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Long-Term Pollen Season Trends Of Fraxinus, Quercus And Ambrosia Artemisiifolia As Indicators Of Anthropogenic Climate Change Impact

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Background
Climate change significantly affects plant life cycles, including flowering, particularly in anemophilous species, which can release high concentrations of allergenic pollen into the air. Changes in meteorological variables and air pollution can lead to earlier onset, prolonged duration, and increased intensity of pollen seasons, with adverse effects on individuals suffering from allergic diseases such as hay fever, rhinitis, or asthma. This study aimed to investigate long-term trends in pollen season characteristics for woody genera *Fraxinus* and *Quercus*, and herbaceous species *Ambrosia artemisiifolia*, and to explore their correlations with climatic and air pollution variables.
Methods
The research was conducted at two urban sites in Slovakia, Bratislava and Banská Bystrica (hereafter B. Bystrica), over the past two decades. Pollen was captured using Hirst-type traps placed at rooftop levels, and samples were analysed following standard aerobiological methods [1]. Daily mean pollen concentrations (pollen grains/m³) were calculated, and the main pollen season (MPS) was defined as the period between the first and last day when daily pollen concentrations reached 10 pollen grains/m³. Characteristics of the MPS were calculated, including start date, end date, duration, peak value, seasonal pollen integral, number of high days (above symptom-causing thresholds: 50 pollen/m³ for *Fraxinus* and *Quercus*, 20 pollen/m³ for *Ambrosia*), and the date of the first high day. Meteorological variables (mean, minimum, and maximum daily temperatures, precipitation, and relative humidity) and air pollutants (PM10, SO2, NO2, O3, CO) were also analysed. To identify trends in these characteristics and variables, the Mann–Kendall trend test was employed. For variables with significant trends, the Theil-Sen estimator was applied to calculate the slope of the trend. Spearman´s correlation analysis was used to assess relationships between pollen season characteristics and significant trends in meteorological and air pollution variables.
Results
The study identified rising trends in temperature, precipitation, and air humidity, alongside mostly declining trends in air pollutants, except for increasing CO levels in B. Bystrica. For the woody taxa, pollen seasons demonstrated earlier onset, prolonged duration, and increased intensity, with *Quercus* showing more pronounced changes. For *Ambrosia*, trends included earlier start dates and extended durations at both locations and more high days and later end dates in B. Bystrica. Rising temperatures during the pre-season correlated with an earlier onset of the pollen season for trees, specifically significant for *Fraxinus* in Bratislava and *Quercus* in B. Bystrica. For *Ambrosia*, the significant delay in the end date of the pollen season correlated with increasing temperatures during its blooming period, particularly in B. Bystrica. Air pollutants, such as SO2 and NO2, negatively correlated with pollen intensity, while CO showed a positive correlation.
Conclusion
This study highlights the significant impact of climate change on the pollen seasons of allergenic plant taxa, emphasising the need for continued monitoring and prediction to mitigate health impacts on allergy sufferers. Understanding these trends contributes to a deeper comprehension of climate change effects on plant life cycles and aids in predicting future pollen seasons.

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