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Effect of Climate Change on Fagaceae Airborne Pollen in Japan as Allergic Causative Agent Associated with Food Allergy

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Abstract

Rational: It is no exaggeration to say that Japanese allergic people has increased according to the increase of Japanese Cedar (JC) pollinosis since the first case report, 1964. In Japan allergenic conifer airborne pollen counts have been increasing with a concomitant change in the start of pollination as a result of climate change during about 30 years. We also investigated as if Fagaceae pollen counts have been affected on climate change. In Japan patients with Fagaceae pollinosis is not so clear although this vegetation distributed almost all of Japan Island. Fagaceae pollen antigen has cross-reactivity to *Betula* (birch) pollen antigen observed in north part of Japan. Especially in Hokkaido district, a lot of patients with birch pollen have rhinoconjunctivitis and pollen related food allergy, oral allergy syndrome (OAS). In order to analyze and ameliorate the suffering of those with pollinosis, we have estimated the correlation between the Fagaceae pollen counts and meteorological conditions affecting those counts and we will inform the tendency of the pollen disperse for prevent and treatment against Fagaceae pollinosis.

Method: There are institutions in fifteen locations monitoring airborne pollen by Durham sampler in Japan between the latitude of 30 to 40 degrees north. At each institute daily airborne pollen samples were collected including holidays and sent to our hospital. We counted pollen grains per cm^2 through 100 to 400-power microscopes, classifying and summarizing them. From 1986 to 2014 we have referred to the change in monthly mean temperature, humidity, total monthly sunshine duration and amount of global solar radiation at the close to 9 of the pollen monitoring locations by the Meteorological Agency open data.

Result: Fagaceae pollen counts have not shown annual fluctuation compared to conifer but have increased gradually. Only total monthly sunshine duration before the pollination in March has a weak significant correlation with Fagaceae pollen counts ($r=0.4\sim0.53$, $p<0.05$) only in some cities. The start of pollination season has been earlier except north of Japan and correlated with March/April mean temperature significantly with the prolongation of pollination season.

Conclusion: Fagaceae pollen counts in Japan have been increasing and in the south of Japan Island the pollination season has prolonged during about 30 years climate change. In near future patients with Fagaceae pollinosis will increase in the southern part of Japan and birch/alder pollinosis with oral allergy syndrome will exacerbate during Fagaceae pollination season. We will inform Fagaceae pollen allergen is important for Japanese allergic people from aerobiology site.

Keywords: Fagaceae pollinosis; Oak; Cross-reactivity; Climate change; OAS

Introduction

In 2016 we reported that allergenic conifer airborne pollen counts have been increasing with a concomitant change in the start of pollination season due to the increase in growing area for more than 30 year-old conifer woodlands as a result of climate change during those about 30 years. We have begun to investigate airborne pollen dispersion through the year by monitoring, its start, intensity and duration as a one of successful approaches to the national problem, Japanese cedar pollinosis, urgently in June 1986 [1,2]. Gravitational sampling by Durham's sampler as a technically simple method which used already by our predecessors was immediately available and easy applicable by clinicians, who had a little knowledge on aerobiology introduced in 1960s. On the gravitational data we reported a significant correlation with Burkard's (volumetric method) data in pollen count [3,4] except very small count of weed pollen.

We also found Fagaceae pollen counts have been increasing. In Japan number of patients with Fagaceae pollinosis is so small although these vegetation distributed almost all of Japan Island that we have not noticed it closely.

In order to inform the precise tendency of the pollen disperse for prevent and treatment against Fagaceae pollinosis effectively, we have estimated the correlation between the Fagaceae pollen counts and meteorological conditions affecting those counts.

