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REVIEW ARTICLE

Weed pollen and its multifaceted impacts: Allergens, health risks, and effects on livestock

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ABSTRACT

Weeds are often classified as undesirable plants that disrupt cultivated areas, but they also pose significant health risks to humans and livestock. This review examines the diverse impacts of weed pollen, focusing on allergenic properties, health risks, and effects on domestic animals. Weeds, such as ragweed, mugwort, feverfew, and plantain, are known to produce potent allergens that contribute to various allergic conditions in humans, including allergic rhinitis, asthma, and contact dermatitis. The review discusses major allergenic proteins found in weed pollen, including pectate lyases, defensin-like proteins, Ole e 1-like proteins, and non-specific lipid transfer proteins, as well as panallergens such as profilins and calcium-binding proteins that cause cross-reactivity among sensitized individuals. Additionally, it highlights the health risks associated with inhaling or ingesting pollen contaminated with toxic compounds. These risks include respiratory distress, food poisoning, and adverse effects on livestock, such as reduced feed intake and weight loss. The review underscores the significance of understanding the allergenic and toxic properties of weed pollen and their impact on human health and livestock.

Keywords:, Allergens, Health risk, Livestock health, Weed pollen

INTRODUCTION

Weeds are unwanted plants that grow wildly among cultivated crops, competing for essential resources such as space, light, and nutrients. Unlike specific plant groups, weeds are a diverse assemblage of species that pose significant agricultural, environmental, and health challenges. In agriculture, weeds can severely impact major crops such as rice (Sreekanth *et al.* 2024, Pawar *et al.* 2022), wheat (Sondhia *et al.* 2023), and soybean (Chander *et al.* 2023), reducing yield and quality by competing for nutrients, water, and sunlight. Additionally, some weeds can interfere with crop physiology by releasing allelopathic compounds that hinder seed germination and growth. Furthermore, weed management is becoming increasingly difficult due to climate change, which influences weed distribution, herbicide efficacy, and environmental sustainability (Sreekanth *et al.* 2023, 2022). Changing temperature and precipitation patterns alter weed-crop competition, potentially favoring invasive weed species that can better adapt to extreme conditions. Certain weed species also act as bioaccumulators, absorbing heavy metals and contributing to soil and water contamination, thereby posing risks to both agriculture and human health (Roy *et al.* 2021).

Beyond their impact on crop production, weeds also pose significant health risks to humans. One of the primary concerns is their role as sources of allergenic pollen, which can trigger severe allergic reactions and respiratory illnesses such as hay fever and asthma. Pollen grains from certain weed species are among the most potent aeroallergens and are responsible for seasonal allergic rhinitis in millions of people worldwide. Several major weed species, including *Ambrosia artemisiifolia* (common ragweed), *Artemisia vulgaris* (mugwort), *Tanacetum parthenium* (feverfew), *Parietaria* spp. (pellitory), *Chenopodium album* (lamb's quarters), *Kali tragus* (Russian thistle), *Plantago* spp. (plantain), and *Mercurialis* spp. (dog's mercury), produce highly allergenic pollen that has been characterized to varying degrees (Gadermaier *et al.* 2004). These allergens are known to contain specific proteins that trigger immune responses in sensitized individuals, leading to symptoms such as sneezing, nasal congestion, watery eyes, and in severe cases, asthma attacks. The prevalence of sensitization to weed

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pollen allergens can exceed 50% in certain regions, complicating medical diagnosis due to cross-reactivity among different pollen types, making effective treatment challenging (Stemeseder *et al.* 2014). Moreover, urbanization and climate change have led to an increase in airborne pollen concentrations, prolonging pollen seasons and exacerbating allergic conditions.

