

**QUANTITATIVE AND QUALITATIVE DYNAMICS OF AIRBORNE ALLERGENIC POLLEN
CONCENTRATION IN THE URBAN ECOSYSTEM OF IVANO-FRANKIVSK
(WESTERN UKRAINE)**

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Abstract

The article presents the findings of aeropalynological research on the urban ecosystem of Ivano-Frankivsk City (the Precarpathian Region, Western Ukraine) over the spring period of 2013. The following pollen grains were observed to dominate in the aeropalynological spectrum of the city: Corylus and Alnus (in March and the first half of April), Carpinus, Betula and Populus (in the second half of April), and Pinaceae (in May). The analysis involved the pollination onset, peak and cessation in the abovementioned taxa as well as the regularities in pollen concentration dynamics with regard to the meteorological situation in the city. The findings show a significant effect of predominant wind directions on the development of the aeropalynological situation in the city. Pollen concentrations of the following taxa were found to exceed the clinically important threshold value: Corylus and Alnus pollen, during four pollination days; Carpinus and Betula, during twelve days. This indicates the necessity for systematic aeropalynological monitoring in the city.

Key words: pollen, pollinosis, aeropalynological situation, spring, meteorological conditions, Western Ukraine

1. INTRODUCTION

Anemophile pollen, which belongs to the group of non-infectious exoallergens, is one of the key factors of biological air pollution. When pollen grains are in the air, they can cause allergic diseases such as pollinosis, whose periodicity is determined by the phenorhythms of the vegetation cover in a certain territory (Воробець, Калинович, 2010). Therefore, data on the flowering and pollination patterns of allergenic plants provide an informational basis for pollinosis prevention, diagnostics and treatment. In view of vegetation cover continuity, wind-blown pollen migration and a significant effect of local and global ecological changes (specifically, climate change) on plant phenorhythm, the effectiveness of aeropalynological research is determined by its spatial and chronological continuity as well as by regular updating of the current pollination calendars. Thus for an adequate assessment of the actual aeropalynological situation on the whole of the European continent and forecast preparation, it is extremely important to upgrade and expand the network of aeropalynological monitoring stations in the countries where such a kind of issue has received little focus. Ukraine is one of such areas (Пухлик, 2012); aeropalynological observation is done in four cities, only three of which are equipped with modern pollen spore traps such as a Burkard apparatus, and two cities (Vinnytsya and Zaporizhya) are members of the European Aeroallergen Network. Given the fact that Ukraine occupies a large territory within a few climatic zones and has a rich phytocenotic composition with a variety of allergenic flora, systematic research in all the regional centres is important not only for observing the aeropalynological situation in the country but also for raising the informativeness of the common European network.

Our research was aimed at trying aeropalynological research techniques in the urban ecosystem of Ivano-Frankivsk (the Precarpathian Region, Western Ukraine), identifying the quantitative and qualitative dynamics of pollen in the atmosphere during spring pollination and analyzing the impact of meteorological factors on the pollination of certain dendrological species in the city (*Corylus L.*, *Alnus L.*, *Populus L.*, *Betula L.*, *Carpinus L.*).

2. MATERIALS AND METHODS

The research was conducted over the period of February-May 2013 in the urban ecosystem of Ivano-Frankivsk (geographic coordinates – 48° 55' north latitude and 24° 42' east longitude, height above the mean sea level – 260m) by means of the gravimetric method with the help of a Durham sampler placed at a height of 24m from the ground. The advantage of this method is its low cost, simplicity and accessibility in comparison with other current aeropalynological methods, for instance the volumetric method; and the disadvantage is that it is impossible to determine the quantity of allergenic pollen per air volume unit (Туроч, Ковтуненко, 2007).

A glycerin-gelatin mixture was used for constant sampling (Мейер-Меликян et al, 1999). Pollen grain count was made using an Olympus CX-300 light microscope (magnification - 400x) along continuous vertical transects. The identification of pollen and its taxon was performed with the help of detectors and reference samples on the basis of the morphological characteristics of pollen grains (Fig. 1).