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Method

There are institutions in fourteen locations monitoring airborne pollen by Durham's sampler in Japan between the latitude of 30 to 40 degrees north (Figure 1). We estimated the pollen count and climatic data close to nine pollen monitoring locations. These are north region, Tohoku and Hokuriku district (Sendai 140°54'E38°16'N, Niigata139°1'E 37°54' N, Toyama 137°12' E36°43'N), central region, Kanto, Tokai and Kinki district (Sagamihara 139°22'E 35°34'N, Hamamatsu 137°43'E34°45'N, Tsu 136°31'E34°44'N, Wakayama 135°10'E34°14'N) and south-west region, Kyushu district (Fukuoka 130°26'E33°42'N, Kumamoto 130°42'E32°49'N). Figure 1 shows the locations of airborne pollen monitoring by Durham's Sampler. We have collaborated these facilities for monitoring. Sendai city (Tohoku University), Niigata city (Fujisaki Clinic, Tsukioka Clinic), Toyama city (Toyama University),Takasaki city (Sato Clinic), Sagamihara city (NHO Sagamihara Hospital), Hamamatsu city (Tokai Pollinosis Institute), Tsu city (NHO Mie Hospital), Wakayama city (Wakayama Red Cross Hosp.), Fukuoka city (Kyushu University), Kumamoto city (Kumamoto University), Miyazaki (Miyazaki University) and Yakushima, Kumageshi city (Kagoshima University, The Foresty Agency). And Japan Weather Support Center, Environmental Ministry, Fukuoka Prefecture Medical Association, Japan Medical University, Oita University have supported our investigation. At each institute daily airborne pollen sample was collected by Vaseline® coated glass slides which were fixed in the Durham's sampler and exchanged every morning, as a rule. The sampling slides were sent to our clinical institute. After staining the samples with saturated basic fuchsine (Calberla's stain) we identified the pollen grains at 400-power and counted them at 100-power through microscope. For the Durham's method, pollen counts were standardized expressing them as the number of pollen grains per cm^2, classifying and summarizing them [5]. The date of starting and ending were also defined. From 1986 to 2014 we have referred to the annual change in monthly mean temperature, humidity, sunshine duration and Amount of global solar radiation (AGSR) using Japan Weather Association Home Page database. We have estimated annual Fagaceae total pollen count and annual starting day of *Quercus* (oak) pollen which is mainly dispersing in Japan with climatic conditions statistically by student t test (JMP 9 soft).

Result

Annual pollen count and climate change

Figure 2 shows Annual fluctuation of the total Fagaceae pollen counts from 1987 to 2014 at the 9 locations in Japan. Each vertical line shows pollen counting per cm^2 per year and horizontal line shows year. We did not express pollen counting logarithmically because that it is difficult to show the annual fluctuation visually. Fagaceae pollen counting is blue bar. The each dotted line shows approximation line rising gradually. Fagaceae pollen counts have been increasing gradually. They have not shown so remarkable annual fluctuation like the annual change of JC and Cypress pollen count according as the climate conditions [2]. The pollen counts/cm^2/year is different from each location. In Sagamihara the most of all Fagaceae pollen count was observed and next in Toyama, Hamamatsu (central in Japan Island) followed as same as JC and Cypress pollen counts. In Tohoku (north Japan) and Kyushu (south Japan) district the pollen counts were less than the other region.

Figure 3 shows Classification of Fagaceae pollen counts in Sendai (north Japan), Toyama (central Japan) and Fukuoka (south Japan). Each vertical line shows pollen counting per cm^2per year and horizontal line shows year.

We can identify *Fugus* (beech), *Quercus* (oak), *Castanear/Castanopsis/Lithcarpus* (castanear/pasania) and others in Fagaceae pollen. Blue lines express beech pollen grains, Orange lines are oak and gray lines are castanear/pasania and others are yellow.

There are different from each area. We were not able to identify these three kinds of pollen precisely for several years from 1987. Only in Fukuoka we can identify again. Oak pollen grains were observed at almost all area where we investigated. In the north and central area beech pollen grains were followed, castanear pollen grains were observed in the south area mainly. Oak, beech and castanear pollen grains have increased gradually.

Table 1 shows the trend of meteorological conditions related with Fagaceae pollen disperse from 1986 to 2014 near the 9 locations. In Japan Fagaceae pollen begin to disperse at March/April mainly. The male flower bud formation is performed in June generally. And then the June climate condition may affect next pollen product. The mean temperature in March is increased at each location except Niigata, Sagamihara and Tsu. In April the mean temperature is increasing at Fukuoka city only. June temperature is increased at all of the 9 locations respectively. On the other hand the mean humidity in the south of Japan is decreased. In March the mean AGSR/sunshine duration is increasing except north area in Japan.

Table 2 shows correlation between Fagaceae pollen counts and meteorological condition before bloom (March, April) and flower bud formed month (Former June). Only in Sagamihara city the plural climate conditions are correlated with annual fluctuation of pollen counts ($r= 0.412$ to 0.536, $P< 0.05$ to 0.01) significantly. AGSR/sunshine duration at only a few locations of all is correlated with pollen count respectively ($r=0.399$ to 0.528, $P<0.05$ To 0.01).

Annual starting day of oak pollen disperse and climate change

Figure 4 shows Annual change of starting day in *Quercus* (oak) pollination at the 9 locations from1987 to 2014. Each vertical line shows days from 1st January and horizontal line shows year. And the dotted line shows the approximate. The starting day is going to be earlier in south part of Japan and at Sagamihara (Kanto district), Niigata (Tohku district) gradually. In Tohoku (Sendai), Hokuriku (Toyama) area the starting days has become later at the locations, Hamamatsu and Tsu city (Tokai, Kinki district). There was not a certain tendency along the regional direction from south to north area in Japan Island.

