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ANALYSIS OF CHANGES IN FLOWERING PHASES AND AIRBORNE POLLEN DISPERSION OF THE GENUS *BETULA* (BIRCH)

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Abstract. The scientists evaluate the climate change by various methods. The long-term phonological observation is a quite significant indicator of this phenomenon. Moreover, the forecasting of plants flowering period or changing of amount of pollen production is important for guarantying of social health. The aim of the research – to analyze the interdependence of flowering changes and pollen concentration under the climate change according to the long-term phenological data and evaluation of aeropalynological situation in Lithuania. For this purpose one based upon the data of birch flowering (1970–1999) and birch flowering and pollen concentration in air (2004–2008). The interpretation of data with statistic methods showed that the start of birch flowering varies in different years (8–32 days) and the regional differences increase (approximately 3 days during 30 years). One phenological station does not reflect the real aerobiological situation in the observation site. Tight analysis of pollen and phenological data basing upon the flowering data allows gathering knowledge about possible change of the pollen seasons in future.

Keywords: *Betula* (birch), pollen, flowering, dispersion, climate change, Lithuania, aeropalynology, phenology.

1. Introduction

The evaluation of climate change is one of the greatest challenges to the modern science. The analysis of natural processes and their changes allows finding numerous essential evidences of climate change. The observation of temperature and changes of other meteorological parameters reveal the change of Lithuanian climate (Bukantis 2001a, b; Rimkus *et al.* 2007), what is important in analysis of influence of the latter phenomenon upon the nature. Non-typical changes of plants development, which appeared due to increasing temperature, may be taken as an example illustrating the present situation. That is why the phenological observations are one of the most important evidences in evaluation of influence of climate change upon the vegetation (Chmielewski and Rötzer 2002). The researches of this character are valuable in analysis of air quality because today the significant part of human population suffers from allergic diseases (D'Amato *et al.* 2007).

Today's researches have shown that higher temperature caused by the climate change may speed up plants flowering (Bradley *et al.* 1999; Menzel *et al.* 2006) and cause the earlier start of the pollen season (Van Vliet *et al.* 2002). Recently more intensive pollen seasons have been determined (Frei and Gassner 2008), higher amount of pollen has been fixed (Wayne *et al.* 2002) and stronger allergy to pollen has been ascertained (Beggs and Bambrick 2005; D'Amato *et al.* 2007). It is obvious that these changes have influence on air quality and people health.

Natural phenomena repeating annually depend particularly on temperature changes (Chmielewski and Rötzer 2002). Their influence upon phytophenology (Snyder *et al.* 1999; Wielgolaski 1999; Wolfe *et al.* 2005; Črepinšek *et al.* 2006; Dose and Menzel 2006) and determination of pollen concentration of plants of various tribes (Emberlin *et al.* 2002; Rodrígues-Rajo *et al.* 2003) is of particular scientists' interest.

Nevertheless, in some cases similar researches (such as analysis of plants flowering dates or changes of pollen concentration and modeling of airborne particles) differ. Of course, there exist the essential relations between plant flowering and quantity of pollen in atmosphere. In some cases the relations between these processes are particularly tight, for example, in cases of determination of long range transport of pollen (Šaulienė and Veriankaitė 2006; Skjøth *et al.* 2007; Šaulienė *et al.* 2007) or relation between phenological stage of flowering and pollen concentration (Latorre 1999; Jato *et al.* 2002; Kasprzyk 2003; Estrella *et al.* 2006).

The conducted researches have shown that people living in urbanized territories suffer more often from allergies caused by pollen in comparison with those who live in country sides, as the components of air pollution interact with airborne pollen allergens (D'Amato *et al.* 2002; D'Amato *et al.* 2007). Lithuanian scientists have defined that the concentration of maximum allowed air pollutants are fixed quite often (Baltrėnas *et al.* 2008b). Moreover, the analysis of pollution degree with mathematical modeling programmes (Baltrėnas *et al.* 2008a; Vyzienė and Girgždys 2009) gives an opportunity to use the results in forecasting of intensity of sensitiveness to pollen. The relation between pollutants and higher spread

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of pollinosis in urbanized territories is determined in separate works (D'Amato *et al.* 2001; Parker *et al.* 2009).

