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EPPO STANDARD - NATIONAL REGULATORY CONTROL SYSTEMS

# PM 9/7 (2) *Ambrosia artemisiifolia*

**Specific scope:** This Standard describes the control procedures aiming to monitor, contain and eradicate *Ambrosia artemisiifolia*.

**Specific approval and amendment:** First approved in 2008–09. Revision approved in 2021–09.

Authors and contributors are given in the Acknowledgements section.

## 1 | INTRODUCTION

*Ambrosia artemisiifolia* L. (Asteraceae) is a monoecious, wind-pollinated, annual herb native to North America. The species was introduced into many countries of the EPPO region at the end of the 19th century (Essl et al., 2015). The introduction and distribution of *A. artemisiifolia* in Europe has been studied thoroughly. To date, there are well-established populations in Western (e.g. Chauvel et al., 2006), Central and Eastern Europe (Follak et al., 2017; Skálová et al., 2017; Afonin et al., 2018; Pinke et al., 2019) as well as in South-Eastern Europe (Galzina et al., 2010).

In the EPPO region, *A. artemisiifolia* thrives in a wide range of open and disturbed habitats. It occurs along roadsides and railway tracks, in old fields and industrial or urban wastelands, and in crop fields, particularly in maize, sunflower and soybean (Essl et al., 2015). The spread of *A. artemisiifolia* is largely driven by human activities, such as the transport of seeds by agricultural machinery from field to field and by mowing machines along roadsides. The transportation of soil, gravel and construction material and landfill waste is involved in the spread of *A. artemisiifolia* as well. Contaminated seed commodities, such as birdseed and seed mixtures for slopes and embankments, may also disperse *A. artemisiifolia* (Essl et al., 2015). However, for bird seed, the EU legislation (Directive 2002/32 EC) restricts the amount of *A. artemisiifolia* seed in animal feed, which reduces the importance of this pathway for EU countries.

*A. artemisiifolia* has been included on the EPPO List of Invasive Alien Plants since 2004 (EPPO, 2021). It has been listed as an A2 pest by the Eurasian Economic Union since 2016. The species is regulated by a number of EPPO countries. In Azerbaijan, Kazakhstan, Russia, Ukraine and Uzbekistan it is listed as an A2 pest. In Jordan it is listed as an A1 pest. In Belarus it is listed as a quarantine pest, and in Spain and Switzerland it is a Regulated Invasive Alien Plant. For further information on classification in the EPPO region refer to EPPO (2021).

*A. artemisiifolia* is still spreading in the EPPO region and its spread is likely to be facilitated by climate warming (Mang et al., 2018).

*A. artemisiifolia* is regarded as a major health problem as it produces large amounts of highly allergenic pollen that can disperse over large distances from the area of origin (Essl et al., 2015). The species temporal emergence pattern and rapid growth contribute to its success as a weed and yield loss can be substantial (Bullock et al., 2012).

Further information on the biology, distribution and economic importance of *A. artemisiifolia* can be found in Essl et al. (2015). Further information on the impact of the weed in agriculture can be found in Sevault et al. (2019).

EPPO member countries at risk are advised to prepare monitoring activities and a contingency plan for the eradication and containment of this pest.

This Standard presents the basis of a national regulatory control system for the monitoring, eradication and containment of *A. artemisiifolia* and describes:

- elements of the monitoring programme that should be conducted to detect a new infestation or to delimit an infested area;
- measures aiming to eradicate recently detected populations (including an incursion);
- containment measures to prevent further spread in a country or to neighbouring countries in areas where the pest is present and eradication is no longer considered feasible.

Regional cooperation is important, and it is recommended that countries should communicate with their neighbours to exchange views on the best programme to implement to achieve the regional goal of preventing further spread of the pest.

For the efficient implementation of monitoring and control at a national level, cooperation between the relevant public bodies [e.g. national plant protection organizations (NPPOs), ministries of environment, ministries in charge of transport, water management], as well as with other interested bodies should be established.