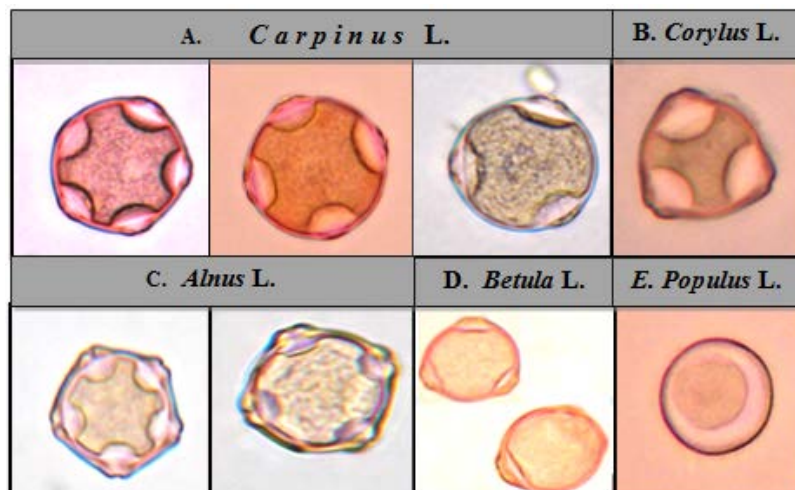


Fig. 1. Morphological characteristics of pollen grains:

A. *Carpinus L.*; B. *Corylus L.*; C. *Alnus L.*; D. *Betula L.*; E. *Populus L.*

For quantitative analysis, the data on the quantity of pollen grains per 1 cm² of the slide was converted into the number of pollen grains per 1m³ of air (pg/m³) (Bassett, Crompton, Parmelee, 1978). Microphotography was done at a zoom of 1000x by means of an Olympus SP – 500 UZ adapter attached to the microscope and Olympus Quick PHOTO MICRO 2.3 software for Windows.

The pollination duration was determined by means of “the 98% method” according to which the pollination season of a plant begins on the day when the amount of its pollen makes up 1% of the total number of pollen grains collected over the year. The end of the period is the day when the amount of pollen collected over the season reaches 99% (Galan, 1995); additionally, we recorded the first and last pollen grains in samples.

With a view to determining statistical interdependence among the key meteorological factors (temperature, relative air humidity and wind direction), the taxonomic variety of pollen grains and the air concentration of *Corylus L.*, *Alnus L.*, *Populus L.*, *Betula L.*, and *Carpinus L.* pollen, we drew on the data from weather report websites. The data was processed by means of the correlation analysis. All calculations and graphic interpretation of the research findings were performed with the help of MS Excel 2010.

3. RESULTS AND DISCUSSION

The aeropalynological research shows that the spring pollination in the urban ecosystem of Ivano-Frankivsk in 2013 began in the first decade of March with the pollination of *Corylus L.* and *Alnus L.* (on the basis of “the 98% method”). First airborne pollen grains were recorded on 22 and 28 February respectively. Over different periods of the spring pollination wave, the pollen of the following species dominated in precipitation: *Corylus L.* and *Alnus L.* (March, first half of April); *Populus L.*, *Betula L.* and *Carinas L.* (second half of April); *Pinaceae L.* (May).

In March, *Corylus L.* and *Alnus L.* pollen grains dominated in the atmosphere. They respectively made up 53.0% and 42.5% of pollen precipitation. There were random pollen grains of the other species such as *Ulmus*, *Fraxinus*, *Acer*, etc, which did not exceed 4.5% (Fig. 2.A).

The first half of April was marked by the appearance of *Populus L.*, *Betula L.* and *Carpinus L.* pollen grains in the atmosphere. The poplar and the birch respectively made up 8.2% and 4.0% of pollen precipitation.

Corylus L. and *Alnus L.* pollen grains were among the predominant pollen grains; their number decreased, making up 35.0% and 43.9% respectively in comparison with the early spring period. *Ulmus*, *Fraxinus*, *Acer*, *Carpinus* pollen and a number of unidentified taxa constituted 8.9% (Fig.2.B).

