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Pest Risk Analysis for

Parthenium hysterophorus

Parthenium hysterophorus ©T.V. Ramachandra Prasad

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This risk assessment follows the EPPO Standard PM 5/3(5) Decision-support scheme for quarantine pests (available at http://archives.eppo.int/EPPOStandards/pra.htm) and uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (available at https://www.ippc.int/index.php).
This document was first elaborated by an Expert Working Group and then reviewed by the Panel on Invasive Alien Plants and if relevant other EPPO bodies. It was finally approved by the Council in September 2014.

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Pest Risk Analysis for *Parthenium hysterophorus*

This PRA follows the EPPO Decision-support scheme for quarantine pests PM 5/3 (5).
A preliminary draft was prepared by Mr Dane Panetta (University of Melbourne). This document has been reviewed by an Expert Working Group (EWG) that met at the EPPO Headquarters in Paris, France on the 2013-07-02/05.

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Content

Stage 1: Initiation

1.01 - Give the reason for performing the PRA

Identification of a single pest

Parthenium hysterophorus (Asteraceae) is an annual plant (or short-lived perennial under certain growth conditions) native to the subtropics of North, Central and South America. The plant has been introduced accidentally to Australia, and many countries in Africa, Asia and the Pacific where it is considered invasive. Within the EPPO region, its distribution is still limited, as occurrence has only officially been reported in Israel so far in the Bet Shean Valley area (Dafni & Heller, 1982) and it is also suspected to occur in Egypt (Boulos & El-Hadidi, 1984). The species is recorded as casual in Belgium (Verloove, 2006) and Poland (Mirek *et al*., 2002). Because *P. hysterophorus* has shown invasive behaviour where it has been introduced elsewhere in the world and has a highly restricted distribution in the EPPO region, it can be considered an emerging invader in the EPPO region. *P. hysterophorus* has been determined as a priority for Pest Risk Analysis according to the EPPO Prioritization process for invasive alien plants (EPPO, 2012).

1.02a - Name of the pest

***Parthenium hysterophorus* L.**

A description of this species can be found in the corresponding EPPO Datasheet.

1.02b - Indicate the type of the pest

Non parasitic plant

1.02d - Indicate the taxonomic position

Reign: Plantae. Family: Asteraceae. Genus: Parthenium. Species: *Parthenium hysterophorus* L.

Parthenium is in the sub-tribe Ambrosiinae of the tribe Heliantheae, family Asteraceae. The genus *Parthenium* includes 17 species, all native to the Americas (Dhileepan & McFadyen, 2012). *P. hysterophorus* may have originated via natural hybridization from the two closely related species *P. confertum* and *P. bipinnatifidum* (Nath, 1988). While *P. hysterophorus* is a single taxonomic entity that can be distinguished from other *Parthenium* species, several biotypes or strains have been identified.

1.03 - Clearly define the PRA area

EPPO Region (see map at www.eppo.int).

1.04 - Does a relevant earlier PRA exist?

no

A risk assessment was prepared for Australia in 2003 (Randall, 2003) using the Weed Risk Assessment (WRA) tool (Pheloung *et al*., 1999). A score of 18 was obtained. This would have led to rejection of the species from introduction in Australia, had it not been introduced earlier.

Risk assessments have also been run for New South Wales (Department of Primary Industries of New South Wales, Undated), Northern Territory (Department of Natural Resources, the Art and Sport, 2010) and Victoria (Department of Primary Industries, Government of Victoria, 2011) in Australia.

However, these risk assessments are not entirely relevant since they have been performed in another risk area outside the PRA area. In addition, the used schemes follow different processes of assessing risk.

1.06 - Specify all suitable habitats. Indicate the ones which are present in the PRA area.

Recorded habitats in native range

P. hysterophorus is considered to originate in the area surrounding the Gulf of Mexico or in central South America. It is currently widespread in North America, South America and the Caribbean, most likely having spread from its original range as a result of human activities (Navie *et al*., 1996a). During his survey work, Dale (1981) reported that *P. hysterophorus* was commonly found in degraded and disturbed habitats, as well as in native grassland, open shrub vegetation and grazed pastures.

Recorded habitats in exotic range

P. hysterophorus grows in a wide range of habitats, including degraded and disturbed lands, banks of streams and rivers. It is a pioneer species that can invade grazing land and degraded pastures, crops, orchards, summer crops, disturbed and cultivated areas, forests, railway tracks and roadsides, recreation areas, as well as river banks and floodplains (Navie *et al*. 1996a).

According to the Corine Land Cover nomenclature, the following habitats are invaded: arable land, permanent crops (e.g. vineyards, fruit tree and berry plantations, olive), pastures, riverbanks / canalsides (dry river beds), road and rail networks and associated land, other artificial surfaces (wastelands).

1.07 - Specify the pest distribution for a pest initiated PRA, or the distribution of the pests identified in 2b for pathway initiated PRA

The global distribution of *Parthenium hysterophorus* is as shown in Figure 1:

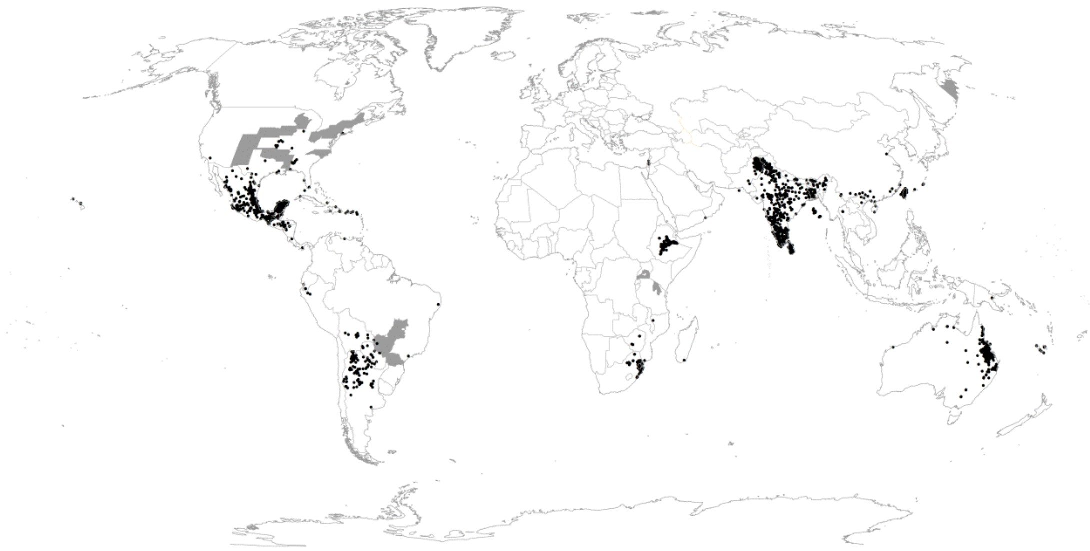


Figure 1: Known global distribution of Parthenium hysterophorus. Source Global Biodiversity Information Facility (www.gbif.org), Clark & Lotter (2011), Dhileepan (2009); Shabbir *et al*., 2012 Department of Natural Resources, the Art and Sport, 2010, assembled by Darren Kriticos. Black dots represent distribution points were *P. hysterophorus* is known to be established, grey areas represent sub-regions were the species in known to be established.

<u>Native distribution:</u>

P. hysterophorus is native to the area bordering the Gulf of Mexico, and has spread throughout southern USA, the Caribbean and Brazil (Towers, 1981). Several biotypes or strains of *P. hysterophorus* have been identified. The main invasive biotype is native to the Gulf of Mexico (North American population), and has subsequently spread throughout the southern USA, the Caribbean and southern Brazil (Navie *et al*., 1996b). A morphologically distinct biotype with yellow flowers and different chemical constituents occurs in Argentina, Bolivia, Chile, Paraguay, Peru, and Uruguay (South American population) (Dale, 1981).

Owing to the lack of information regarding the history of spread of *P. hysterophorus* in the Americas, for the sake of simplicity, all American occurrences of this weed are considered here to occur within its native distribution and were assembled from GBIF.

North America: Bermuda, Mexico, USA (Alabama, Arkansas, Connecticut, Delaware, District of Columbia, Florida, Hawaii, Illinois, Kansas, Louisiana, Maryland, Massachusetts, Michigan, Missouri, Mississippi, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, South Carolina, Texas, Virginia).

Central America and Caribbean: Belize, Costa Rica, Cuba, Dominican Republic, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Mexico, Netherlands Antilles, Nicaragua, Puerto Rico, Saint Barthelemy, Republic of Panama, Trinidad and Tobago.

South America: Argentina, Bermuda, Bolivia, Brazil, Chile, Cuba, Dominican Republic, Ecuador, French Guiana, Guyana, Peru, Paraguay, Suriname, Uruguay, Venezuela.

<u>Exotic distribution:</u>

EPPO Region: Israel (Dafni & Heller, 1982; Joel & Liston, 1986) (see Appendix 2).

Note: The species is recorded as casual in Belgium (Verloove, 2006) in 1999 in the Ghent port area (a single plant) and in 2013 in the port of Roeselare (several individuals). It is suspected that these plants did not maintain (no ripe fruits had been observed in November 2013). In Ghent, the species was found at the Ghent train terminal where all kinds of cereals are introduced, and it was found among typical soybean aliens, it is therefore suspected that *P. hysterophorus* may have been introduced as a contaminant of cereals or of soybean consignments. In Roeselare, it was found on rough ground surrounding a petfood mill, it is then suspected that the species could have been introduced as a contaminant of birdseed or other petfood (Filip Verloove, pers. comm., 2014). *P. hysterophorus* has also been recorded as casual in Poland in 1938 (Mirek *et al*., 2002; Urbisk, 2011), but no detail is provided on its possible introduction.

Oceania: Australia (Queensland, New South Wales, Northern Territory, Western Australia) (Parsons & Cuthbertson, 1992; Navie *et al.*, 1996a; Penna & MacFarlane, 2012), French Polynesia (Florence *et al*., 2007), several Pacific islands (Global Invasive Species Database), Christmas island (Anonymous, 2011), New Caledonia (Gargomini *et al*., 1996) and Vanuatu (Adkins *et al*., 2005).

Note: The species was recorded from Papua New Guinea but has been declared as eradicated (SPC-PPS, 2003; Kawi & Orapa, 2010). This population was found in a site subject to frequent disturbance.