## 2 | MONITORING OF *A. ARTEMISIIFOLIA*

Staff of organizations in charge of the monitoring of the species should be trained to recognize the plant at all stages in its lifecycle, even when present as small populations. This may include staff of NPPOs, botanists, agronomists, farmers, nature conservation managers, municipal authorities, and road and rail maintenance workers. As this plant has the potential to grow in a range of habitats, citizen science projects may be implemented to encourage landholders and other citizens to report sightings of *A. artemisiifolia* (e.g. Nimis et al., 2018).

Regular surveys (see ISPM 6: *Surveillance*; FAO, 2018) are necessary to determine the geographical distribution of the plant and its prevalence. Monitoring can concentrate on areas that are climatically suitable and most vulnerable to colonization (arable land, ruderal environments such as roadsides and transport corridors).

## 3 | ERADICATION OF *A. ARTEMISIIFOLIA*

Any eradication programme for *A. artemisiifolia* in the case of recently detected populations is based on the delimitation of the infested area within the country and the application of measures to both eradicate and prevent further spread of the pest. The feasibility of eradication depends on the size and designation of the infested area, the density of the population and the accumulated seed bank, and accessibility of the site. Eradication may only be feasible in the initial stages of infestation.

Measures are described in Appendix 1.

## 4 | CONTAINMENT OF *A. ARTEMISIIFOLIA*

The containment programme for *A. artemisiifolia* in the case of established populations is based on the application of measures to prevent further spread of the species in a country or between neighbouring countries.

Measures are described in Appendix 2.

## 5 | COMMUNICATION AND COLLABORATION

Regional cooperation is essential to promote phytosanitary measures and information exchange in identification and management methods. NPPOs can provide land managers and stakeholders with identification guides and facilitate regional cooperation, including information on site-specific studies of the plant, control techniques and management. Professionals (e.g. administration, foresters) should be informed about the threat to natural and managed land, and about preventive measures. Integrated management, involving different sorts of land managers and various management measures, will be more effective and efficient.

The International Ragweed Society (http://internationalragweedsociety.org/) is an association that promotes exchanges of information on *Ambrosia* species within the international scientific community. There are already some initiatives in the EPPO region, such as the French and Walloon ragweed observatories (French Ministry of Solidarity and Health, 2021; Liege University, 2021), which implement and monitor national control strategies and ensure cooperation between the various public authorities concerned. For example, in France, public authorities encourage municipalities to name "ragweed referents" that are in charge of this monitoring within their territories (FREDON France, 2019).

## ACKNOWLEDGEMENTS

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## APPENDIX 1-ERADICATION PROGRAMME

The national regulatory control system involves four main activities:

1. surveillance to fully investigate the distribution of the pest
2. containment measures to prevent the spread of the pest
3. treatment and/or control measures to eradicate the pest when it is found
4. verification of pest eradication.

Additional supporting mechanisms can be established by the responsible authority (i.e. border control or restrictions on the movement of used machinery).

Eradication depends on effective surveillance to determine the distribution of the pest and containment to prevent spread while eradication is in progress. Any eradication measures must be verified by surveillance to establish if attempts and measures have been successful. Staff in charge of the control of the plants should be warned about the health risk associated with the species and should avoid touching the plant with bare skin.

### 1. Surveillance

A delimitation survey should be conducted to determine the extent of the distribution of *A. artemisiifolia*. Surveillance should be carried out in likely places of introduction of *A. artemisiifolia*, such as disturbed habitat complexes and arable land. High-risk places of introduction include private gardens, along roads and railway lines, sunflower fields, wheat stubble, construction areas, field and forest edges, riverbanks, surroundings of grain and fodder warehouses, oil mills, grain processing factories and fodder industry factories where contaminated plant material is stored or processed. Particular attention should be given to areas adjacent to infested sites that might receive seeds by natural and human-assisted spread such as transportation networks, crop fields and ruderal environments. Its presence is mostly related to habitats with natural or human disturbance. Surveillance should also be increased in areas of the EPPO countries where *A. artemisiifolia* invasion is in the phase of increased spread and naturalization (e.g. the British Isles, Germany and Poland). Several European modelling studies predict a northerly and altitudinal spread of *A. artemisiifolia* fostered by climate change (Essl et al., 2015).

