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European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes PM 9/20 (1)

National regulatory control systems
Systèmes de lutte nationaux réglementaires

PM 9/20 (1) *Parthenium hysterophorus*

Specific scope

This Standard describes control procedures aiming to monitor, contain and eradicate *Parthenium hysterophorus*.

Specific approval and amendment

First approved in 2015–09.

Introduction

Details on the biology, distribution and economic importance of *Parthenium hysterophorus* can be found in EPPO (2014).

Parthenium hysterophorus (Asteraceae) is an annual or short-lived perennial plant native to the subtropics of North and South America. Within the EPPO region, the species is at present officially recorded as established only in Israel. It is recorded as naturalized in Egypt (Boulos & El-Hadidi, 1984) and it has also been observed as transient (=casual), not established in Belgium (Verloove, 2006) and Poland (recorded twice in 1938 and 1939 in one locality; Scheuermann, 1956; Mirek *et al.*, 2002). It is thought to have been introduced in Israel in 1980, probably through the import of contaminated grains from the USA for use as fish food in ponds (Dafni & Heller, 1982). The species was also introduced in India and Ethiopia as a contaminant of grain from the USA. There are also records of its introduction as a contaminant of pasture seed and attached to used vehicles (harvesters in Australia and China, military machinery in Ethiopia and Pakistan and other vehicles in Papua New Guinea, see Brunel *et al.*, 2014 for a review of entry pathways).

Parthenium hysterophorus reproduces by seeds and is known to be highly prolific, as a single plant produces on average 40 000 seeds (Dhileepan, 2012). Seeds[1] are dispersed locally by wind and water and as a contaminant of hay, seed, harvested material, soil and by vehicles, machinery or animals over longer distances. The species tolerates a wide variety of soils and is a pioneer that can colonize a wide range of habitats: grazing land, summer crops, disturbed and cultivated areas, roadsides, recreation areas, as well as river banks and floodplains.

Parthenium hysterophorus aggressively colonises disturbed sites and causes major negative impacts on pastures and crops. In India, it has been observed that *P. hysterophorus* can cause yield losses of up to 40% in several dryland crops (Khosla & Sobit, 1981; cited in Kandasamy, 2005). In Ethiopia, the yield of *Sorghum bicolor* grain was reduced by between 40% and 97% when *P. hysterophorus* was left uncontrolled throughout the season (Tamado *et al.*, 2002). In Queensland (Australia), the species has invaded 170 000 km^2 of high quality grazing areas and losses to the cattle industry have been estimated to be 22 million AUD per year in control costs and loss of pasture (Chippendale & Panetta, 1994). Infestations of *P. hysterophorus* can also degrade natural ecosystems, and outcompete native species (Ramachandra Prasad *et al.*, 2010a,b). The species is also a threat in several nature reserves (e.g. in Australia, Ethiopia, India, Pakistan, South Africa and Zimbabwe, see Dhileepan, 2009). Because the plant contains sesquiterpenes and phenolics, it is toxic to cattle (Navie *et al.*, 1996). In addition, meat and milk produced from livestock that has eaten the plant can be tainted (Towers & Subba Rao, 1992). Frequent contact with the plant or its pollen can produce serious allergic reactions such as dermatitis, hay fever and asthma in humans and livestock, especially horses (McFadyen, 1995).

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

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

[1]Seeds of this species are held in cypselas: an achene fruit derived from an inferior ovary, characteristic of plants in the composite family.

– 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, in order 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 Health, Ministries of Environment, Ministries in charge of transport, water management, etc.), as well as with other interested bodies (e.g. associations) should be established.

Monitoring of *Parthenium hysterophorus*

Staff of organizations in charge of the monitoring of the species should be trained to recognize the plant both in flowering and non-flowering stages even when occurring in small populations. This may include staff of NPPOs, nature conservation managers as well as botanists, agronomists, farmers, etc. As this plant grows in a wide range of habitats and has direct impacts on people's health, citizen science projects may be implemented to encourage landholders and other citizens to report sightings of *P. hysterophorus*.