Asia:
Bangladesh (Navie *et al.*, 1996a), Bhutan (Parker, 1992), China (Guangdong, Guangxi, Guizhou, Hunan, Yunnan, Navie *et al.*, 1996a), India (Rao, 1956; Mahadevappa & Patil, 1997), Japan (Iwatsuki *et al*., 1993), Nepal (Adhikari & Tiwari, 2004), Malaysia (Rezaul, 2013), Pakistan (Razaq *et al*., 1994; Shabbir & Bajwa, 2006), Sri Lanka (Jayasurya, 2005), Oman (Kilian *et al.*, 2002), Republic of Korea (Alien Plants in Korea Website), Taiwan (Peng *et al.*, 1988), Vietnam (Nath, 1988), Yemen (Alhammadi, 2010),

Note: In China, a different biotype genetically distinct to the one found in the south of the country (Guangxi, Yunnan, etc.) is recorded in the North Eastern Province of Shandong, according to Tang *et al*. (2009).

Africa:
Comoros (herbarium voucher 17/02/1975, n° 00209281, Herbier P, MNHN), Egypt (Boulos & El-Hadidi, 1984), Eritrea (Hedberg & Edwards, 1989), Ethiopia (Tamado & Milberg, 2000; Fessehaie *et al.*, 2005), Kenya (Njoroge, 1991), Madagascar (Tamado *et al.,* 2002), Mauritius (Parson & Cuthbertson, 1992), Mayotte (herbarium voucher 17/10/2001, n°00229532, Herbier P, MNHN), Mozambique (Da Silva *et al.*, 2004), Reunion (Le Bourgeois *et al*., 2010), Seychelles (Nath, 1988), Somalia (Ayele, 2007), South Africa (MacDonald *et al.*, 2003), Swaziland (Dhileepan & McFadyen, 2012), Tanzania (Mersie *et al*., undated), Uganda (Mersie *et al*., undated) and Zimbabwe (Tamado *et al*., 2002).

Note: due to its inconspicuous appearance, the species may well be present but unreported in additional African or other countries (Wise *et al*., 2007).

History of distribution
In China, the first herbarium specimen of *P. hysterophorus* was confirmed in the Yunnan Province in 1926, which is adjacent to north Vietnam where the species was first recorded in 1924 (Tang *et al*., 2009). The species was first recorded in Pune in India in 1956 (Rao, 1956). In Nepal, the first specimen of *P. hysterophorus* was recorded in 1967 and was suggested to enter through an open border with India (Shabbir & Adkins, 2010). In Israel, the species was first reported in 1980 in the Jordan Valley (Eastern Israel), and is since then moving to the Jezreel Valley (Giladi *et al*., 2010), in the Beit Shean Valley, and in the Jordan Valley (see Appendix 2 for details on the distribution). In Pakistan, it was first recorded in 1994 (Razeq *et al*., 1994). *P. hysterophorus* was first reported in Uganda in 2008 (IPM-CRSP, 2010).

Altitudinal ranges
P. hysterophorus is distributed over a wide altitudinal rnage. In China, it is distributed from sea level to an altitude of 2400 m (Li & Gao, 2012). In Ethiopia, it has been found from 900 to 2500 m (Taye *et al*., 2004) and in Bhutan from 200 to 1700 m above seas level (Parker, 1992).

Stage 2: Pest Risk Assessment Section A: Pest categorization

1.08a - Do you want to go to the main Pest Risk Assessment or to continue with the pest categorization?

Yes, go to the main Pest Risk Assessment.

The species has a well-documented history of being an invasive alien plant (Navie *et al*., 1996a).

Stage 2: Pest Risk Assessment Section B: Probability of entry of a pest

2.01a - Describe the relevant pathways and make a note of any obvious pathways that are impossible and record the reasons. Explain your judgement

Entries as a contaminant of agricultural produce and machinery have historically been important pathways for the introduction of *P. hysterophorus* in new regions. The following pathways are considered further in the assessment:

- Contaminant of seed

The introduction of *P. hysterophorus* to central Queensland, Australia originated from infested pasture seeds (grass) imported from Texas in 1958 (Everist, 1976). Bhomik & Sarkar (2005) state that during the 1950s *P. hysterophorus* was introduced in Africa, Asia and Oceania in cereal and grass seed shipments from the USA. Similarly, extensive spread of *P. hysterophorus* in Egypt has followed a roughly contemporaneous single introduction (1960) of the weed through impure grass seed imported from Texas (Boulos & El-Hadidi, 1984). In the Shandong Province in China, Li & Gao (2012) report that the species may have been introduced in 2004 through the importation of soybean seeds from the USA. *P. hysterophorus* is reported to have entered areas of Sri Lanka as a contaminant of onion seed from India (Jayasuriya, 2005).

It is believed that the Roper River and Borroloola infestations in Northern Territory in Australia originated from infested tomato seed (P. Jeffery and M. Fuller, pers comm. 2007; Department of Natural Resources, the Art and Sport, 2010). Though, this statement cannot be verified and the origin and the production procedure of the seeds is unknown.

- Contaminant of grain

In India, *P. hysterophorus* was first observed in Poona in 1956 (Rao, 1956) on the rubbish heaps in the neighbourhood of the Agricultural College where it is considered to have been accidentally introduced. It was most likely introduced through large scale import of infested wheat and other cereals from the USA (Sushilkumar & Varshney, 2010) under a PL480 grant to counter food shortage. Through public distribution of these infested cereals, *P. hysterophorus* has ultimately spread over 35 million ha of the Indian sub-continent through various spread pathways (except Western Ghats and snow covered areas of Northern and North – Eastern parts) (Yaduraju *et al.,* 2005; Sushilkumar & Varshney, 2010; Ramachandra Prasad *et al*., 2010a).

It is suspected that *P. hysterophorus* may have been introduced into Ethiopia through infested grain (type unknown) from the USA (Fasli, 1994, cited in Ayele, 2007; Frew *et al.*; 1996; Fessehaie *et al*., 2005). However, the mode and source of introduction in other countries in Africa are unknown (Dhileepan, 2009). It is expected that *P. hysterophorus* entered Maputo harbour in Mozambique through grain imports, possibly as food aid (Wise *et al*., 2007).

P. hysterophorus was accidentally introduced into Israel in 1980, probably through import of infested grains from the USA for use as fish food in ponds (Dafni & Heller 1982). In Belgium as well, the species is suspected to have entered as a contaminant of grain (Verloove, 2006).

In China, Tang *et al*. (2009) provide another hypothesis than Li & Gao (2012) for the introduction of the species in the Shandong Province. They demonstrate through genetical analyses that the presence of *P. hysterophorus* in the Shandong province is the result of a recent, independent introduction from areas outside China, and it is thought that it spresence in this part of China is the result of a separate introduction from the USA. It is notable that the Shandong population is geographically adjacent to Rizhao, the largest seaport for food grain importation in China. Tang (2012) therefore suggests that the species was introduced as a contaminant of grain.

- Contaminant of used machinery

P. hysterophorus can also enter new territories as a contaminant, either on machinery (e.g. seeds lodged on the radiators and grills of automobiles) or as seeds in soil attached to machinery, such as harvesters and other vehicles.

Harvesters

Of the outbreaks of new *P. hysterophorus* infestations on private properties in New South Wales during the period 1982-2004, over 70% were attributable to the combined movement of contaminated grain harvesters (59.4%), and vehicles/trucks and other machinery (14.1%) (Blackmore & Johnson, 2010). In the Shandong Province, harvesters are reported as a pathway as well (Li & Gao, 2012).
Only used machinery would represent a risk, and these could represent pathways of entry when exchanged from one country to another.

Other vehicles
Numerous references report vehicles as a pathway of introduction and spread (Li & Gao, 2012). *P. hysterophorus* is considered to have entered Bangladesh from India most probably through transport vehicles (Shabbir & Adkins, 2010).
The species was considered to have entered Papua New Guinea through second hand vehicles imported from Australia. The plant was only found in a compound where these imported vehicles were parked (Kawi & Orapa, 2010).

Military equipment
The first reported record (1955) of *P. hysterophorus* in Australia was in southern Queensland (Auld *et al.*, 1983), attributed to the movement of aircraft and machinery parts into Australia during the second World War coming from the USA (Parsons & Cuthbertson, 1982).
Farmers in several regions in eastern Ethiopia believed that *P. hysterophorus* had been introduced to their area by army vehicles during the Ethiopian-Somalian war (Frew *et al.* 1996; Tamado & Milberg, 2002).
In Pakistan, it is believed that *P. hysterophorus* was spread to Chitral, Hango and Swat and a frontier region of Bannu from Islamabad with the movement of military vehicles. The species is also suspected to have been introduced into Pakistan through the Indus Highway with the transportation of fuel, food and equipment by NATO and the USA (Khan, 2012).

- Contaminant of growing media adherent to plants for planting

P. hysterophorus is considered to spread locally as a contaminant of potting mix/soil coming along the movement of ornamental plants (trade) in Pakistan (Shabbir *et al.*, 2013). The species has also been reported to enter Kashmir in India from Poona (where it was initially observed) along with some Jasmine rooted cuttings (Hakoo, 1963 in Anonymous, Undated).
As movement of plants for planting with adherent soil exists among EPPO countries, this pathway needs to be considered as an entry pathway.

- Contaminant of soil

Movement of material for road construction purposes has aided the spread of *P. hysterophorus* in the Indian sub-continent (Ramachandra Prasad *et al*., 2010a). The movement of construction materials from one place to the other has aided in spread of *P. hysterophorus* in many parts of India as well (Krishnamurthy *et al*., 1977; Sushilkumar & Varshney, 2010). Sand transported from a river to another place has also been determined as a spread pathway for *P. hysterophorus* in Sri Lanka (Jayasuriya, 2005).
This could be one of the pathways for spread of *P. hysterophorus* from one place to the other within a country (spread pathway) or between countries (entry pathway).

- Contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage

Seed dispersal of *P. hysterophorus* in mud adhering to human feet has been observed in Sri Lanka (Jayasuriya, 2005).

- Contaminant on packing material

P. hysterophorus has been found as a contaminant on packing material (Parson & Cuthbertson, 1992).

- Hitchhiker on fruits, vegetables and timber

P. hysterophorus is supposed to have been introduced in Melsiripura in Sri Lanka as a contaminant of chillies from India. It may also have entered Sri Lanka as a contaminant of mustard imported from India, and as a contaminant of condiments from India (Jayasuriya, 2005). The species is also believed to have been introduced into Kashmir through timber piles from Dandeli in Karnataka in India (Maheshwari, 1968).

