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EVALUATION OF METEOROLOGICAL PARAMETERS INFLUENCE UPON POLLEN SPREAD IN THE ATMOSPHERE

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Abstract. The elements determining the meteorological conditions are the main parameters in processes of airborne pollen modeling. In modern research the influence of different meteorological element or their complex is analyzed basing upon the statistic methods or using dispersion models in which the possible influence of meteorological parameters upon airborne pollen is described in equations. The correlation of meteorological indicators and pollen concentration in the atmosphere fixed in Klaipėda Aerobiological Station is analyzed in this article. The coefficients of correlation of meteorological parameters and pollen concentration are calculated basing upon the Spearman's rank correlation method. The analysis of various factors was used for determining the complex influence of meteorological parameters upon the pollen concentration in the air. After evaluation of influence of meteorological parameters as separate factors one has determined that more than a half of analyzed pollen types showed statistically reliable ($p < 0.05$) correlation of pollen amount in the air and relative air humidity (89%), air temperature (74%) and amount of precipitation (52%). The investigation results showed that 37% of pollen amount of indicated plants genera and families in the atmosphere was determined by wind velocity. After evaluation of complex influence of meteorological factors on the concentration of pollen spread in the air one has determined that relative humidity and/or air temperature are one of the most significant environmental factors determining the amount of pollen in the atmosphere during the vegetation. Their influence was determined for all the three cases under study.

Keywords: pollen, air temperature, relative humidity, precipitation, wind velocity, multiple regression.

1. Introduction

Big part of human population is sensitive to pollen of some plants. Composition and seasoning, as well as strength of polynosis, time and provocatives of pollen floating in the air differs over different locations in the world. Aerobiological monitoring in Lithuania has started only in 2003, a lot later than in bigger European countries, so data range is smaller. With increase of environmental pollution and climate changes airborne pollen monitoring is becoming of greater importance medically and socio-economically. Despite this situation net of monitoring is maintained only by the initiative groups of scientists in the national dimension. This definitely reduces the expansion of researches and use of data for forecasts shaping. Nowadays in Lithuania there are wide analyses air pollutants such as NO_x, CO (Juostas and Janulevičius 2009) or particulate matter (Baltrėnas *et al.* 2007; Vyzienė and Girgždys 2009). Attention for last-mentioned is particularly increased, but united opinion still underrates joint analysis of abiotical and biotical particles. The main reason might be the lack of information about the reveal of biological particles in the air and their relation with meteorological factors.

Meteorological conditions have significant influence upon the composition of atmosphere aerosol (Rimkus *et al.* 2006; Baltrėnas *et al.* 2007; Feizienė *et al.* 2009). During the vegetation besides the abiotic particles there are pollen of anemophilous plants in the air. They increase the general concentration of inhaled particles. Anthropogenic pollution emissions are controlled by various biofilters (Baltrėnas and Zagorskis 2010). Moreover, the pollen allergens not only cause the unpleasant sensations, outbreaks of allergies and complicate the course of pulmonary diseases but also worsen the quality of people life.

The elements determining the meteorological conditions are the main parameters in processes of pollen spread modeling (García-Mozo *et al.* 2002; Smith and Emberlin 2006). While modeling the pollen spread the average, minimal and maximal air temperatures are evaluated, the influence of precipitation intensity upon the pollen spread is determined (Laaidi 2001; Rodríguez-Rajo *et al.* 2003; Smith and Emberlin 2006). These meteorological parameters are separated as the most significant and determinant for pollen amount in atmosphere.

After summarizing all researches related to possibilities of evaluation of meteorological conditions influence upon the pollen spread several main tendencies are becoming apparent. Firs of all, the particular meteorological elements (e.g. air temperature) (Andersen 1991; Jato *et al.* 2004) or combinations of meteorological elements (e.g. air

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temperature and amount of precipitation) (Makra *et al.* 2004; Peternel *et al.* 2005) are indicated as the most significant factors determining the amount of pollen in atmosphere.