In addition to human health risks, weed pollen may also have adverse effects on livestock. Inhalation or ingestion of allergenic weed pollen can lead to respiratory distress, allergic dermatitis, and digestive disorders in farm animals. Reduced feed intake, weight loss, and overall lowered productivity are some of the consequences observed in livestock exposed to high levels of allergenic weed pollen. Furthermore, some weed species produce toxic compounds that can contaminate fodder and grazing pastures, leading to poisoning in cattle, sheep, and other livestock species. For instance, weeds such as *Parthenium hysterophorus* can cause skin irritation and toxicity in both humans and animals, highlighting the need for integrated weed and pasture management strategies. The increasing prevalence of weed pollen due to changing climatic conditions and land-use patterns could exacerbate these impacts, necessitating further research and mitigation strategies. This review aims to explore the multifaceted impacts of weed pollen, focusing on its allergenic properties, associated health risks, and implications for livestock. By synthesizing current knowledge on weed pollen biology, its allergenic potential, and its effects on both human and animal health, to get insights into effective mitigation strategies to address the growing challenges posed by allergenic weed pollen in agriculture, public health, and livestock management.

Major weed pollen allergens

Four major protein families appear to be primarily responsible for allergic reactions to weed pollen: the ragweed Amb a 1 family of pectate lyases; the defensin-like Art v 1 family from mugwort, feverfew, and possibly sunflower; the Ole e 1-like allergens Pla l 1 from plantain and Che a 1 from goosefoot; and the nonspecific lipid transfer proteins Par j 1 and Par j 2 from pellitory. Additionally, weed pollen contains pan allergens such as profilin and calcium-binding proteins, which contribute to widespread cross-reactivity among patients sensitized to pollen (Gadermaier *et al.* 2004). Weed pollen that triggers allergic reactions spans several botanical families, with numerous allergenic molecules identified to date. Clinically significant allergens from weed pollen are found in *Ambrosia artemisiifolia*, *Artemisia vulgaris*, *Tanacetum parthenium*, *Parietaria* spp., *Chenopodium album*, *Kali tragus*, *Plantago* spp., and *Mercurialis* spp. Notably, the primary allergens from weed pollen are categorized into four main protein families: pectate lyases, defensin-like proteins, Ole e 1-like proteins, and non-specific lipid transfer proteins. Weed pollen also contains pan allergens like profilin and polcalcin, which are highly cross-reactive molecules recognized by patients sensitized to pollen (Gadermaier *et al.* 2014). Gupta *et al.* (1996) discovered a unique hydroxyproline-rich glycoprotein as the primary allergen in *P. hysterophorus* pollen. Feverfew pollen has been characterized to contain multiple allergenic proteins, with a notable IgE reactivity observed in sensitized patients (Pablos *et al.* 2017). Agriculture experts are apprehensive about *P. hysterophorus* impacting various crops, given that pollen and dust from this weed can induce allergic contact dermatitis (Gunaseelan 1987, Morin *et al.* 2009). Moreover, climate change is exacerbating pollen-related health issues by increasing pollen production, extending pollen seasons, and enhancing allergenicity due to rising CO_2 levels (Ziska and Beggs 2012). Exposure to *P. hysterophorus* pollen is also linked to allergic bronchitis (Towers and Subba Rao 1992). Increased concentrations of weed pollen correlate with higher rates of allergic rhinitis and medication prescriptions, particularly for tree and weed pollen (Saha *et al.* 2021).

Ambrosia spp.

Ragweed (*Ambrosia artemisiifolia*) is a major allergen, particularly in North America, causing respiratory issues and other allergic diseases (Zhao *et al.* 2016). The genus Ambrosia includes approximately 40 species, found in Eastern and Central North America. Among these, *Ambrosia artemisiifolia, Ambrosia elatior* and *Ambrosia trifida* triggers type I allergic reactions during late summer and fall. In the USA and Canada, over 15 million people suffer from ragweed pollen allergies, affecting about 45% of susceptible individuals (Boulet *et al.* 1997). Currently, eleven allergenic molecules from Ambrosia pollen have been identified and documented in the official IUIS allergen database. Ragweed pollen, particularly from the species *Ambrosia artemisiifolia*, is a major allergen responsible for significant allergic reactions, especially in late summer and autumn. This invasive plant has spread globally, exacerbated by climate change and urbanization, leading to increased pollen concentrations and extended pollen seasons.