Regular delimiting surveys (according to the International Standard for Phytosanitary Measures no. 6 *Guidelines for surveillance*) are necessary to determine the geographical distribution of the plant and its prevalence. Monitoring should concentrate on areas that are climatically suitable and most vulnerable to colonization (cultivated fields, pastures, managed areas, areas near sea ports, along roadsides and railway tracks, etc.). Monitoring should include crossing of surveyed area, walking along roads, railway tracks (following national guidance on health and safety precautions) etc. and looking for the plant which should be identified directly in the field or in the laboratory, if necessary.

Eradication of *Parthenium hysterophorus*

The eradication programme for *P. hysterophorus* in the case of recently detected populations (including an incursion) is based on the delimitation of the invaded area within the country and the application of measures to both eradicate and prevent further spread of the pest. The feasibility of eradication for *P. hysterophorus* depends on the size of the area infested, the density of the plants, the size of the accumulated seed bank and accessibility of the site.

Measures are described in Appendix 1.

Containment of *Parthenium hysterophorus*

The containment programme for *P. hysterophorus* in the case of established populations is based on the application of measures to prevent further spread of the pest in the country or to neighbouring countries. These measures are described in Appendix 2.

Communication and collaboration

Professionals (e.g. administration, farmers) should be informed about the threat to agriculture and human health and about preventive measures. Integrated management, involving different sorts of land managers and various management measures will be more effective and efficient. The involvement of regional groups in the development of site-specific integrated management plans has shown good results (Adkins & Shabbir, 2014).

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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. It must be verified by surveillance to establish if it has been successful.

1) Surveillance

   A delimitation survey should be conducted to determine the extent of the pest distribution. Infested areas and adjacent areas that might receive seed should be monitored.

2) Containment measures

   Unintentional transport of seed through the transfer of soil material, human activity including the import of plant products, the movement of grazing animals and by vehicles should be avoided. Movement of soil from infested fields should be prohibited. Equipment and machinery should be cleaned to remove soil before moving to an uninfected area. The International Plant Protection Organization is currently drafting a Standard on 'International movement of used vehicles, machinery and equipment', providing guidance on how to treat, how to set up facilities and waste disposal, and how to check procedures (IPPC, 2014). On arrival from an infested area or before departure from it, grazing animals should be held in yards or small paddocks until seed have dropped or been removed from their coats and tails prior to their release. Infestations around yards can be easily spotted and controlled.

In Australia, where the species is declared noxious, reporting the species is mandatory and vehicles (machinery, cars, etc.) coming from infested areas must be cleaned to remove its seeds. Washing vehicles can be carried out using a high pressure hose or by using roadside wash-down facilities (Parsons & Cuthbertson, 1992).

3) Treatment and control programme

Chemical control

Herbicides, either as pre- or post-emergence applications, can provide effective control of *P. hysterophorus* in crops. Timing of chemical control is important, and the species should be treated when plants are small and at a pre-flowering stage, in any case before the plant sets seeds. In pastures, the use of selective herbicides that do not kill other plant species is recommended to maintain competition.

Chemical control is only financially feasible within high-value crops and in specific circumstances such as along road sides to prevent weed spread, or in public parks or on small areas (Adkins & Shabbir, 2014).

Khan *et al.* (2012) showed that *P. hysterophorus* control was highest at rosette stage with glyphosate (96% control) and metribuzin (87% control) at 4 weeks after treatment. Other herbicides such as atrazine, bromoxynil+MCPA, S-metolachlor, 2,4-D, triasulfuron + terbutryn, pendimethalin did not provide satisfactory control when applied later (i.e. at bolted stage with plant height of 56–96 cm) even at high rates. These findings are supported by Singh *et al.* (2004) who reported that 2,4-D, atrazine, metribuzine, metsulfuron, chlorimuron and glufosinate failed to control *P. hysterophorus*, while glyphosate at 2.7 and 5.4 kg per ha provided >95% control of bolted plants 18 weeks after treatment.

With any long-term chemical management approach, the potential for herbicide resistance exists. Indeed, glyphosate resistance has developed in *P. hysterophorus* in horticultural situations as a result of regular use of this herbicide (Crane *et al.*, 2006; Vila-Aiub *et al.*, 2008). In Western Colombian fruit orchards, resistance to glyphosate (plants tolerant to this herbicide at up to 3.5 times the concentration required to kill susceptible individuals) was evident after 15 years of continuous glyphosate selection (Vila-Aiub *et al.*, 2008). Resistance to paraquat has occurred in both the Caribbean (Hammerton, 1981; cited in Kandasamy, 2005) and Kenya (Njoroge, 1991). In Brazil, Gazziero *et al.* (2006) confirmed the resistance of *P. hysterophorus* to ALS-inhibiting herbicides and cross resistance to herbicides belonging to the chemical groups of imidazolinones (imazethapyr), triazolopyrimidines (cloransulam-methyl) and sulfonylureas (clorrimuron-ethyl and iodosulfuron methy sodium).