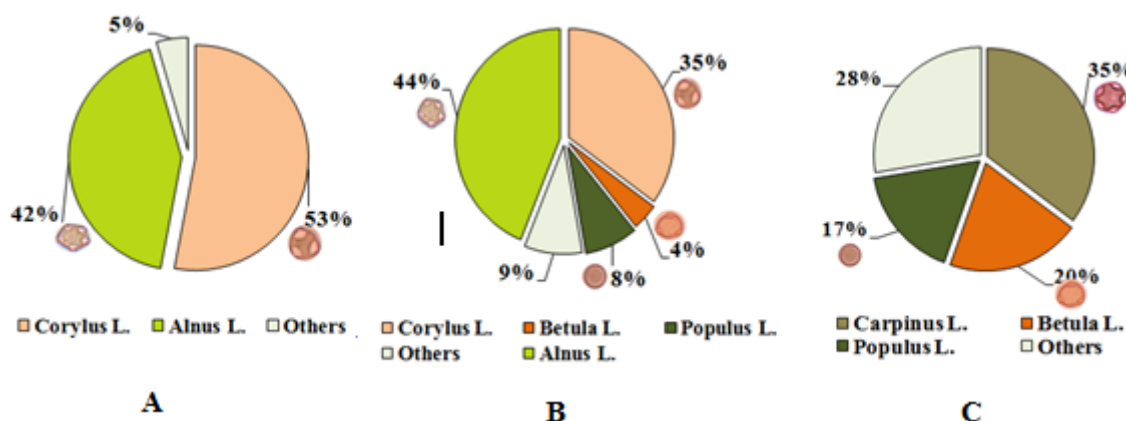


Fig. 2. Qualitative diversity of pollen grains in the air (the urban ecosystem of Ivano-Frankivsk City:

A. March; B. the first half of April; C. the second half of April

The second half of April is characterized by an increase in pollen concentration in the city's atmosphere and a shift in the taxa dominating in pollen precipitation. *Carpinus L.* (35.2%) *Betula L.* (20.2%), *Populus L.* (17%) pollen grains predominated in the air. The pollen grains of the other taxa (*Fagus*, *Salix*, *Larix*, *Quercus*, *Fraxinus*, *Acer*, *Corylus*, *Alnus*, *Pinus*, *Picea* and a number of unidentified taxa) constituted 27.6 % (Fig.2.C).

Beginning with the first decade of May, there was intensive pollination of *Pinaceae*. In May, *Pinus*, *Picea* and *Abies* made up 74.8% of the pollen precipitation in the atmosphere of Ivano-Frankivsk urban ecosystem. Among deciduous trees, *Quercus*, *Juglans*, *Fagus*, *Salix* dominated in pollen precipitation. Beginning with the second decade of May, pollen grains of plant species such as *Poaceae*, *Plantago*, and *Rumex* were recorded.

Let us consider the aeropalynological situation in the urban ecosystem of Ivano-Frankivsk in terms of concrete taxa with enhanced allergenicity. Among early flowering tree plants whose pollen grains can cause allergic diseases, hazelnut and alder have a significant place in the dendrological flora of the urban ecosystem. There is evidence that in Central Europe their flowering can begin as early as the second half of January (Piotrowska, 2008).

In 2013 in the urban ecosystem of Ivano-Frankivsk, the first *Corylus L.* pollen grains were recorded on 22 February at a freezing average daily temperature (-0.8°C) and a relative air humidity of 89%; the last pollen grains were detected on 20 May at a temperature of 16.9°C and a humidity of 73.3% (Fig. 3).

