ISSN (ONLINE) 2583-2506
http://publications.rayatbahrauniversity.edu.in
RBIJMR-Rayat Bahra International Journal of Multidisciplinary Research, Vol. 03, Issue 02, December 2023

Pollen Allergy: Causes, Symptoms, Diverse Plant Groups involved and Environmental Interaction

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Abstract: Pollen Allergy is one of the most common trigger of seasonal allergies. Many people know this allergy as "hay fever" and experts usually refer it as seasonal allergic rhinitis. Pollen is fine grains released from grasses, weeds and trees that fertilize other plants. It is carried by insects, birds or the wind and can travel very long way from the plants. People allergic to pollen may experience symptoms such as sneezing, nasal congestion, runny or itchy nose, itchy or watery eyes, and throat irritation. Globally, 10-30% of population is affected by allergenic reactions. However, different forms of allergens affect more than 25% of total Indian population. Pollen production and dispersal from year to year depend on the patterns of preseason weather and on the conditions prevailing at the time of anthesis. The allergenic content of the atmosphere varies according to climate, geography and vegetation, thus, it is usually possible to forecast the chances of encountering high atmospheric allergenic pollen concentrations in different areas. Aerobiological and allergological studies show that the pollen map changes as a result of cultural factors (importation of plants for urban parklands), greater international travel (colonization by ragweed in France, Hungary, etc.) and climate change. This review, thus, focuses on collecting information about different factors associated with pollen allergy, including allergenic potential of diverse plant forms as well as environmental conditions affecting their pathogenicity.

Key words: *Pollen allergy, hay fever, allergic rhinitis, bronchial asthma, climate change*

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1. Introduction

Pollen is fine grains released from grasses, weed and trees that fertilize other plants. It is carried by insects, birds or the wind and can travel very long way from the plants. Pollen is major outdoor air borne allergens responsible for allergic rhinitis, asthma and atopic dermatitis [1, 2]. Pollen allergy (allergic rhinitis/pollinosis) is considered as one of the global health issues by the world allergy organization- WAO [3]. About 10-30% of worldwide population is affected by pollen allergy. Pollen allergens mostly affect predisposed children and adults. Common symptoms among allergy suffering people include bronchial asthma, atopic rhinitis, dermatitis, eczema, urticaria and oral and gastrointestinal symptoms, ocular allergy, and even life- threatening anaphylaxis [4]. Allergic rhinitis, allergic asthma and food allergy are among the most common chronic diseases globally with prevalence of 20 to 30% in adults and up to 40% in children, usually persisting throughout life [5]. Numerous studies conducted in aerobiological research have revealed that pollinosis is expected to increase in the future due to change in climatic variability, urbanization, industrialization and pollutant emission [6].

The growing incidences of asthma, allergic rhinitis/hay fever and other pollen causing diseases has become an important issue in recent years. Today more than 30% of the population globally is suffering from pollen allergy ailments. The immune system of individuals with pollen allergies mistakenly identifies pollen as a harmful invader, triggering immune responses [7]. This response aims to eliminate the perceived threats but lead to the symptoms such as sneezing, itching and congestion [8;9]. Respiratory allergy is prevalent among all populations with increasing trends all over the world. Epidemiological studies carried out in different countries indicate the prevalence of respiratory allergy as 15-30%. The rising incidence of respiratory diseases has been attributed to increasing air pollution, urbanization and climate change [10].

The plants involved in causing these pollen allergic reactions include *Morus alba*, *Celtis occidentalis*, *Eucalyptus* sp., *Callistemon* sp., *Cassia fistula*, *Szygium cumini*, *Pinus* sp., *Phyllanthus emblica*, *Cedrus* sp., *Betula* sp., *Cycas* sp., *Pyrus communis*, *Albizia lebbeck*,

Ricinus communis, etc. [7; 11; 12]. Among the weeds, *Artemisia vulgaris, Plantago lanceolata, Ambrosia artemisiifolia*, *Parthenium hysterophorus*, etc. [13; 14; 15] and among grasses, *Sorghum polcalcin*, *Lolium perenne, Cynodon dactylon, Paspalum notatum, Poa pratensis*, etc. [11;16;17;18] are the common allergenic pollen producers.

