

Doi: 10.46793/MAK2026.380M

## ***AMBROSIA ARTEMISIIFOLIA* AS A PUBLIC HEALTH CONCERN**

**Siniša Mitrić<sup>1</sup>, Biljana Kelečević<sup>1\*</sup>, Zlatan Kovačević<sup>1</sup>, Dragoslava Bjelošević<sup>2</sup>**

<sup>1</sup>University of Banja Luka, Faculty of Agriculture, Republic of Srpska, Bosnia and Herzegovina,

<sup>2</sup>Government of Brčko District, Mayor Office of Brčko District of Bosnia and Herzegovina,

\*Corresponding author: [biljana.kelecevic@agro.unibl.org](mailto:biljana.kelecevic@agro.unibl.org)

**Abstract:** *Ambrosia artemisiifolia* (ragweed) is an annual broadleaf plant native to North America, in the Europe it was introduced in the second half of the 19th century with the potatoes and seeds of wheat and red clover. Ragweed is an invasive weed species and one of the most important causes of seasonal allergies in Europe, including the Balkan region. Due to its highly allergenic pollen, it has a significant public health concern. A single plant can produce billions of pollen grains, and allergic symptoms may occur even at very low pollen concentrations. Ragweed flowers from August to October, with peak flowering in late summer, and its pollen is readily dispersed by wind over long distances. Pollen of ragweed can cause a range of adverse health effects in sensitized individuals, including allergic rhinitis (nasal congestion, rhinorrhea, and sneezing), allergic conjunctivitis (eye redness, tearing, and burning), exacerbation of asthma symptoms, and a reduced quality of life manifested by fatigue, sleep disturbances, and decreased work and school productivity). Allergic diseases have substantial public health implications, including increased healthcare costs (medications and medical examinations), higher rates of absenteeism from work and school, and an increased burden on healthcare systems during the allergy season. Public health is defined as a set of knowledge, skills, and activities aimed at promoting health, preventing and controlling disease, and prolonging and improving quality of life through organized societal measures. The public health system comprises the structures and processes that create conditions for the preservation and improvement of population health through the activities of public health stakeholders. These stakeholders include, among others, local government units, public media, companies, public enterprises, entrepreneurs, and citizens. Given the fact that ragweed pollen causes a serious health risk, which is further exacerbated by ongoing climate change, regular and systematic monitoring of ragweed occurrence and control is essential. Community-level prevention and management measures include the systematic removal of ragweed before flowering (e.g., uprooting and mowing), maintenance of neglected areas (such as construction sites, roadsides, and agricultural land), public education and engagement of local communities in preventing the spread and ensuring timely control of ragweed, and the development of legislation obligating landowners to implement control measures.

**Keywords:** Ragweed, Public health, Control

### INTRODUCTION

#### **General Characteristics of Weed Species *Ambrosia artemisiifolia* L.**

Ragweed is an annual invasive weed from the family *Asteraceae* (Compositae). Originated from the southern desert regions of North America, spread to Europe and Asia in the late 19th and early 20th centuries. In Europe, its main areas of distribution is France, Ukraine

and northern Italy the Pannonian Basin, particularly Hungary, Serbia, Croatia, Slovakia (Sikoparija et al., 2017), as a Bosnia and Herzegovina (Trkulja et al., 2015). In last decades, a northward shift in the species' distribution range has been observed (Grewling, 2016). International trade and climate change are considered key drivers of ragweed invasion (Sikoparija et al., 2017). Ragweed exhibits all the characteristics of an invasive plant: it efficiently exploits environmental resources, tolerates extreme environmental conditions, and displays pronounced genetic plasticity due to the presence of numerous ecotypes, enabling rapid spread and invasive expansion (Buttenschøn et al., 2010).

Ragweed is an annual herbaceous plant that survives unfavorable periods of the year in the form of seeds; it is classified as a therophyte and reproduces exclusively by seed. Seeds can persist in the soil for up to 40 years. Approximately 85% of seeds retained their germination capacity after 20 years of burial; however, in shorter-term experiments lasting two to three years, annual seed mortality rates of 7 and 12% were recorded (Charles et al., 2021). Ragweed plants grow particularly well in abandoned, degraded, and disturbed soils resulting from human activities and deforestation (Albertini et al., 2022). Seed production varies with plant size, population density, and habitat characteristics, with plants growing at lower densities producing more seeds than those in dense stands. In a study of several ragweed populations in France, seed production per plant ranged from 346 to 6.114, with an average of approximately 2.500 seeds per plant (Buttenschøn et al., 2010). Ragweed germinates early in spring and exhibits rapid growth, showing strong competitiveness at early developmental stages. Plant height can range from 30 cm to 2 m and is strongly influenced by air temperature, soil fertility, soil moisture availability, and competition from other plants. Ragweed can germinate within small-grain crops and remain in a juvenile stage until harvest; once exposed to light, it resumes rapid growth. The species is adapted to well-illuminated sites and slightly acidic, nutrient-rich soils, but it is also tolerant of drought (Buttenschøn et al., 2010). Vučković et al., (2011) reported a high abundance of ragweed seeds in soil under maize cultivation. At a soil depth of 0-10 cm, 2.813 seeds m<sup>-2</sup> were recorded; at 10-20 cm, seed density was 2.343 seeds m<sup>-2</sup>; and at 20-30 cm, 313 seeds m<sup>-2</sup>. Consequently, the total abundance of ragweed seeds in the plough layer reached up to 5.469 seeds m<sup>-2</sup>.