When evaluating the general influence of meteorological conditions upon the pollen spread, air temperature, relative air humidity, amount of precipitation, wind velocity are included into complex factor (Rodríguez-Rajo *et al.* 2003; Gioulekas *et al.* 2004; Alcázar *et al.* 2009). Moreover, the influence of every meteorological element upon the particular or several pollen types of plants genera (families) is specified in the research (Galán *et al.* 2000; Rodríguez-Rajo *et al.* 2003; Crimi *et al.* 2004). The former influence is analyzed in two ways: i.e. basing upon the statistic methods and comparing the data of pollen concentrations with meteorological data (Crimi *et al.* 2004; Gioulekas *et al.* 2004; Alcázar *et al.* 2009) or using the models in which the possible influence of meteorological parameters upon pollen spread is described in equations (Andersen 1991; Laaidi 2001; Jato *et al.* 2004; Smith and Emberlin 2006).

The influence of meteorological elements upon the pollen spread depends on geographical situation; therefore, not only the values of particular parameters, but also the complex values or separate meteorological elements may vary (Veriankaitė *et al.* 2010a, b). The correlation of meteorological indicators and pollen concentration in atmosphere fixed in Klaipėda Aerobiological Station is analyzed in this article.

Klaipėda region is not only the most important country traffic centre connecting the West and the East, but also the most attractive of all county regions for development of arriving and local tourism. Therefore, it is very important to know the regularities of airborne pollen particles and especially allergens concentration determined by meteorological conditions.

2. Investigation methods

Aerobiological station of Klaipėda (21º07'32 E, 55º45'20 N) is located near the coastal zone in the western part of Lithuania. The station is surrounded by a large forested region with *Pinaceae* as dominant trees. The pollen trap is mounted at the height of 20 m above the ground and equipped with the Hirst-type continuous volumetric pollen sampler (Fig. 1), the 7-day recording version. Air throughput is 10 litres per min. Particles are impacted on adhesive-coated transparent plastic tape supported on clockwork-driven drum. Samples for taking micro-spores were being prepared under standard methodology and chemical compounds, given in user manual of the aerobiological device. Pollen were counted in twelve cross bars method, with microscope, with magnification of 400 times (Mandrioli *et al.* 1998). The average daily pollen concentration was assessed by scanning the area under the microscope slide, and referring to the results of pollen in that area to 1 m^3 of sampled air averaged over 24 hours (pollen grains/m^3).

Pollen counts were monitored from 2004 to 2008, totally 37 pollen types was identified every year. Pollen was grouped according to the rules of International Aerobiological Association, i. e. routine pollen identification carried out until the level which is possible by using an optical microscope. Pollen seasons was determined by assume that the cumulative pollen sum for the particular year reaches 2.5% of the total annual pollen count (Corden *et al*. 2002; Adams-Groom *et al*. 2002). Data from this aerobiological station is currently in operation and provides the information to the European Aeroallergen Network, EAN (http://www.polleninfo.org).

The relationship between pollen dispersal and meteorological conditions was studied using daily average meteorological data (air temperature, relative air humidity, amount of precipitation and wind velocity) for the period 2004–2009, provided by the Lithuanian Hydrometeorological Service (LHMS). The data of pollen concentration and meteorological parameters were statistically processed. The correspondence of pollen season data to the normal distribution was established by using the Kolmogorov-Smirnov test.

Correlation coefficients of meteorological parameters and pollen concentrations were calculated using the Spearman rank correlation method.

The influences of meteorological conditions on the atmospheric pollen counts were estimated by using the multiple regression analysis. The pollen data were standartised (to match the normal distribution) in order to apply this method and to calculate correlation coefficients.