The primary allergens identified in ragweed include Amb a 1 and Amb a 11, with sensitization rates varying among other allergens (Chen *et al.* 2018, Chiara *et al.* 2022). Individuals sensitized to ragweed may also react to other weed pollens, such as mugwort and dandelion, indicating significant cross-allergenicity (Kim *et al.* 2015; Preda *et al.* 2024).

Artemisia spp.

The genus Artemisia encompasses approximately 350 species distributed across the Northern hemisphere and Australia. *A. vulgaris* is the utmost significant and trigger allergic reactions in 10–14% of pollinosis patients in Europe (Wopfner *et al.* 2005) and 11.3% of asthma and/or rhinitis patients in China (Li *et al.* 2009). Other species like *A. annua* are grown for their antimalarial properties (White 2008). Individuals allergic to Artemisia often experience harmful reactions (Egger *et al.* 2006). Currently, six allergenic molecules from mugwort have been formally recognized by the IUIS allergen nomenclature sub-committee.

Parthenium hysterophorus L.

Pollen grains of parthenium induce numerous allergies such as contact dermatitis, hay fever, asthma, and bronchitis in humans. Common allergens found in this weed include parthenin, coronopilin, tetraneuris, and ambrosin. Parthenium pollen can trigger asthma (allergic bronchitis), particularly affecting humans. Contact with the plant can cause dermatitis, spreading discomfort throughout the body (Wiesner *et al.* 2007). Clinically, parthenium dermatitis manifests in five types: (1) classical airborne contact dermatitis (ABCD), affecting areas like the face, eyelids, neck, chest, elbows, and knees (2) chronic actinic dermatitis (CAD), presenting as lichenified papules, plaques, or papulonodules on exposed areas such as the forehead, ears, cheeks, neck, forearms, and hands (3) a mixed pattern combining classical and CAD features, with scaly papules on exposed parts and dermatitis in other areas; (4) photosensitive lichenoid eruption, appearing as pruritic, flat, violaceous papules and plaques on sun-exposed areas; and (5) prurigo nodularis-like pattern, characterized by hyperkeratotic papules and nodules on extremities, resembling prurigo nodularis (Aneja 1991, Sharma *et al.* 2012). Deleterious effect of parthenium on men and animals' health's due to its pollens' allergic nature has also been highlighted by Sushilkumar (2014).

Feverfew pollen predominantly elicits type IV hypersensitivity reactions but has also been implicated in allergic rhinitis among sensitized individuals (Lakshmi and Srinivas 2007). The major allergen, is known as Par h I and is recognized by over 90% of Parthenium-sensitized patients (Gupta *et al.* 1996). Interestingly, the identified defensin domain shares significant sequence homology with SF18 protein from sunflower (88%), Amb a 4 (80%), and Art v 1 (61%). However, due to incomplete sequence information, comprehensive molecule-based studies, including IgE cross-inhibitions with other defensin-like allergens, are still required.

Chenopodium album L.

Chenopodium spp. are annual or perennial plants and pollinate from June to October. Recently, there has been an increase in *C. album* sensitization in the desert areas of Saudi Arabia, Iran, and Kuwait, attributed to the use of this plant in greening initiatives (Barderas *et al.* 2002). In Kuwait, for instance, Chenopodium pollen is a major allergen for patients with allergic rhinitis or asthma (Dowaisan *et al.* 2000).

Salsola kali L.