At the same time it is necessary to remember that pollen dispersion is determined by the flowering of local plants; therefore, the comparative analysis of phytophenological phenomena and aerobiological data is necessary. The season of birch pollen has been chosen for this research due to several reasons. First of all, the birch is common in Lithuanian forests (Navasaitis *et al.* 2003). During the flowering the plants of this tribe release great densities of pollen into air, which become a part of bioaerosol in atmosphere (Šaulienė *et al.* 2007). Secondly, these pollens are the most frequent causative agents of pollinosis in the North, West Europe.

The aim of our research – to analyze the relation of flowering of local plants and airborne pollen concentration basing upon long-term phonological data and aerobiological situation in Lithuania. The researches of such character provide information for evaluation of climate change and fluctuation of pollen season.

2. Research methods

Airborne pollen of the *Betula* species were collected using the 7-days spore traps of Hirst type standing in Vilnius, Klaipėda and Šiauliai. Pollen concentration has being measured since the year 2004 till the year 2008 using the standard Mandrioli *et al.* (1998) methods of sample taking. The season of birch pollen is a period the start and the end of which is signified by concentration, which includes 2.5% of general annual pollen quantity (Corden *et al.* 2002; Adams-Groom *et al.* 2002).

The data of *Betula pendula* Roth. flowering start were get from the Lithuanian Hydrometeorological Service. In this research we use the data of two periods (1970–1999 and 2004–2008). The data of thirty years flowering were collected from 15 agrometeorological stations and subdivisions. At the same time 12 different Lithuanian places were set in observation stations since the year 2004, representing the present phenologic situation.

The statistic analysis was used for evaluation of plants flowering influence upon the pollen spread in atmosphere. The calculations of mean, median, standard deviation, coefficient of variation, normal distribution and coefficient of correlation were done using the software SPSS Statistic 17.0. The compliance with normal distribution was stated using the test of Kolmogorov-Smirnov and Shapiro-Wilk. The got results were used as a basis for choice of coefficient of correlation.

3. Results and discussion

3.1. Phenological situation of birch in Lithuania

The data of phenological situation of thirty years (1971–1999) revealed the variation in date of flowering start (Table 1).

Summarized data of observation in some cases are far away form the mean because in south and north part of Lithuania the birch flowering stars at different time. The difference from average flowering date in certain years may vary up to 30 days. The comparison of phenological observation data of agrometeorological stations showed that the start of flowering varies in interval of 26–44 days. Basing upon the annual fluctuation the start of flowering may vary in interval of 24 days.

The results of our research have revealed the fact that the change of birch flowering dates in stations from year to year is sufficiently high. Such variability may be related to environmental factors (meteorological conditions, soil etc.) or biological peculiarities of the plants (Latorre 1999; Jato *et al.* 2002; Latałowa *et al.* 2002; Bartková-Ščevková 2003; Jato *et al.* 2007; Kasprzyk and Walanus 2007; Frei and Gassner 2008).

The difference between the earliest and the latest start of birch flowering is showed in the Figure 1. It is obvious that the difference between the earliest and the latest start of flowering varies significantly (8–32 days). The distance between the minimal and maximal the earliest and the latest start of flowering was similar, i.e. in other interval of 35–38 days. Such irregularity of plants flowering demonstrates that environmental conditions are

Table 1. The basic statistic of the start of birch flowering in Lithuania (in Julian days)

Years	Mean	Median	Standard Deviation	Coefficient of variation
1970	130	128	3.26	2.51
1971	128	128	3.87	3.03
1972	126	126	2.11	1.67
1973	126	126	3.33	2.64
1974	124	124	3.76	3.03
1975	126	124	5.30	4.21
1976	133	133	4.27	3.21
1977	127	126	4.88	3.83
1978	126	126	4.67	3.71
1979	136	134	6.11	4.50
1980	132	133	6.35	4.82
1981	135	135	2.29	1.70
1982	128	128	6.79	5.29
1983	123	124	6.84	5.55
1984	115	113	5.82	5.08
1985	128	130	6.16	4.80
1986	122	122	5.01	4.12
1987	126	126	1.95	1.55
1988	127	126	3.73	2.94
1989	112	110	8.89	7.93
1990	106	108	6.79	6.43
1991	119	120	9.87	8.29
1992	129	129	3.91	3.03
1993	117	118	2.20	1.88
1994	120	120	2.92	2.44
1995	120	118	5.99	5.01
1996	119	119	3.74	3.15
1997	132	133	3.53	2.68
1998	120	120	3.40	2.84
1999	111	108	6.70	6.01

very important for plants development. The trend of differences of birch flowering start in Lithuania is shown in the Fig. 1. During the period of thirty years the differences between flowering dates in various Lithuanian regions increased in approximately 3 days ($p > 0.05$). It is not a reliable change; however, there exists the tendency that differences between regions in Lithuania may change remarkably considering the environmental changes (they are likely to increase).