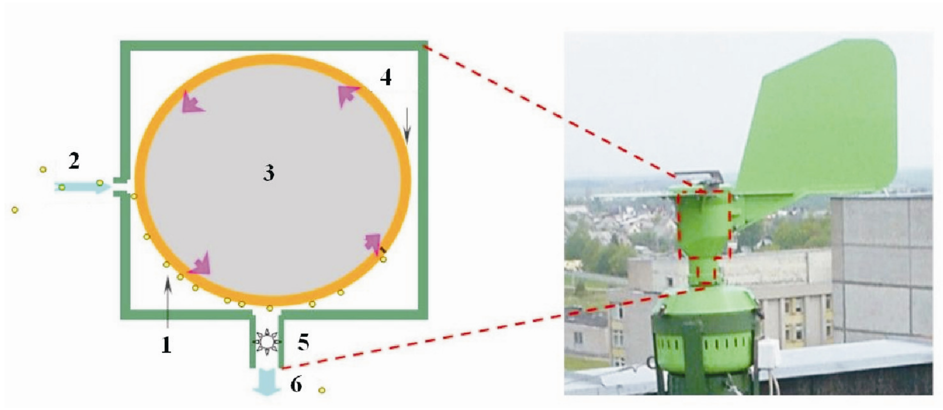

Fig. 1. Hirst-type continuous volumetric pollen sampler and scheme of working block: 1 – adhered pollen; 2 – air flow; 3 – recording drum; 4 – "Melinex" tape; 5 – pump; 6 – air flow

According to M. Reci *et al.* (1997) the log(p+1) was used for calculation, where p – pollen concentration. The influence of meteorological parameters on the estimated amount of pollen concluded from these multiple regression equations. Such situation is often faced with the problem of multicollinearity, which arises from the fact that predicted characteristics are correlated (Čekanavičius and Murauskas 2002). Variables have been eliminated considering that correlation coefficient value is not decrease after removal of the variable. The Student criterion was used to ascertain the reliability of multiple regression. Only statistically significant cases was selected and analyzed regarding not only to multiple regression, but also the reliability of predicted characteristics ($p < 0.05$ and $p < 0.01$).

3. Results and discussion

3.1. Analysis of separate meteorological parameters influence upon the amount of pollen in the atmosphere

The marine climate of mid latitude transient to the continental climate prevails in Klaipėda and is greatly influenced by the Baltic Sea (Jaagus *et al.* 2010). During the analysis of possible influence of air temperature, relative air humidity, amount of precipitation and wind velocity upon the pollen spread of various plants genera and families in Klaipėda, at first the relations between the meteorological parameters and pollen concentration during the pollen season (the years 2004–2009) was determined.

The analysis of research results showed different correlation of air temperature and concentration of pollen of identified plants families (genera) (Fig. 2). Besides that, the dependency of the pollen amount in the air and air temperature was determined in 74% of cases ($p < 0.05$). The majority (70% of cases when $p < 0.05$) of calculated correlation coefficients were positive. Thereby, the amount of pollen in atmosphere grows with the increase of air temperature. This regularity is especially significant as the global warming of climate increases the possibility of pollen amount growth in the air (García-Mozo *et al.* 2006; Frei and Gassner 2008) and the number of people suffering from pollen disease what needs additional expenses both from patients and government.

Especially sensitive to air temperature are the plants, which vegetations starts early in spring (Kulienė and Tomkus 1990; Črepinšek *et al.* 2006; Veriankaitė *et al.* 2010b). We have conducted the correlation of many years of *Alnus* L. and *Corylus* L. pollen concentration in atmosphere and air temperature that has not proved the abovementioned regularity. The correlation coefficient, by-turn, has shown statistically reliable correlation of air temperature and concentration of pollen of plants flowering in June-October. The highest positive correlation coefficient ($r_s = 0.57$, $p < 0.01$) in Klaipėda was determined for *Urticaceae* plants and air temperature. When evaluating the significance of temperature of separate years upon the spread of *Urticaceae* pollen Spanish scientists (Galán *et al.* 2000) got the contradictory results; however, the reliable correlation was determined in all cases. It may seem that generalized data may misrepresent the situation predicted for a particular year. However, the tendencies determined by long-term data are more useful when modeling these processes for the purposes of climate change analysis.

Taking into consideration the fact that air temperature determines the processes of pollen release from plants (Veriankaitė *et al.* 2010a) and the spread of particles may be determined by other meteorological parameters, the significance of air humidity for modeled processes was evaluated. The research results revealed (Fig. 3) statistically reliable ($p < 0.05$) negative correlation coefficient (from –0.18 up to –0.72, 89% of cases) of the concentration of pollen of almost all plants families (genera) identified during the monitoring and relative air humidity during the vegetation.