Citizen science projects can be implemented to encourage landholders and other citizens to report sightings of *A. artemisiifolia* (e.g. Nimis et al., 2018).

### 2. Containment measures

NPPOs should provide land managers, farmers and stakeholders with identification guides including information on preventive measures and control techniques. See, for example, Karrer et al. (2016) and Buttenschøn et al. (2009). Unintentional transport of seeds through the transfer of contaminated soil material, grain (animal feed), and by vehicles and machinery must be avoided. Movement of soil from infested areas should be prohibited. Equipment and machinery should be cleaned to remove soil before moving to an uninfested area (see ISPM 41: *International movement of used vehicles, machinery and equipment*; FAO, 2017).

### 3. Treatment and control

It is technically possible to achieve eradication of *A. artemisiifolia* by a combination of chemical and mechanical means, but this it is applicable only to small infestations and outbreaks.

Hand weeding (uprooting) is very effective (Figure 1) for the control of *A. artemisiifolia* (e.g. Trognitz et al., 2020) and can be applied in various habitats (crop fields, ruderal habitats). Plants should be pulled out before flowering, ensuring the complete removal of the root system. As contact allergenic reactions may occur, long-sleeved clothes and gloves will protect the skin from contact with the plant. Control of blooming stands should preferably be done in the afternoon as the pollen is mainly released in the morning. Non-blooming and non-fruiting plants should be composted, and pulled-out plants should be stored so their roots do not have contact with the soil as they might regrow. Otherwise, plants pulled out later with ripening seeds should be put into plastic bags and given for waste collection, or this plant material should be burnt. If done properly, fermentation in biogas plants and composting can kill the seeds of *A. artemisiifolia* (Starfinger & Sölter, 2016).


**FIGURE 1** The results of hand weeding *Ambrosia artemisiifolia*. EPPO Global Database. Courtesy: S. Follak

Herbicides, and mechanical and thermal control options applied to individual plants or patches (spot treatment) may allow effective control of the species (see Appendix 2).

**4. Verification of pest eradication**

Measures should be conducted until no emergence of *A. artemisiifolia* is found. *A. artemisiifolia* forms a persistent soil seed bank. Seeds can enter primary dormancy and germinate the following spring, or enter secondary dormancy after failure to germinate in spring and remain dormant in the soil seed bank. Seeds can remain alive in the soil for decades, but if unburied seeds lose their viability quickly within a few years (Essl et al., 2015). Therefore, a continuous survey of treated sites over many years is important to prevent re-establishment.

## APPENDIX 2-CONTAINMENT PROGRAMME

In the case of established and large populations in agricultural areas and noncrop areas, eradication is difficult to achieve. As *A. artemisiifolia* is an annual plant, control measures should aim at reducing seed production and the depletion of the soil seed bank. In addition, treatments should occur before the flowering of the plant to reduce pollen production to avoid allergies. Control measures will be determined depending on the situation in different habitats, climates, levels of infestation and legal requirements in the countries. In crops, a more diverse combination of herbicide sites of action, crop rotation and tillage practices will help to reduce population size.

**1. Surveillance**

A delimitation survey should be conducted to determine the extent of the distribution of *A. artemisiifolia*. Surveillance should be carried out in likely places of introduction and occurrence of *A. artemisiifolia*. Priority areas for control are crop fields (especially spring-sown crops), roadsides and construction areas, followed by private gardens (near bird-feeding areas), forest edges, riverbanks, surroundings of grain and fodder warehouses, oil mills, grain processing factories and fodder industry factories where contaminated plant material is stored or processed (see Appendix 1).