Allergic diseases have become a major health concern worldwide, with India being no exception. India is a land of diverse climates, vegetation, populace, and food habits, and has been reported to have a broad range of allergens [19]. Due to these reasons, the Indian population is exposed to a rich and varied range of aerobiological particles. Currently, more than 25% of the total population of India is sensitized with different forms of allergens. Major sources of the allergens in this sub-continent are the pollen grains, fungal spores, contaminated food, insects, and dust mites [20]. In the last two decades, 83 pollens, 34 fungi, 6 dust mite and 19 insect species were reported as allergenic, often contributing to heavy allergenic exposure in indoor and outdoor environments [21]. Therefore, the purpose of this review is to compile the information available about the different factors associated with pollen allergy and the effect of environmental conditions on the frequency of allergic reactions.

2. Causes of pollen allergy

The male reproductive structures of plants, pollen grains, as aeroallergen are well studied across the world and are the primary causative agent of pollen allergy or pollinosis. Pollinosis encompasses allergic responses such as rhinitis (hay fever) and asthma and globally is an increasing public health concern. Apart from inducing asthma and allergic diseases, a high abundance of pollen has also been associated with nonallergic respiratory diseases, such as chronic obstructive pulmonary disease, stroke, myocardial infarction, and even suicide [22].

High atmospheric levels of grass pollen, in particular, seem to be positively associated with severe asthmatic reaction in temperate climates [23]. Pollen is a common cause of these respiratory diseases, as more than 150 pollen proteins have been proved to cause allergic sensitisation [24]. For respiratory disorders, broadly the risk factors are occupational agents, indoor pollution from cooking fuel and tobacco smoke, and environmental exposure to air pollutants from traffic and fossil fuel burning, all of which are manageable and preventable factors but are

underestimated by governmental agencies across the world, despite timely release of monitoring, status, and health impact reports of such diseases by the World Health Organization (WHO) and other international bodies. The plant-derived particles (pollens) also interact with air pollution (particulate matter, ozone) to modulate the allergenicity, in turn leading to increased airway sensitization [25]. The common triggers for asthmatics in India are dust (49%) and air pollution (49%), while only 5% reported pollen as a trigger [26].

3. Sources of pollen allergy

Pollen grains diameter ranges from 5 to 200 μm, so they can only enter the upper airways. Nonetheless, in the last decades it was proven that pollen allergens can also be carried by small particles of 2–5 μm in diameter, such as particulate matter (PM) and plant fragments [27]. In this way, they can reach the lower, narrower airways, triggering allergic asthma. This situation often occurs during thunderstorms, when higher concentrations of pollen are resuspended in the air, and meteorological conditions promote the transfer of its allergens to other particles. This "thunderstorm asthma" also occurs in pollinosis sufferers with no prior diagnosis of asthma [23].

Pollen grain dispersal mechanisms such as pollination from anemophilous or wind-pollinated plants are the most potent allergen sources, whereas pollens from entomophilous or insect-pollinated plants are known to cause fewer allergic symptoms based on a type I hypersensitivity mechanism [28]. Some authors also recorded a dose-response association between pollen exposure and asthma symptoms, suggesting threshold concentrations for different pollen types [29]. High atmospheric levels of grass pollen, in particular, seem to be positively associated with severe asthmatic reactions in temperate climates [23].

Common aeroallergens of relevance to allergic rhinitis and asthma in India include house dust mite, cockroach, pollen, and mould spores. A seminal study from Eastern India revealed that 96% of patients with naso-bronchial allergy showed sensitisation to house dust mite with predominant mites being *Dermatophagoides pteronyssinus, Dermatophagoides farinae, and Blomia tropicalis* at 75.06%, 63.72%, and 72% respectively [26]. Similar studies from Western, Northern, and Southern India revealed somewhat lower rates of

sensitisation, although *D. pteronyssinus* was the major offending allergen. Dominance of *D. pteronyssinus* sensitisation is further validated by another recent study from Eastern India [26].