Such results allow us claiming that the amount of pollen in the air decreases with the increase of daily air humidity. Moreover, the correlation coefficients determined during the pollen season of relative air humidity and pollen concentration are definite and less variable in comparison with the correlation coefficients of air temperature and pollen concentration.

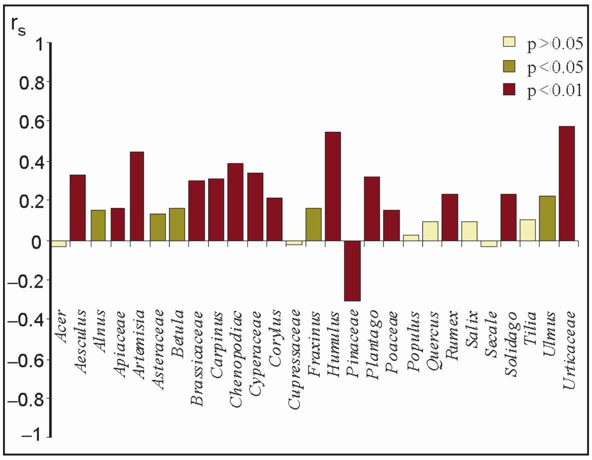

Fig. 2. Correlation coefficients (r_s) of plants pollen concentration of various genera and families during the pollen season and air temperature in 2004–2009

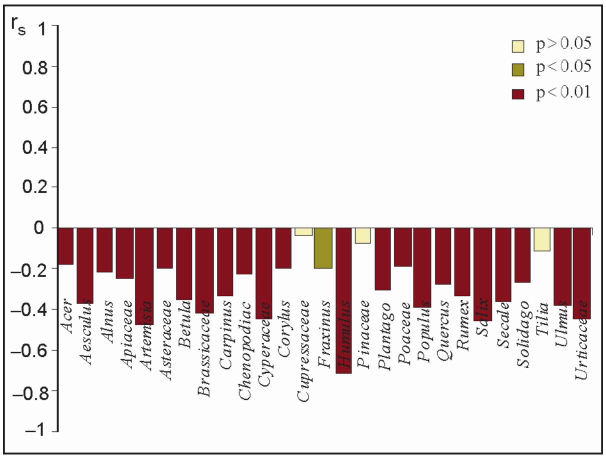

Fig. 3. Correlation coefficients (r_s) of plants pollen concentration of various genera and families during the pollen season and relative air humidity in 2004–2009

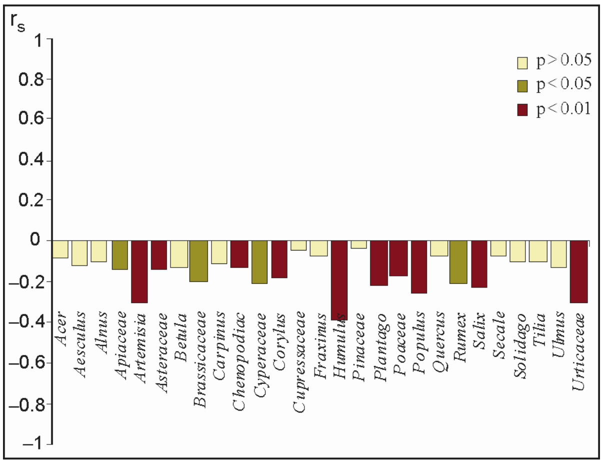

Fig. 4. Correlation coefficients (r_s) of plants pollen concentration of various genera and families during the pollen season and amount of precipitation in 2004–2009

Correlation coefficients of amount of precipitation and pollen concentration (Fig. 4) showed statistically reliable ($p < 0.05$) but very weak, weak or mid intensity relation (from –0.13 up to –0.39) of these parameters. In some cases the determined correlation is very weak and unreliable. Taking into consideration the fact of negative correlation coefficient dominance, one can make a presumption that the increase of precipitation amount decreases the amount of pollen in atmosphere.