Other pathways not considered:

- Contaminant of livestock

P. hysterophorus is thought to have entered Sri Lanka within or on goats accompanying an Indian military mission (Jayasurya, 2005). Beef cattle and sheep may also feed on *P. hysterophorus* in dry season when there is little green grass available in the pastures (Mr & Mrs David Chandellor, beef cattle farmers in South Central Queensland; Mr Bruce Boele, a shepherd in south west Queensland, pers. comm., 2013). In India, goat and sheep feed on young foliage and flowers at the tip of *P. hysterophorus* (Sushilkumar & Varshney, 2010; Ramachandra Prasad *et al*., 2010a). The movement of livestock (goats, beef, sheep) from one country to another may be a pathway of entry of the species. Within a country, this also represents a pathway for spread.
The entry of *P. hysterophorus* as a contaminant of livestock would need to be assessed and managed with the collaboration of Animal Health authorities. However, this information is to be passed on to relevant Animal Health institutions.

- Natural spread and spread along corridors (transport infrastructure)

The propagule of *P. hysterophorus* is a cypsela with two appended sterile florets, which act as air sacs and increase both mobility in the air and flotation (Navie *et al*., 1996a). Dispersal occurs locally by wind, but whirlwinds can carry seeds for considerable distances (Haseler, 1976). The spread of *P. hysterophorus* on either side of roads in many parts of India is also evident (Sushilkumar & Varshney, 2010; Ramachandra Prasad *et al*., 2010a). Dispersal by water is also important, as indicated by spread along waterways in central Queensland (Auld et al., 1983) and in many parts of India (Ramachandra Prasad *et al*., 2010a).
P. hysterophorus could also be spread by wild animals. In Australia, it is dispersed by feral pigs, wallabies and some birds (Grice, Undated). It is considered that *P. hysterophorus* would achieve limited natural spread via wind and wild animals, but could spread over considerable distances if infestations were located close to watercourses and in areas prone to flooding.
Entry through open borders are reported, as for instance the entry in Nepal through India (Shabbir & Atkins, 2010), and in China through Vietnam (Shabbir & Atkins, 2010).
Flooding associated with the bursting of Panshet dam in Maharashtra during the 1960s has caused spread of *P. hysterophorus* to many parts of Maharashtra and neighbouring Karnataka also (Krishnamurthy *et al*., 1977).
In general, however, this represents a spread (rather than an entry pathway) pathway and will be considered under Stage 2.
In the context of the present pest risk assessment, the sole official occurrence of *P. hysterophorus* in the PRA area is in Israel. The risk that the weed would spread by natural means from Israel to other countries within the PRA is considered to be negligible.

- Introduction and spread through Farm Yard Manure/city composts

Weeds including *P. hysterophorus* grow robustly around manure pits, as seen in many places around villages in India. If not properly cleaned, *P. hysterophorus* seeds will have ample chance of getting mixed with manure and spread to the fields when used. In addition, Farm Yard Manure is prepared by covering the top of the pit or heap and churning once in one month with little moisture to kill weed seeds including *P. hysterophorus*. This method of composting has shown to reduce the chances of weed establishment by more than 98%. From the city of Bangalore, transportation of city compost to nearby villages during late 1970s has enabled faster spread of *P. hysterophorus* in India in the 1980s (Ramachandra Prasad, personal communication, 2013).
Farm Yard Manure may represent a spread pathway of *P. hysterophorus* within EPPO countries and will be considered in stage 2.

- As a flower in imported bouquets

Sweddy (2011) reports that in Tanzania, flower sellers pick the freely available *P. hysterophorus* flowers which are then included in the rose flower bouquets, which spread the species. *P. hysterophorus* flowers may be at different stages of maturation; a cut plant of *P. hysterophorus* may be carrying relatively mature fruits. When disposed of, if they are put into gardens or compost heaps, seeds of *P. hysterophorus* may be spread to suitable habitats.
Making bouquets of *P. hysterophorus* also occurs in India (Prof. Ramashandra Prasad, pers. comm., 2013), as well as in Pakistan (Marion Steir, pers. comm., 2014) though the flowers only survive 1 day in bouquets. The use of

P. hysterophorus for exported bouquets is unlikely to happen as flower exporters are trading flowers they produce on a large scale.

- Introduced as a bioterrorism agent

Raghunath D (2001) discusses biological warefare and bioterrorism and states that 'while there is no evidence that the introduction of Parthenium was a deliberate act, it demonstrates a course of action that could be taken by unscrupulous adversaries'.

The Expert Working Group members considered that as it may take several dozens of years before impacts are serious, the use of *P. hysterophorus* as a bioterrorism agent in the EPPO region is very unlikely.

2.01b - List the relevant pathways that will be considered for entry and/or management. Some pathways may not be considered in detail in the entry section due to lack of data but will be considered in the management part.

The following pathways have therefore been considered:

- Contaminant of seed
- Contaminant of grain
- Contaminant of used machinery
- Contaminant of soil
- Contaminant of growing media adherent to plants for planting
- Contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage
- Hitchhiker on fruits, vegetables, timber, packaging material, etc.

Pathway 1: Contaminant of seed

According to ISPM n°5, seeds are defined as 'a commodity class for seeds for planting or intended for planting and not for consumption or processing'.

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Moderately likely

***Level of uncertainty*: medium**

Movement of *P. hysterophorus* throughout its introduced range has been strongly associated with cropping and the transport of agricultural products, in particular seed intended for sowing (Navie *et al.*, 1996a; Fessehaie *et al*., 2005; Sushilkumar & Varshney, 2010; Blackmore & Johnson, 2010).

The following seeds have been suspected to be infested with *P. hysterophorus*:

- Infested pasture seed (grass) from Texas into central Queensland (Everist, 1976), as well as in Egypt from Texas in the 1960s (Boulos & El-Hadidi, 1984);
- Infested cereal seed from the USA in Africa, Asia and Oceania (Bhomik & Sarkar, 2005);
- Infested tomato seed in Northern Territory in Australia (Department of Natural Resources, the Art and Sport, 2010).
- Infested onion seed from India to Sri Lanka (Jayasuriya, 2005).
- Infested soybean seed from the USA in the Shandong Province in China in 2004 (Li & Gao, 2012);

<u>Pasture seeds</u>

Moderately likely

The life cycle of *P. hysterophorus* and produced pasture seeds coincide. *P. hysterophorus* has been recorded as occurring in pastures in Australia (Navie *et al*., 1996a), India (Sushikumar & Varshney, 2010), etc. and is able to reach high densities.

<u>Cereals and soybean seeds</u>

Moderately likely

The risk is considered to be higher for summer crops such as soybean and summer cereals, rather than in winter cereals, considering the phenology of the plant. Risk of presence in certified seed lots is nonetheless lower than for pasture seeds due to the major difference in appearance between cultivated Poaceae and the weed. Non Poaceaeous cereals such as *Fagopyrum esculentum* may be at higher risk due to their great similarity to *P. hysterophorus*.

<u>Vegetables seeds</u>

Unlikely

Vegetable seeds (e.g. tomato, eggplant, peppers) are produced in a way that is not expected to facilitate infestation of seed lots as only the fruits are picked, which reduces the risk of infestation with *P. hysterophorus* seed, especially in certified or standard seed lots.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* **conditions?**

Moderately likely

***Level of uncertainty:* medium**

Although management practices are limiting the prevalence of *P. hysterophorus*, in particular with the use of herbicides, they may not totally remove the species from the fields and therefore from the commodity, as indicated by control percentages by different herbicides (Reddy & Bryson, 2005).

<u>Pasture seeds</u>

The probability of pasture seeds being infested may be higher as lots may be composed from different species of different seed size. The plant may go unnoticed during field certification control schemes due to its size and unconspicuouness, in particular if it is present in low densities. Post-harvesting techniques (e.g., blowing, densimetry tables) are nonetheless used to minimize infestation of seed lots.

Cereal and soybean seeds
The use of herbicides in the USA is considered to reduce the densities of *P. hysterophorus* in fields and post-harvesting techniques are used to minimize infestation of seed lots. Nonetheless, there is a contemporary example of invasions due to this pathway, as soybean seed from the USA introduced *P. hysterophorus* into the Shandong Province in China in 2004 (Li & Gao, 2012).

Vegetable seeds
According to the ISTA and OECD seed certification schemes, certified seeds should not be infested by *P. hysterophorus* as they are cleaned at seed treatment facilities, and as there is a major difference in seed morphology (e.g. tomato seed). Contamination is also more likely in seed crops grown in open fields.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Moderately likely

Level of uncertainty: **medium**

The International Seed Federation (see http://www.worldseed.org/isf/seed_statistics.html) provides figures for seeds imports and exports for 2011. It appears that thousands of tonnes of seeds of field crops and vegetable crops are imported, as shown in table 1.

Country	Imports of field crop seeds (in tonnes)	Imports of vegetable crop seeds (in tonnes)
Germany	195 159	15 562
France	125 701	4 389
the Netherlands	140 899	12 253
Italy	186 203	5 856
the Russian Federation	47 221	3 691
Spain	153 174	6 462
the United Kingdom	49 061	5 627
Belgium	48 898	2 872
Poland	68 322	956
Turkey	21 150	1 844

Table 1. Imports per country of field crop seeds and vegetable crop seeds for 2011, according to the International Seed Federation.

It is to be noted that a large proportion of traded seeds are produced within the EPPO region (except for the USA), as shown in Table 2. The volume of movement is considered as moderately likely.

Country	Production of field crop seeds (in tonnes)	Production of vegetable crop seeds (in tonnes)
France	534 826	8 700
the Netherlands	119 862	10 426
USA	354 040	17 853
Germany	100 752	1 691
Hungary	128 168	2 200
Chile	50 125	1 847
Italy	94 722	10 827
Denmark	130 044	6 985
Canada	182 950	148

Table 2. Production per country of field crop seeds and vegetable crop seeds for 2011, according to the International Seed Federation.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Moderately likely

***Level of uncertainty:* high**

According to monthly imports of wheat seed reported by EUROSTAT, monthly imported are of the same order of magnitude and imports are somehow regular along the year. The Panel considered that the frequency is moderately likely to support entry of *P. hysterophorus*.

2.07 - How likely is the pest to survive during transport or storage?