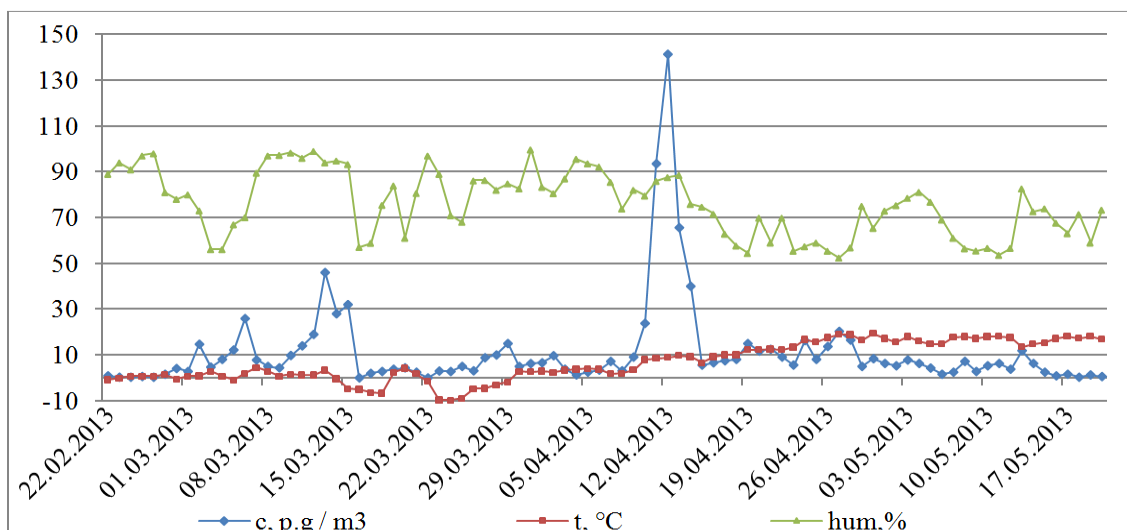


Fig. 3. Quantitative dynamics of *Corylus* pollen concentration (c , p.g / m^3) in the air of urban ecosystem of Ivano-Frankivsk in connection with a change of temperature (t , °C) and humidity (hum , %).

Peak concentrations of hazelnut pollen were recorded on 11 and 12 April at air temperatures of +8.5 and +8.9°C, humidity of 87.6 and 88.5% and the predominance of south-east winds. Changes in hazelnut pollen concentrations in the city's air are determined by the phenorhythmic peculiarities of the taxon and the direction of predominant winds, which indicates a significant role of aerodynamic processes in the formation of pollen precipitation in the early spring period.

Positive dynamics of pollen concentrations were observed at south-east and east winds; negative, at north-west and north winds as well as in windless conditions. As a result, there was an increase in pollen grains from 27 February to 6 March (from 4 to 26 pg/ m^3); on 13 March (46 p.g/ m^3); on 11-12 April (94 and 141 p.g/ m^3); on 19 and 27 April (15 and 20 pg/ m^3).

The second decade of March was marked by the biggest decrease in *Corylus L.* pollen concentrations in the city's atmosphere (to 2 pg/ m^3 , and on 16 and 22 March to 0), which happened in anomalous weather conditions: a sudden drop in temperature to -5°C, a relative air humidity of 97%, north-west and north wind gusts, snow showers. The interdependence between hazelnut pollen grains in precipitation content, atmospheric temperature and relative air humidity is statistically invalid: $r_{t^{\circ}C} = 0.042$; $r_{hum\%} = 0.150$ (Fig. 4).

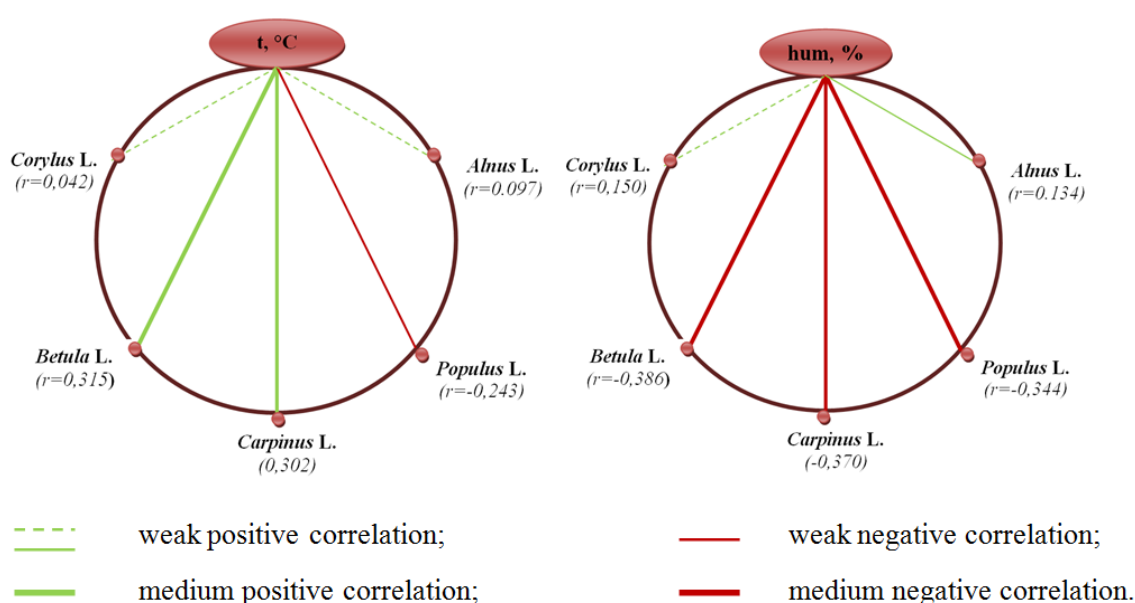


Fig. 4. Correlation between pollen concentrations in the air with the basic meteorological parameters in the city: temperature and humidity.