**2. Containment measures**

Containment measures regarding the prevention of the spread through the movement of soil, machinery or any contaminated commodity such as grain (animal feed) should be applied (see Appendix 1).

**TABLE 1** Examples of herbicides to control *Ambrosia artemisiifolia* in different crops. Effectiveness depends on local conditions, density and developmental stage of *A. artemisiifolia*. Sequential herbicide application (pre-emergence [PRE] and post-emergence [POST]) and mixtures of herbicides are recommended

| Crop | Herbicide(s) | Period of application |
|---|---|---|
| Maize | Bromoxynil | POST |
| | Dicamba | POST |
| | Isoxaflutole | PRE/early POST |
| | Mesotrione | POST |
| | Prosulfuron | POST |
| | Tembotrione | POST |
| | Terbuthylazin | PRE/POST |
| Soybean | Imazamox | POST |
| | Metribuzin | PRE |
| Potatoes | Metribuzin | PRE/early POST |
| | Metobromuron | PRE/early POST |
| Sunflower | Halauxifen-methyl<br>Imazamox[a] | POST<br>POST |
| | Flurochloridone | PRE |
| | Tribenuron-methyl[a] | POST |
| Cereals | Clopyralid | POST |
| | Fluroxypyr | POST |
| | 2,4-Dichlorophenoxyacetic acid (2,4-D) | POST |
| Sugar beet | Clopyralid | POST |
| Perennial crops, field crops (during intercropping period) and non-agricultural areas | Glyphosate<br>Pelargonic acid | POST<br>POST |

[a]These active ingredients can only be used in herbicide tolerant varieties of sunflower.

## 3. Treatment and control

*Chemical control*

It should be highlighted that the availability of products containing active ingredients will vary nationally and other products may be available and effective. Indications of the approved uses for each active ingredient may be incomplete. Products should be used following the instructions on the label and in line with the relevant plant protection product regulations.

Chemical control is widely used in crop fields and non-crop areas. Many studies have evaluated herbicides and herbicide combinations for *A. artemisiifolia* control in different crops in the EPPO region (e.g. Bohren et al., 2008; Kazinczi & Novák, 2014; Meinlschmidt et al., 2014). In the relevant current publications (guidebooks) on herbicide selection in the individual crops or the instruction manuals of the products, *A. artemisiifolia* is often listed separately to facilitate selection.

In major crops, such as spring cereals maize and sunflower, *A. artemisiifolia* can be controlled with pre- and post-emergence herbicides, while in minor crops (e.g. oil pumpkin, vegetables, various legume crops) a limited number of effective herbicides is currently available (Table 1). Effective active ingredients are from the group of synthetic auxins (e.g. clopyralid), triketones (tembotrione, mesotrione), sulfonylureas (e.g. tribenuron-methyl, thifensulfuron-methyl, prosulfuron), imidazolinones, triazines and triazinones (metribuzin, terbuthylazin). The use of sunflower cultivars that are tolerant to the acetolactate synthase-inhibiting herbicides tribenuron-methyl and imazamox is an option in infested areas. However, the use of such herbicide-tolerant varieties (HTVs) must be done with care, following good agricultural practices. After studying agricultural practices associated with the use of HTVs in France (short crop rotations, application of herbicides in the same class of acetolactate synthase (ALS) inhibitors for weed control as in other crops of the rotation), ANSES (2020) identified that weeds (including *A. artemisiifolia*) are at risk of developing resistance to herbicides.

The efficacy of several active ingredients against the species is influenced by the developmental stage at application and local conditions. *A. artemisiifolia* is most susceptible at the two- to four-leaf stage, while larger individuals (more than six- to eight-leaf stage) may survive and re-sprout (Bohren et al., 2008; Verschwele et al., 2012). In particular, the effectiveness of soil-active herbicides depends on optimal weather conditions after application (moist soil needed). Sequential treatments may improve herbicide efficiency, and a combination of leaf and residual active ingredients is recommended to achieve lasting control because the species has a long germination period.