Among the Amaranthaceae family, *Salsola* is extensively studied for its allergenic properties (Ferrer *et al.* 2010). One of the most recognized species is *S. kali*, commonly known as Russian thistle, which thrives in saline soils with limited rainfall. Sensitization to *S. kali* pollen was first documented in Arizona in 1993, and currently, over 30% of allergic patients in certain regions of Spain exhibit positive skin reactions to this pollen (Carnes *et al.* 2003). Notably, *S. kali* pollen sensitization affects approximately 75% of pollen-allergic individuals in Iran, making it the primary cause of pollinosis in the country (Assarehzadegan *et al.* 2009).

Amaranthus retroflexus L.

Pollen from *A. retroflexus* is a significant allergen in Iran, with a sensitization rate of 69% among allergic patients. Significant IgE cross-reactivity with other species in the Amaranthaceae family has been observed (Tehrani *et al.* 2010).

Plantago spp.

The genus *Plantago* comprises approximately 250 species widely distributed worldwide, predominantly thriving in humid meadows and roadsides. Due to its exclusion from routine allergy testing, precise sensitization rates in large populations are not readily available. However, certain studies indicate sensitization frequencies ranging from 20% to 40% among pollinosis patients (Couto *et al.* 2011, Gadermaier *et al.* 2004). Allergy to plantain pollen is often linked with grass pollen allergy, and cross-reactive components such as a 30 kDa protein with similarity to Phl p 5 have been identified, though their clinical significance remains uncertain (Asero *et al.* 2000).

Parietaria spp.

The pollen of *Parietaria judaica* and *Parietaria officinalis* are the most significant allergenic species within this genus. Sensitization rates to *P. judaica* can be notably high in Southern European countries, reaching 60–90% in certain coastal regions. A high prevalence of asthma and bronchial hyper-responsiveness has been observed in patients sensitized to Parietaria (Gadermaier *et al.* 2004). Currently, four allergens from *P. judaica* and one allergen from *P. officinalis* are officially recognized.

Mercurialis annua

M. annua, native to Europe, is recognized as a significant source of allergens in the Mediterranean regions of Spain and Italy (Garcia-Ortega *et al.* 2004). Sensitization to Mercurialis pollen has been reported at high levels, ranging from 28% to 56% in various areas of Spain during the late 1990s. Two allergenic components, sized at 15.3 and 14.1 kDa, have been identified as profilins and designated as Mer a 1. Studies involving pollen extracts from other plants containing allergenic profilins have shown modest yet significant levels of IgE cross-reactivity (Vallverdu *et al.* 1997). Recognized by more than 50% of individuals allergic to Mercurialis pollen, Mer a 1 is considered a major allergen from this pollen source (Vallverdu *et al.* 1998).

Medicago sativa L.

Comparing sensitization to pollen allergens and subsequent clinical manifestations between human patients and their domestic animals such as dogs, cats, and horses is a topic of significant interest (Schafer *et al.* 2008). Pollen hypersensitivity is associated with Canine Atopic Dermatitis (CAD), characterized by elevated specific IgE levels against environmental allergens (Halliwell 2006). Generally, pollen sensitization is thought to have minimal impact on allergic dogs, despite earlier studies suggesting similar nasal congestion symptoms in both humans and dogs exposed to ragweed pollen (Tiniakov *et al.* 2003).

In Australia, intradermal tests on over 1000 atopic dogs revealed sensitization rates of 10% to 25% to various types of pollen (grass, tree, weed) (Mueller *et al.* 2000). A more recent cross-sectional study involving 651 atopic dogs indicated statistically significant associations between sensitization to tree, weed, and grass pollen in 94% of cases, distinguishing them from sensitization to other allergen sources (Buckley *et al.* 2013). The authors emphasized the importance of distinguishing between sensitization and clinically relevant sensitization that leads to symptoms.

Various toxic compounds have been identified in the pollens of agricultural weeds, including alkaloids, glycoalkaloids, lectins, and secondary metabolites, which can induce a range of adverse effects when ingested or inhaled. For instance, solanidine alkaloids found in nightshade weed pollens have been linked to digestive disturbances in livestock (Knudsen *et al.* 2006).