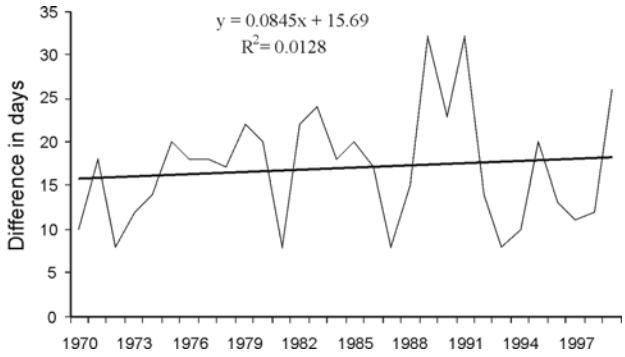

Fig. 1. The difference between the earliest and the latest dates of birch flowering in Lithuania

The calculated coefficient of correlation has shown the existence of a reliable relation between the earliest and the latest dates of flowering start (0.65 ($p < 0.01$)). Also the relation between the earliest flowering date and Lithuanian regional differences was determined (–0.58 ($p < 0.05$)). Therefore, if birch flowering becomes earlier, the difference between the earliest and the latest flowering of plants in Lithuania will increase. Menzel *et al*. (2006) has shown that the greatest differences between phenological stages are determined early in spring for plants beginning vegetation. It is naturally that the situation of pollen season start is analogical. The Swiss scientists have determined the clear trend of pollen season beginning becoming earlier (Frei and Gassner 2008). The statistic methods used in our research allow supposing that regional differences between start of plant flowering will increase.

The problems analyzed above are only a part of fluctuation of plant flowering. It is acknowledged that climate change has a tendentious influence upon the phenological phases of plants (Bradley *et al.* 1999; Badeck *et al.* 2004; Dose and Menzel 2004; Gordo and Sanz 2005; Wolfe *et al.* 2005; Parmesan 2006; Schwartz *et al.* 2006; Miller-Rushing *et al.* 2008; Frei and Gassner 2008; Gallagher *et al.* 2009; Kalvāne *et al.* 2009). The analysis of trends of birch flowering shows that the flowering in Lithuania is becoming earlier (Fig. 2).

The changes of flowering are remarkable and obvious. The difference of 10–15 days ($p < 0.05$) has been stated basing upon phenological data of thirty days. Since the flowering phase and pollen season are related, it is necessary to underline that the analysis of phenological data is necessary.

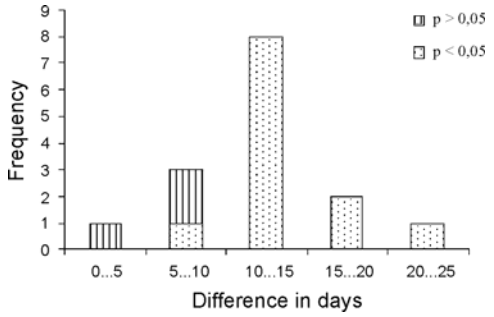

Fig. 2. Trend distribution during birch flowering according to size and reliability of changes (1970–1999)

3.2. Pollen season of *Betula* species

119 012 of birch pollen m^{-3} was calculated during the research period. Pollen season of *Betula* species changes form year to year and its duration in the years 2004–2008 varied from 15 up to 41 days. According to aerobiological situation the amount of pollen changes from approximately more than 2 000 up to 34 000 pollen m^{-3}. The collected data show that the peak of pollen was determined during the shortest pollen season. However, this assumption can not be proven due to little number of available measure data. Pollen analysis of 5 years has shown that the start of birch pollen season varies since the middle of April till the first days of May (Šaulienė and Veriankaitė 2006; Šaulienė *et al*. 2007). General annual pollen concentration changes due to unrevealed reasons. The highest densities were determined in the year 2006. In this year abnormally high densities of pollen were measured all over Europe (Siljamo *et al.* 2008).

The mean of many years of aerobiological monitoring data shows principled season of birch pollen (Fig. 3).

