

# Respiratory allergies: Salicaceae sensitization (Review)

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**Abstract.** Seasonal allergic rhinitis (SAR) is one of the most frequent chronic conditions of the modern world. Pollen carried by the wind from pollinated trees is a major source of SAR. Betulaceae, Oleaceae and Platanus are the most important sources of airway sensitization with regard to tree pollen and, therefore, they are included in the official recommendations of skin prick testing by different official societies. Salicaceae pollen is a moderate source of pollen sensitization. Conversely, large areas are covered with poplars and willows around the world. A number of studies from many countries showed that in some particular situations (large and compacted areas covered by Salicaceae, weather conditions, air pollution, urban ornamental vegetation), poplar and willow pollens may become of local importance in producing SAR. The aim of this review was to present a synthesis of information regarding Salicaceae pollen allergy showing that, if various unfavorable aspects are brought together, a minor problem (Salicaceae sensitization) can become a public health problem.

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## 1. Introduction

The Salicaceae family initially included *Salix* and *Populus* genera, but later more genera were classified into the Salicaceae family, containing over 1,000 species (1). The Salicaceae family is a woody shrub plant family with wide distribution in cold, tropical, and warm temperate regions and sporadic presence in different varied habitats (1). *Populus* species play important roles in the ecosystem (land management), plant domestication, conservation (phytoremediation), important sources for wood industry (timber, pallets, plywood, matchboxes, chopsticks, wooden shoes), energy (biomass) and fuel (biofuel) (1,2). Genus *Populus* contains 29-70 species and, based on their morphological characteristics, they have been grouped into the following six sections: *Abaso*, *Turanga*, *Populus*, *Leucoides*, *Aigeiros*, and *Tacamahaca* (1,3). English names applied to different species include poplar, aspen, and cottonwood. Genus *Salix* contains approximately 450 species, and two main subclades have been identified (1,4). They are primarily found on moist soils in the Northern Hemisphere, with a wide natural distribution from the tropics to the arctic zones and an extensive cultivation around the world (5). Willows are also used in wood industry (boxes, cricket bats, dolls, toys, turnery, tool handles, veneer), agriculture, energy (biomass), environment (constructed wetlands, hedges, phytoremediation, shelterbelt) (6). Pollens from different species of *Salix* and *Populus* species were implicated in the respiratory allergic sensitization to wind-transported pollens. The aim of this review is to present the importance of sensitization to Salicaceae pollen in the context of modern respiratory allergies.

## 2. Populus family

The poplar is among the most widely adaptable and distributed tree species in the Northern Hemisphere (latitude 22-70° N), including large areas in countries such as the United States, Canada, Russia, China, Italy and France (7). In Romania, the poplar has been for decades the most used ornamental tree along all the important roads between different towns and villages, in order to prevent the snow in winter. Among the

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many species of poplar that grow worldwide, some of them were investigated regarding their role in pollinosis: *Populus trichocarpa* (7), *Populus deltoides* (8), *Populus tomentosa* (9), *Populus hybrida* (10). Recent studies evaluated the allergenic capacity of *Populus* pollen. In total, 28 proteins from *P. deltoides* were identified as putative allergens. The expression patterns across various tissues showed that several allergenic genes are highly expressed in *Populus* pollen with great attention being paid to the profilin allergen family (8). Proteomics analysis was used to characterize the allergens from *P. tomentosa* mature pollen. In total, 27 proteins were identified as putative allergens, such as heat shock protein, enolase, pollen Ole e 1 allergen, thioredoxin and profilins using the Structural Database of Allergenic Proteins (SDAP) tool and Allergen Online (9).

In the following paragraphs, we shall present several studies that evaluated the presence of *Populus* pollens in the atmosphere in different parts of the world. Generally, in the Northern Hemisphere, pollination period starts at the beginning of March and ends in late April (10). Spain was one the countries where the presence of *Populus* pollen was frequently studied. In the region of Extremadura, weekly concentrations over 4 years were 40 grains/m<sup>3</sup> for *Populus nigra* and the percentage of sensitization was 32.3% (11). *Populus* pollen showed maximum concentrations between 12:00 p.m and 06:00 p.m in the region of Toledo, with a progressively increased concentration during the study period: 2005-2008 with maximum of 606 grains/m<sup>3</sup>/h in 2007 (12). In a more recent study from the town of Guadalajara, *Populus* pollen (*P. alba* and *P. nigra*) accounted for 7.8% of the total pollen count and the elevated pollen levels coincided with both easterly and westerly winds blowing in from areas containing rivers and streams (13). Another study realized by the same principal author, Jesús Rojo, recorded a 7.8% for *Populus* pollen in the same region of Guadalajara for the period 2008-2013, with a medium concentration of 100-199 grains/m<sup>3</sup>, class 7 (14). Monthly airborne pollen concentrations of *Populus* pollen were significantly positively correlated with monthly admissions with asthma or dyspnea in spring in the town of Porto, Portugal, another region of the Iberian Peninsula (10).