Ragweed is a monoecious plant species with numerous, small flowers arranged in unisexual capitate inflorescences. The male inflorescences are hemispherical and pendulous, containing a larger number of flowers (10-15) and are aggregated into dense, terminally positioned racemose inflorescences. The female inflorescences consist of single flowers enclosed within a corolla and are located below the male inflorescences in the axils of the upper leaves (Bonnot, 1967; Wayne et al., 2002, cited in Vrbničanin, 2015). This floral arrangement results in the production of a disproportionately large number of pollen grains relative to the number of ovaries (gynoecia).

It is a short-day plant. In Central Europe, plants usually flower from July to October, with seed production beginning in mid-August. The relatively late flowering and seed maturation limit the species' distribution into more northern climatic zones. However, temperature changes over the past 30 years have resulted in an extended growing season by approximately 8-10 days in Germany thereby enabling ragweed to expand northward and to higher altitudes (Buttenschøn et al., 2010).

## Production and Atmospheric Distribution of Ragweed Pollen

Ragweed poses a significant public health problem due to its anemophilous and highly allergenic pollen (Albertini et al., 2022). More than 50% of pollen-induced allergic reactions are attributed to ragweed pollen (Frenz, 1999; D'Amato et al., 1998, cited in Janjić and Lazić, 2015). Ragweed pollen production is commonly expressed as the number of pollen grains per  $\text{m}^3$  of air ( $\text{P m}^{-3}$ ), either on a daily basis or as the total annual pollen load. The clinical threshold concentration for allergic symptoms is approximately 30 pollen grains  $\text{m}^{-3}$ . Trkulja et al. (2010) reported, based on a seven-year monitoring period (2007-2013) in the city of Banja Luka, that the total annual pollen counts were 8.669  $\text{P m}^{-3}$  in 2007, 5.841  $\text{P m}^{-3}$  in 2008, 4.084  $\text{P m}^{-3}$  in 2009, 7.045  $\text{P m}^{-3}$  in 2010, 9.587  $\text{P m}^{-3}$  in 2011, 8.993  $\text{P m}^{-3}$  in 2012, and 5.004  $\text{P m}^{-3}$  in 2013. In the research Šikoparija et al. (2018) during three flowering seasons in the Pannonian part of Serbia (2014-2016), pollen production per day ranged from 6.38 billion to 770 billion pollen grains for the experimental field (10 m $\times$ 10 m patch with soil from a heavily infested agriculture area). Ragweed pollen can be transported over long distances (long-distance transport, LDT), even across thousands of kilometers, and this phenomenon has been observed in many European countries. Numerous studies indicate that ragweed pollen grains have the potential to trigger allergic reactions not only in areas with high ragweed abundance but also in regions where ragweed populations are absent or scarce (Grewling et al., 2017). Research by de Weger et al. (2016) as a Weryszko-Chmielewska and Piotrowska (2008) show that, under favorable atmospheric conditions, ragweed pollen released from the Pannonian Plain can be lifted into higher atmospheric layers and entrained in air masses moving toward northwestern Europe, where the pollen subsequently deposits to the ground. Research by Celenk and Malyer (2017) showed that ragweed pollen grains in Bursa (Turkey) did not originate from local sources but were transported over long distances from potential source regions around the Sea of Azov in Russia and Ukraine, as well as from the Black Sea region in Turkey, Romania, and Bulgaria. Damialis et al. (2005) investigated the abundance of weed pollen grains, including ragweed, in relation to wind direction, speed, and persistence. The distance traveled by pollen after its release into the atmosphere is closely associated with wind as a vector. Damialis et al. (2005) investigated the effects of wind direction, speed, and duration (persistence) on the transport of the 12 most abundant pollen taxa in Thessaloniki. For most of the studied plant taxa, amount of airborne pollen was correlated either with wind persistence alone or with the interaction between wind persistence and wind speed, whereas for only two taxa was correlated solely with wind speed. These findings highlight the importance of wind persistence in pollen transport, particularly in regions where weak winds prevail for a substantial part of the year, such as Thessaloniki. Damialis et al. (2005) further demonstrated that both the movement and abundance of ragweed pollen were significantly correlated with wind persistence, while no statistically significant correlation was found between ragweed pollen abundance and wind speed, nor with the combined effect of wind speed and persistence (persistence  $\times$  speed). As an expression of the plasticity of this weed species, which directly influences the duration of the ragweed allergy season, the occurrence of early-flowering ragweed forms has been recorded in Hungary (Magyar et al., 2022). With the emergence and spread of these early morphotypes, allergic symptoms may begin several weeks earlier, resulting in a prolonged ragweed pollen season.