The conducted statistic analysis has shown that the data of pollen concentration are characterized by high standard deviation (from 121 up to 1015 depending on the year). Undoubtedly, the amount of pollen in catchers and spread of pollen in the air depend on atmospheric physical and dynamic processes and the intensity of plant flowering (Jato *et al.* 2002; Kasprzyk and Walanus 2007; Siljamo *et al*. 2008).

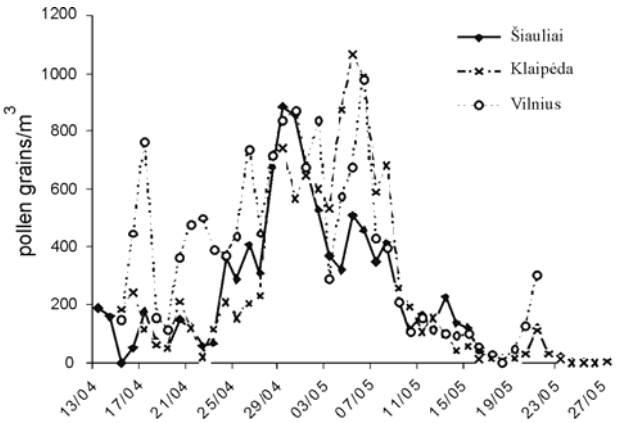

Fig. 3. Mean birch pollen season, according to aerobiological data from all aerobiological stations (2004–2008)

Respectively, in the Fig. 3 it is obviously shown that the differences between the stations exist. However, the duration of pollen season does not vary remarkably; nevertheless, the differences between the pollen amount are obvious. Meanwhile, the highest densities of birch pollen in every station are determined at different time. The analysis of such type is important for pollen forecasting and spread of information between allergic people (Kasprzyk 2003; Estrella *et al.* 2006).

3.3. Birch flowering and pollen season in Lithuania

According to data of our monitoring birch flowering and pollination does not concur frequently. In these cases the comparative analysis is complicated due to methodological problems. Therefore, the revelation of this situation is especially valuable for scientists and clinicians. The comparison of concentration of airborne birch pollen and phenological data is presented in the Fig. 4.

The analysis of phenological data of the years 2004–2008 has shown that the duration of birch flowering in Lithuania varies from 11 up to 27 days. Basing upon the data of birch pollen season of three Lithuanian aerobiological