In non-agricultural areas, non-selective active ingredients such as glyphosate and pelargonic acid are appropriate to control both pollen and seed production of *A. artemisiifolia*. Repeated application may be needed (Gauvrit & Chauvel, 2010; Trognitz et al., 2020).


**FIGURE 2** Using infrared to control *Ambrosia artemisiifolia*


**FIGURE 3** Destroyed individuals after application. EPPO Global Database. Courtesy: S. Follak

*Thermal control*

Temperatures above 60°C cause irreversible damage of plant tissue, leading to necrosis and the death of the plant (Figures 2 and 3). Available machinery for thermal control of *A. artemisiifolia* works with flames, an infrared burner, hot water (steam or boiling water) or hot foam. Depending on plant density, developmental stage and local weather conditions, multiple applications may be necessary for successful control (Rask & Kristoffersen, 2007; Sölter & Verschwele, 2016).

It has been shown that flaming (600°C) and hot water (99°C) applied to *A. artemisiifolia* along the roadside led to significant reduction in biomass of *A. artemisiifolia* compared to individuals in untreated plots (Sölter & Verschwele, 2016). Trognitz et al. (2020) tested in a 1-year field trial of the effect of infrared and hot foam on *A. artemisiifolia*. The infrared thermal control element was quite effective. However, a few individuals resprouted and further treatments were thus necessary. Hot foam is hot water in combination with foam made from natural, nontoxic ingredients, including plant oils and sugars. It was very effective when hot foam was applied directly to *A. artemisiifolia* individuals.

*Cultural control*

In cropping systems, cultural practices, including crop density, planting date, row spacing and choice of cultivar, affect the crop's ability to compete with *A. artemisiifolia*. All these practices can maximize the degree to which the crop occupies space early in the growing season, thus diminishing the growth and competitive pressure of *A. artemisiifolia* on the respective crop (Shresta et al., 2001; Verschwele et al., 2012).

A high crop rotation diversity is advisable as it allows the use of different and effective herbicides and other weed management options. In highly infested crop fields, the adaptation of the crop rotation is recommended by, for example, inclusion of winter cereals combined with a high level of control during the intercropping period to reduce or even empty the seed bank, or autumn-seeded cover crops.

Enforcing competitive vegetation is a method for agricultural or non-crop areas. Studies have ascertained the effectiveness of seeding competitive vegetation from a native species mixture of hayseed in controlling *A. artemisiifolia* (Gentili et al., 2015; Cardarelli et al., 2018). Gentili et al. (2015) demonstrated that seeding mixtures of grassland species (*Festuca rubra*, *Lolium multiflorum*, *Lotus corniculatus*, *Poa pratensis* and *Trifolium hybridum*) can successfully suppress *A. artemisiifolia* in the first year of establishment on a vegetation-free site. Cardarelli et al. (2018) showed that seeding competitive vegetation from a native species mixture of hayseed both overseeded over the resident plant community or after ploughing suppressed the establishment of *A. artemisiifolia* and reduced its growth habit.

*Mechanical control*

In cropping systems, production techniques such as tillage and harrowing systems help to reduce *A. artemisiifolia* populations:

- Directly after harvest of the (winter) crop, early ploughing (using a cultivator) of stubble fields (8–10 cm deep) should be performed (Delabays et al., 2005) to destroy *A. artemisiifolia* plants (Figure 4). They can still complete their life cycle. After harvest of a crop field destined to spring sowing a primary plough (25–30 cm deep) should be performed.
- A false seedbed should be made in spring prior to the sowing of the crop so that *A. artemisiifolia* emerges before sowing and then can be harrowed. If done repeatedly (i.e. cultivation followed by harrowing), this would lead to an effective depletion of the seedbank (Murphy et al., 2006).