## Allergenic Potential of Ragweed Pollen and Public Health Risk

Ragweed flowers from August to October, with peak flowering in late summer, and its pollen is readily dispersed by wind over long distances. Pollen of ragweed can cause a range of adverse health effects in sensitized individuals, including allergic rhinitis (nasal congestion, rhinorrhea, and sneezing), allergic conjunctivitis (eye redness, tearing, and burning), exacerbation of asthma symptoms, and a reduced quality of life manifested by fatigue, sleep disturbances, and decreased work and school productivity). Allergic diseases have significant public health implications, including increased healthcare costs (medications and medical examinations), higher rates of absenteeism from work and school, and an increased burden on healthcare systems during the allergy season. Public health is defined as a body of knowledge, skills, and activities aimed at promoting health, preventing and controlling disease, and prolonging and improving quality of life through organized societal measures. The public health system encompasses the structures and processes that create conditions for the preservation and improvement of population health through the activities of public health stakeholders. These stakeholders include, among others, local government units, public media, companies, public enterprises, entrepreneurs, and citizens. Given the fact that ragweed pollen poses a serious health risk, which is increased by ongoing climate change, regular and systematic monitoring of ragweed occurrence and control is essential. Prevention and management measures at the community level include systematic removal of ragweed before flowering (e.g., pulling and mowing), maintenance of neglected areas (such as construction sites, roads, and agricultural land), public education and engagement of local communities in preventing the spread and ensuring timely control of ragweed, and the development of legislation that obliges landowners to implement control measures. Agnew et al. (2018) argue that it is necessary to improve our understanding of predisposing factors for ragweed allergic sensitization and disease, with a particular focus on factors that are potentially modifiable (i.e., environmental factors). Sensitization to ragweed pollen was strongly associated at levels above 5,000 pollen grains  $\text{m}^{-3}$  per year and above these levels the risk of sensitization was 12-16 times higher than in areas with low pollen levels of around 400 pollen grains  $\text{m}^{-3}$  per year. Genetic factors were strongly associated with sensitization, but almost all potentially modifiable factors were insignificant. The allergenicity of ragweed pollen is determined by the strength of its antigenic potential. Strong ragweed pollen allergens are those capable of inducing the production of large amounts of antibodies upon entry into the human body. The antigenic potency of ragweed pollen allergens depends on several properties that are necessary, though not sufficient on their own. Antigenic potency generally increases with increasing molecular weight. In addition, the allergenic potential of ragweed pollen, as well as that of other allergens, depends on the chemical structure of their molecules. Structurally, ragweed pollen allergens are predominantly proteins or proteins associated with polysaccharides or lipids. The allergenic potency of ragweed pollen is specific to each individual allergen. The specificity of individual ragweed pollen allergens depends on the content and relative proportions of aromatic amino acids, carboxyl groups, and amino groups. Each ragweed pollen allergen induces the production of specific antibodies; however, this specificity has certain limitations, such that closely related allergens may elicit cross-reactive responses. The determinants of allergen specificity are not yet fully understood. It is clear, however, that allergen specificity does not depend on the entire molecular structure of the allergen. Therefore, the molecular weight of the determinant group responsible for allergen specificity must be considerably lower than that

of the antibody. The determinant group does not necessarily have to be a protein, but may also be a polysaccharide, as is the case for certain plant pollen allergens (Bagarozzi and Travis, 1998).