In the urban ecosystem of Ivano-Frankivsk, the first alder pollen grains (2 pg/m^3) were detected on 28 February at a temperature of 0.7°C , relative humidity of 78% and predominant south-west winds (Fig. 5).

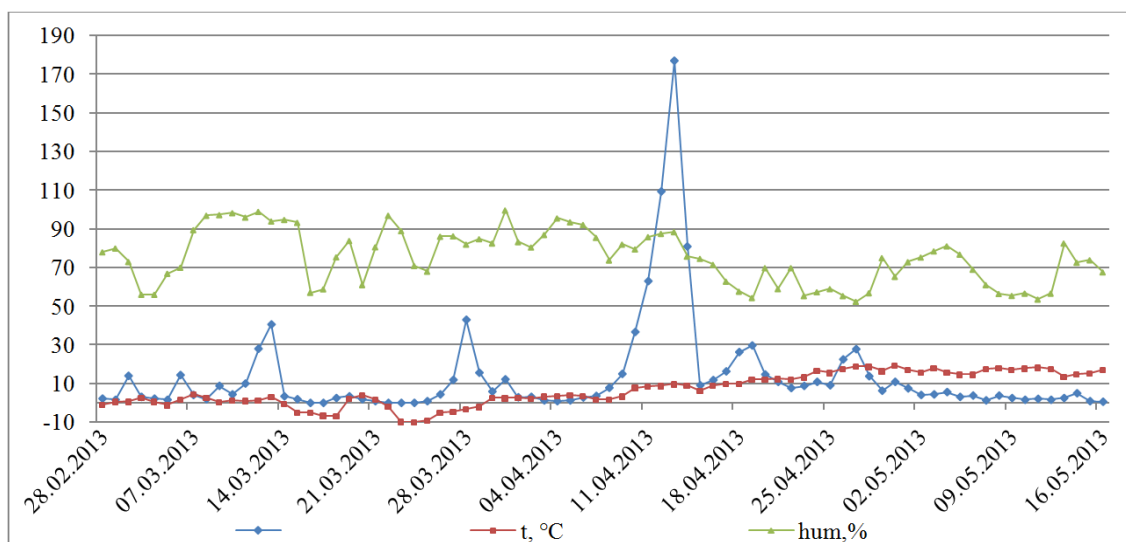


Fig. 5. Quantitative dynamics of *Alnus pollen* concentration ($c, \text{pg/m}^3$) in the air of urban ecosystem of Ivano-Frankivsk in connection with a change of temperature ($t, ^\circ\text{C}$) and humidity ($\text{hum}, \%$).

Pollen concentration increased at south-west or south-east winds in the first decade of March (to 41 pg/m^3) and in the second decade of April. Pollination peaks occurred on 12 and 13 April (109 and 177 pg/m^3) at a rise in temperature to $+8.5...+8.9^\circ\text{C}$ and a relative humidity of $85.9\% - 87.6\%$. Sharp drops in pollen concentrations were observed at the predominance of north and north-west winds, a significant rise in humidity and a drop in air temperature.

Specifically, this was observed during the March weather anomaly on 14-24 March ($0 - 4 \text{ pg/m}^3$ at $t^\circ = -9.8 - +4.2^\circ\text{C}$, humidity $\% \leq 97.0\%$, north and north-west wind gusts and snowstorms) and during the first decade of April ($1-3 \text{ pg/m}^3$ at $t^\circ = +2.9 - 4.2^\circ\text{C}$, humidity $\% = 57.0 - 99.7\%$ and north and north-west winds). In the third decade of April, alder pollination gradually decreased, which is indicated by a progressive decrease in pollen concentration in the air. Random pollen grains were detected till 16 May. Therefore, *Alnus L.* pollination period, calculated by means of the "98% method", lasted 71 days, and pollen precipitation contained the pollen of this taxon during 77 days.