Very likely

***Level of uncertainty:* low**

P. hysterophorus present as seed is likely to survive all modes of transport and extended periods of storage. There is evidence that seed is highly persistent during periods of dry storage. For example, seed dry-stored at 20^{O}C ± 2^{O}C demonstrated no appreciable loss of germinability over a 24 month period (Tamado *et al.*, 2002b). There is no reason to suspect that survival would differ significantly at other temperatures, provided that seed is transported or stored dry.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

Very unlikely

***Level of uncertainty:* low**

P. hysterophorus is a plant and would be unable to complete its life cycle during transport or storage.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Very likely

***Level of uncertainty:* high**

The seed of *P. hysterophorus* is very small (see the picture below), measuring a few millimetres.

Picture 1: Achenes of *Parthenium hysterophorus* compared to an American dime.

Since invasive alien plants are not covered by the Plant Health Directive 2000/29, there is no plant listed as a quarantine pest and therefore no specific inspection procedures in the EU. In the EU and in Israel, inspection procedures are in place for the control of seeds but they do not target *P. hysterophorus*.
Plant Health legislation or seed regulation targeting *P. hysterophorus* are not known in other EPPO countries.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Likely

***Level of uncertainty:* low**

As seeds infested by *P. hysterophorus* are intended for sowing, it is certain that seed of this weed will transfer to a suitable habitat as the seed will be planted in a field which represents a suitable habitat.

2.11 - The probability of entry for the pathway should be described

Moderately likely

***Level of uncertainty:* medium**

Given its past history of introduction around the world (Boulos & El-Hadidi, 1984; Navie *et al.*, 1996a; Fessehaie *et al.*, 2005; Sushilkumar & Varshney, 2010), primary introductions of *P. hysterophorus* are moderately likely to occur via pasture and cereal seeds. Due to seed certification schemes, the risk of entry through vegetable seed is considered to be low.

Pathway 2: Contaminant of grain

According to ISPM n°5, grain is defined as 'a commodity class for seeds intended for processing or consumption and not for planting'.

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Likely

***Level of uncertainty:* low**

Movement of *P. hysterophorus* throughout its introduced range has been strongly associated with cropping and the transport of agricultural products, in particular grain (Navie *et al.*, 1996a; Fessehaie *et al*., 2005; Sushilkumar & Varshney, 2010; Blackmore & Johnson, 2010).

Wheat and other cereals were reported for the introduction of *P. hysterophorus* in India (Sushilkumar & Varshney, 2010), and sorghum is also reported to be infested in Ethiopia (Tamado *et al*., 2002). It is assumed that *P. hysterophorus* entered Maputo harbour in Mozambique through grain imports, possibly as food aid (Wise *et al*., 2007). It is also expected that *P. hysterophorus* entered in Israel with grains from the USA for use as fish food in ponds (Dafni & Heller 1982).

All cereal fields may be affected (wheat, sorghum, millet, oats, rye, barley), as well as maize.

P. hysterophorus is a summer annual which normally germinates in spring and early summer, produces flowers and seed and dies in autumn. Spring cereals and maize have therefore the same life cycle, and seeds of *P. hysterophorus* could be mature at the time of harvest. Winter cereals may be affected as well.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* conditions?

Moderately likely

***Level of uncertainty:* medium**

In the USA, *P. hysterophorus* is not a major weed because of less favourable temperate climatic conditions, in particular because of the extensive use of herbicide in crops and of tillage and cultivation (Reddy & Bryson, 2005). The species is therefore maintained to a low density, and the risk of contamination in this case seems to be highly reduced though the risk is not eliminated. In spite of these measures, almost all known reported infestations of grain originate from the USA.

The situation and current management conditions may be different for developing countries where *P. hysterophorus* occurs, and where climate would be more suitable to the weed, and where less herbicide intensive practices could lead to a higher density of *P. hysterophorus*. High densities have been observed in sorghum field in Ethiopia for instance (Tamado *et al*., 2002) (see Appendix 3).

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Likely

***Level of uncertainty*: low**

The volumes of import of wheat, sorghum, maize, oats, rye and millet into EPPO countries and neighboring EPPO countries have been checked in FAOSTAT from countries where *P. hysterophorus* occurs and are provided in Appendix 4. Thousands of tonnes are imported each year in EPPO countries. For examples, the United States of America imported 101.440 tonnes of wheat to Morocco, 59.396 tonnes to Israel, 55.526 tonnes to Turkey in 2010.

It appears that the USA remains the main exporter of cereals to the EPPO region. The Expert Working Group considered that the volume of grain is likely to support entry.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Likely

Level of uncertainty: medium

The Expert Working Group considered that the imports of cereals are expected to be frequent.

2.07 - How likely is the pest to survive during transport or storage?

Very likely

Level of uncertainty: low

P. hysterophorus present as seed is likely to survive all modes of transport and extended periods of storage.
There is evidence that seed is highly persistent during periods of dry storage. For example, seed dry-stored at 20^{O}C $\pm$ 2^{O}C demonstrated no appreciable loss of germinability over a 24 month period (Tamado *et al.*, 2002b). There is no reason to suspect that survival would differ significantly at other temperatures, provided that seed is transported or stored dry.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

Very unlikely

Level of uncertainty: low

P. hysterophorus is a plant and would be unable to complete its life cycle during transport or storage.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Very likely

Level of uncertainty: low

The seed of *P. hysterophorus* is very small (see picture 1 on Q 2.09 of the pathway of contaminant of seed).
In the EU, there is no specific regulation on *P. hysterophorus*, but there is legislation on the infestation of grain from *Ambrosia* species (Commission regulation No 574/2011), which requests that the grain be clean from *Ambrosia* spp. seeds. However, the size of the seeds of *Ambrosia* spp. and *P. hysterophorus* are totally different, the ones from *P. hysterophorus* being smaller. This regulation would therefore not prevent the infestation of grain from *P. hysterophorus*.
There is no inspection procedure in Israel that would allow detection of *P. hysterophorus*.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Moderately likely

Level of uncertainty: high

The level of risk of transfer to a suitable habitat depends upon the end use of the infested product.
When the grain is processed, the seeds of *P. hysterophorus* are expected to be destroyed.
Where infested grain is destined for processing, it is possible that *P. hysterophorus* seeds will be dispersed through 'leakage' during transport by road or railway. In this case, seeds would probably be deposited in or fairly close to suitable habitats, where local establishment could provide 'staging areas' of the species for spread to other habitats. The same could happen when infested product is stored or loaded at various destinations.
Grain for processing is in addition usually cleaned before being processed. If the product of this cleaning is released into the environment, seeds of *P. hysterophorus* and of other invasive alien plants may transfer. Such pathway of entry has been hypothetized for the introduction of *Diplanche fusca* in Turkey (Uludag & Yildirim, 2006).
When infested grain is destined for animal feed, the seeds of *P. hysterophorus* ingested by animals would be spread to suitable habitats (e.g. pastures). In the EU, millet (grains of *Panicum miliaceum*) and sorghum (grains of *Sorghum bicolor*) are not directly fed to animals. Other possibly infested cereals such as wheat or barley are expected to be fed to animals.

2.11 - The probability of entry for the pathway should be described

Moderately likely

Level of uncertainty: low

Given its past history of introduction around the world (Sushilkumar & Varshney, 2010; Wise *et al.*, 2007), primary introductions of *P. hysterophorus* are moderately likely to occur through contaminated grain.

Pathway 3: Contaminant of used machinery

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Likely

***Level of uncertainty*: low**

Agriculture machinery

Movement of *P. hysterophorus* in Australia has been strongly associated with the transport of agricultural machinery (Auld *et al.* 1983; Blackmore & Johnson, 2010). Indeed, in Australia, the seasonal shift of grain harvesting machinery accross States of Australia was identified as a major potential carrier of *P. hysterophorus* seeds. In their determination of sources of outbreaks of *P. hysterophorus* in New South Wales (Australia) Blackmore & Johnson (2010) listed harvesting machinery (grain headers) as most important. Other machinery have been assessed: cotton harvesting machinery, hay and silage making machinery, earthmoving machinery, mining and mineral exploration machinery, cars and caravans, but according to this study, none has been considered of sufficiently high risk to be actively regulated despite a small number of infestations that have been linked to some of them (Blackmore & Johnson, 2010). Although the movement of used machinery is undertaken in the same country in Australia, within the EPPO region, used machinery could be exchanged across different countries. These types of machinery are also relevant to the introduction of *P. hysterophorus* to the PRA area and this categorisation will therefore be followed here.

Parthenium hysterophorus is usually spread in mud or adhering soil by agricultural and road construction and maintenance machinery (Williamson & Faithfull, 1998) but it is likely that seed may be attached independent of soil, especially on radiators and in cabins.

In areas where it occurs, *P. hysterophorus* is commonly present along roadsides, so seeds situated on fruiting plants could become attached to machinery, or seeds situated either on the soil surface or in soil could be picked up by moving machinery.

Cattle trucks used to transport livestock in *P. hysterophorus* infested areas may potentially carry/spread seeds. For example, most of central Queensland where *P. hysterophorus* is present is a beef cattle area. Any such type of vehicle used to transport cattle (including sheep) in the infested area could potentially spread seed.

Other vehicles

Numerous references report vehicles as a pathway of introduction and spread (Li & Gao, 2012). *P. hysterophorus* is considered to have entered Bangladesh from India most probably through transport vehicles (Shabbir & Atkins, 2010).

The species was considered to have entered Papua New Guinea through second hand vehicles imported from Australia. The plant was only found in a compound where these imported vehicles were parked (Kawi & Orapa, 2010).

In Australia, mining machinery and equipment have been associated with the spread of the species, and this could also be a pathway of entry when moving such equipment across EPPO countries.

Military equipment

Military equipment (Parsons & Cuthbertson, 1982; Frew *et al.* 1996; Tamado & Milberg, 2002) comprises an additional vector to be considered. *P. hysterophorus* was first reported in Australia in 1955 near Toogoolawah in Queensland and it has been suggested that this introduction was probably the result of the movement of aircraft and machinery parts into Australia during World War II from the USA (Parsons & Cuthbertson 1992). Farmers in several regions in eastern Ethiopia believed that *P. hysterophorus* had been introduced to their area by army vehicles during the Ethiopian-Somalian war (Frew *et al.* 1996; Tamado & Milberg, 2002). In Pakistan, it is believed that *P. hysterophorus* was spread to Chitral, Hango and Swat and a frontier region of Bannu from Islamabad with the movement of military vehicles. The species is also suspected to have been introduced into Afghanistan from Pakistan through the Indus Highway with the transportation of fuel, food and equipment by NATO and the USA (Khan, 2012).