Basing upon the results the precipitation amount may be included into meteorological factors limiting the pollen spread. When evaluating the significance of precipitation as a separate factor for the pollen spread in atmosphere, the scientists of European countries (Rodríguez-Rajo *et al.* 2003; Gioulekas *et al.* 2004; Alcázar *et al.* 2009) present tendencies analogous to those determined by us.

The correlation method determined the slight influence of wind velocity upon the pollen concentration, i.e. approx. 37% of all cases under study showed reliable ($p < 0.05$) but very weak or weak correlation of pollen concentration and wind velocity (Fig. 5).

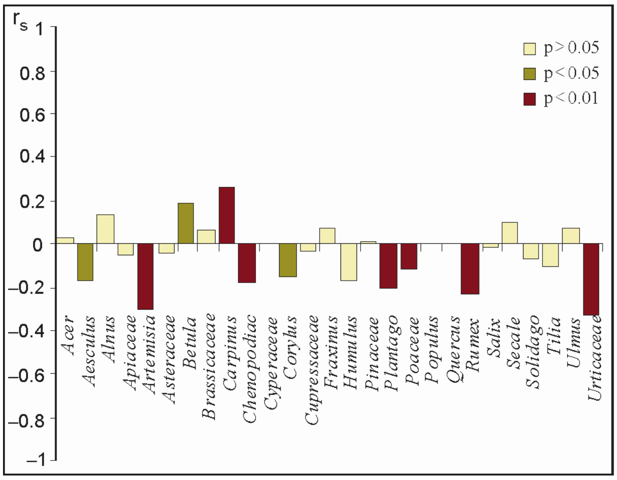

Fig. 5. Correlation coefficients (r_s) of plants pollen concentration of various genera and families during the pollen season and wind velocity in 2004–2009

The results analysis underlined that positive correlation coefficient was got in 7% of all cases under study and negative coefficient – in 30% of cases, when $p < 0.05$. It is officially believed that the growth of wind velocity increases the pollen concentration in the air (Rodríguez-Rajo *et al.* 2003). However, the results of long-term monitoring conducted in the Lithuanian shore do not completely reflect the mentioned presumption. This situation may be determined by marine climate and geographical location of airborne pollen sampler.

The results analysis presented above shows that the linear dependency of every separate meteorological factor and pollen concentration in the air does not reveal the significance of climate conditions for the amount of pollen. The fact that the influence of one meteorological variable upon the pollen amount in the air is complicated to establish is underlined by other European scientists (Altintaş *et al.* 2004; Gioulekas *et al.* 2004). Moreover, when modeling the pollen spread and processes determining it we usually come across the influence of complex meteorological factors.

3.2. Analysis of complex meteorological parameters influence upon the amount of pollen in the atmosphere

The multiple regressive analysis was conducted in order to evaluate the influence of meteorological parameters the results of which are presented in the Table 1. The data in this Table illustrate the multiple regressive equations made by basing upon the pollen concentration and average daily air temperature, relative air humidity, amount of precipitation and wind velocity. The general regressive equations for the years 2004–2009 ($p < 0.01$) describe on average 2–40% of pollen data variation (Table 1).

The got low coefficients of determination do not decrease the interpretation of results as the analyzed sampling covers the data from 140 (*Ulmus* L. cases) up to 450 (*Poaceae* cases). Moreover, the equations were made by following the principle that the level of significance of both the equation and variables would satisfy the condition ($p < 0.05$); therefore, the obtained results may be the evidence of meteorological parameters influence upon the pollen spread. It is complicated to conclude the linear dependency of pollen and meteorological parameters. It is also revealed by low correlation coefficients; however, the obtained results show the obvious influence of meteorological conditions upon the dynamics of pollen concentration in the air.