Table 3 shows the correlation between starting day of oak pollination and meteorological conditions, mean temperature, humidity and AGSR/sunshine duration.

We found almost all significant negative correlation ship between the starting day and the mean temperature in March/April when oak pollen grains were near beginning to disperse from 1987 to 2014 ($r= -0.394$ to -0.784, $p<0.05$ to 0.001) even though earlier and later in the annual change of the starting day.

Annual change of the term of oak pollination season

Figure 5 shows annual change of the pollination terms from 1987 to 2014. Each vertical line shows the number of days from starting to ending of pollen scattering and horizontal line shows year. And the dotted line shows the approximate tendency.

At the locations in Kumamoto, Fukuoka city (Kyushu district), Wakayama city (Kinki district), Hamamatu city after the location moved (Tokai district) and Sagamihara city (Kanto district), oak

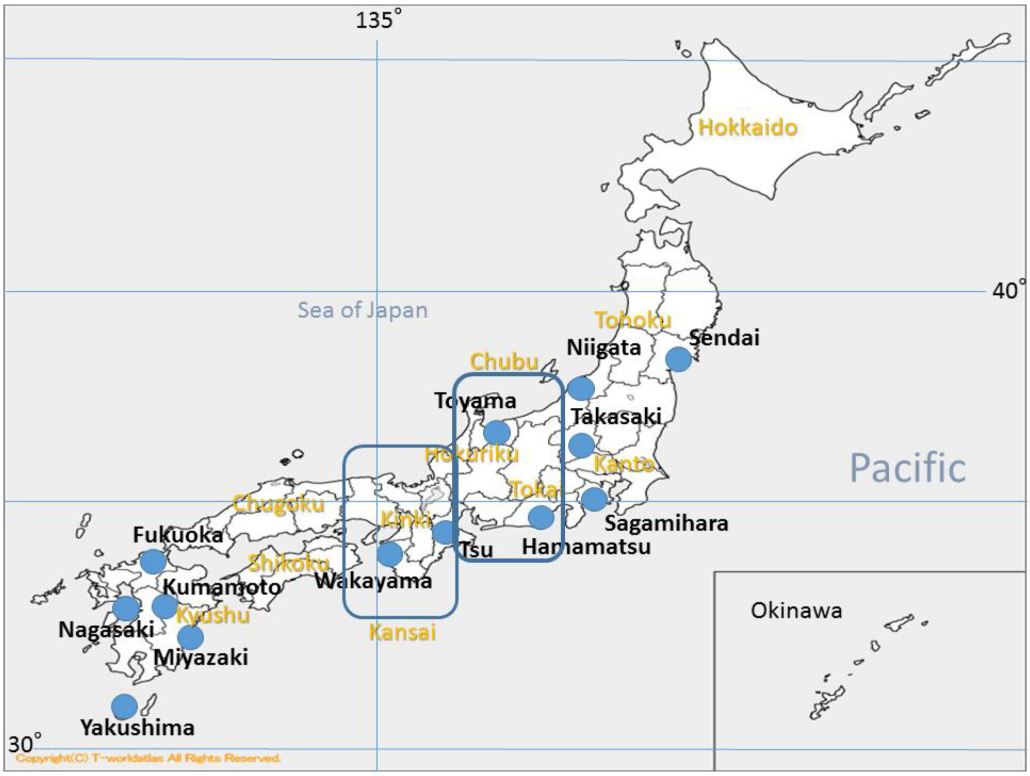
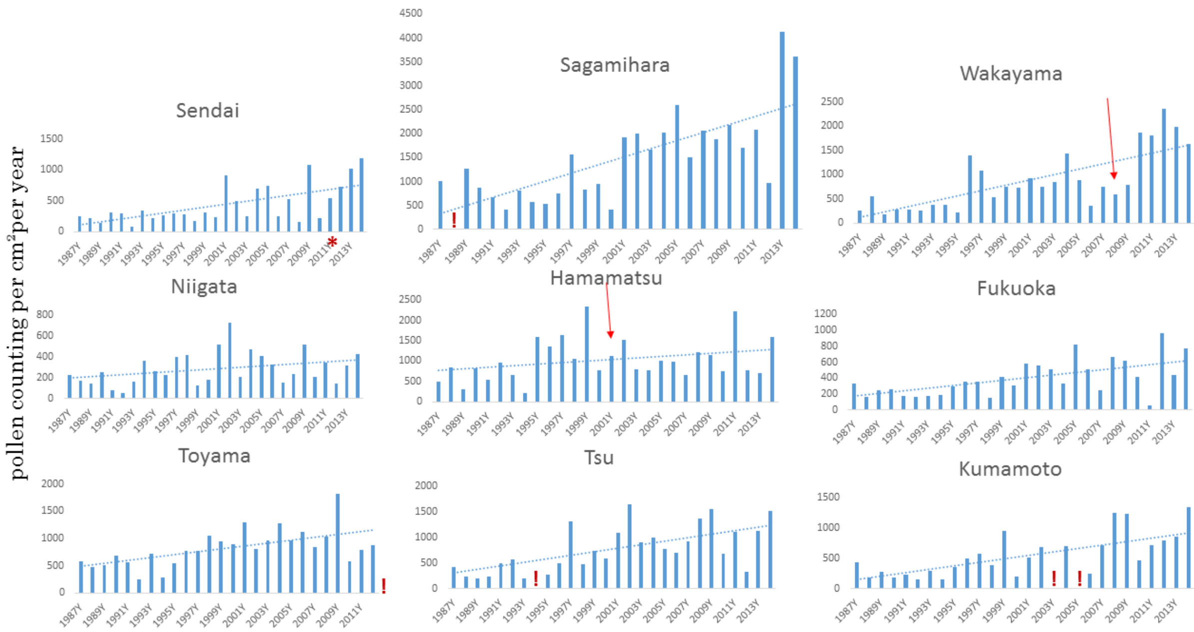