It is known that the threshold concentration level of *Corylus* allergenic pollen in the atmosphere is 35 pg/m^3 ; that of *Alnus L.*, $45 - 50 \text{ pg/m}^3$ (Weryszko-Chmielewska, Rapiejko, 2007). In 2013 in Ivano-Frankivsk, *Corylus L.* concentrations remained higher than the threshold level during five days (13 March and 11-14 April); and *Alnus L.* concentrations, during four days (11 - 14 April). It indicates a high risk of pollinosis in vulnerable population groups and the necessity of monitoring the aeropalynological situation in the city thoroughly.

Birch pollen, which is one of the most common allergens in North and Central Europe, aggravates the aeropalynological situation in Ivano-Frankivsk City in the early spring season. (Sofiev, Bergmann, 2013). The birch pollination season in Ivano-Frankivsk urban ecosystem lasted 40 days (on the basis of "the 98% method"), and pollen grains were constantly detected in samples during 52 days (Fig. 6).

During the year, birch pollen was first detected on 6 April at an average daily air temperature of $+3.8^\circ\text{C}$ and a relative humidity of 92.2% . During the next two weeks, pollen concentration was low and varied from 1 to 5 pg/m^3 . Beginning from 24 April, there was a significant rise in birch pollen grain concentration – to 78 pg/m^3 – at an average air temperature of $+16.8^\circ\text{C}$ and a relative air humidity of 57.3% . The pollination peak was recorded on 27 April (359 pg/m^3), when the average air temperature rose to 19°C and the relative air humidity fell to 52.3% . From 29 April, birch pollen in the atmosphere gradually decreased, with random grains being

detected till 26 May. There is a positive correlation between the content of *Betula L.* pollen grains in the air and air temperature ($r_{t^{\circ}C} = 0,315$) and a negative correlation between the analyzed parameter and air humidity ($r_{hum\%} = -0,386$) (Fig. 3). The statistical analysis results are in line with those obtained in similar studies made in Poland (Puc, Wolski, 2002). Sharp drops in birch pollen concentrations were also observed after massive atmospheric precipitation, which agrees with the physics of finely dispersed particle movement in the air.

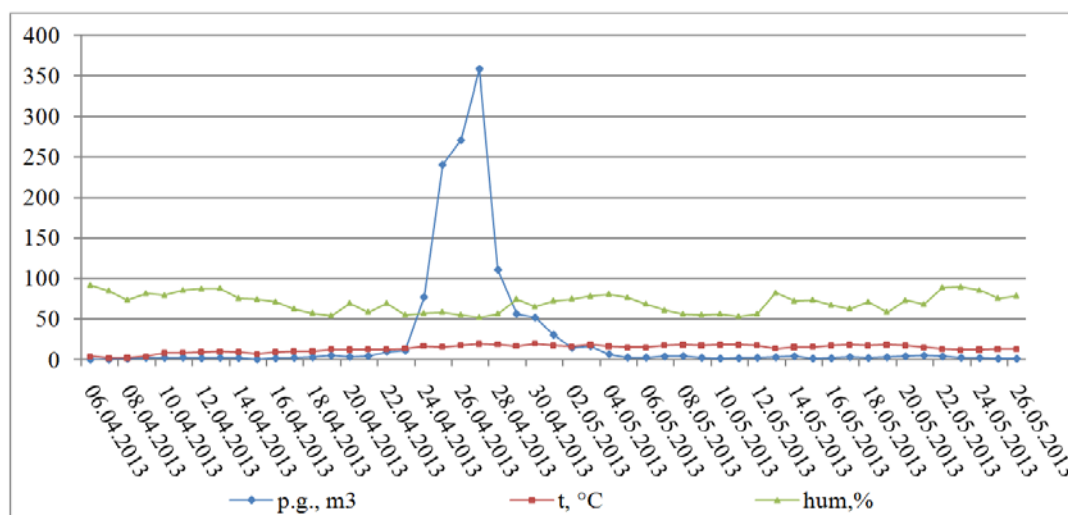


Fig. 6. Quantitative dynamics of *Betula pollen* concentration (c, p.g / m³) in the air of urban ecosystem of Ivano-Frankivsk in connection with a change of temperature (t, °C) and humidity (hum,%).