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* conditions?

Likely

***Level of uncertainty*: low**

There is legislation on the cleaning of machinery in Israel. According to the Israeli legislation, machinery should come from an area free from *Striga* spp. The machines should be sprayed with sodium hypochlorite 2% and an insecticide. The machines should be treated with methyl bromide as follows:

- If the area is not free from *Striga* spp. or if there is no declaration in the Phytosanitary Certificate for freedom from *Striga* spp., machinery should be sprayed with methyl bromide at 160 g/m^3 at 16 c.d. or above for 24 hr (but this substance is subject to restricitions in some countries).
- In situation of positive evidence with phytosanitary declaration: 64 g/m^3 at 10 c.d. or above for 12 hrs.

The inspector should ensure that the machine is free from soil and plant materials before cleaning the machine.

In Norway, when used machinery and equipment intended to be used in agriculture, forestry or horticulture is imported, an official statement must accompany the consignment stating that it has been thoroughly cleaned and if necessary disinfected and that it is free from soil, plant remains and contamination from pests. The country of export's plant inspection service, or an equivalent official agricultural authority shall issue this certification (Regulations of 1 December 2000 no. 1333 relating to plants and measures against pests).

There is no other known management practice for cleaning agricultural machinery, vehicles or military equipment in the EPPO region. However, a draft ISPM 'International movement of used vehicles, machinery and equipment' is under preparation (IPPC, 2014). Currently, no measures on machinery apply in the EPPO countries other than Norway and Israel.

While recommendations abound for the control of *P. hysterophorus* in crops (e.g. DEEDI, 2011) it is difficult to find information on the degree to which the weed is controlled in these situations. Regardless, it is notable that in Australia, infested agricultural machinery (grain headers) is the major pathway for introduction of *P. hysterophorus* from central Queensland, where it is a common weed, to New South Wales (Blackmore & Johnson, 2010).

Nguyen (2011) undertook a study on material washed off vehicles at off-road wash down facilities in 5 sites in central Queensland and identified that *P. hysterophorus* was present in the sludge at all 5 facilities with an average of 1340 seeds per tonne of dry sludge. A typical wash down facility was removing up to 4000 viable *P. hysterophorus* seeds per week.

It is therefore likely that any type of vehicle is likely to be infested by *P. hysterophorus* in countries where the species occurs, taking into account management conditions.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Moderately likely

***Level of uncertainty*: high**

The volumes of machinery are difficult to estimate.

For what concerns harvesters, sale of second-hand vehicles may sometimes occur between EU or EPPO countries, in particular through the internet, though it is considered to remain a rare phenomenon.

Vehicles circulate freely within European countries, and circulate as well among different EPPO countries, so the volume of vehicles to potentially spread *P. hysterophorus* would be high if the species would be present in a ground connected EPPO country.

The potential involvement of military equipment will be related to future geopolitical developments.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Moderately likely

***Level of uncertainty*: medium**

Vehicles and harvesters may circulate quite frequently across EPPO countries.

The movement of military equipment is dependent upon geopolitical developments.

2.07 - How likely is the pest to survive during transport or storage?

Very likely

***Level of uncertainty*: low**

P. hysterophorus present as seed is likely to survive all modes of transport and extended periods of storage.
There is evidence that seed is highly persistent during periods of dry storage. For example, seed dry-stored at 20^{O}C $\pm$ 2^{O}C demonstrated no appreciable loss of germinability over a 24 month period (Tamado *et al.*, 2002b). There is no reason to suspect that survival would differ significantly at other temperatures, provided that seed is transported or stored dry.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

Very unlikely

***Level of uncertainty*: low**

P. hysterophorus would be transported or stored (dry) as seed and would be unable to complete its life cycle in either situation.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Very likely

***Level of uncertainty*: low**

In the absence of routine machinery inspection and cleaning procedures, it is likely that *P. hysterophorus* would enter the PRA area undetected.
There is no known inspection of machinery in the EU countries, and most generally in EPPO countries, except in Israel and Norway where imported machinery is inspected (see Q. 2.04).

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Likely

***Level of uncertainty*: low**

Australian *P. hysterophorus* infestations found in paddocks, along roadsides and in the vicinity of wash-down areas have been attributed to this pathway, in both Queensland and New South Wales (Auld *et al.*, 1983; Blackmore & Johnson, 2010; Nguyen, 2011).
Infested vehicles are expected to drive on roads, sometimes in nearby agricultural fields (in particular for agricultural equipment), or natural areas. In any case, the release of seeds of *P. hysterophorus* from the vehicles on road networks may facilitate its transfer to other unintended habitats connected by roads, as observed in India (Krishnamurthy *et al*., 1977; Sushilkumar & Varshney, 2010: Ramachandra Prasad *et al*., 2010a).

2.11 - The probability of entry for the pathway should be described

Likely

***Level of uncertainty*: low**

Given evidence of a history of introduction via machinery (Parsons & Cuthbertson, 1982; Tamado & Milberg, 2002), it is considered to be moderately likely.

Pathway 4: Contaminant of soil

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Likely

***Level of uncertainty*: medium**

In India, *P. hysterophorus* is seen spreading through transportation of soil for the purpose of filling road sides and other purposes (Krishnamurthy *et al*., 1977; Ramachandra Prasad *et al*., 2010a).

In studies undertaken in Australia, the germinable soil seed bank comprised between 3 284 to 44 639 seeds per m² (Navie *et al*., 2004). Navie & Tamado (2002) found a density of 6 332 seeds perm², which is very similar to Nguyen (2011) who found a density of 6 387 seeds per m². In the infested areas, soil to be traded as a commodity is likely to be infested by seeds as *P. hysterophorus*, as the plant occurs in a wide range of habitats where soil could be taken.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* conditions?

Very likely

***Level of uncertainty*: low**

There are no management practices for soil. Soil sterilization could kill the seeds, but this is neither required nor done and would not be economically feasible.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Unlikely

***Level of uncertainty*: high**

Movement of soil from countries where *P. hysterophorus* occurs is expected to be low as countries where *P. hysterophorus* occur are too far for the importation of soil to be practical. However, there are no data available on this point.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Unlikely

***Level of uncertainty*: high**

Movement of soil from countries where *P. hysterophorus* occurs is expected to be quite infrequent and rare, but there are no available data on this point.

2.07 - How likely is the pest to survive during transport or storage?

Very likely

***Level of uncertainty*: low**

P. hysterophorus present as seed is likely to survive all modes of transport and extended periods of storage, in particular in soil.

There is evidence that seed is highly persistent during periods of dry storage. For example, seed dry-stored at 20°C ± 2°C demonstrated no appreciable loss of germinability over a 24 month period (Tamado *et al.*, 2002b). There is no reason to suspect that survival would differ significantly at other temperatures, provided that seed is transported or stored dry.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

Very unlikely

***Level of uncertainty*: low**

P. hysterophorus is a plant and would be unable to complete its life cycle during transport or storage.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Likely

***Level of uncertainty*: medium**

The seeds of *P. hysterophorus* are brown and very small and are expected to remain undetected in soil.

However, according to the Directive 2000/29 (point 14 of annex III, part A), soil or growing media introduced from Turkey, Belarus, Moldavia, Russia, Ukraine and third countries not belonging to continental Europe, other than Cyprus, Israel, Libya, Morocco and Tunisia is prohibited of import in the EU. There are no specific requirements for soil or growing media coming from authorised countries (Cyprus, Israel, Libya, Morocco, Malta and Tunisia). Soil is unlikely to be imported from other continents (European Union, 2010, amended Council Directive 2000/29/EC of 8 May 2000).

In other EPPO countries, import of soil is prohibited.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Likely

***Level of uncertainty*: low**

Seeds in soil will be able to germinate where the soil will be transported.

2.11 - The probability of entry for the pathway should be described

Unlikely

***Level of uncertainty*: medium**

Considering that countries where *P. hysterophorus* occurs are very distant from the EPPO region, the pathway of soil is expected to be almost nonexistent, and the probability of entry of *P. hysterophorus* along this pathway is therefore considered as unlikely.

Pathway 5: Contaminant of growing media attached plants for planting

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Moderately likely for plants produced indoors, likely for plants produced outdoors

Level of uncertainty: **medium**

P. hysterophorus is considered to spread locally as a contaminant of potting mix/soil associated with the movement of ornamental plants (trade) in Pakistan (Shabbir *et al*., 2013). The species has also been reported to enter Kashmir in India from Poona (where it was initially observed) along with some Jasmine rooted cuttings (Hakoo, 1963 in Anonymous, Undated).

P. hysterophorus would be able to form large stands in and around production areas, producing large amounts of seeds spread by wind and water. Production material such as machinery could be infested as well.

Trees and potted plants production nurseries

There are reports of nurseries infested with *P. hysterophorus* in countries where the species occurs. As the plant produces seeds in summer which are spread by wind and are viable for at least 7 years, it is likely that the growing media of plants for planting can contain seeds of *P. hysterophorus*.

Protected production nurseries

Bulk media prepared outdoors, then used for plants produced indoors (e.g. vegetables) would be moderately likely to be infested as well. Growing media is rarely steamed. Any type of growing media, even inorganic, could be infested, and the seeds would wait for suitable conditions and growing media to germinate.

The risk for plants produced in glasshouses is considered to be moderately high as contamination of the growing media would only occur when it is outdoors, not during the plant production in glasshouses.

Irrigation could favour the contamination of a growing medium with seeds of *P. hysterophorus*, in particular if the stock of water is in open air. However, the viability of seeds in water is unknown.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* **conditions?**

Moderately likely

***Level of uncertainty*: medium**

Although the species could be quite easily controlled with targeted sprays of herbicides, it is usually uncommon to use herbicides in nurseries in this way.

Trees and potted plants production nurseries

Trees may stay in production for a few years.

In nurseries, weeding could be done manually, mechanically or weeds controlled through chemicals. As *P. hysterophorus* would germinate the following year, some plants would be removed, but not all seeds would be expected to have germinated.

Protected production nurseries

Vegetables are in production for only weeks to months, though some seeds of *P. hysterophorus* infesting the growing media may germinate and be removed. However, as the production time is short, some seeds may not have the time to germinate and could remain in the growing media.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Moderately likely

***Level of uncertainty*: medium**

According to AIPH (2008), fruits trees and shrubs are imported into the EU, and these may have some growing media attached infested with seeds of *P. hysterophorus*.