All products should be used following the label instructions and in line with the relevant plant protection product regulations. In the European Union, some herbicides have been phased out as they did not gain Annex I listing during the active review process. Of the remaining active substances, availability varies significantly from country to country and the current product approvals are subject to change under the EU review process for plant protection products. New products which are approved and marketed for control of weeds in arable crops, and particularly those new products which are recommended for control of *Ambrosia* spp., may be suitable also for control of *Parthenium hysterophorus.*

Manual and mechanical control

Hand pulling is a common strategy used in developing countries such as Bangladesh, India, Nepal and Pakistan. However, manual removal through hand pulling may affect the health of workers as it is known to provoke dermatitis and asthma and regrowth will occur from cut or partly pulled plants that still have a root system (Adkins & Shabbir, 2014). The risk of allergies can be reduced by wearing protective clothing.

Before crops are planted, plants of *P. hysterophorus* can be ploughed into the soil, or pre-emergent herbicides can be used. Pasture can also be established after the plant is ploughed in before the flowering stage (Adkins & Shabbir, 2014). Tamado & Milberg (2004) showed that under experimental conditions, twice hand-hoed treatments consistently suppressed *P. hysterophorus*.

4) Verification of pest eradication

Chemical or mechanical measures should be conducted until no sign of *P. hysterophorus* is found. This should be confirmed by regular surveys of infested and adjacent areas conducted at least annually in the growing season. As the half-life of buried seeds is reported to be 7 years, the maximum longevity is expected to be 17 years. Preventive measures in infested fields are recommended for at least this long.

Appendix 2 – Containment programme

In the case of an established population, eradication is difficult to achieve. Containment measures aiming to prevent further spread of the pest to endangered areas or to neighbouring countries should be applied. While different approaches have been used to manage *P. hysterophorus*, no single method alone has proven successful and an integrated approach is therefore recommended.

Surveillance

Surveillance should be carried out in likely places of introduction of *P. hysterophorus*: for instance along roadsides and railway tracks, places near sea ports and in crops fields. In Australia, most of the detections (>70%) have occurred on roadsides (Panetta, 2012).

Containment measures

Containment measures regarding the prevention of the spread naturally or through the movement of soil, machinery, cattle or any contaminated commodity should be applied (see point 2 of Appendix 1).

Cultural control

The effects of smother crops have been tested. Tamado & Milberg (2004) trialled under experimental conditions the effect of *Vigna unguiculata* (Cowpea) in Sorghum fields. The use of this smother crop reduced *P. hysterophorus* biomass, but the reduction was only substantial when combined with hoeing.

As *P. hysterophorus* invades pastures, in particular overgrazed pastures, reduction in the stocking rate and more appropriate rotational timings between grazing events are useful methods to manage the species (Adkins & Shabbir, 2014). Pastures maintained in good condition will limit *P. hysterophorus* colonization. Drought and the subsequent effects on pasture cover create the ideal opportunity for *P. hysterophorus* to establish (Queensland Government, 2011).

Management of *P. hysterophorus* in pastures through burning is not considered to be an option (Adkins & Shabbir, 2014). Fire experiments in Australia highlighted that the overall effect is to create open niches in the landscape, in which a large number of *P. hysterophorus* seed are able to germinate in the absence of vegetation.

Biological management

New management options include biological management through the use of suppressive plants, or by the authorised release of insects or pathogens as specific biological control agents.