The results showed that in the majority of cases among the complex of meteorological factors the relative air humidity influences the pollen concentration in the air. This tendency was determined for 50% ($p < 0.01$) of pollen types during the analyzed period. At the same time, the influence of other meteorological parameters is also obvious. It was stated, that in the complex meteorological parameters influence the air temperature was a significant factor for 11% ($p < 0.05$) of pollen types. The complex of several meteorological parameters determines the concentration of pollen in the air. According to the long-term data collected in Klaipėda Aerobiological Station such

Table 1. Regression models for the pollen seasons of plants genera and families (2004–2009) made according to the method of variables inclusion. Variables: T – air temperature, RH – relative air humidity, P – amount of precipitation, WV – wind velocity (R^2 – coefficient of determination, p – level of significance according to Stjudent's criterion)

Pollen type	Regression models	R^2	p<
Alnus Mill.	1.870–0.008RH	0.03	0.01
Apiaceae Lindl.	0.559–0.006RH	0.07	0.01
Artemisia L.	1.855–0.026RH+0.088T–0.098WV	0.34	0.01
Betula L.	3.597–0.028RH	0.16	0.01
Carpinus L.	–0.469+0.049T+0.087WV	0.28	0.01
Chenopodiaceae Vent.	–0.304+0.027T	0.12	0.01
Corylus L.	0.683–0.004RH–0.030WV	0.05	0.01
Fraxinus L.	0.911–0.008RH	0.07	0.01
Pinaceae Lindl.	4.196–0.104T–0.018RH	0.17	0.01
Poaceae (R. Br.) Bernhart	1.249–0.011RH+0.029T	0.07	0.01
Populus L.	1.449–0.014RH	0.15	0.01
Quercus L.	1.265–0.010RH	0.06	0.01
Rumex L.	1.202–0.012RH–0.043WV+0.015T	0.19	0.01
Salix L.	1.853–0.019RH	0.26	0.01
Solidago L.	–0.292+0.021T	0.04	0.05
Tilia L.	0.240–0.002RH	0.02	0.01
Ulmus L.	0.933–0.009RH	0.17	0.01
Urticaceae Juss.	1.418+0.075T–0.078WV–0.013RH	0.4	0.01

situation was determined for 39% of plants pollen types. It should be mentioned that the complex influence for separate pollen types consists of certain meteorological parameters, e.g. air temperature, wind velocity and relative humidity (43%), air temperature and relative humidity (29%), wind velocity and relative humidity (14%) or air temperature and wind velocity (14%). In spite of the fact that Spearmen's correlation coefficient (Fig. 4) and conducted multiple regression analysis showed that wind velocity is not the most significant factor causing the pollen spread, however, alongside the other meteorological parameters it undoubtedly determines the amount of pollen in atmosphere.

It is interesting, that precipitation amount was not included into the regression model. In spite of the fact that progressions made of more than 5000 data were evaluated for every variable, precipitation amount was determined as a significant factor in no cases. Portuguese aerobiologists (Ribeiro *et al.* 2003) evaluate precipitation amount as insignificant factor in the complex of meteorological parameters and the research results of other climate characteristics are similar to those presented in this articles.

The results of multiple regression (Table 1) revealed that relative air humidity and air temperature are among the most significant factors determining the variation of pollen amount. This statement is proved by the fact that relative air humidity and/or air temperature are the variables in the regression equations even in case of presence of complex influence of meteorological factors upon the pollen concentration. These equations are not intended for preparation of future forecasts. This is the way that allows revealing the influence of meteorological parameters upon the concentration of pollen in atmosphere bioaerosol.

4. Conclusions

1. After the evaluation of influence of meteorological parameters as separate factors it was stated that more than a half of analyzed pollen types showed statistically reliable ($p < 0.05$) correlation of pollen concentration and relative air humidity (89%), air temperature (74%) and precipitation amount (52%).
2. It was determined that in 30% of cases of pollen types recorded in Klaipėda the pollen concentration in atmosphere increased with decrease of wind velocity ($p < 0.05$). Other cases are little influenced by wind velocity.
3. After the evaluation of complex influence of meteorological factors upon the airborne pollen concentration it was stated that relative air humidity and/or air temperature are among the most significant environmental factors determining amount of pollen in atmosphere during the vegetation. Their influence was determined in all cases under study.
4. The original researches showed that it is necessary to evaluate the distinctive correlation of meteorological parameters and amount of pollen of analyzed plant family (genus) in the air when modeling the airborne pollen in Lithuania.