AIPH provides values of import, but no figures of unit numbers of plants imported. In 2007, amounts of 906 000 € are imported in the EU from European countross (non EU), 1 046 000 € from Africa, 352 000 € from Asia (excluding the Middle East), 303 000 € from the Middle East, 636 000 € from North America and 738 000 € from Latin America.
The Expert Working Group considered that there is movement along the pathway, and assessed it a moderately likely to support entry, with a medium uncertainty.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Moderately likely

***Level of uncertainty*: high**

There are no figures of frequency of movement of growing media attached to plants available, but such movement may occur all year long.

2.07 - How likely is the pest to survive during transport or storage?

Very likely

***Level of uncertainty*: low**

P. hysterophorus present as seed is likely to survive all modes of transport and extended periods of storage.
The seed will be transported in soil and remains viable many months.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

Very unlikely

***Level of uncertainty*: low**

P. hysterophorus would be unable to complete its life cycle during transport or storage.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Very likely

***Level of uncertainty*: low**

The current requirements of the EU Plant Health Directive do not cover specifically seeds in growing media. Though, the Directive 2000/29 (European Union, 2010) requires that plants for planting coming from Turkey, Belarus, Georgia,, Moldova, Russia, Ukraine, and other non European countries other than Algeria, Egypt, Israel, Libya, Malta, Morocco, and Tunisia be at the time of planting: free from soil and organic matter or were subject to appropriate heat treatment or fumigation against pests (thermic treatment or fumigation, which may be efficient against seeds of *P. hysterophorus*).

In Turkey, although there are some checks for certain pests, plants and seeds are not explicitely mentioned. In Russia, introduction of plants with soil is restricted.

Seeds (2 mm or less) are not visible in the growing media and they may remain undetected.
In EU, as *P. hysterophorus* is not regulated, phytosanitary measures would not apply and seeds may be present in plants for planting with growing media attached coming from countries where it occurs.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Likely

***Level of uncertainty*: low**

Plants for planting will be planted in suitable habitats for *P. hysterophorus*. Indeed, ornamental plants may be planted in gardens or on road sides and public areas. Plants of vegetables will be planted in glasshouses, fields or gardens.
All of these habitats are suitable for the plant to establish and to transfer to further suitable habitats.
Seeds of *P. hysterophorus* may germinate and produce other seeds and would be further spread by wind, water, animals, machinery, etc.

2.11 - The probability of entry for the pathway should be described

Moderatley likely

***Level of uncertainty*: medium**

Although the pathway of infested growing media attached to plants for planting has only been reported for local spread, the probability of entry with this pathway is considered moderate.

Pathway 6: Contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Moderately likely

***Level of uncertainty*: high**

Seed dispersal in mud adhering to human footwear has been observed in Sri Lanka (Jayasuriya, 2005).

In infested areas, the soil of fields, gardens, road sides, pastures, waste lands, etc. can be infested with high numbers of seeds. Seeds are less than 2 mm and could be present on travellers' foot wear, as well as in their clothes and luggage.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* conditions?

/

***Level of uncertainty*: /**

Not relevant.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Likely

***Level of uncertainty*: medium**

There is no data available, the volume of people travelling is considered to be high. There is an estimated 700 million people crossing international borders as tourists each year (McNeely, 2006).

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Likely

***Level of uncertainty*: medium**

No data available, the frequency of people travelling is considered to be high.

2.07 - How likely is the pest to survive during transport or storage?

Very likely

***Level of uncertainty*: low**

P. hysterophorus present as seed is likely to survive all modes of transport and extended periods of storage.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

Very unlikely

***Level of uncertainty*: low**

P. hysterophorus would be unable to complete its life cycle during transport or storage.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Very likely

***Level of uncertainty*: low**

No measures are in place for soil as a contaminant on travellers' footwear or other things carried or worn.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Moderately likely

***Level of uncertainty*: high**

Footwear could spread the plant on roadsides, fallowlands, etc. which are suitable habitats for the species.

The probability of transfer from infested clothes or luggage is lower than for footwear.

2.11 - The probability of entry for the pathway should be described

Moderately likely

***Level of uncertainty*: high**

The probability of entry of *P. hysterophorus* as a contaminant of travellers and their luggage is considered as moderately likely.

Pathway 7: Hitchhiker on fruits, vegetables, timber, packing material, etc.

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

Unlikely

***Level of uncertainty*: high**

P. hysterophorus is supposed to have been introduced in Melsiripura in Sri Lanka through seeds contaminating chillies from India. It may also have entered Sri Lanka as seeds contaminating mustard imported from India, and as seeds contaminating condiments from India (Jarasuriya, 2005). The species is also believed to have been introduced into Kashmir through timber piles from Dandeli in Karnataka in India (Maheshwari, 1968).
P. hysterophorus has also been found as a contaminant on packing material (Parson & Cuthbertson, 1992).

Commodities could potentially be infested with seeds spread through wind. However, this remains unlikely.

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* conditions?

Moderately likely

***Level of uncertainty*: high**

There are no specific current management practices in place to detect and remove small seeds of *P. hysterophorus* on commodities.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

Likely

***Level of uncertainty*: medium**

The volume of all potentially infested commodities (e.g. vegetables, fruits, timber, etc.) produced in countries where *P. hysterophorus* occurs and imported into the EPPO region is massive.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

Likely

***Level of uncertainty*: medium**

All potentially infested commodities (e.g. vegetables, fruits, timber, etc.) produced in countries where *P. hysterophorus* occurs are imported frequently into the EPPO region.

2.07 - How likely is the pest to survive during transport or storage?

Very likely

***Level of uncertainty*: low**

P. hysterophorus present as seed is likely to survive all modes of transport and extended periods of storage.
There is evidence that seed is highly persistent during periods of dry storage. For example, seed dry-stored at $20^{O}C \pm 2^{O}C$ demonstrated no appreciable loss of germinability over a 24 month period (Tamado *et al.*, 2002b). There is no reason to suspect that survival would differ significantly at other temperatures, provided that seed is transported or stored dry.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

Very unlikely

***Level of uncertainty*: low**

P. hysterophorus would be unable to complete its life cycle during transport or storage.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

Very likely

***Level of uncertainty*: low**

There are no phytosanitary measures in place to detect *P. hysterophorus*, and the seeds a very small (less than 2 mm) and very likely to remain undetected.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Unlikely

***Level of uncertainty*: high**

Despite the large range of commodities on which hitchhiking could occur, it is considered that few of them would support the transfer to a suitable habitat as potentially infested items may most likely be trashed.

2.11 - The probability of entry for the pathway should be described

Unlikely

***Level of uncertainty*: high**

It is considered unlikely that *P. hysterophorus* would enter as a hitchhiker.

Stage 2: Pest Risk Assessment Section B: Probability of establishment

Select the factors that may influence the limits to the area of potential establishment and the suitability for establishment within this area.

For each question which was answered with a "yes", detailed information is provided after the table.

No.	Factor	Is the factor likely to have an influence on the limits to the area of potential establishment?	Is the factor likely to have an influence on the suitability of the area of potential establishment?	Justification
1	**Suitable habitats (see note for Q3.01)**	**Yes (see 3.01)**	**Yes (see 3.09)**	
2	**Alternate hosts and other essential species**	**No**	**No**	*P. hysterophorus* does not require specialised pollinators in order to reproduce. Gupta & Chanda (1991) reported that *P. hysterophorus* is most likely either entomophilous (insect-pollinated) or amphiphilous (pollen dispersed mainly by insects and partially by wind). However, Seetharamaiah *et al.* (1981) surveyed the air-borne pollen in Bangalore over a year and reported that the pollen of *P. hysterophorus* is wind-borne in significant amounts either as individual grains or as pollen clusters. The highest incidence of *P. hysterophorus* pollen (up to 48% of the total pollen count) was observed during June-September, during the main growing season of the plant. Insects reported to visit *P. hysterophorus* flowers include honeybees, ants, house flies and other dipterans (Gupta & Chanda, 1991), none of which are specialised pollinators.
3	**Climatic suitability**	**Yes (see 3.03)**	**Yes (see 3.11)**	
4	**Other abiotic factors**	**No**	**Yes (see 3.12)**	*P. hysterophorus* prefers neutral to alkaline pH soils, but tolerates a wide variety of soil types (Navie *et al.*, 1996a; Annapurna & Singh, 2003).
5	**Competition and natural enemies**	**No**	**Yes (see 3.13)**	*P. hysterophorus* is a weak competitor (Asha Kumari *et al.*, 2010). Competition and natural enemies will not affect the limit of its potential range, but may have an influence on the suitability of the area.
6	**The managed environment**	**Yes (see 3.06)**	**Yes (see 3.14 / 3.15)**	
7	**Protected cultivation**	**Yes (see 3.07)**	**No**	*P. hysterophorus* is reported in glasshouses, but would only be reported to persist within the glasshouse environment. Survival within a glasshouse only affects the limit of the range.

Suitable habitats

3.01 - Identify and describe the area where the host plants or suitable habitats are present in the PRA area outside protected cultivation.

P. hysterophorus is a pioneer species that can invade grazing land, cultivated areas and in particular summer crops which are the most at risk due to the phenology of *P. hysterophorus*, as well as disturbed areas, roadsides, recreation areas, river banks and floodplains. According to the Corine Land Cover nomenclature, the following habitats are invaded: arable land, permanent crops (e.g. vineyards, fruit tree and berry plantations, olive), pastures, riverbanks / canal sides (dry river beds), road and rail networks and associated land, other artificial surfaces (wastelands).

As land use is a major determinant of the occurrence and abundance of *P. hysterophorus*, details are provided below for its occurrence with different land uses. Where information is available for the impacts of *P. hysterophorus* in these land uses, this is provided at 6.01 and 6.08.