Beneficial plants have been shown to suppress the growth of *P. hysterophorus* through tests conducted in Australia, India, South Africa and Pakistan. For instance, in India, the seedlings of *Cassia uniflora* (Caesalpinioideae) suppress the growth of *P. hysterophorus* seedlings, causing a reduction in their height, dry weight and the number of flowers they produce (Joshi, 2011). Khan *et al.* (2014) undertook field experiments in Pakistan and in Australia and found out that *P. hysterophorus* can be sustainably managed under diverse agro-ecological conditions through the use of plants having a suppressive ability such as *Astrebla squarrosa* (Poaceae), *Cenchrus ciliaris* (Poaceae), *Setaria incrassata* (Poaceae; see also Bowen & Adkins, 2007; Adkins *et al.*, 2010, for information on suppressive plants). This approach would suppress the growth of *P. hysterophorus* and simultaneously produce adequate amounts of fodder biomass for livestock production and in the long term reduce seed set, seed bank size and hence spread into other areas. Shabbir *et al.* (2013) showed that suppressive plants combined with biological control agents can act together significantly to reduce the biomass and seed production of *P. hysterophorus*. This had previously been observed as a result of the combined action of the stem-galling moth (*Epiblema strenuana*) and buffel grass (*Cenchrus cilliaris*; Navie *et al.*, 1998).

Table 1. The biological control agents that have been released around the world to help manage *P. hysterophorus* and the status of their establishment, from Adkins & Shabbir (2014)

Insect/pathogen	Order – Family	Origin	Country released	Establishment
Epiblema strenuana	Lepidoptera – Tortricidae	Mexico	Australia, Israel*, China†	Yes
Zygogramma bicolorata	Coleoptera – Chrysomelidae	Mexico	Australia, India, Pakistan‡, Nepal‡, South Africa, Tanzania	Yes
Listronotus setosipennis	Coleoptera – Curculionidae	Argentina	Australia, Tanzania	Yes
Smicronyx lutulentus	Coleoptera – Curculionidae	Mexico	Australia	Yes
Conotrachelus albocinereus	Coleoptera – Curculionidae	Argentina	Australia	Yes
Carmenta sp. nr *ithacae*	Lepidoptera – Sesiidae	Mexico	Australia	Yes
Bucculatrix pathenica	Lepidoptera – Bucculatrigidae	Mexico	Australia	Yes
Platphalonidia mystica	Lepidoptera – Tortricidae	Argentina	Australia	No
Stobaera concinna	Homoptera – Delphacidae	Mexico	Australia	No
Puccinia abrupta var. *partheniicola*	Basidomycota – Pucciniaceae	Mexico	Australia, India*, South Africa*, Kenya*, Nepal‡, Ethiopia*, China*	Yes
Puccinia xanthii f. sp. *parthenii-hysterophori*	Basidomycota – Pucciniaceae	Mexico	Australia, South Africa, Sri Lanka	Yes

*Source unknown.
†First released as biological control agent against ragweed, *Ambrosia artemisiifolia*.
‡Entered via a neighbouring country, India.

Biological control agents have been released against *P. hysterophorus* in Australia, India, South Africa, Sri Lanka and Tanzania. Ethiopia and the Republic of Vanuatu are in the process of releasing these agents and some agents have accidentally arrived in China, Ethiopia, Kenya, Nepal and Pakistan (Table 1). In Australia, only three agents, a stem-galling moth (*Epiblema strenuana*), a leaf-feeding beetle (*Zygogramma bicolorata*) and a stem-boring weevil (*Listronotus setosipennis*) appear to be having a significant impact upon *P. hysterophorus* (Dhileepan, 2009). Both of the rust species, *Puccinia abrupta* var. *partheniicola* and *Puccinia xanthii* var. *parthenii-hysterophori* have established but their prevalence and impact is highly variable and sporadic, depending upon the local climatic conditions (Dhileepan *et al.*, 1996; Table 1).

Mycoherbicides are fungal-based bioherbicides which, unlike herbicides, have no or very limited non-target damage. Experiments on the use of such mycoherbicides have been conducted in Ethiopia, India and South Africa, but effectiveness in the field is unknown (Dhileepan, 2009; Dhileepan & McFadyen, 2012).

Disposal

If removed from a localised outbreak, *P. hysterophorus* should be bagged and destroyed. In infested areas it may be destroyed by burning under controlled conditions, used for biogas production or composted industrially in a way which achieves specified temperatures for a specified time. However, ordinary *P. hysterophorus* compost contains high levels of parthenin and phenolics which impede the early growth, development and dry matter yield of both monocotyledons and dicotyledons.