The Mediterranean region is another part of the globe where the *Populus* species are widely found. In 2009, in the Osijek-Baranja county of north-eastern Croatia, poplar pollen was found with 3,113 grains/m<sup>3</sup>, second after birch pollen (15). *Populus* pollen was low (0.84%) in the air in the area of Zagreb, capital of Croatia, as indicated in a previous study (16). A study conducted in the city of Vinkovci, Northeastern Croatia, found a high pollen concentration (76 grains/m<sup>3</sup> on a peak day) and 2.03% from all pollens counted (17). A 13.8% of all pollens counted at different sampling sites in the region of Zagreb, in a study performed in 2003, was ascribed to *Populus* pollen with a peak concentration in the interval 4.00-8.00 a.m. (18). The pollen of trees from the *Populus* genus (*P. alba*, *P. nigra*, and *P. canadensis*) was investigated together with many other pollens in a 10-year aerobiological study (1994-2003) on the Mediterranean island of Crete, Greece, and it was found that 6.07% of polysensitized patients were sensitive to them (19). Three studies carried out in Turkey at the beginning of the 2000s studied the *populus* pollen along with other pollens. Skin prick tests among children with respiratory allergies

carried out in the Trakya region of Turkey showed high intensity in the children with allergic rhinitis and living in rural areas (20). *Populus* pollen represented 3.1% in 1996 and 6.38% in 1997 in a study conducted in Kayseri, Turkey from all pollens measured. A 38% of the patients showed positive reaction to *Populus alba* pollen and 30% to *Populus tremuloides* pollen (21). Allergy to *Populus alba* pollen in patients with seasonal allergic rhinitis living in the region of Ankara provoked a mild clinical picture, despite high *Populus alba* pollen counts being measured (22).

Central Europe is a region with many areas covered by poplars. *Populus* pollen concentration in the atmosphere of Lublin (eastern Poland), along with many other pollens, was measured in 2001-2002. High values of mean 24-h concentrations of pollen grains (of 2 years) (631 grains/m<sup>3</sup>) for a relative long period of time (8 days) were recorded (23). Another study carried out by the same authors in the same town for a long period (2001-2012) concluded that taxa *Populus* was characterized by a large number of days (11), in which its pollen concentrations exceeded the threshold values (24). A study carried out in Bratislava, Slovakia, measured the correlation between airborne pollen counts and the length of pollen season on the concentration of sIgE antibodies. *Populus* pollen represented 8.02% of all pollens measured in 2002 and 7.11% in 2003. A strong and significant positive correlation between pollen counts and sIgE levels in the two years analyzed was observed (25). The Szeged region is another part of Central Europe where aerobiological studies, were performed. Daily pollen counts (average daily pollen count per cubic meter of air) of different taxa, including *Populus*, were taken over the period 1997-2007. *Populus* pollen counted for 9.6% from all pollens measured, with *Populus alba* (White Poplar) and *Populus canescens* (Grey Poplar) being prevalent in the city and characteristic in floodplain forests along the Tisza and Maros Rivers and I-273 Poplar and *Populus x euroamericana* (Canadian Poplar) frequently planted in urban parklands and public places (26).

Studies regarding the sensitization and concentration of *Populus* were also realized on other continents. Two studies are from Canada. The sensitization to poplar pollen was 12.1% in a research performed at a University-based clinic from Edmonton, Canada (27). *Populus* (aspen, poplar) pollen was small, but significant associated with acute exacerbations of asthma, severe enough to require hospitalization (28). Poplar sensitization was significant in the dry zones of Mexico in a nationwide skin prick test chart review (29). *Populus* pollen had a maximum weekly daily average of 103 grains/m<sup>3</sup> in the first week of September (1,470 grains/year) in the region of Talca, Chile (30).

### 3. Salix family

The *Salix* genus consists of willow trees and shrubs, mostly found in the Northern Hemisphere, with the greatest diversity in China, approximately 100 species in North America, through Europe, and in the Andes. Flowering occurs from February through May, depending on the region (for mid-Europe, including Romania, substantial concentrations are observed between February and May). Willows are amphiphilous trees, with both wind and insect vectors playing important roles.

Willow pollen could become an important factor in pollinosis based on the high quantities caught on different types of samples worldwide (31). There is a strong cross-reactivity between *Salix* and *Populus* pollens based on skin testing and P-K neutralization and moderate cross-reactivity between Salicaceae and Fagales based on passive hemagglutination and P-K neutralization (31). Rabensteiner *et al* showed, in an elegant manner, that pollens from different species (including *Salix*) presented proteolytic activity and degradation of tear fluid and epithelial cells, which may play an important role in the pathogenesis of allergic reactions affecting the ocular surface (32). Using the SDS-PAGE technique, Ribeiro *et al* revealed distinct bands in allergic patients sera for different tree pollens, including *Salix babylonica*: A band with a molecular weight of approximately 52 kDa (*P. occidentalis*, *A. negundo*, *S. babylonica*, *Q. robur*, *B. pendula* and *P. hybrida*); two bands with molecular weights of approximately 35 and 31 kDa (*P. occidentalis*, *A. negundo*, *S. babylonica* and *B. pendula*) and two other bands with molecular weights of approximately 19 and 16 kDa (*P. occidentalis*, *A. negundo* and *S. babylonica*) (10).