Health impacts on humans and livestock:

Inhaling weed pollen particles that carry toxic compounds can induce allergic reactions and respiratory distress in humans. Moreover, consuming food products contaminated with toxic weed pollen can lead to food poisoning, presenting symptoms such as nausea, vomiting, and diarrhea (D'Amato *et al.* 2007). Livestock grazing on pastures contaminated with toxic weed pollens may experience reduced feed intake, weight loss, and even mortality. Weed pollens containing alkaloids, such as those from jimsonweed (*Datura stramonium*), are particularly notorious for their harmful effects on livestock (Panter *et al.* 1999). The significant impacts of various weed pollens are detailed in **Table 1**.

Conclusion

In conclusion, the multifaceted impacts of weed pollen on human health, livestock, and agriculture underscore the critical need for continued research and proactive management strategies. This review highlights the significant role of weed pollen in triggering allergic reactions in humans, with various species such as ragweed, mugwort, and plantain being major contributors to seasonal allergies. The identified allergens from these weeds, including pectate lyases, defensin-like proteins, and nonspecific lipid transfer proteins, underscore the complexity of allergic responses and the challenge in managing cross-reactivity among different pollen types. The review underscores the severe health implications of weed pollen exposure, including respiratory issues and dermatitis in humans, and highlights the detrimental effects on livestock, such as reduced feed intake and potential mortality from consuming contaminated pollen. Additionally, the toxic compounds found in some weed pollens, like alkaloids and mycotoxins, pose risks not only to human health but also to agricultural productivity and

