DOI: 10.1111/epp.12783

EPPO STANDARD - NATIONAL REGULATORY CONTROL SYSTEMS

PM 9/31 (1) *Ambrosia trifida*

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

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

Authors and contributors are given in the Acknowledgements section.

1 | INTRODUCTION

Further information on the biology, distribution and economic importance of *Ambrosia trifida* can be found in EPPO (2019, 2021).

Ambrosia trifida L. (Asteraceae) is a summer annual plant native to North America (Bassett & Crompton, 1982). The species was introduced into many countries of the EPPO region at the end of the 19th century (Follak *et al.*, 2013; Chauvel et al., 2015, 2021). Many of the occurrences of *A. trifida* are considered casual populations (Follak et al., 2013). However, there are well-established populations in south-west France (Chauvel et al., 2015). *A. trifida* is also considered established in parts of Italy (Acta Plantarum, 2020) while further local populations can be found in Serbia, Russia and Bulgaria (Follak et al., 2013; Stoyanov et al., 2014; EPPO, 2019, 21). Occurrences are also known from Asia including Japan, South Korea and China (EPPO, 2019, 21).

In its native range, *A. trifida* has historically been recorded in naturally disturbed habitats (e.g. along the banks of water courses) (Bassett & Crompton, 1982). Today, it is regarded as a major weed in agricultural systems and it has also become established in disturbed habitats (Regnier et al., 2016). In the EPPO region, *A. trifida* occurs in crop fields, ruderal habitats, including railway tracks, and naturally disturbed habitats such as riparian systems (Follak et al., 2013; Chauvel et al., 2015).

Globally, there have been numerous interceptions of *A. trifida* as contaminant of seed for planting or as a contaminant of grain for human or animal consumption (EPPO, 2019). *A. trifida* has been introduced in Europe with imports of grain for the agri-food industry and seeds for planting (Verloove, 2006; EPPO, 2019). There are documented cases of introduction of *A. trifida* into the EPPO region via seed imported from North America (Follak et al., 2013; Chauvel et al., 2015). This includes contaminated soybean seed (Chauvel et al., 2015), maize seed (Stoyanov et al., 2014; Chauvel et al., 2015) and seed of other spring crops (sunflower, sorghum) (G. Fried, pers. comm., 2019).

In North America, the economic consequences associated with the presence of *A. trifida* are considered to be major. The plants' temporal emergence pattern, rapid and aggressive growth, and herbicide resistance contribute to its success as a weed in crop fields (Harrison et al., 2001; Regnier et al., 2016). Yield reductions of 13–50%, and more, have been observed, with losses being greatest when the crop and the weed grow simultaneously (Harrison et al., 2001; Barnett & Steckel, 2013). In the EPPO region, *A. trifida* currently occurs only locally in agricultural areas (Follak et al., 2013; Chauvel et al., 2015). In south-west France, however, farmers report additional costs associated with hand weeding, and even the destruction of plots before harvesting due to very high densities of *A. trifida*, meaning the total loss of the crop (EPPO, 2019).

Moreover, *A. trifida* is regarded as a health problem as it produces a large amount of highly allergenic pollen (Oh, 2018). Thus, populations of *A. trifida* are likely to contribute to seasonal allergic rhinitis caused by *Ambrosia* pollen (EPPO, 2019). There is also the potential for impacts on biodiversity within the EPPO region as the species is highly competitive and can form annual monospecific stands in meso-hygroscopic environments (river banks, wet grasslands, gravel pits and ditches) (EPPO, 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. trifida* 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. NPPOs, ministries of environment, ministries in charge of transport, water management, etc.), as well as with other interested bodies (associations) should be established.

2 | MONITORING OF *A. TRIFIDA*

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, nature conservation managers as well as botanists, agronomists, farmers, forest managers etc. 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. trifida*. The morphological characteristics of *A. trifida* (size of the seedling, shape of the leaves) allow its identification at all stages of development.

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, riparian habitats, ruderal environments like roadsides and transport corridors; see EPPO (2019) for a more comprehensive list of habitats).

3 | ERADICATION OF *A. TRIFIDA*

Any eradication programme for *A. trifida* in the case of recently detected populations (including an incursion) 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. TRIFIDA*

The containment programme for *A. trifida* 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 & Health, 2021), which implement and monitor national control strategies and ensure cooperation between the various public authorities concerned. Citizen science projects may be implemented to encourage landholders and other citizens to report sightings of *A. trifida*. A project on this pest (“A la recherche de l'*Ambroisie trifide*”) has already been launched in France (https://www.tela-botanica.org/mission/ambrosiatrifida/).