### **Effects of Climate Change on Ragweed Pollen Production**

Climate change is reflected in increasing air temperatures and rising atmospheric CO<sub>2</sub> concentrations. The increase in atmospheric CO<sub>2</sub> concentration is one of the most certain predictions of climate change models. Atmospheric CO<sub>2</sub> levels have increased by approximately 29% since the pre-industrial era and are expected to double again between 2050 and 2100. Ziska and Caulfield (2000) investigated ragweed pollen production under different atmospheric CO<sub>2</sub> concentrations, ranging from pre-industrial levels (280 μmol mol<sup>-1</sup>), through current concentrations (370 μmol mol<sup>-1</sup>), to projected concentrations for the 21st century (600 μmol mol<sup>-1</sup>). They found that exposure to elevated CO<sub>2</sub> increased ragweed pollen production by 131 and 320%, respectively, compared with plants grown under pre-industrial CO<sub>2</sub> concentrations. The stimulation of pollen production was attributed to an increase in the number of male flowers and enhanced pollen output. From pre-industrial to current CO<sub>2</sub> concentrations, the number of male flowers did not change, but pollen production per inflorescence increased significantly. With further increases in CO<sub>2</sub> concentration, from the current 370 μmol mol<sup>-1</sup> to the projected 600 μmol mol<sup>-1</sup>, no change in pollen production per inflorescence was observed; however, the number of inflorescences increased significantly, nearly doubling (Ziska and Caulfield, 2000). Wayne et al. (2002) examined ragweed pollen production by growing plants in a greenhouse under near-ambient CO<sub>2</sub> concentrations (350 μmol mol<sup>-1</sup>) and at doubled concentrations (700 μmol mol<sup>-1</sup>). They found that pollen production under elevated CO<sub>2</sub> conditions was 61% higher than under ambient concentrations, while increased CO<sub>2</sub> did not significantly affect the average pollen grain size. Elevated CO<sub>2</sub> also stimulated shoot biomass growth by 63%. In addition, shoot height and total seed mass were higher under elevated CO<sub>2</sub> conditions, by 9 and 31%, respectively. Wayne et al. (2002) concluded that a doubling of atmospheric CO<sub>2</sub> concentration significantly stimulates ragweed pollen production, suggesting that the incidence of hay fever and related respiratory diseases may increase in the future. Atmospheric carbon dioxide concentrations in urban environments were approximately 30% higher than those in rural areas. Under urban conditions, ragweed exhibited faster growth, earlier flowering, and produced significantly greater aboveground biomass and higher amounts of pollen. Scientific studies suggest that, as a result of projected future climate warming and increasing atmospheric CO<sub>2</sub> concentrations, total ragweed pollen production is likely to increase (Ziska et al., 2003). As a confirmation of this prediction, we can cite research of Hamaoui-Laguél et al. (2015) who predicted that by 2050 airborne ragweed pollen concentrations will be about 4 times higher than they are now, which mostly depends on the seed dispersal rate assumptions. About a third of the airborne pollen increase is due to on-going seed dispersal, irrespective of climate change. The remaining two-thirds are related to climate and land-use changes that will extend ragweed habitat suitability in northern and eastern Europe and increase pollen production in established ragweed areas owing to increasing CO<sub>2</sub>. Therefore, climate change and ragweed seed dispersal in current and future suitable areas will increase airborne pollen concentrations, which may consequently heighten the incidence and prevalence of ragweed allergy.

Rasmussen et al. (2017) used the MAXENT v3.3.3k software to model the spatial distribution of all three ragweed species (*Ambrosia artemisiifolia*, *Ambrosia psilostachya*, and *Ambrosia trifida*) in Europe. MaxNet is a package in the R program that uses maximum entropy modeling to enable users to model the spatial distribution of species. The authors assessed future areas with a high risk of allergies (“high allergy risk”, HAR) under two scenarios: RCP 6.0 and RCP 8.5. RCP stands for Representative Concentration Pathway, referring to trajectories of greenhouse gas concentrations in the atmosphere. These are standardized scenarios used by the Intergovernmental Panel on Climate Change (IPCC) to project future climate change based on different levels of greenhouse gas emissions. RCP6.0 represents a scenario in which greenhouse gas emissions increase until around 2080, after which they stabilize and slow down during the second half or toward the end of the 21st century. RCP8.5 is a high-end scenario (or “worst-case scenario”) in which greenhouse gas emissions continue to rise throughout the entire 21st century without significant mitigation. In both cases, the scenarios lead to ice melt, rising temperatures, changes in precipitation, and other climatic variables, with RCP8.5 being considerably more extreme than RCP6.0. Rasmussen et al. (2017) estimate that by 2100 the distribution range of ragweed will expand toward northern and eastern Europe under all climate scenarios (Figure 1).

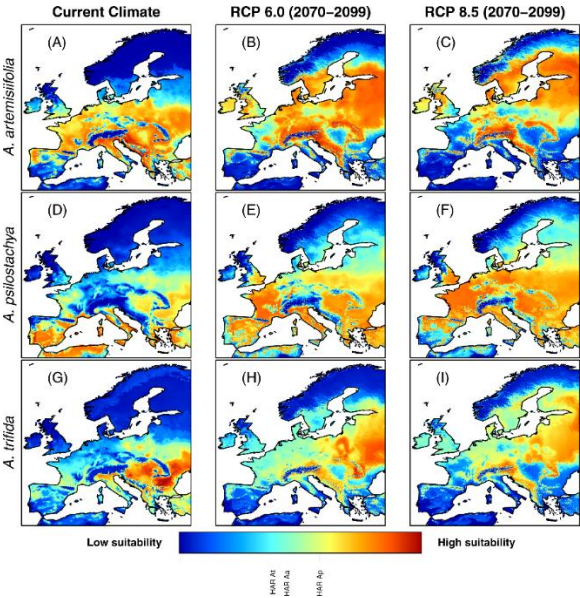


Figure 1. Habitat suitability of common ragweed (*A. artemisiifolia*) (A-C), perennial ragweed (*A. psilostachya*) (D-F) and giant ragweed (*A. trifida*) (G-I) in Europe under current climate conditions, and future climates (projections for years 2070-2099) assuming RCP 6.0 and RCP 8.5. (Rasmussen et al., 2017, doi.10.7717/peerj.3104 )

New areas with a high allergy risk (“high allergy risk”, HAR) will be mainly located in Denmark, France, Germany, Russia, and the Baltic countries, overlapping with densely populated cities such as Paris and Saint Petersburg. Also, they conclude that areas in Europe affected by severe ragweed-related allergy problems are likely to increase substantially by 2100, impacting millions of people. To prevent this outcome, management strategies must be developed to limit the spread of ragweed and the establishment of new populations. Precautionary measures should restrict the dispersal of ragweed seeds and reduce existing

populations. Only through the implementation of coordinated management plans across different countries can land managers mitigate future health risks and the economic consequences of ragweed spread in Europe.