Cropping, dryland

P. hysterophorus is recorded as infesting a broad range of dryland crops. It has been reported from grain sorghum (*Sorghum bicolor*) (Navie *et al*., 1996a; Tamado & Milberg, 2004), sunflower (*Helianthus annuus*) and wheat crops (*Triticum* spp.) in Australia (Navie *et al*., 1996a; Australian Weeds Committee, 2012), but also cereal crops, cotton (*Gossypium hirsutum*), maize (*Zea mais*), pearl millet (*Pennisetum glaucum*), oil seeds, potato (*Solanum tuberosum*), pulses (*Fabaceae*), soybean (*Glycine max*) (Basappa, 2005; Kandasamy, 2005; Sushikumar & Varshney, 2010), vegetables and fruits such as curcuma (Anwar *et al*., 2012) in Pakistan (Javaid & Anjum, 2005). The plant has also been reported in oil seed crops in Bijapur Districts of Karnataka (Patil, 1997 in Sushilkumar & Varshney, 2010). In Bangladesh, *P. hysterophorus* has also been reported invading potato (*Solanum tuberosum*), pea (*Pisum sativum*), bottle gourd (*Lagenaria siceraria*), mustard (*Brassicaceae*) and onion (*Allium cepa*) (Hossain, 2012), as well as in Tef (*Eragrostis tef*) in Ethiopia, which provides a significant proportion of the national food (Tefera, 2002).

Cropping, irrigated

Annual crops

P. hysterophorus is recorded in cotton (*Gossypium hirsutum*), pineapple (*Ananas comosus*), rice (*Oryza sativa*), sorghum (*Sorghum bicolor*) and tomato (*Lycopersicum esculentum*) in India (Channappagoundar *et al*., 1990; Kandasamy, 2005) and sugarcane (*Saccharum* sp.), onion (*Allium cepa*), cucumber (*Cucumis sativus*), bitter gourd (*Momordica charantia*) (Shabbir *et al*., 2013) and watermelon (*Citrullus lanatus*), in Pakistan (Javaid, 2007). In Israel, *P. hysterophorus* is recorded in tomato, cotton and forage fields (Joel & Liston, 1986, Rubin *et al*., 2012).

In Karnataka (India), the species has also been recorded in finger millet (*Eleusine coracana*), groundnut (*Arachis hypogaea*), tobacco (*Nicotiana tabacum*) (Ramachandra Prasad, 2010b). Yaduraju *et al*. (2005) also report the presence of *P. hysterophorus* in garlic (*Allium sativum*), eggplant (*Solanum melongena*), beans and capsicum (*Capsicum* sp.). In Kerala (India), it has been reported in vegetables (Abraham & Girja, 2005).

In Guangxi (China), *P. hysterophorus* is reported in eggplant fields, bank of paddy field, sugarcane, maize (*Zea mays*) and Vigna field (*Vigna unguiculata*) (Tang, 2012). In the Shandong Province in China, the species is found in great abundance in peanut, cotton, potato and maize fields (Li & Gao, 2012).

Perennial crops

In Israel, *P. hysterophorus* is recorded in alfalfa (*Medicago sativa*) and clover (*Trifolium* sp.) (Joel & Liston, 1986, Rubin *et al*., 2012).

In Kerala (India), it has been reported in banana (*Musa* sp.), cardamom and ginger (*Zingiber officinale*) (Abraham & Girja, 2005).

P. hysterophorus is a weed in Western Colombian fruit orchards. It is also a weed of grapes (*Vitis vinifera*), coconut (*Cocos nucifera*), areca nut (*Areca catechu*), mango (*Mangifera indica*), mulberry (*Morus* sp.), citrus and other orchard crops in India (Kandasamy, 2005; Sushilkumar & Varshney, 2010; Sushilkumar, 2012; Ramachandra Prasad, 2010b; Ramachandra Prasad, Pers. Comm., 2013), citrus and falsa (*Grewia asiatica*) and dates (*Phoenix dactylifera*) in Israel (T. Yaacoby, pers. obs, 2013). In the Kasur district in Pakistan, *P. hysterophorus* infested fields of curcuma (*Curcuma longa*) at all stages of the crop (Anwar, 2012).

Pasture: dryland, grassland and rangeland

P. hysterophorus is recorded as infesting dryland pastures and/or rangeland in Australia (Navie *et al*., 1996a), Ethiopia (Ayele, 2007), India (Sushikumar & Varshney, 2010), Nepal (Timsina *et al*., 2010), the USA (Ruddy & Bryson, 2005) and Pakistan (Khan, 2012).

Natural environments

P. hysterophorus is recorded in sal (*Shorea robusta*) forest and Pench National Park of Madhya Padesh in India (Sushikumar & Varshney, 2010). This specific habitat is not present in the EPPO area, but other types of forests are present. *P. hysterophorus* is also found in riparian zones (Lawes & Grice, 2010) and in native grassland communities in Australia (Navie *et al*., 1996a; Fensham, 1999) and in Nepal (Timsina *et al*., 2011), and similar habitats are present in the EPPO region.

Transport corridors

P. hysterophorus occurs along roadsides and railway tracks in Australia (Navie *et al*., 1996a), India (Lakshmi & Srinivas, 2007) and canal banks in India (Lakshmi & Srinivas, 2007).

Wastelands

P. hysterophorus occurs in wasteland throughout its range worldwide (e.g. Dale, 1981; Navie *et al*., 1996a; Javaid, 2007; Lakshmi & Srinivas, 2007).

Details on the EUNIS habitats where the pest occurs are provided in Appendix 1.

Pastures as well as suitable annual (e.g. tomato, eggpalnts, capsicum, maize, garlic, beans, and potato) and perennial (e.g. alfalfa, clover, fruits orchards, graps, citurs, dates) crops are widely grown in the whole Mediterranean area of the EPPO region, as well in the warmest parts of the temperate area.

Climatic suitability

3.03 - Does all the area identified as being suitable for establishment in previous question(s) have a suitable climate for establishment?

Yes

P. hysterophorus has a maximum photosynthetic response at temperatures between 25-30°C, and a temperature optimum at 28°C (Doley, 1977). Pandey *et al*. (2003) found maximum photosynthetic response to temperature at 25-35°C, while the net photosynthetic rate was reduced considerably at 7°C. Excessive increase in transpiration with temperature, especially at 47°C (noon temperature during summer in the plains of northern India) appears to be disadvantageous for the leaves when conservation of water is of prime importance. In warmer climates it is capable of completing 2-3 life cycles in a year if rainfall is suitably distributed (Pandey *et al*., 2003; Kandasamy, 2005; Fatimah & Ahmad, 2009). *P. hysterophorus* is best suited to areas with an annual summer rainfall greater than 500 mm (Chamberlain & Gittens, 2004).

McConnachie *et al*. (2010) performed a climatic projection using CLIMEX for *P. hysterophorus*. While their main focus was Africa, their geographical projection indicated that in the EPPO region, the Mediterranean Basin (Algeria, Croatia, France, Greece, Israel, Italy, Morocco, Spain, Tunisia, Turkey, etc.) is at risk from the species. It should be noted in this evaluation that a hot/dry stress parameter was used (among other factors). This climatic projection was therefore considered to underestimate the potential distribution of *P. hysterophorus* in Mediterranean climates (Macconnachie *et al*., 2010). It should be noted that *P. hysterophorus* has for a long time (since 1980) occurred in the Mediterranean climate in Israel (Dafni & Heller, 1982).

Worldwide, *P. hysterophorus* is predominantly a weed of agriculture in areas with a distinct wet/dry season climate (Dhileepan & McFadyen, 2012), as is found in the Mediterranean Basin. However, given that the weed is adapted to a warm wet season, cool conditions during the growing season can be expected to be suboptimal.

P. hysterophorus also occurs in semi-arid conditions in Israel in the Jordan and Bet Shean valleys and even in areas at 210 m below sea level (Joel & Liston, 1986, Rubin *et al*. 2012) and as high as 2600 m in Bhutan, Ethiopia, India and Pakistan. In southern regions of Pakistan, *P. hysterophorus* is found under a very hot and dry climate, resembling that where it occurs in Israel (A Shabbir, personal observations). Its occurrence in Oman (Kilian *et al*., 2002) and Yemen (Alhammadi, 2010) further demonstrates its tolerance of extremes in both temperature and humidity availability.

P. hysterophorus is able to establish and persist in cooler areas (although perhaps at relatively low abundances) even where very cold winters occur, as evidenced by its current distribution in North America (Reddy & Bryson, 2005). In cold temperate regions it overwinters as seed and behaves strictly as a summer annual (Dale, 1981; Reddy & Bryson, 2005). However, in contrast to its behaviour under the warm, summer-wet climates to which *P. hysterophorus* is well-adapted (Chamberlain & Gittens, 2004), it is not able to complete more than one life cycle per year in North America, except in Texas and Florida (Reddy & Bryson, 2005).

Analogous situations are expected to exist in other areas than the Mediterranean Basin within the EPPO region.

While abundant over large areas of Australia, *P. hysterophorus* does not occur in New Zealand (New Zealand Virtual Herbarium Website). Based on an analysis using BIOCLIM, Panetta & Mitchell (1991) concluded that relatively low summer temperatures could contribute to this absence. In most cases, the mean maximum temperature of the warmest month for New Zealand locations was considerably lower than the minimum for this parameter in the climate profile for *P. hysterophorus* (28.2°C) (Panetta & Mitchell, 1991).

The managed environment

3.06 Is all the area identified as being suitable for establishment in previous questions likely to remain unchanged despite the management of the environment?
P. hysterophorus is recorded in irrigated crops (cotton, pineapple, rice, sorghum and tomato in India according to Krishnamurty *et al*., 1977; Channappagoundar *et al*., 1990; Kandasamy, 2005) and sugarcane, onion, cucumber, bitter gourd (Shabbir *et al*., 2013) and watermelon, in Pakistan (Javaid, 2007). Irrigation in arid areas may allow the establishment of the species and therefore increase its potential distribution. Irrigation would render areas suitable for establishment, as has been observed in southern Pakistan (Shabbir, 2012).

However, its distribution and abundance may be affected markedly by land use, since it favours open habitats subject to a relatively high frequency of disturbance (Navie *et al*., 1996a; Dale, 1981). Closed vegetation that experiences low levels of disturbance will not be suitable for establishment. This perhaps explains why *P. hytserophorus* is found in extremely wet regions such as Bangladesh under conditions that are apparently unsuitable in its native range in South America (see Appendix 2 on climatic modelling).

Protected Cultivation

3.07 Are the hosts grown in protected cultivation in the PRA area? If the pest is a plant, has it been recorded as a weed in protected cultivation elsewhere?
P. hysterophorus is occurring in glasshouses in India (Prof. Ramashandra Prasad, pers. comm., 2013, see Appendix 3 for pictures) and off-season vegetable growing tunnels in Pakistan (Shabbir, pers. comm., 2013).
The species could therefore occur in glasshouses in the whole EPPO region. Though, weeds can easily be managed in glasshouses.