ACKNOWLEDGEMENTS

This Standard was prepared by Mr S Follak (AT) based on the work conducted by an Expert Working Group (EWG) in 2019 on the pest risk analysis for *Ambrosia trifida*. The EWG included the following participants: Mr D Chapman (GB), Mr S Follak (AT), Mr B Chauvel (FR), Mr G Fried (FR), Ms Y. Kulakova (RU), Ms D. Marisavljevic (RS), Ms E Regnier (US), Mr U Starfinger (DE), Mr J Van Valkenburg (NL) and Mr M Chouibani (MA). The Panel on Invasive Alien Plants reviewed the Standard.

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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.

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 risks 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. trifida*. Surveillance should be carried out in likely places of introduction of *A. trifida*, such as disturbed habitat complexes, arable land, the banks of major watercourses and the banks of streams or canals. High-risk places of introduction include harbour and cargo yards (places of loading). Particular attention should be given to areas adjacent to infested sites that might most likely receive seeds by natural and human-assisted spread such as ruderal environments, e.g. transportation networks and crop fields. The presence of *A. trifida* is mostly related to habitats with natural or human disturbance. Surveillance should also be increased in areas of EPPO countries where there is a high risk of invasion by the species (EPPO, 2019).

2. Containment measures

Unintentional transport of seeds through the transfer of contaminated soil material and by vehicles and machinery should 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). NPPOs should provide land managers, farmers and stakeholders with identification guides including information on preventive measures and control techniques. See for example "*Ambrosia* in Europe habitus, leaves, seeds" (Karrer et al., 2016) and "Biology and Management of Giant Ragweed" (Johnson et al., 2007).

3. Treatment and control

It is technically possible to achieve total control of *A. trifida* by a combination of chemical and mechanical means, but this is most applicable to small infestations and outbreaks.

- Hand weeding (uprooting) is effective for the control of *A. trifida* and can be applied in various environments (crop fields, ruderal habitats and banks of watercourses). Plants should be pulled out before flowering ensuring the complete removal of the root system.
- Herbicides applied to individual plants or patches (spot treatment) may allow effective control of the species (see Appendix 2).

4. Verification of pest eradication

A continuous survey of treated sites is important to prevent re-establishment. Mechanical measures and chemical application should be conducted until no emergence of *A. trifida* is found. It is believed that seeds of *A. trifida* remain viable in soil for >4 years (up to 20 years depending on burial depth; EPPO, 2019) and thus the species forms a long-term persistent seedbank. Repeated visits should therefore be made to treated sites for at least 5 years or more.

APPENDIX 2-CONTAINMENT PROGRAMME

In the case of established and large populations in agricultural areas, eradication is difficult to achieve. 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. trifida*. Surveillance should be carried out in likely places of introduction of *A. trifida*, such as disturbed habitat complexes, arable land and the banks of major watercourses (see Appendix 1).

2. Containment measures

Containment measures regarding the prevention of the spread naturally or through the movement of soil, machinery, livestock or any contaminated commodity should be applied (see Appendix 1).

3. Treatment and control

Chemical control

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

TABLE 1 Selection of herbicides to control *Ambrosia trifida* in different crops. Effectiveness may depend on the scale, site and presence of herbicide-resistant biotypes. Sequential herbicide application (PRE and POST) and mixtures of herbicides are recommended. For further details see the main text

Crop	Herbicide	Period of application	Reference
Maize	Mesotrione	PRE/POST	Wichert et al. (1999)
	Dicamba	POST	Johnson et al. (2007)
	Isoxaflutole	PRE/POST	Knezevic et al. (2019)
Soybean	Imazamox	POST	B. Chauvel, pers. comm. (2020)
Sunflower	Imazamox	POST	B. Chauvel, pers. comm. (2020)
	Tribenuron-methyl	POST	
Cereals	Fluroxypyr	POST	Johnson et al. (2007), Robinson et al. (2012)
	Clopyralid	POST	
	2,4-D	POST	
Field crops (post-harvest), also non-crop areas	Glyphosate	POST	Robinson et al. (2012)

It is difficult to control *A. trifida* consistently with single applications of pre-emergence (PRE) or post-emergence (POST) herbicides due to the plants' temporal and late emergence pattern, rapid and aggressive growth, and herbicide resistance. Thus, the most effective herbicide programs combine PRE and POST herbicide treatments, and two or more herbicide modes of action (Johnson et al., 2007).

Many North American studies have evaluated herbicides and herbicide combinations for *A. trifida* control in different crops, including soybean, cotton and maize. Multiple applications of herbicides are necessary to control *A. trifida*. The following PRE and POST herbicides from different herbicide groups can be used to control *A. trifida*: glyphosate, acetolactate synthase (ALS) inhibitors (e.g. imazamox, cloransulam-methyl, sulfentrazone), photosystem II inhibitors (atrazine), protoporphyrinogen oxidase (PPO) inhibitors (saflufenacil) and auxin-type herbicides (dicamba, 2,4-D) (e.g. Johnson et al., 2007; Soltani et al., 2011; Wuerffel et al., 2015; Knezevic et al., 2019, as well as other references listed in Table 1). For example, Knezevic et al.. (2019) showed that herbicide combinations of different mode of actions provided greater than 90% control of (glyphosate-resistant) *A. trifida* populations in maize and soybean (Nebraska/USA).