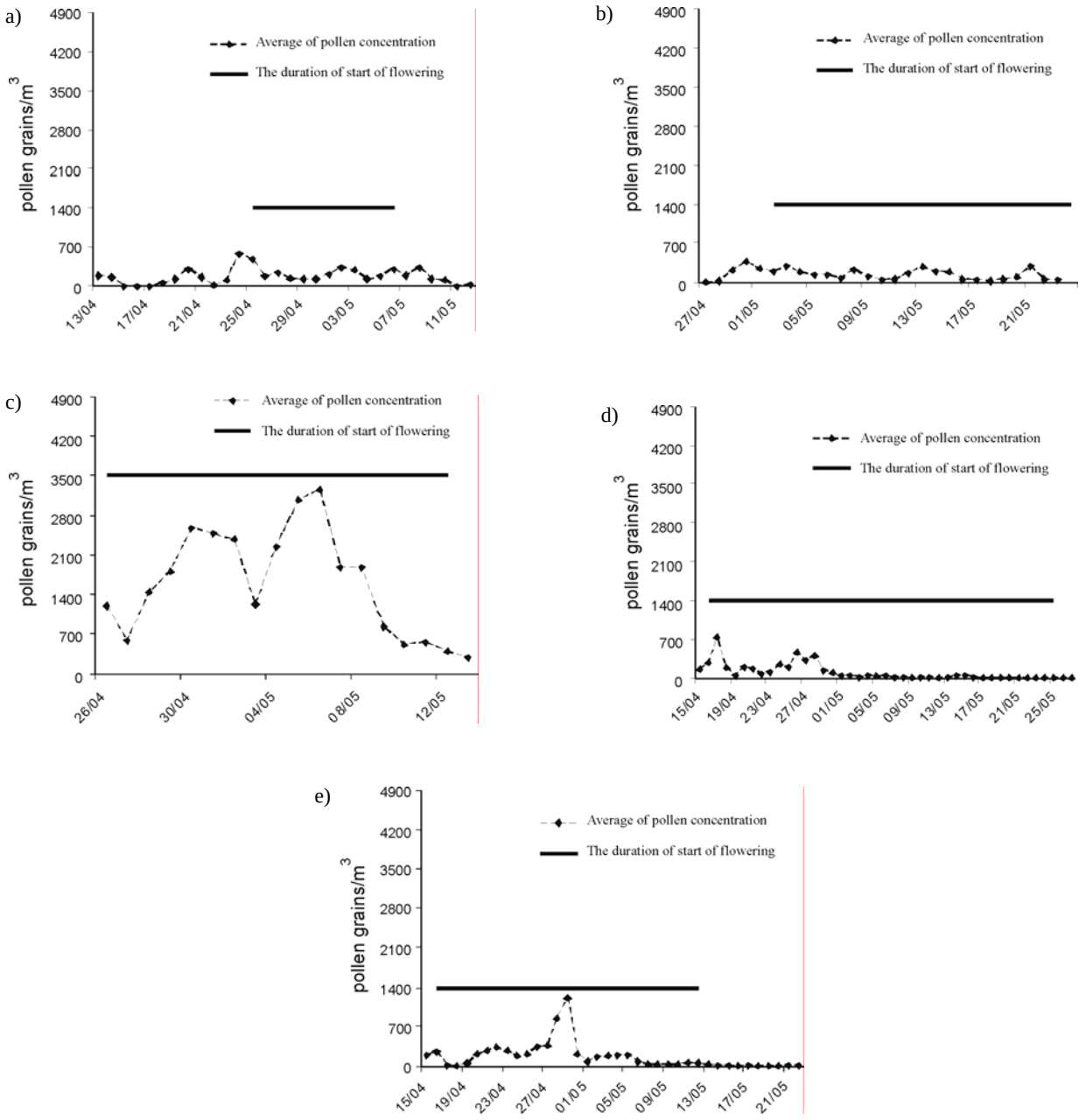

Fig. 4. Birch pollen season and the duration of start of birch flowering in Lithuania: a) 2004; b) 2005; c) 2006; d) 2007; e) 2008

station and general dates of birch flowering in Lithuania one has revealed the existence of the coincidence of general phenological situation in Lithuania and pollen season. The most distinctive cases were determined in the year 2004. The Fig. 4a shows the long-range transport of pollen. Basing upon the phenological data the pollen season in Lithuania has begun earlier than the flowering of plants. The second picture (Fig. 4b) indicates less obvious long-range transport of pollen (Šaulienė and Veriankaitė 2006). However, these facts do not give us opportunity to rely on the pattern of pollen long-range transport. He analysis of data (Fig. 4c, d, and e) has shown that there can be possible coincidence of pollen season and duration of flowering in Lithuania.

Our conducted research allows noticing that it is impossible to relate the local representational phenological station to the aerobiological station in the concrete place. The spread of pollen is determined by meteorological conditions depending on the processes taking place in atmosphere (Clot 2001; Emberlin *et al*. 2002; Rasmussen 2002; Skjøth *et al*. 2007; Siljamo *et al*. 2008). However, phenological situation is important for preparation of aerobiological forecasting (Jato *et al*. 2002; Estrella *et al*. 2006). The relation between the duration of birch flowering start in Lithuania, pollen season and pollen concentration is presented in the Table 2.

Table 2. The relationship between the duration of birch flowering start, pollen season and pollen concentration according to Spearmen's correlation

Aerobiological station	DF and DPS	PC and DF	PC and DPS
Klaipėda	0.7	–0.3	–0.3
Šiauliai	0.7	–0.8	–0.7
Vilnius	0.99**	–0.4	–0.4
All stations	0.689**	–0.401	–0.456

Note.** significant at the 0.01 level (2-tailed), * significant at the 0.05 level (2-tailed)
DF – duration of flowering start over Lithuania
DPS – duration of pollen season
PC – pollen concentration

The correlation ($p > 0.05$) of the pollen season and duration of flowering start has shown the relationship between the birch pollination and flowering start in Lithuania. These statistic data (in spite of the fact they are not significant) form the assumption concerning the tendencies of season prolongation: the pollen season is proportional to the duration of birch flowering start.