Figure 1: Locations of airborne pollen monitoring by Durham's Sampler in Japan. There are institutions in fifteen locations monitoring airborne pollen by Durham sampler between the latitude of 30 to 40 degrees north. In Fukoka and Niigata city there are 2 institutions. We estimate the pollen counts and meteorological condition open data at the close to 9 of the all locations. Japan Island divided into the districts, Hokkaido, Tohoku (north area), Kanto, Chubu, Kansai (central area) and Chugoku, Shikoku, Kyushu (south area) from north/east to south/west.



↓: Location moved in Wakayama from April 2001 and Hamamatsu from March 2008.
*: Tohoku earthquake in 2011, ! : Incomplete sampling

Figure 2: Annual fluctuation of the total Fagaceae pollen counts from 1987 to 2014 at the 9 locations in Japan. Each vertical line shows pollen counting per cm^2 per year and horizontal line shows year. And the dotted line shows the approximate. The each dotted line shows approximation.

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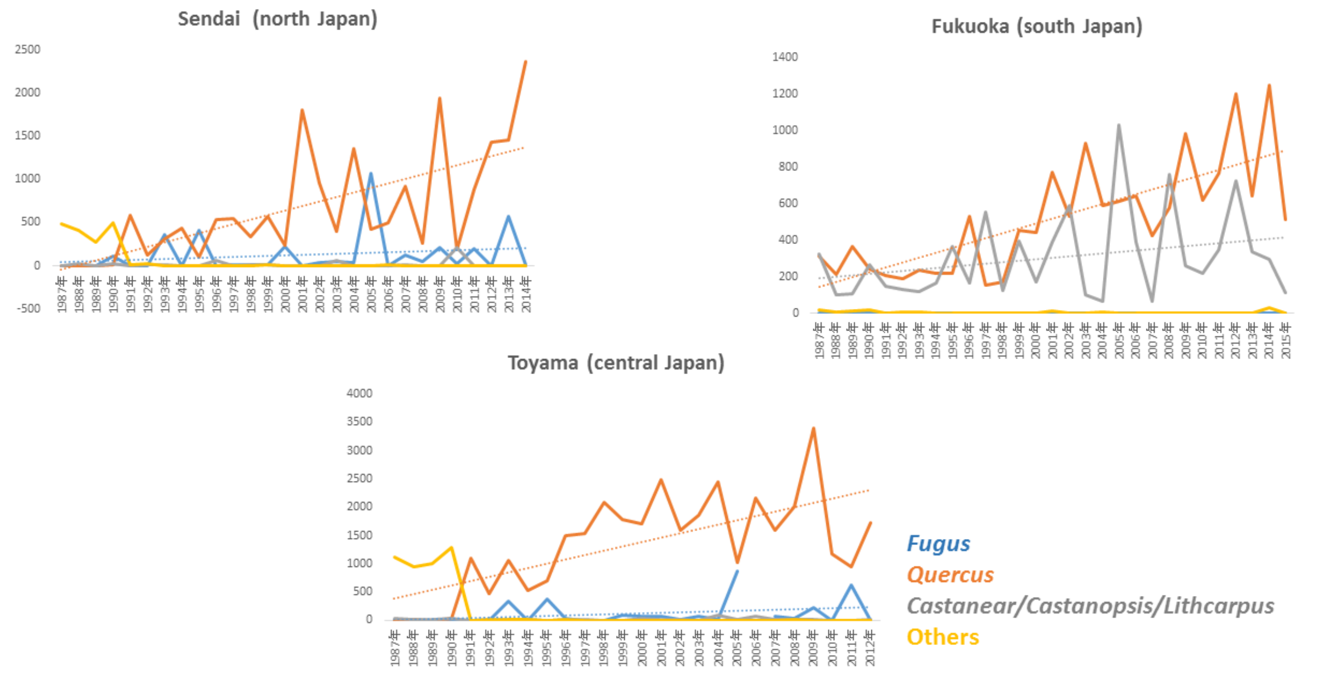
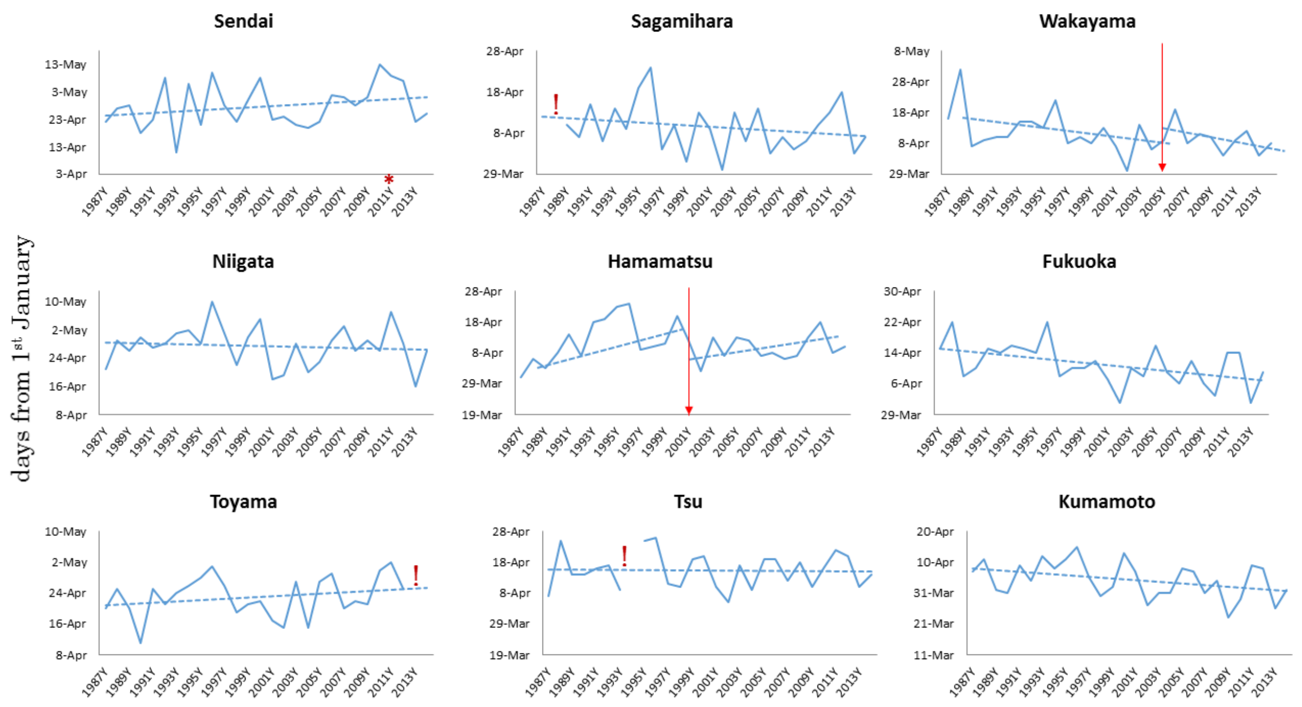


Blue line express Fagus (beech) pollen grains, Orange lines Quercus (oak), gray lines are Castanea/Castanapsis/Lthcarpus (castanear/pasania) and other are yellow lines. The each dotted line shows approximation.

Figure 3: Classification of Fagaceae pollen counts in Sendai (north Japan), Toyama (central Japan) and Fukuoka (south Japan). Each vertical line shows pollen counting per cm2 per year and horizontal line shows year.