4. Symptoms associated with pollen allergy

The common symptoms of pollen allergic reactions include cough, sneezing, nasal congestion, runny or itchy nose, roof of mouth or throat, itchy or watery eyes, sinus pressure, bruised-appearing skin under the eyes and decreased sense of taste or smell. In severe cases, allergic reactions can lead to asthma exacerbations [30].

5. Diversity among plant groups in producing allergenic pollen grains

Pollen grains are produced by flowering plants (angiosperms) and gymnosperms (naked seed plants). Of the 250,000 well-identified and detailed pollen-producing plant species, fewer than 100 are known to induce pollinosis. Pollen grains or subparticles less than 2.5 to 10 μm readily enter the human body via upper respiratory tract mucosa for eliciting allergic sensitization. The critical threshold pollen concentration expressed as grains per cubic meter of air required to elicit symptoms of seasonal allergic rhinitis varies for different plant taxa: for grasses, the reported value is 50; for *Olea*, 400; and 1 to ~50 for *Ambrosia* pollen. The population, globally as well as in India, is exposed to a variety of pollen grains from deciduous and coniferous trees, grasses, and various flowering plants growing in different regions. Specific plants that produce allergens include birch, cedar, pine, grasses (ryegrass and bermuda grass) and various weed species.

6. Effects of environmental conditions on pollen allergy

Climate change is a constant process that affects allergy, and its impact on pollen may be one of the most important consequences for human health. Several studies are oriented toward assessing the adverse effects of increasing temperature and increased carbon dioxide (CO_2) on phenology regarding productivity, especially for staple and cash crops. The impact of climate change on the environment, biosphere, and biodiversity has become more evident in the recent years. Human activities have increased atmospheric concentrations of CO_2 and other greenhouse gases. Change in climate and the correlated global warming affects the quantity, intensity, and frequency of precipitation type as well as the frequency of extreme events such as heat

waves, droughts, thunderstorms, floods, and hurricanes [25].

Table 1: List of plant families and species producing allergenic pollen grains reported from various parts of the world. Source: 10.1159/000490805 [31]

Region	Family	Species
Africa	Asteraceae, Amaranthaceae	*Cocus nucifera, Mangifera indica, Acacia auriculiformis, Senna siamea, Pinus kasiya, Amaranthus spinousus, Mimosa* spp.
South America	Poaceae, Pinaceae, Cupressaceae	*Acer, Populus, Ambrosia, Alnus*
North America	Poaceae, Betulaceae, Fagaceae, Aceraceae	*Phleum pratense, Cynodon dactylon, Poa pratensis, Queraus* spp., *Betula* spp., *Acer* spp., *Pinus* spp., *Ambrosia* spp., *Artemisia* spp., *Amaranthus* spp.
Antartica	Betulaceae, Fagaceae, Cupressaceae	*Parietaria, Olea, Cypressus, Ambrosia*
Europe	Poaceae, Pinaceae, Fagaceae, Myrtaceae, Amberaceae	*Olea, Helianthemum, Alder, Hazel, Parietaria, Betula, Ambrosia*
Australia	Myrtaceae, Fagaceae, Asteraceae, Poaceae	*Cynodon dactylon, Cynodon* spp., *Lilium* spp., *Quercus* spp., *Plantanus* spp., *Pinus* spp., *Plantago* spp., *Rumex* spp., *Allocasuarina* spp.
North India	Asteraceae, Arecaceae, Cheno/Amaranthaceae, Poaceae	*Holoptelea integrifolia, Rumex acetosa, Ailanthus excelsa, Eucalyptus* spp., *Pinus* spp., *Cedrus deodara, Platanus orientalis*
Eastern India	Cheno/Amaranthaceae, Poaceae, Asteraceae	*Trema orientalis, Areca catechu, Cocos nucifera, Borassus flabellifer, Phoenix sylvestris, Azadirachta indica, Acacia auriculiformis, Delonis regia, Xanthium strumarium*
South India	Cheno/Amaranthaceae, Cyperaceae, Poaceae	*Casuarina equisetifolia, Parthenium hysterophorus, Spathodia campanulata, Cocos nucifera, Peltophorum*
Western India	Poaceae, Cheno/Amaranthaceae	*Casurina equisetifolia, Parthenium hysterophorus, Moringa oleifera, Prosopis julifera, Eucalyptus* spp., *Sizygium* spp.
Central India	Poaceae, Asteraceae, Apocynaceae, Cyperaceae, Cheno/Amaranthaceae	*Rosa* spp., *Ricinus communis, Ailanthus excelsa, Holoptelea integrifolia, Cicer aurietinum, Argemone mexicana, Cocos nucifera, Hibiscus* spp.