**FIGURE 4** *Ambrosia artemisiifolia* can be found in stubble fields after harvest and is quite easy to control by stubble cultivation (to avoid seed set)

In general, hoeing techniques can reduce *A. artemisiifolia* densities within crop fields. Hoeing is most efficient at an early developmental stage of *A. artemisiifolia* (two- to four-leaf stage) (Buttenschøn et al., 2009); hoeing is quite effective only up to the eight-leaf stage. Nevertheless, some studies indicated that hoeing alone and with less intensity (i.e. number of treatments) showed poor control efficacy (Delabays et al., 2005; Verschwele et al., 2012).

In non-crop areas and along roadsides, mowing (cutting) is the most common method for (large) populations of *A. artemisiifolia*. Mowing immediately before flowering will reduce pollen production, but it will not kill the plants completely because of the high ability of *A. artemisiifolia* to re-sprout and to produce seeds. In general, *A. artemisiifolia* plants should be cut as low as possible (2–6 cm above soil level) to reduce the number of buds that might be able to re-sprout. Timing of mowing is crucial as it greatly influences the plant's biology. Milakovic et al. (2014) showed that carefully timed mowing could influence seed production per plant. It is suggested that the best mowing strategy for the reduction of the size of the soil seed bank is one cut just after the beginning of female flowering (around the third week of August in Eastern and Central Europe) followed by a second cut 2–3 weeks later (early September) (Milakovic & Karrer, 2016).

For roadside populations (particularly along major roads) where mowing must occur earlier for security reasons, an effective mowing strategy consists of a first cut shortly before male flowering (end of June), to limit the quantities of released pollen, followed by subsequent cuts (every 3–4 weeks) before the onset of new flowers on the re-sprouting lateral shoot (Milakovic et al., 2014). The carry-over of ripened seeds along road verges via contaminated equipment (mowers) must be prevented under all circumstances [e.g. by not mowing after seed ripening (September)].

*Biological control*

*A. artemisiifolia* has been a target for biological control for a long time. In Australia, the beetle *Zygogramma bicolorata* Pallister 1953 (Coleoptera: Chrysomelidae) and the moth *Epiblema strenuana* Walker 1863 (Lepidoptera: Tortricidae), which were released as biocontrol agents against *Parthenium hysterophorus*, have greatly reduced


**FIGURE 5** *Ophraella communa*, a promising biocontrol agent for *Ambrosia artemisiifolia*. EPPO Global Database. Courtesy: Matteo Maspero, Centro MiRT – Fondazione Minoprio (IT)


**FIGURE 6** Defoliated *Ambrosia artemisiifolia* plant. EPPO Global Database. Courtesy: S. Follak

*A. artemisiifolia* populations (Coutinot et al., 2008). *Ophraella communa* LeSage 1986 (Figure 5) (Coleoptera: Chrysomelidae), the ragweed leaf beetle, is used as a successful biological control agent in China (Guo et al., 2011). In Russia and neighbouring countries, deliberately released biological control agents (e.g. *Zygogramma suturalis* Fabricius 1775 [Coleoptera: Chrysomelidae]) have had limited success (Essl et al., 2015). *Ophraella communa* was accidentally introduced and first recorded in 2013 in northern Italy and in southern Switzerland (Müller-Schärer et al., 2014). Since then, the beetle has expanded its range within Italy and to Slovenia and Croatia due to its high dispersal ability (Zandigiacomo et al., 2020). *O. communa* preferentially feeds on *A. artemisiifolia* and can completely defoliate the plant (Figure 6), reducing seed and pollen production significantly and thus reducing health costs (Müller-Schärer et al., 2014; Cardarelli et al., 2018; Schaffner et al., 2020. At present, *O. communa* is not used as a deliberately released biological control agent in Europe, but this may change in the future.