In general, POST herbicides should be applied when *A. trifida* plants are small (<15 cm tall). This minimizes early-season interference with the crop and can provide the most effective control of existing plants. However, both glyphosate and 2,4-D provided effective control of 10- to 25-cm and even 26- to 46-cm tall *A. trifida* plants. Glyphosate application in Indiana, USA, controlled *A. trifida* with 94–100% of plants killed (at 840 or 1120 g/ha), whereas 2,4-D controlled *A. trifida* with 99–100% of plants killed (at 280–1120 g/ha) (Robinson *et al.*, 2012).

In the EPPO region, some experience with the control of *A. trifida* with herbicides is available from France. Based on this it is recommended to use the ALS inhibitors imazamox in soybean and imazamox as well as tribenuron-methyl in sunflower (both herbicides are only applicable in herbicide tolerant sunflower varieties). In maize, *A. trifida* can be controlled by most of the available herbicides for the control of dicot weeds (B. Chauvel, pers. comm., 2020; Table 1).

It is of particular importance to survey crop fields after weed control measures have been applied to control escapes or very late emerging plants of *A. trifida* (Johnson et al., 2007). Here, hand weeding is most applicable.

Tillage

Ambrosia trifida can be problematic in commonly used tillage systems (Barnes et al., 2004; Regnier et al., 2016). The species was observed more frequently in mulch-tilled fields (49%) compared to no-till (37%) or conventional-till (32%) fields. Utilization of no-till or conventional tillage practices (ploughing) reduced *A. trifida* incidence by 10–15%. No-till leaves *A. trifida* seeds on the soil surface where they are more prone to predation by insects and other soil organisms (Harrison et al., 2003). Using a plough buries some of the seeds deep enough to reduce emergence in the following spring. Tillage practices that result in an intermediate level of soil disturbance may place seeds of *A. trifida* at more optimum depths for survival and emergence (Regnier et al., 2016). Ganie et al. (2016, 2017) detailed that preplant tillage (tandem disc) provided effective early-season control of *A. trifida* and complements the application of PRE and/or POST herbicides in maize and soybean.

Cultivation

Cultural practices, including crop density, planting date, row spacing and choice of cultivar, affect the crop's ability to compete with *A. trifida*. All these practices can maximize the degree at which the crop occupies space early in the growing season, thus diminishing the growth and competitive pressure of *A. trifida* on the respective crop. For example, *A. trifida* grown with soybeans planted in 19-cm rows produced less biomass than weed in 76-cm rows, but *A. trifida* affected soybean yield loss similarly in both row spacings (Hock et al., 2006). Planting date has a significant influence on crop-weed competition and delayed planting of summer annual crops could also be a tactic to control *A. trifida* to minimize the percentage of *A. trifida* seedlings that emerge after the crop (Schutte et al., 2008). High-density maize (9 plants/m^2) can effectively compete with and suppress *A. trifida* with little impact on yield (Page & Nurse, 2015).

Crop rotation

Summer crops such as maize, soybean and sunflower in the crop rotation system are a factor that strongly promotes *A. trifida* and thus should be avoided where possible in infested areas. 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, autumn-seeded cover crops, perennial pasture and hay crops (Regnier et al., 2016; Goplen et al., 2017; B. Chauvel, pers. comm., 2020). Results of Goplen et al. (2017) indicated that *A. trifida* seed inputs in the cropping systems studied (Minnesota, USA) only need to be prevented for 2 years (i.e. zero-weed threshold) to reduce the seedbank by 96%. Maximizing crop rotation diversity is advisable as it allows the use of different and effective herbicides and other weed management options in the other crops. Cereals (e.g. wheat) are usually harvested prior to *A. trifida* seed production, thus diminishing replenishment of the seedbank. Moreover, crops such as wheat and alfalfa provide a less suitable habitat due to a greater crop canopy for seed predators that may reduce *A. trifida* seedbanks.

Biological control

At present, there are no biological control agents available for *A. trifida* in the EPPO region. Pathogens have been reported to adversely affect *A. trifida* (Chauvel et al., 2021). For example, *Puccinia xanthii* forma specialis *ambrosia-trifidae* is a species-specific rust fungus that has potential as a biocontrol agent (Batra, 1981). The rust attacks the leaves of *A. trifida* and reduces seed and pollen production.