperature at all weather stations, but with precipitation only at the weather stations in the northern area, where 124316 ha account for 85.7% of all plantations and which appears to be the source of the pollen in the southern area.

The results of the present study show that precipitation in Okayama Prefecture is influenced by geographic features and that it varies according to locality. We confirmed that the annual variations in temperature in July are almost the same in all areas, but the variations in precipitation are quite different. Thus, whenever it is necessary to investigate precipitation, the data for the area in which the pollen grains originated must be used.

If an observation site lies in the basin of an inland prefecture, the source of the pollen grains can be in any direction, and some sources of airborne pollen grains of *C. japonica* and Cupressaceae have not been determined, making it impossible to investigate correlations between the pollen counts and meteorological conditions in the area in which the pollen originated. This seems to be the reason for the conflicting findings between pollen counts and precipitation.

C. japonica pollen has been reported to exhibit cross-allergenicity with Cupressaceae pollen [13, 14], and some clinical reports [2, 3] have concluded that the variations in numbers of pollinosis patients correlate with the yearly combined pollen count of *C. japonica* and Cupressaceae. It is therefore very important to predict the combined pollen count of *C. japonica* and Cupressaceae and to provide the information to pollinosis patients. Based on the findings in the present study, we will be able to estimate the yearly pollen counts of *C. japonica* and Cupressaceae on the basis of the meteorological conditions in the area where the pollen originated.

Acknowledgments

We are grateful to Ms. K. Kouhara of Kurashiki Shitei Hospital, Mr. T. Horibe of Kitagawa Hospital, and Prof. N. Miyoshi of Okayama University of Science for kindly providing the pollen count data for *C. japonica* and Cupressaceae.

References

(1) Horiguchi, S. and Saito, Y. : Japanese cedar pollinosis in Nikko, Japan. *Jpn. J. Allergol.* **13**, 16-18 (1964). (in Japanese)

(2) Kishikawa, R., Nagano, H., Katsuta, M. and Sou, N. : The annual variations in airborne *Cryptomeria japonica* pollen counts and meteorological conditions in Fukuoka City. *Jpn. J. Allergol.* **37**, 355-363 (1988). (in Japanese)

(3) Sahashi, N., Ikuse, M., Ohmoto, T., Saito, Y., Tanahashi, Y. and Takeda, H. : Relationship between seasonal and annual combined pollen count of *Cryptomeria japonica* and Cupressaceae and number of outpatients with Sugi pollinosis in central Japan. *Rev. Palaeobot. Palynol.* **64**, 79-86 (1990).

(4) Namba, H., Tsuboi, A. and Miyoshi, N. : Annual variations in counts of airborne *Cryptomeria japonica* and Cupressaceae pollen and possibility of pollen forecasting. *Jpn. J. Palynol.* **43**, 87-96 (1997). (in Japanese)

(5) Namba, H., Saitou, K. and Sahashi, N. : Assumption of the area supplying Okayama Prefecture with *Cryptomeria japonica* and Cupressaceae airborne pollen, and of their scattering routes. *Jpn. J.*

Allergol. **48**, 1337-47 (1999). (in Japanese)
(6) Okayama Local Meteorological Observatory : Climatography in Okayama prefecture. 8-10, (1991). (in Japanese)
(7) Durham, O. C. : The volumetric incidence of atmospheric allergens. Ⅳ. A proposed standard method of gravity sampling, counting, and volumetric interpolation of results. *J. Allergy* **17**, 79-86 (1946).
(8) Okayama Local Meteorological Observatory : Monthly reports of Okayama local meteorological observatory June 1984 - September (1999).
(9) Okayama Local Meteorological Observatory : Report of the topographical map and the points of AMeDAS in Okayama Prefecture. (1998). (in Japanese)
(10) Osaka District Meteorological Observatory : Climatic chart of mesh climatic data in area of Osaka district meteorological observatory (precipitation and snow cover). 1-55 (1992). (in Japanese)
(11) Yamazaki, F., Mizuno, M., Shida, T. and Shimizu, T. : Studies of the pollen grains causative of pollinosis (1). *Jpn. J. Allergol.* **28**, 732-737 (1979). (in Japanese)
(12) Ogasawara, H., Yoshimura, H., Goto, M., Tuyu, M., Fujitani, T. and Nakahara, T. : The increase of the total pollen counts of Sugi (*Cryptomeria japonica*) due to the increasing area of mature Sugi forests. *Jpn. J. Palynol.* **44**, 97-105 (1998). (in Japanese)
(13) Takahashi, Y., Ide, T., Ashida, T., Tabata, S. and Araki, T. : Major allergens of Hinoki- and Sugi-pollen exist on their grain wall. *Jpn. J. Palynol.* **38**, 51-57 (1992).
(14) Ide, T. and Ashida, T. : Cross-reactivity between the arboreal pollens of *Cryptomeria japonica* (Japanese cedar) and Cupressaceae. *Allergy in Practice.* **11**, 174-178 (1991). (in Japanese)

スギ・ヒノキ科花粉数と前年７月の降水量の関係

難波　弘行[1)]・斎藤　勝剛[2)]・佐橋　紀男[3)]

[1)] 倉敷市立児島市民病院薬局, [2)] 内科　〒711-0921　岡山県倉敷市児島駅前２-39
[3)] 東邦大学薬学部　〒274-8510　千葉県船橋市三山２-２-１

日本では、スギ、スギ・ヒノキ科花粉飛散数と前年７月の降水量との間に相関関係が認められたという報告は少ない．岡山県では、県南部で観測されたスギ・ヒノキ科花粉数と降水量との間に良い相関関係が認められたのは、県北部の各気象測候所であった．一方、これら花粉数と前年７月の最高気温平均値の相関関係は、全ての気象測候所で良い相関関係が認められた．

岡山県北部のスギ・ヒノキ植林面積は、85.7% を占めており、南部へのスギ・ヒノキ科花粉の供給地と考えられる．今回の調査で、７月の最高気温平均値の年間推移は県北部と県南部で良く一致しているが、降水量は一致していないことが確認された．そのため、これら花粉数と全ての気象測候所の最高気温平均値の間に相関関係が認められたのに対し、降水量は、県北部の気象測候所でのみ良い相関関係が認められたものと思われる．

このことより、植林面積，地勢図そして降水量などの気象条件から統計学的に花粉供給地を推定し、その地域の気象条件を用いることで正確な年間花粉数を予測することが可能と思われる．