### **Ragweed Control as a Key Measure for Reducing Public Health Risk**

In order to mitigate ragweed-induced allergic reactions, besides allergen avoidance, pharmacotherapy, and allergen immunotherapy, ragweed control measures are essential for the long-term prevention of ragweed allergies (Cheng et al., 2025). To achieve this, exceptional attention must be devoted to the control and prevention of the spread of this allergenic plant, with all measures and activities being systematic and science-based (Janjić et al., 2007). A range of measures and practices are available for the control and prevention of ragweed spread; however, all of them must be aligned with the biology of the species and applied across the entire infested area. When ragweed occurs over large areas, agrotechnical and mechanical measures are less suitable, as effective control over extensive areas within a short time period is difficult to achieve. For these and other reasons, the application of herbicides is commonly practiced for ragweed control (Janjić et al., 2007). Preventive measures are of greater importance in areas where ragweed is still absent or occurs at low densities. These measures include organizational, administrative, and educational actions aimed at the timely detection of the first ragweed individuals in a given area, followed by their removal and destruction before flowering and seed set. The most effective strategy in combating this weed is the prevention of invasion, which encompasses preventive actions such as early detection and eradication, prevention of seed dispersal, proper land management, and control of ragweed on ruderal habitats (Janjić 1999, Janjić et al., 2011).

Since ragweed spreads only by seed, therefore, the strategic basis for controlling this weed is the prevention of viable seed production. In areas where ragweed has not yet been recorded or where only isolated plants are present, early detection is crucial, followed by the timely uprooting of plants and prevention of seed set and further spread. In regions where ragweed is already widespread and well established, control strategies are likewise based on preventing seed production (Bohren, 2008), although the organization of control measures is considerably more complex. Besides herbicides, ragweed control can be achieved through non-herbicidal measures as a proper maintenance of grasslands and stubble, measures (pulling, mowing, mulching, soil tillage), biological and physical measures. Grassland management should ensure that perennial species resume growth in spring at optimal densities, allowing them to effectively compete with ragweed (Buttenschön et al., 2010, cited in Mitrić et al., 2015).

Mechanical control should be carried out in a way that completely destroys the whole plant, without the possibility of regeneration. Such efficiency is achieved only by uprooting, while mowed ragweed will regenerate to a certain extent. Selected herbicides, applied at a certain dose and phenophase of ragweed, must ensure complete plant death, therefore the effectiveness of the applied herbicides must be monitored to the end. Any measure that does not ensure complete plant death must be supplemented with other measures that will enable a complete interruption of the life cycle (Bohren, 2008, cited in Mitrić et al., 2015). The ragweed stem is easily broken, but ragweed has a pronounced ability to regenerate. It tolerates damage caused by removing the top of the stem from the foliage and has a high

regeneration capacity, which allows the plant to re-flower, produce pollen and produce seeds after mowing or other disturbances in growth. The ability of regeneration depends on the phenophase of the ragweed in which it was mechanically cut-mown, i.e. in which it was treated with herbicides, as well as on the dose of herbicide. Thus, Nedelcu et al. (2010) indicate that the regeneration ability was greater if ragweed was controlled when it had 8-10 leaves, in relation to when it had 5-6 leaves, or 3-4 leaves. Also, the regeneration ability did not depend only on the plant phenophase, but also on the applied herbicides. The same authors state that when were applied the active substance foramsulfuron+iodosulfuron-methyl-sodium in the phenophase 8-10 leaves, the degree of regeneration was 54%; with the active substance tembotrione, at the same phenophase, 34%, and when were applied the active substance terbuthylazine + bromoxynil heptonoate, there was no regeneration. With increasing herbicide doses, the regeneration ability of ragweed decreased and was the lowest when it was used recommended dose of herbicides. Mataruga (2006) determined that the efficiency of paraquat decreases at second estimate because of ragweed regeneration. Uprooting should be done before flowering, and it can be done in smaller areas, with low and medium ragweed abundance. Uprooted ragweed plants must be kept out of contact with the soil after uprooting, and it would be best to place them into plastic bags, then dry or compost them (Buttenschøn et al., 2010, cited in Mitrić et al., 2015).