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METEOROLOGINIŲ PARAMETRŲ ĮTAKOS ŽIEDADULKIŲ SKLAIDAI ATMOSFEROJE ĮVERTINIMAS

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S a n t r a u k a

Meteorologines sąlygas nusakantys elementai yra pagrindiniai parametrai modeliuojant žiedadulkių sklaidą. Nūdienos moksliniuose tyrimuose tam tikro meteorologinio elemento ar jų komplekso poveikis analizuojamas statistiniais metodais arba taikant sklaidos modelius, kuriuose pagrindinėmis lygtimis aprašoma galima meteorologinių parametrų įtaka žiedadulkių sklaidai. Straipsnyje analizuojama meteorologinių rodiklių sąsajos su Klaipėdos aerobiologinėje stotyje fiksuota žiedadulkių koncentracija ore. Meteorologinių parametrų ir žiedadulkių koncentracijų koreliacijos koeficientai apskaičiuoti Spearman ranginės koreliacijos metodu. Tiriant kompleksinę meteorologinių parametrų įtaką žiedadulkių koncentracijai ore, išanalizuota įvairūs veiksniai. Atskirai įvertinus įvairių meteorologinių parametrų įtaką, nustatyta statistiškai patikima ($p < 0,05$) daugiau nei pusės analizuotų žiedadulkių tipų žiedadulkių kiekio ore ir santykinės oro drėgmės (89 %), oro temperatūros (74 %) ir kritulių kiekio (52 %) sąsaja. Tyrimo rezultatai rodė, kad vėjo greitis turi įtakos 37 % identifikuotų augalų genčių ir šeimų žiedadulkių kiekiui ore. Įvertinus kompleksinę meteorologinių veiksnių įtaką oru sklindančių žiedadulkių koncentracijai, nustatyta, kad santykinis drėgnumas ir/arba oro temperatūra yra vieni reikšmingiausių aplinkos veiksnių, lemiančių žiedadulkių kiekį atmosferoje vegetacijos metu.

Reikšminiai žodžiai: žiedadulkės, oro temperatūra, santykinis drėgnumas, krituliai, vėjo greitis, daugiafunkcinė regresija.

ОЦЕНКА ВЛИЯНИЯ МЕТЕОРОЛОГИЧЕСКИХ ПАРАМЕТРОВ НА ДИСПЕРСИЮ ПЫЛЬЦЫ В АТМОСФЕРЕ

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Р е з ю м е

Элементы, описывающие метеорологические условия, являются основными параметрами в процессах моделирования дисперсии пыльцы. В современных исследованиях воздействие каждого метеорологического элемента или их комплекса анализируется с помощью статистических методов и моделей распространения, в которых фундаментальными уравнениями описываются возможные эффекты воздействия метеорологических параметров на распространение пыльцы. Статья посвящена анализу соотношения метеорологических величин с концентрацией пыльцы, зафиксированной на аэробиологической станции Клайпеды. Коэффициенты корреляции между метеорологическими параметрами и концентрацией пыльцы вычислены на основе метода ранговой корреляции Спирмена. Анализ различных факторов был использован для определения комплексного влияния метеорологических параметров на концентрации пыльцы в воздухе. Оценка метеорологических параметров как отдельных факторов показала, что более половины анализируемых типов пыльцы свидетельствует о статистически значимой ($p < 0,05$) связи между пыльцой в воздухе и относительной влажностью (89%), температурой воздуха (74%) и осадками (52%). Результаты исследования показали, что скорость ветра оказывает влияние на количество в атмосфере 37% определенных семейств и родов пыльцы. Оценка комплексного влияния метеорологических факторов на концентрацию пыльцы в воздухе показала, что относительная влажность воздуха и(или) температура воздуха являются одними из наиболее важных экологических факторов, определяющих количество пыльцы в атмосфере в течение вегетационного периода. Их влияние выявлено во всех изученных случаях.

Ключевые слова: пыльца, температура воздуха, относительная влажность, осадки, скорость ветра, мульти-регрессия.

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