Short period of aerobiological monitoring (5 years) decreases the opportunity to evaluate the other reasons of pollen season and airborne pollen characteristics. Today there still exists no common opinion concerning physiological periods of birch development (Jäger *et al*. 1991). The changes of metrological conditions and climate are the inevitable factors, which are difficult to be forecasted. Such variety of independent and dependant variables limits the opportunity to find the clear answers. In order to understand the influence of climate change upon pollen spread our next step will be oriented to transference of got knowledge to the plane of significant modeling.

4. Conclusions

1. The research has shown that the airborne pollen data may be used for indication of climate change. Aeropalynological data provide the relation between the season of plants flowering and pollination over Lithuania. The main gap is too short data sequence for statistic significance of consistent pattern.

2. The analysis of the data has shown that the main quantity of airborne birch pollen is determined by the flowering of local plants. The amount of pollen in one cubic meter of air may vary from 2 000 up to 34 000.

3. The evaluation of phenological data has revealed the fact that the duration of birch flowering start over Lithuania varies up to approximately 30 days. Basing upon the influence of climate change on the flowering the differences between the regions may change a little.

4. The trends of phenological data of thirty years have shown that the start of birch flowering has become remarkably earlier up to approximately 10–15 days ($p < 0.05$). It is obviously in future the allergenic pollen will appear in air earlier due to climate change. This situation will oblige the responsible institutions to revise the landscape management and human recreation aspects.

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BERŽO GENTIES ŽYDĖJIMO FAZIŲ IR ŽIEDADULKIŲ SKLAIDOS POKYČIŲ ANALIZĖ

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Santrauka

Klimato kaitą mokslininkai vertina įvairiais metodais. Labai reikšmingas šio reiškinio indikatorius – daugiamečių fenologinių stebėjimų duomenys. Augalų žydėjimo laiko ar žiedadulkių produkcijos kiekio pokyčio prognozavimas yra svarbus visuomenės sveikatai užtikrinti. Tyrimo tikslas – pagal ilgamečius fenologinius duomenis ir įvertinus aeropalinologinę situaciją Lietuvoje išanalizuoti žydėjimo pokyčių ir žiedadulkių koncentracijos tarpusavio priklausomumą vykstant klimato kaitai. Šiam tikslui remtasi beržo žydėjimo (1970–1999 m.) ir beržo žydėjimo bei žiedadulkių koncentracijos ore (2004–2008 m.) duomenimis. Duomenis interpretuojant statistiniais metodais nustatyta, kad beržo žydėjimo pradžia įvairiais metais varijuoja (8–32 dienos), ir didėja regioniniai skirtumai (apytiksliai 3 dienos per 30 metų). Viena fenologinė stotis neatspindi realios aerobiologinės situacijos stebėjimo vietoje. Glaudi žiedadulkių ir fenologinių duomenų analizė, remiantis žydėjimo duomenimis, leidžia daryti prielaidas apie galimą žiedadulkių sezonų kaitą ateityje.

Reikšminiai žodžiai: *Betula*, žiedadulkės, žydėjimas, sklaida, klimato kaita, Lietuva, aeropalinologija, fenologija.

АНАЛИЗ ИЗМЕНЕНИЙ В ЦВЕТЕНИИ РОДА БЕРЕЗЫ И ДИСПЕРСИИ ПЫЛЬЦЫ

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Резюме

Для оценки изменения климата ученые используют различные методы. Значительным показателем этого явления являются многолетние фенологические наблюдения. Кроме того, прогнозирование времени цветения или изменения продукции пыльцы растений является важным этапом в управлении здравоохранением. Целью нашего исследования было на основании многолетних фенологических наблюдений и оценки аеропалинологической ситуации в Литве проанализировать взаимосвязь между изменением цветения и концентрацией пыльцы в воздухе в связи с изменением климата. Для этой цели были использованы данные цветения березы за период 1970–1999 гг., цветения березы и данные концентраций пыльцы в воздухе, охватывающие период 2004–2008 гг. Благодаря применению статистических методов для интепретаций данных, было установлено, что начало цветения березы колеблется из года в год (8–32 дня), увеличиваются региональные различия (около 3 дней за 30 лет). Показано, что одна фенологическая станция не отражает реальную аеропалинологическую ситуацию.

Сравнительный фенологический и пыльцевой анализ, проведенный на основании данных цветения, свидетельствует о возможных изменениях в пыльцевых сезонах в будущем.

Ключевые слова: *Betula*, пыльца, цветение, распространение, изменение климата, Литва, аэропалинология, фенология.

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