The majority of the studies investigating *Salix* pollen are performed in Asia. Iran is a country in which some of the studies were conducted. The sensitization to willow pollen was among the common allergies in a cohort of 666 patients from the town Ahvaz, Iran (33). Another retrospective cross-sectional study was carried out in the same town, Ahvaz, which evaluated 408 patients with allergic rhinitis and asthma using total and specific IgE and found 28.2% sensitization to *Salix caprea* (34). Turkey is a country where many aerobiological and sensitization studies were carried out. Pollen grains of *Salix* species constituted 3.46% of the total pollen in the atmosphere of Bitlis with pollen season starting in the first week of April and lasting until the last week of May (35). *Salix* species pollens represented 2.17% from all pollens measured in the region of Bilecik, Turkey (36). *Salix* species pollen was included in the five most frequent arboreal pollen producers in the atmosphere of Eskisehir: Pinaceae (48.13%), *Salix* spp. (9.16%), Cupressaceae (6.21%), Rosaceae (3.53%) and *Quercus* spp. (3.03%) (37). The salicaceae pollen was considered to be one of 12 allergens able to detect almost all sensitized patients suffering from respiratory symptoms in Lebanon, according to a study that included 2,350 patients from the period 2004-2011 in the region of Beirut (38). The *Salix* pollen was measured with important concentrations in the atmosphere of two important towns of Georgia, Tbilisi and Kutaisi (39). Eastern Asia is a part of the globe where the willow pollen was also studied. *Salix nigra* sensitization was evaluated in 0.5% patients of 419 Taiwanese patients with allergic rhinitis (40). Willow black pollen sensitization (5% from the total lot of the study) was found in a group of pregnant women from Taiwan (41). The rate of sensitization to willow pollen was 4.07% in a pediatric population from the region of Incheon, South Korea (42). Pollen of various species of *Salix* was measured in an aerobiological study carried out in the region of Zagreb, Croatia at the beginning of the 2000s and represented 6.17% from all pollens counted (16). A trend towards a peak-date and increased quantities of pollen produced was identified for willow pollen in a study that evaluated pollen season trends for the period 1973-2013 carried out in the region of Stockholm,

Sweden (43). *Salix* (willow) pollen has been considered to have minimal importance as an aeroallergen, with the airborne pollen loads often being low according to a recent study in Great Britain (44). In a pediatric study carried out in the Great Basin desert region (encompassing most of Nevada and a large portion of Utah, with major cities of Las Vegas and Reno, Nevada, and Salt Lake City, Utah), willow pollen was a significant early sensitizer with an important prevalence in children ages 2-3 years, suggesting that the willow's wide presence in the Great Basin area may account for its ability to provoke allergic sensitization response (45). The need to differentiate between local and systemic conditions mimicking allergic reactions is particularly important (46-48). Previous data suggest that tumor genesis and allergic reactions pathways are entangled (49). Notably, the clinical diagnosis may be complicated by associated pathology, such as diabetes and hepatitis C (50). Various medications can trigger violent immune response and accentuate previous chronic pathology (51,52). Allergies of the *Salix* family require further research of the innate interactions between lymphocytes (53).

#### 4. Conclusions

According to the aforementioned authors and the statements of official societies, such as EAACI (European Academy of Allergy and Clinical Immunology), the Salicaceae pollen is considered a minor allergen that was not included in the recommended aeroallergens to be tested as routine in a patient with presumption of allergic rhinitis. However, there are regions around the world where we can find large areas covered by poplars and willows and where the conditions to have sufficient airborne pollens quantities to provoke sensitization to humans can be accomplished. Allergists and otorhinolaryngologists must be aware of local flora when investigating patients with suspicion of allergic rhinitis or asthma.

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#### Authors' contributions

AC and ONB contributed substantially to the conception and design of the study, the acquisition, analysis, and interpretation of the data, and were involved in the drafting of the manuscript. RC, MD, and AN, contributed substantially to the acquisition, analysis and interpretation of the data and were involved in the drafting of the manuscript. LGP, CG and DV contributed substantially to



acquisition of the data and were involved in the critical revisions of the manuscript for important intellectual content. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All the authors read and approved the final version of the manuscript.

### Ethics approval and consent to participate

Not applicable.

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Not applicable.

### Competing interests

The authors declare that they have no competing interests.

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