Biological measures of ragweed control are becoming more important. In many countries, a large number of authors have studied the possibility of biological control of ragweed. Some types of pathogenic organisms and harmful insect species can be used to control ragweed. For example, the fungus *Fusarium oxysporum* f. sp. *erythroxyli* (its phytotoxic protein designated as NEP 1) and *Pseudomonas syringae* pv *tagetis* can cause necrosis and desiccation of ragweed leaves (by 60-80%). *Fusarium* can reduce the dry mass of the above-ground part of ragweed by 41%, and *Pseudomonas* by as much as 82%. Bohar and Kiss (1999) established the presence of *Sclerotinia sclerotiorum* as a pathogen of ragweed, and Bohar and Schwarczinger (1999) *Septoria* spp. in America, one species has even been identified, which was called *Septoria ambrosiae*. *Plasmopara halstedii* and *Puccinia xanthii* cause infection in ragweed, but due to their low aggressiveness, ragweed plants continue to grow (Arsenijević et al., 1996; Petrović, 1997; Vajna, 2002; Petanović et al., 2000, cited in Mitrić et al., 2015).

In the biological control of ragweed, the use of various insect species is also possible. Igrc (1987) determined that 28 species of insects have been identified that use ragweed for their food, however, due to their polyphagous nature, they cannot be successfully used to control it. Research of *Ophraella communa* and *Epiblema strenuana* shows that they have strong potential in biological control of ragweed (Zhou et al., 2014; Kim and Lee, 2019). They exert effective control over the proliferation and dissemination of ragweed through direct herbivory on its leaves and stems, thereby diminishing its reproductive potential and constraining its growth and spread. The *Zygogramma suturalis* (F.) and *Epiblema strenuama* (Walker) are most effective in controlling ragweed (Igrc, 1987, 1988). In conditions with low predator pressure, these insects can cause major damage, but they cannot reduce the number of ragweed plants. Other insect species such as *Stobaera concinna* (Stal), *Trigonorhinus tomentosus* (Say), *Euaresta bella* (Loew), *Tarachidia condefacta* (Hübner) have been studied in some countries (Russia, Australia, Yugoslavia, China) for ragweed control (Reznik et al., 1994; Sheppard et al., 2006).

Thermal weed control is an alternative to chemical or mechanical control and is suitable for those areas where mechanical control is not possible or chemically not allowed. Thermal control would be particularly suitable for non-agricultural areas, especially areas around roads, where the use of herbicides is limited. The principle of thermal control is based on the fact that temperatures above 60°C in plants cause protein denaturation. This leads to irreversible damage to plant tissues and plant necrosis. Thermal weed control machines use an open flame, heated vapor and hot water or steam. Thermal control would be suitable in organic agriculture, however, most thermal weed control machines are more adapted for smaller areas, such as the edge of the sidewalk, but they are not suitable for agricultural areas and the area around roads (shoulders).

Sölter and Verchwele (2014) in a comparative study of the effectiveness of thermal control of ragweed, herbicide treatment (dicamba and MCPA) and mowing determined that herbicides are significantly more effective than thermal treatment and mowing. The authors used open flame at 600°C, superheated air at 370°C and hot water at 99°C for thermal control of ragweed. Also, they treated ragweed twice, when it had 6-8 leaves (BBCH 16-18) and when it was already branched and had 2-9 shoots (BBCH 22-29). Significantly greater reduction in weed mass was observed in younger stages of ragweed. Thermal control of agricultural land is carried out using specially designed devices, the so-called flame cultivators ("weed burners") that use various fuels to produce a flame, which directly destroys plants.

## CONCLUSION

Climate change, reflected in rising air temperatures, increased atmospheric CO<sub>2</sub> concentrations, and a prolonged growing season, will enhance habitat suitability for ragweed, enabling its spread into new areas and strengthening its invasive potential. Under elevated CO<sub>2</sub> conditions, ragweed produces a higher number of male flowers, and the pollen is often more allergenic because it contains a greater amount of allergens per grain. Under altered climatic conditions, ragweed begins flowering earlier and ceases flowering later, resulting in prolonged exposure to pollen throughout the year. Therefore, systematic removal of ragweed before flowering is essential, along with the maintenance of neglected areas (construction sites, roadsides, agricultural fields), as well as public education and the education of local authorities, and the legal obligation of landowners to carry out mandatory ragweed control measures.

## REFERENCES

- Agnew, M., Banic, I., Lake, I.R., Goodess, C., Grossi, C.M., Jones, N.R., Plavec, D., Epstein, M., Turkalj, M. (2018). Modifiable Risk Factors for Common Ragweed (*Ambrosia artemisiifolia*) Allergy and Disease in Children: A Case-Control Study. *International Journal of Environmental Research and Public Health*, 15(7), 1339.
- Albertini, R., Veronesi, L., Eugenia Colucci, M., Pasquarella, C. (2022). The scenario of the studies on ragweed (*Ambrosia* Sp.) and related issues from its beginning to today: a useful tool for future goals in a one health approach. *Acta Biomed*, 93(5), 1-19.
- Bagarozzi, D., Travis, J. (1998). Ragweed pollen proteolytic enzymes: possible roles in allergies and asthma. *Phytochemistry*, 47(4), 593-598.
- Bohar G.Y., Schwarczinger I. (1999). First report of a *Septoria* sp. on Common Ragweed (*Ambrosia artemisiifolia*) in Europe. *Plant Disease*, 83(7), 696.