There were rises in the threshold concentration levels (>30 pg/m³), which can cause the first clinical symptoms of pollinosis (Clot, 2001), during eight days (24 April -1 May).

In the urban ecosystem of Ivano-Frankivsk, poplar pollen also plays a significant role; recorded data on its allergenic properties are ambiguous and even (Клименко, 2012; Sofiev, Bergmann, 2013). Research on poplar pollination has significant implications due to a tendency to replace female species with male ones in urban greening practices, which will gradually lead to an increase in *Populus L.* pollen grains in urban air. In 2013 in the urban ecosystem of Ivano-Frankivsk, the pollination season of poplar was short in comparison with that of the other species, but it was intensive. Poplar pollen was detected in the atmosphere from 9 April (2 pg/m³) to 5 May at a temperature range from +3.5 to 19.4°C and humidity fluctuations from 52.3 to 80% (Fig.7).

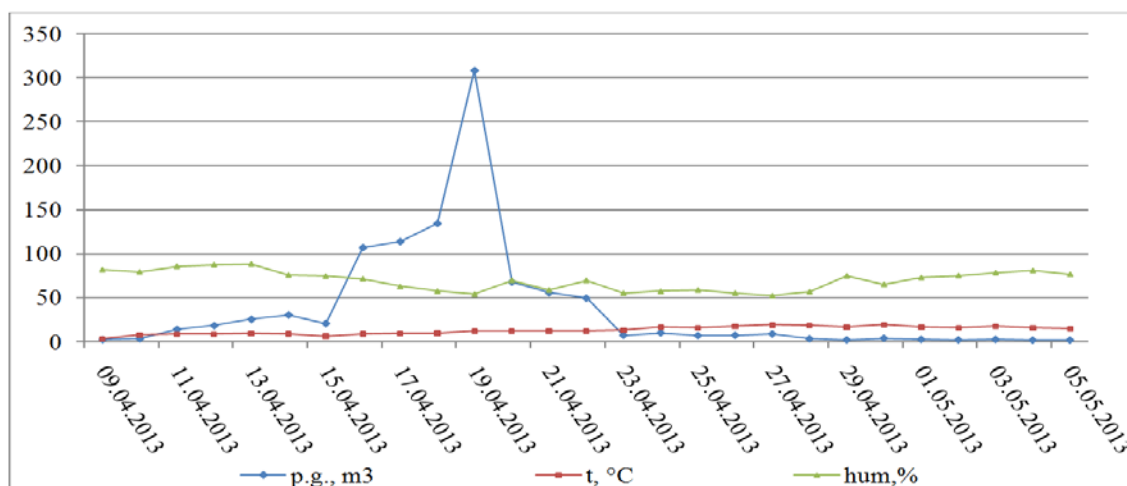


Fig.7. Quantitative dynamics of *Populus pollen* concentration (c, p.g / m³) in the air of urban ecosystem of Ivano-Frankivsk in connection with a change of temperature (t, °C) and humidity (hum, %).

A sudden rise in pollen concentration was recorded on 16 April (107 pg/m³) at a temperature of 9.2°C, a relative humidity of 71.5% and predominant south-east winds. Maximum pollen concentration was recorded on 19 April (308 pg/m³) at an air temperature of +12.4°C, a fall in humidity to 54.3% and east wind. From 23 April, the number of pollen grains in the atmospheric air gradually decreased. The poplar pollination season lasted 21 days, which was calculated by means of “the 98% method”.

The *Carpinus L.* taxon has the most prominent place in the aeropalynological spectrum of Ivano-Frankivsk urban ecosystem during the second half of April. Random pollen grains of the hornbeam were detected in the pollen precipitation of Ivano-Frankivsk beginning from 8 April (Fig. 8) at an air temperature of 2°C, a relative humidity of 73.8% and predominant south-east winds.