Table 1. Impact of weed pollens on human beings and livestock

Weed	Effect	Reference
Parthenium hysterophorus	Contact dermatitis: Skin rashes, redness, itching, and blistering	Sharma *et al.* 2011
	Allergic rhinitis: Sneezing, a runny or stuffy nose, and itchy or watery eyes	Sharma *et al.* 1998
	Asthma exacerbation: Increased wheezing, shortness of breath, and chest tightness	Pahwa *et al.* 2008
	Allergic conjunctivitis: Redness, itching, and swelling of the eyes	Shah *et al.* 2014
	Contact urticaria: Sudden appearance of hives and itching at the site of contact	Mahendra and Meena 2016
	Oral Allergy Syndrome (OAS): OAS may occur in individuals who ingest foods cross-reacting with Parthenium pollen, leading to itching and swelling of the lips, tongue, and throat	Erwin *et al.* 2006
Xanthium strumarium	Contact Dermatitis and Skin Irritation: Skin irritation, leading to symptoms such as redness, itching, and rashes	Bharali and Talukdar 2013
	Allergic Reactions in Humans: Sneezing, runny or stuffy nose, and itchy or watery eyes	Panico *et al.* 1992
	Gastrointestinal Disturbances: Nausea, vomiting, and diarrhea. The seeds contain toxic compounds that can be harmful when ingested	Cheesbrough and Kolbezen 1997
	Liver and Kidney Damage: Liver and kidney damage. The plant contains compounds known as carboxyatractylosides that are toxic to these organs	Radostits *et al.* 2006
	Neurological Effects: Convulsions and tremors	Krishnamurthy 1990
	Death in Livestock: Severe cocklebur poisoning can lead to the death of livestock	Saha *et al.* 2016
Chenopodium album	Allergic rhinitis and allergic conjunctivitis: Pollen from *C. album* can trigger allergic rhinitis (hay fever) in sensitive individuals. Symptoms include sneezing, runny or stuffy nose, and itchy or watery eyes	Cecchi *et al.* 2010
	Respiratory Allergies: Inhalation of *C. album* pollen can lead to respiratory allergies, particularly in regions where the weed is abundant	Kumar, 2016
	Cross-Reactivity: Cross-reactivity between *C. album* pollen and other allergenic pollens can lead to complex allergic responses and increased sensitivity in individuals with multiple pollen allergies	Scala *et al.* 2017
	Skin Irritation: Contact with *C. album* pollens can sometimes cause skin irritation, resulting in redness, itching, and rashes, particularly in individuals with sensitive skin	Behera and Basak 2013
	Oral Allergy Syndrome (OAS): OAS can occur in individuals who consume foods cross-reacting with *C. album* pollen. Symptoms may include itching and swelling of the lips, tongue, and throat	Villalta *et al.* 2011
Rumex dentatus	Mild Allergic Reactions: Pollen from *R. dentatus* may cause mild allergic reactions in some individuals, including symptoms like sneezing, runny or stuffy nose, and itchy or watery eyes	D'Amato, G., *et al.* 2007
	Skin Irritation: Contact with the plant or its pollen may lead to skin irritation in sensitive individuals, resulting in redness, itching, and skin rashes	Mahendra and Meena 2016
	Oral Allergy Syndrome (OAS): In some cases, individuals may experience OAS when consuming foods cross-reacting with *R. dentatus* pollen. Symptoms can include itching and swelling of the lips, tongue, and throat	Scala *et al.* 2017
	Respiratory symptoms: While *R. dentatus* is not a major pollen allergen, it may contribute to respiratory symptoms in individuals who are sensitive to a variety of pollen types or have multiple pollen allergies	Katelaris and Beggs 2018
Sorghum bicolor	Aflatoxins and fumonisins mycotoxins are present in sorghum pollen. These mycotoxins have been associated with a range of health issues, including liver and kidney damage, and have raised concerns about the safety of handling and inhaling sorghum pollen	Wu *et al.* 2014
Avena fatua	*A. fatua* pollen can be contaminated with mycotoxins, such as ergot alkaloids, which are known to cause symptoms ranging from hallucinations to gangrene. The presence of such toxic compounds in wild oat pollen poses a potential risk to agricultural workers and nearby communities	Panaccio *et al.* 2006
Ambrosia spp.	The pollen produced by ragweed plants is a major cause of hay fever or allergic rhinitis and can trigger asthma in sensitive individuals. Exposure to ragweed pollen can lead to sneezing, itchy eyes, runny nose, and other allergy symptoms. The pollen grains are small and easily inhaled, causing respiratory discomfort and exacerbating asthma in some cases	Rogers *et al.* 2006; Mendes *et al.* 2015
Urtica dioica	Skin irritation and allergic reactions when it comes into contact with the skin. People working in gardens or fields with a high presence of nettles may experience skin rashes and itching. Nettle pollen can cause skin irritation upon contact, leading to dermatitis and allergic reactions. Allergenic compounds in nettle pollen can also induce respiratory symptoms in some individuals	Haneke *et al.* 2015, Sequeira *et al.* 2018, Ghiani *et al.* 2013
Heracleum mantegazzianum	Its flowering can release allergenic pollen, which may exacerbate respiratory allergies	Asero 2009
Plantago spp.	Hay fever, sneezing, congestion, and other respiratory symptoms. Rhinitis and asthma.	Suphioglu *et al.* 2009, Smith *et al.* 2017, Niederberger *et al.* 2002
Artemisia spp.	Allergic rhinitis and exacerbate symptoms in individuals with asthma. In some cases, it can lead to food allergies due to cross-reactivity with certain foods. It pollen is known to cause allergies, with symptoms including rhinitis and conjunctivitis. The pollen can also be a trigger for asthma in some individuals.	Tunon *et al.* 1995, Pauli *et al.* 2006, Yoon *et al.* 2018

animal welfare. Overall, addressing the challenges posed by weed pollen requires a multifaceted approach that includes better allergen identification, improved control measures, and increased awareness of the health risks associated with these ubiquitous plants. Future research should continue to explore the molecular mechanisms underlying allergenicity and toxicity, aiming to mitigate the adverse effects and enhance our understanding of how to manage and protect against the diverse impacts of weed pollen.

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