- Bohar, G.Y., Kiss L. (1999): First report of a *Sclerotinia sclerotiorum* on Common Ragweed (*Ambrosia artemisiifolia*) in Europe. *Plant Disease*, 83(3), 302.
- Bohren, C. (2008). *Ambrosia artemisiifolia*-a motivation for European-wide control. 1st International Ragweed Conference, Budapest, Hungary, September 10-13.
- Buttenschön, R.M., Waldspühl, S., Bohren, C. (2010). Guidelines for management of common ragweed, *Ambrosia artemisiifolia*.
- Celenk, S., Malyer, H. (2017). The occurrence of *Ambrosia* pollen in the atmosphere of Northwest Turkey: investigation of possible source regions. *Int J Biometeorol*, 61(8), 1499-1510.
- Charles, L., Mohler, J.R., Di Tommaso, T. A. (2021). Manage weeds on your farm. A guide to ecological strategies - Ragweed, common. SARE Outreach Edition, 1-416.
- Cheng, Z.-L., Ma, T., Gao, Z., Ming, W., Yang, M., Wang, X. (2025). Global Ragweed Allergy: Molecular Allergens and Integrated Control Strategies. *J Asthma Allergy*, 18, 403-416. doi: 10.2147/JAA.S506897. PMID: 40099306; PMCID: PMC11911648.
- Damialis, A., Gioulekas, D., Lazopoulou, C., Balafoutis, C., Vokou, D. (2005). Transport of airborne pollen into the city of Thessaloniki: the effects of wind direction, speed and persistence. *Int J Biometeorol*, 49(3), 139-145.
- de Weger, L.A., Pashley, C.H., Škoparija, B., Skjøth, C.A., Kasprzyk, I., Grewling, Ł., Thibaudon, M., Magyar, D., Smith, M. (2016). The longdistance transport of airborne *Ambrosia* pollen to the UK and the Netherlands from Central and south Europe. *Int J Biometeorol*, 60(12), 1829-1839.
- Grewling, Ł., Bogawski, P., Jenerowicz, D. *et al.* (2016). Mesoscale atmospheric transport of ragweed pollen allergens from infected to uninfected areas. *Int J Biometeorol*, 60(10), 1493-1500.
- Hamaoui-Laguel, L., Vautard, R., Liu, L. *et al.* (2015). Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe. *Nature Clim Change*, 5, 766-771.
- Igrc, J. (1987). Značaj vrste *Ambrosia artemisiifolia* u svijetu i u nas. *Fragmenta Herbologica Jugoslavica*, 16(1-2), 47-55.
- Igrc, J. (1988). Influence of temperature on development of *Zygogramma suturalis* – an insect used to control *Ambrosia artemisiifolia*. Proc. VII. Int. Symp. Biol. Contr. Weeds, 6-11 March, Rome, Italy, Delfosse, E.S. (Eds.) *Ist. Sper. Patol. Veg. (MAF)*, 613-621.
- Janjić, V. (1999). Značaj ruderalne i akvatične flore i potreba za njenim suzbijanjem. *Acta herbologica*, 8(2), 23-34.
- Janjić, V., Mataruga, D., Malidža, M., Radivojević, L.J., Mitrić, S., Stefanović, L., Stanković-Kalezić, R., Golić, D. (2007). Ograničenje širenja i suzbijanje ambrozije. In: Janjić, V., Vrbičanin, S. (Eds.). *Ambrozija*. Herbološko društvo Srbije, Beograd, 103-118.
- Janjić, V., Stanković-Kalezić, R., Radivojević, L.J., Jovanović V. (2011). Common Ragweed (*Ambrosia artemisiifolia* L.) a harmful weed ruderal and allergenic plant in the territory of Belgrade. *Acta herbologica* 20(2), 1-18.
- Kim, H.G., Lee, D.H. (2019). Review of the biology and ecology of a ragweed leaf beetle, *Ophraella communa* (Coleoptera: Chrysomelidae), which is a biological control agent of an invasive common ragweed, *Ambrosia artemisiifolia* (Asterales: Asteraceae). *Biocontrol Science and Technology*, 29(2), 185-200.
- Magyar, D., Novák, R., Udvardy, O. *et al.* (2022). Unusual early peaks of airborne ragweed (*Ambrosia* L.) pollen in the Pannonian Biogeographical Region. *International Journal of Biometeorology* 66, 2195-2203.
- Mataruga, D. (2006). Proučavanje efikasnosti folijarnih herbicida u suzbijanju ambrozije (*Ambrosia artemisiifolia* L.). Magistarski rad. UniverPoljoprivredni fakultet. Banja Luka, 2006.
- Nedelcu, C.A., Lauer, K.F., Ștef, R. (2010). Chemical control with herbicides at species *Ambrosia artemisiifolia* in Timisoara, *Research Journal of Agricultural Science*, 42(4), 122-128.
- Rasmussen, K., Thyrring, J., Muscarella, R., Borchsenius, F. (2017). Climate-change-induced range shifts of three allergenic ragweeds (*Ambrosia* L.) in Europe and their potential impact on human health. *PeerJ* 5:e3104