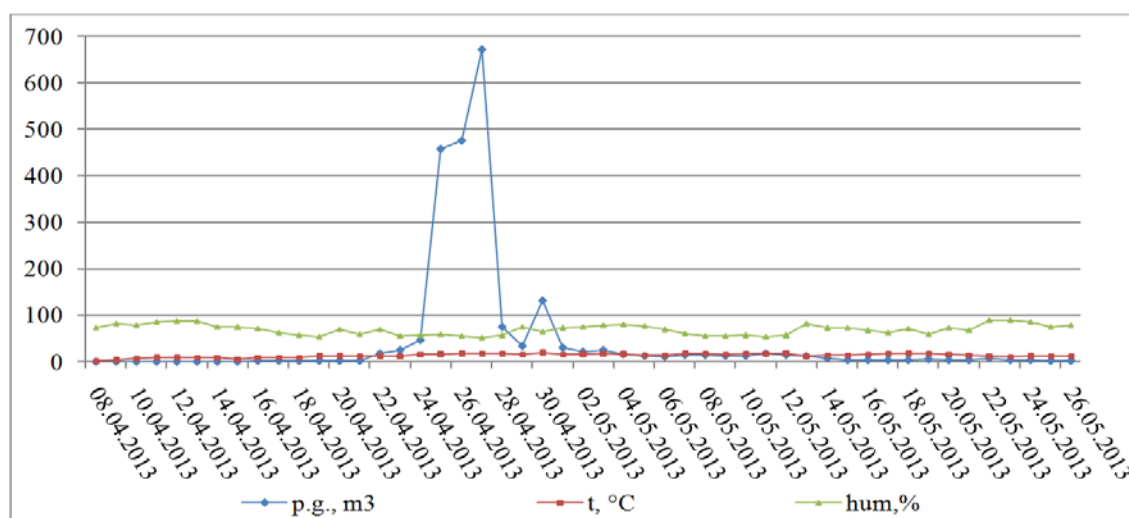


Fig. 8. Quantitative dynamics of *Carpinus* pollen concentration (c, pg / m³) in the air of urban ecosystem of Ivano-Frankivsk in connection with a change of temperature (t, °C) and humidity (hum,%).

Beginning from 28 April, there was a sudden rise in pollen concentration (458 pg./m³) at a rise in temperature to 15.8°C and a fall in humidity to 58.9%. The pollination peak occurred on 27 April, when pollen concentration in the air reached 671 pg/m³, with the air temperature being 19°C and the relative humidity reaching 52.2%. The pollen concentration was in a positive valid correlation with the atmospheric temperature ($r_{t^{\circ}C} = 0.302$) and in a reverse correlation with relative air humidity ($r_{hum\%} = -0.370$). From 28 April, the content of hornbeam pollen in the air of the city's ecosystem made up 75 pg/m³ and continued to fall gradually. As an exception to this tendency, there was a rise in pollen concentration to 133 pg/m³, detected on 30 April, which occurred on the background of a change in wind direction from south-east to north-west and was probably connected with air movement processes from the neighbouring areas. Random pollen grains were found in pollen precipitation on 29 May. The pollination season (calculated on the basis of “the 98% method”) lasted 31 days, with pollen grains being detected in samples during 52 days. Clinically significant hornbeam pollen concentrations were recorded over eight days – from 24 April to 5 May.

4. CONCLUSIONS

During the spring pollination season in the urban ecosystem of Ivano-Frankivsk, the pollen grains of the following taxa predominated: *Corylus L.* and *Alnus L.* – in March and the first half of April; *Carpinus L.*, *Betula L.* and *Populus L.* – in the second half of April; *Pinaceae* – in May.

On 11-14 April, there was a high risk of pollinosis in vulnerable population groups due to a rise in the threshold concentration of *Corylus L.* and *Alnus L.* pollen; and on 24 April - 5 May, due to excessive concentration of *Betula L.* and *Carpinus L.* pollen in the atmosphere.

The concentration of *Betula L.* and *Carpinus L.* pollen grains in the atmosphere of the urban ecosystem shows a valid positive correlation with the air temperature, and there is a reverse correlation with relative air humidity. In

2013, the pollination patterns in early spring species have seen significant transformations owing to the March weather anomaly.

The direction of predominant winds has a dominant influence on the concentration of *Corylus L.* and *Alnus L.* pollen grains in the air; it was observed that pollen concentrations rise at south-east winds and fall at north-west winds. This indicates that the aeropalynological situation in the city largely depends not only on the phenorhythmic characteristics of the aboriginal flora but also on pollen aerodynamics, i.e. pollen movement from the neighbouring territories.

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