↓: Location moved in Wakayama from April 2001 and Hamamatsu from March 2008.
*: Tohoku earthquake in 2011, ! : Incomplete sampling

Figure 4: Annual change of starting day in Quercus (oak) pollination at the 9 locations from 1987 to 2014. Each vertical line shows days from 1st January and horizontal line shows year. And the dotted line shows the approximate.

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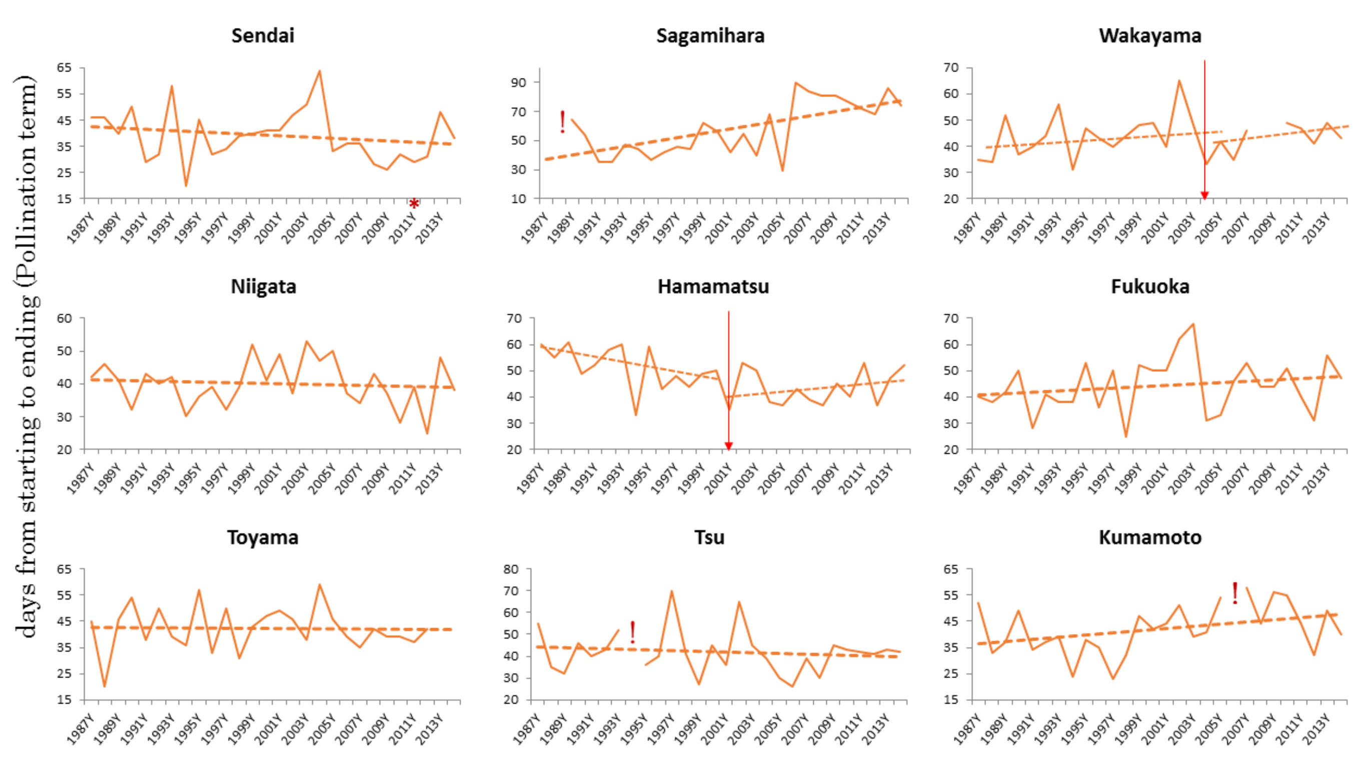

And the dotted line shows the approximate.
↓: Location moved in Wakayama from April 2001 and Hamamatsu from March 2008.
*: Tohoku earthquake in 2011, ! : Incomplete sampling.

Figure 5: Annual change of the days from the starting to ending of pollen scattering from 1987 to 2014. Each vertical line shows days from starting to ending and horizontal line shows year.

pollen pollination term have become prolonged gradually. At the other location where the starting day has become later they are not change or decreasing a little bit respectively.