- Reznik, S.Y., Belokobyl, S.A., Lobanov, A.L. (1994). Weed and herbivorous insect population densities at the broad spatial scale: *Ambrosia artemisiifolia* L. and *Zigogramma saturalis* F. (Col. *Chrysomelidae*). Journal of Applied Entomology 118, 1-9.
- Sheppard, A.W., Shaw, R.H., Sforza, R. (2006). Top 20 environmental weeds for classical biological control in Europe: a review of opportunities regulations and other barriers to adoption. Weed Research, 46(2), 93-117.
- Sikoparija, B., Skjoth, C.A., Celenk, S. *et al.* (2017). High temporal resolution of airborne *Ambrosia* pollen measurements above the source reveals emission characteristics. Atmospheric Environment 192, 13-23.
- Sölter, U., Verschwele, A. (2014). Thermal, mechanical and chemical control of ragweed (*Ambrosia artemisiifolia*) in different habitats. 26th German Conference on weed Biology an Weed Control, Braunschweig, Germany.
- Šikoparija, B., Mimić, B., Panić, M. *et al.* (2018). Spatial and temporal variations in airborne *Ambrosia* pollen in Europe. Aerobiologia, 33(2), 181-189.
- Vučković, B., Kovačević, Z., Vrbničanin, S., Janjić, V. (2011). Određivanje sadržaja sjemena korova u zemljištu metodom fizičke ekstrakcije i metodom naklijavanja. Acta herbologica, 20(1), 35-42.
- Wayne, P., Foster, S., Connolly, J., Bazzaz, F., Epstein, P. (2002). Production of allergenic pollen by ragweed (*Ambrosia artemisiifolia* L.) is increased in CO<sub>2</sub>-enriched atmospheres. Annals of Allergy, Asthma & Immunology, 88(3), 279-282.
- Weryszko-Chmielewska, E., Piotrowska, K. (2008). Ecological features of *Ambrosia artemisiifolia* L. flowers and characteristics of *Ambrosia* L. pollen seasons in the condition of Lublin (Poland) in the years 2001-2008. Acta Agrobotanica, 61(2), 35-47.
- Zhou, Z.S., Chen, H.S., Zheng, X.W., Guo, J.Y., Guo, W., Li, M., Luo, M., Wan, F.H. (2014). Control of the invasive weed *Ambrosia artemisiifolia* with *Ophraella communa* and *Epiblema strenuana*. Biocontrol Science and Technology, 24(8), 950-964.
- Ziska, L. H., Gebhard, D. E., Frenz, D. A., Faulkner, S., Singer, B. D., Straka, J. G. (2003). Cities as harbingers of climate change: Common ragweed, urbanization, and public health. J Allergy Clin Immunol, 111(2), 290-295.
- Ziska, L.H., Caulfield, F.A. (2000). Rising CO<sub>2</sub> and pollen production of common ragweed (*Ambrosia artemisiifolia*), a known allergy-inducing species: implications for public health. Aust. J. Plant Physiol., 27, 893-89.
- Vrbničanin, S. (2015). Biologija pelenaste ambrozije (*Ambrosia artemisiifolia* L.). In: Janjić, V., Mirjanić, D., Kuzmanović, R. (Eds.). Ambrozija opasna invaziona i alergena biljna vrsta. Akademija nauka i umjetnosti Republike Srpske, Bosna i Hercegovina, Banja Luka, 143-158.
- Janjić, V., Lazić, N. (2015). Osnovne karakteristike alergena polena ambrozije. In: Janjić, V., Mirjanić, D., Kuzmanović, R. (Eds.). Ambrozija opasna invaziona i alergena biljna vrsta. Akademija nauka i umjetnosti Republike Srpske, Bosna i Hercegovina, Banja Luka, 121-142.
- Mitrić, S., Malidža, G., Janjić, V., Mataruga, D., Radivojević, Lj. (2015). Ograničenje širenja i suzbijanje ambrozije. In: Janjić, V., Mirjanić, D., Kuzmanović, R. (Eds.). Ambrozija opasna invaziona i alergena biljna vrsta. Akademija nauka i umjetnosti Republike Srpske, Bosna i Hercegovina, Banja Luka, 173-198.
- Trkulja, V., babić, G., Čurković, B., Kovačić Jošić, D., Mihić Salapura, J. (2015). Dinamika cvjetanja i produkcija polena ambrozije. In: Janjić, V., Mirjanić, D., Kuzmanović, R. (Eds.). Ambrozija opasna invaziona i alergena biljna vrsta. Akademija nauka i umjetnosti Republike Srpske, Bosna i Hercegovina, Banja Luka, 143-158.