An altered climate will affect the range of allergenic plant species and the length of the pollen season, and elevated atmospheric CO_2 levels may increase plant productivity and pollen production, affecting plant ecology [32]. The pollen count, pollen abundance, dispersal, and allergenicity are the parameters that are affected by the local climate. With changing climatic conditions, these variables fluctuate as the phenology is affected. The concentrations of airborne pollen or spores and durations of exposure to these allergens have been found to be important factors influencing the exacerbation of allergic symptoms, which continuously increases with these changing climatic conditions [33].

Pollen levels can fluctuate with the changing seasons. Spring and early summer typically see higher pollen counts, as many trees release their pollen during this period. Grass pollen is more prevalent in late spring and early summer, while weed pollen is more common in late summer and fall [34]. Because the influence of climate change is complex, there is no predictable quantitative assessment of how climate change may affect pollen allergy in the future.

7. Incidences of pollen allergy

A long-term, detailed, cause-effect study spanning 27 years (1981–2007) was carried out to assess the effect of climate variables on pollen counts, meteorological factors, and allergic sensitization rate in western Liguaria (northwest Italy). The study revealed that climatic variables may increase the duration of pollen seasons for *Parietaria* by 85 days, olive (18 days), and cypress (18 days). They reported constantly increased pollen sensitization throughout the year, with an increasing pollen load in comparison with stable sensitization to the house dust mite [35].

An investigational study from Gyeonggi Province, Seoul, Korea, from 1999 to 2008 revealed a possible correlation of skin test positivity results and hospital visits of tree pollen allergy patients as a result of temporary meteorological variations. This study revealed that the increased minimum temperature in the preflowering period may be associated with elevated pollen counts, which may be leading to increased tree pollen sensitization and hospital visits [36].

Another study from 2008 to 2013 from Seoul, Korea evaluated the changes in pollen count and skin prick test (SPT) patterns. A correlation was observed among the annual

increase in pollen count for trees, grasses, and weeds and skin positivity rates. Increased SPT positivity may be either due to increased pollen allergenicity or efficient pollen dispersal and longer suspension in the air due to climate change [37].

A recent study from Japan showed that seasonal allergic rhinitis, which is caused by JC pollen (i.e., sugi-pollinosis) is alarmingly affecting one-third of all Japanese individuals and it has been increasing for the past 20 years. Sugi-pollinosis has been attributed to an increased number of cedar pollens as a result of global climate change and tree-planting programs initiated by the Japanese government after World War II [38].

8. Conclusions

Pollen allergenicity monitoring is an old problem that requires new solutions.

The risk factors for diverse allergenic reactions include dust, indoor and outdoor pollution, and level of pollens in environment. Nasal congestion, itchy nose, watery eyes and bruised appearing skin under the eyes are the common symptoms of allergy. The most important process that affects allergy is climate change, where alteration in climatic parameters changes plant productivity and pollen production. In addition, a number of plant species belonging to diverse groups of trees, grasses and weeds are involved in causing allergy in human beings exposed to different kind of pollen grains. This review, thus, attempts to compile the information about all these diverse factors which affect the pollen allergy in different parts of the world.

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