Discussion

Laurisivae forest (evergreen broad-leaved forest) is one of our country forest component not artificial plantations. In Japan *Fagus, Quercus, Castanea, Castanopsis, Lithocarpus, Cyciobalanopsis* in Fagaceae are main native vegetated [6,7] except some of *Castanea* (Chesnut) trees planted for eating around the localized area. We can identify beech, oak, castanea/pasania and others as total Fagaceae pollen grains. From aerobiology site we found that oak pollen distributed through all Japan Island. Beech pollen grains are observed in the north part mainly and castanea/pasania in the south part of Japan Island frequently. From June 1986 to 2014 we have continued to investigate every year for information on the only important pollen antigen in Japan for the prevention and treatment against pollinosis [8], including Fagaceae pollen grains at each location not mainly.

Fagaceae pollen count has increased

We recognize Fagaceae pollen grain has allergenisity and cross-reactivity to birch and alder pollen antigen. The patients with Fagaceae pollinosis are not so common in Japan that we have only reported the information as the other tree pollen until now. This time we have estimate the pollen disperse during these years from 1986 to 2014. Fagaceae pollen counts are increasing clearly at each 9 locations monitoring airborne pollen even by gravitational method respectively.

After we estimated correlation annual pollen counts between annual climate pleural conditions at 9 locations respectively we found only AGSR/sunshine duration in a few area has significant correlation ship with the pollen count. In Sagamihara city the total pollen count is most of all and has significant correlation with annual climate change in March and April. But in June when male flower bud formed almost all climate conditions was not correlation with next pollen counting everywhere. The reason why we have to do research in future is, "The starting day and dispersing days of Oak pollen grains"

The starting day at each location was dependent upon annual change of mean temperature before bloom in March and April. Only in the southwest area of Japan Island the starting day has become earlier and the pollination term has become prolonged as shown in Figures 3 and 4. We surprised there were different from the tendency of annual changes of climate condition with starting day at each area in Japan Island between the latitude of 30 to 40 degrees north. Moreover we thought that effecting factors to the pollen disperse are not meteorological conditions but also artificial factors as city planning around environment. In Finland airborne *Betula* pollen concentration has increased remarkably correlated with temperature change during 31 years with earlier onset of pollination [9] as same as in Hokkaido, Japan during even shorter 10 to 19 years [10,11]. We are not able to clear precisely the correlation ship between annual change of pollen count and climate change although conifer pollen counts were correlated with meteorological conditions significantly [2]. We thought that our gravity method is near qualitative analysis and Fagaceae pollen counts less than that of conifer except Sagamihara's most of all data.

	March	April	June
Sendai city			
Temp.	⇑	→	⇑
Humidity	→	→	↓
AGSR	→	→	⇑
Niigata city			
Temp.	→	↓	⇑
Humidity	→	→	→
AGSR	→	→	⇑
Toyama city			
Temp.	⇑	→	⇑
Humidity	↓	→	→
AGSR	→	→	⇑
Sagamihara city			
Temp.	→	→	⇑
Humidity	↓	↓	→
Sunshine	⇑	⇑	↓
Hamamatsu city			
Temp.	⇑	→	⇑
Humidity	↓	→	⇑
Sunshine	⇑	⇑	↓
Tsu city			
Temp.	→	→	⇑
Humidity	→	↓	→
Sunshine	⇑	⇑	↓
Wakayama city			
Temp.	⇑	⇑	⇑
Humidity	↓	↓	↓
Sunshine	⇑	⇑	↓
Fukuoka city			
Temp.	⇑	⇑	⇑
Humidity	↓	↓	↓
AGSR	⇑	⇑	→
Kumamoto city			
Temp.	⇑	→	⇑
Humidity	↓	↓	↓
AGSR	⇑	⇑	→

Table 1: The trend of meteorological conditions related with Fagaceae pollen dispersing from 1986 to 2014 near the 9 locations.

Oak pollen has cross-reactivity to birch/alder pollen

In our country Furuya reported thirteen patients with oak pollinosis in 1970's [12,13]. Their symptoms are mainly bronchial asthma with allergic rhinitis and rhinoconjuncititis with pharyngitis. All of the patients have positive skin test and positive challenge test. There was no oak single sensitized patient. They were sensitized to not only oak pollen but also alder, grass, mugwort, elm, Japanese cedar and house dust mite. He reported the importance of cross-reactivity to birch pollen allergen, too [13,14].

In the latter 1980's huge number of patients with JC pollinosis were so increased that Japanese government has begun to take the measures only against conifer pollinosis as one of the nationwide problems [2]. And then policy of other kind of pollinosis was not standing out. From 1990's birch and alder pollinosis with OAS have begun to be reported by ENT doctors and dermatologist in Japan [15-17].

Fagaceae pollen antigen has cross-reactivity to *Betula* (birch)/*Alnus* (alder) pollen antigen generally. In north part of Japan, especially in Hokkaido district, there is a lot of patients with birch pollen and they have highly pollen related food allergy, OAS. Recently birch pollen count has increased in Hokkaido [18].

Until now in Japan conifer (Japanese Cedar and Cypress), grass, birch/alder, mugwort and ragweed pollen antigens are important [6]. Fagaceae pollen grains are not careful as one of important allergic pollens. In near future not only in north part of our country but also the other districts patients with pollinosis will be increasing and being in great problem due to OAS. In 2015 an infant of severe food allergy related oak pollen allergy case has been reported in Fukuoka [19].

On the other hand at least one of birch pollen antigens (Bet *v*1 family) has become common gradually on the cross-reactivity to oak tree and other Fagaceae pollen in Europe and Australia. They say same respiratory and allergy symptoms become worse in the area without *Betula* vegetation [20-24].

Conclusion and Perspective

Fagaceae pollen counts in Japan have been increasing and in the south of Japan Island the pollination season has prolonged during about 30 years climate change. In near future patients with Fagaceae pollinosis will increase in the southern part of Japan and birch/alder pollinosis with oral allergy syndrome will exacerbate during Fagaceae pollination season. We will inform Fagaceae pollen allergen is important for Japanese allergic people from aerobiology site.

Sendai city	March	April	Former June
Temp.	NS	NS	NS
Humidity	NS	NS	NS
AGSR	NS	r=0.528; p<0.01	r=0.399; p<0.05
Niigata city			
Temp.	NS	r=0.392; p<0.05	
Humidity	NS	NS	NS
AGSR	r=0.523; p<0.01	NS	NS
Toyama city			
Temp.	NS	NS	NS
Humidity	NS	NS	NS
AGSR	r=0.473; p<0.05	NS	NS
Sagamihara city			
Temp.	r=0.536; p<0.01	NS	NS
Humidity	r=0.417; p<0.05	r=0.448; p<0.05	NS
Sunshine	r=0.497; p<0.01	r=0.412; p<0.05	NS
Hamamatsu city			
Temp.	NS	NS	NS
Humidity	NS	NS	NS
Sunshine	NS	NS	NS
Tsu city			
Temp.	NS	NS	NS
Humidity	NS	NS	NS
Sunshine	r=0.490; p<0.05	NS	NS
Wakayama city			
Temp.	NS	NS	NS
Humidity	NS	NS	NS
Sunshine	NS	NS	NS
Fukuoka city			
Temp.	NS	NS	NS
Humidity	NS	NS	NS
AGSR	NS	NS	NS
Kumamoto city			
Temp.	NS	NS	NS
Humidity	NS	NS	NS

Table 2: Correlation between Fagaceae pollen counts and meteorological conditions before bloom (March, April) and male flower bud formed month (former June). NS: Not Significant.

Sendai city (n=28)	March	April	Former June
Temp.	NS	r=0.445; p<0.05	NS
Humidity	NS	NS	NS
AGSR	NS	NS	NS
Niigata city (n=28)			
Temp.	r=0.402; p<0.05	r=0.394; p<0.05	NS
Humidity	NS	NS	NS
AGSR	NS	NS	NS
Toyama city (n=26)			
Temp.	r=0.578; p<0.01	r=0.586; p<0.05	NS
Humidity	r=0.511; p<0.01	NS	NS
AGSR	NS	NS	r=0.482; p<0.05
Sagamihara city (n=27)			
Temp.	r=0.681; p<0.01	r=0.409; p<0.05	NS
Humidity	NS	NS	NS
Sunshine	NS	NS	NS
Hamamatsu city (n=28)			
Temp.	r=0.520; p<0.01	NS	NS
Humidity	NS	NS	NS
Sunshine	NS	NS	NS
Tsu city (n=27)			
Temp.	r=0.506; p<0.01	r=0.524; p<0.01	NS
Humidity	NS	NS	NS
Sunshine	NS	NS	NS
Wakayama city (n=28)			
Temp.	r=0.670; p<0.01	NS	NS
Humidity	NS	NS	NS
Sunshine	NS	NS	r=0.524; p<0.01
Fukuoka city			
Temp.	r=0.784; p<0.001	NS	NS
Humidity	NS	NS	NS
AGSR	r=0.429; p<0.05	NS	NS
Kumamoto city (n=28)			
Temp.	r=0.635; p<0.001	r=0.432; p<0.05	NS
Humidity	NS	NS	NS
AGSR	NS	NS	NS

Table 3: Correlation between oak pollen dispersal starting day and meteorological conditions before bloom (March, April) and male flower bud formed month (former June). NS: Not Significant.

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