3.08 - By combining the cumulative responses to previous questions with the response to question 3.07, identify the part of the PRA area where the presence of host plants or suitable habitats and other factors favour the establishment of the pest.

The Mediterranean Basin, the warmest parts of the temperate area and glasshouses are the parts of the PRA area where *P. hysterophorus* could establish.

Host plants and suitable habitats
See Appendix 1 for a detailed list of EUNIS habitats where *P. hysterophorus* could establish.

The crops and habitats at risk are the following (following the Corine landcover classification):

- Annual crops associated with permanent crops
- Construction site
- Dump sites
- Estuaries
- Fruit trees and berry plantations
- Green urban areas
- Natural grasslands
- Non irrigated arable land
- Olive groves
- Pastures
- Permanently irrigated arable land
- Roads and rail networks and associated land
- Sparsely vegeted areas
- Vineyards
- Water courses
- Glasshouses

3.09 - How likely is the distribution of hosts or suitable habitats in the area of potential establishment to favour establishment?

Likely

***Level of uncertainty*: low**

Dry land cropping and grazing are both common land use types throughout the Mediterranean region and *P. hysterophorus* is expected to be able to establish in these habitats.
It is considered that *P. hysterophorus* could establish in irrigated systems, but in some circumstances it will not achieve high densities owing to a high level of interspecific competition under well-watered conditions.

Climatic suitability

3.11 - Based on the area of potential establishment already identified, how similar are the climatic conditions that would affect pest establishment to those in the current area of distribution?

Moderately similar

***Level of uncertainty:* low**

While CLIMEX modelling by McConnachie *et al*. (2010) suggests that the Mediterranean Basin may be suitable to *P. hysterophorus*, this region differs from most of the weed's current distribution in that it has a predominantly winter-dominant rainfall regime, whereas *P. hysterophorus* grows best under high temperatures (25-35°C; Annapurna & Singh, 2003) and is currently most abundant in areas where rainfall is summer-dominant (Chamberlain & Gittens, 2004).
According to Agriculture & Resource Management Council of Australia & New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers (2001), the species is unlikely to become a major weed in winter-rainfall areas as seedling growth is reduced when night temperature falls below 5°C, although established plants are able to withstand at least one night frost (-20°C). These statements are nevertheless not based on any solid projection.

According to the CLIMEX projection performed during the EWG, the countries at risk are the following:
Albania, Algeria, Azerbaijan, Bosnia & Herzegovina, Bulgaria, Cyprus, Croatia, Former Republic of Macedonia, France,

Greece, Hungary, Israel, Italy, Jordan, Kazakhstan, Kyrgyzstan, Malta, Moldova, Morocco, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Tunisia, Turkey, Ukraine and Uzbekistan, as shown in Figure 2.
The highest risk is considered to exist in Algeria, Israel, Jordan, Morocco, Spain, Tunisia and Turkey.

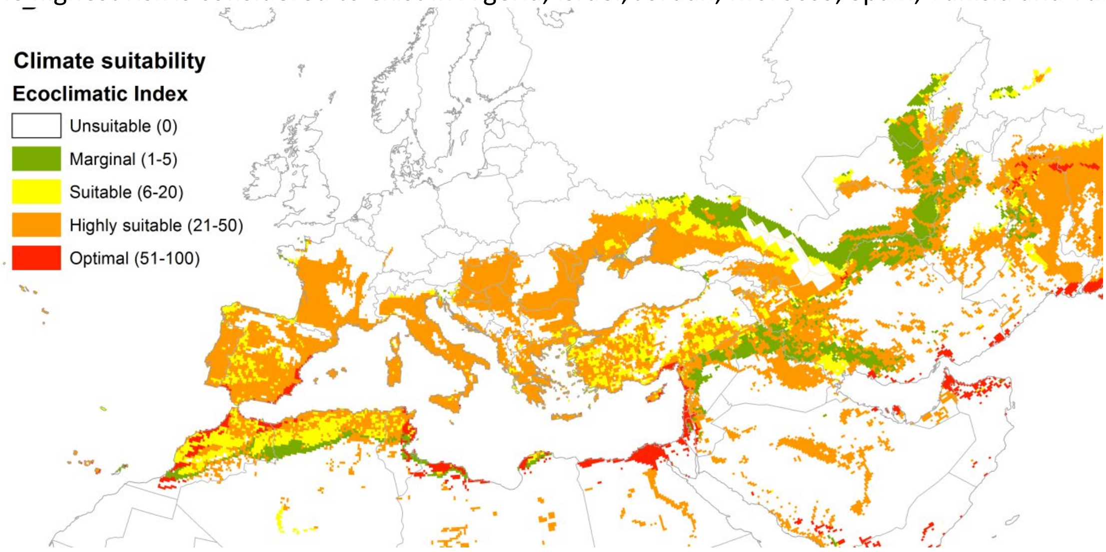


Figure 2. Climate suitability for *Parthenium hysterophorous* modelled using CLIMEX with the CM10_1975H_WO_V1.1 climate dataset (Kriticos *et al*., 2012), including the effect of irrigation (Siebert et al., 2005) in Europe and North Africa.

Under the climate change scenario explored here, the modelled pest risks from *P. hysterophorus* extend poleward over longer periods compared with the current climate risks (Figure 3). Within the EPPO region, many countries that are incapable of supporting established populations of *P. hysterophorus* may become at risk of becoming climatically suitable in the future due primarily to rising temperatures (Austria, Belarus, Belgium, the Czech Republic, Germany, Estonia, Latvia, Lithuania, the Netherlands, Poland, Slovenia, the United Kingdom, as well as larger parts of Bosnia and Herzegovina, Hungary, Kazakhstan, Moldova, Russia, Slovakia, Switzerland, Turkey, Ukraine, the southern coast of Sweden).

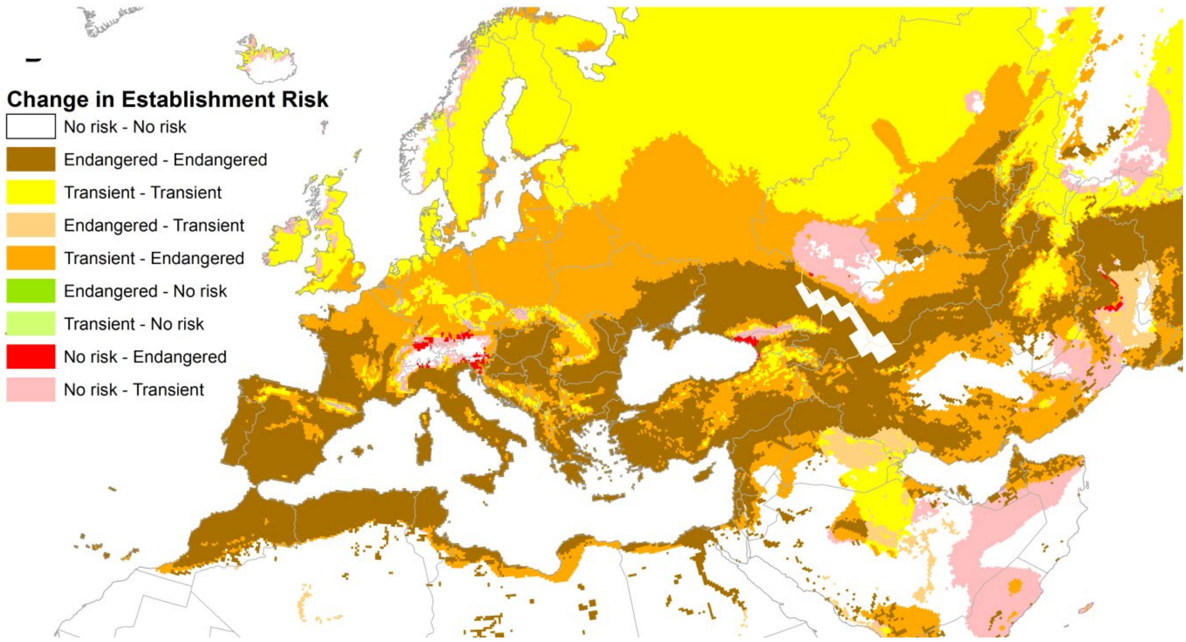


Figure 3 – Future climatic establishment risk scenario simulated using the CM10_2070_CS_A2_V1.1 climate scenario. Further details on the parameters used for the climatic projection are provided in Appendix 2.

Glasshouses all over the EPPO region are suitable as well for the establishment of *P. hysterophorus*. Though, weeds can easily be managed in glasshouses.

Other abiotic factors

3.12 - Based on the area suitable for establishment already identified, how similar are other abiotic factors that would affect pest establishment to those in the current area of distribution?

Similar

***Level of uncertainty*: medium**

P. hysterophorus has demonstrated a marked preference for black, alkaline, cracking clay soils of high fertility but will grow on a wide variety of soils (Dale, 1981; Navie *et al*. 1996a). Acidic soils therefore appear to be less suitable for the establishment of the species.

Germination can occur in a wide range of soil pH (from 2.5 to 10) but the optimum pH for germination is between 5.5 to 7.0 (Muniyappa & Krishnamurthy, 1977, cited in Kandasamy, 2005). Alkalinity may suppress weed growth, but seed production remains unaffected (De & Mukhopadhyay, 1983). There is an uncertainty on the soil tolerance of the species in the literature.

Annapurna & Singh (2003) have experimentally demonstrated various changes in the weed's phenology, growth dynamics, biomass partitioning and reproductive traits that occur with changes in soil texture, allowing *P. hysterophorus* to establish and persist on a range of soil types.

In India, the species is not present in lateritic soils (Krishnamurthy *et al*., 1977; Ramachandra Prasad *et al*., 2010a)) which are acidic and where bases are leached out under high rainfall conditions. Lateritic soils are reported in central Europe, and these would therefore be less favorable for the establishment of the species.

In the area where the species would be expected to establish, topsoil pH is either neutral to alkakine (see the soil pH map of the world based on HWSD: http://www.globalsoilmap.net/content/soil-ph-map-world-based-hwsd). Soils occurring in the area are therefore similar to those where *P. hysterophorus* occurs, and soils are not considered to influence the suitability of the area of establishment.

Competition and natural ennemies

3.13 Based on the area of potential establishment, how likely is it that establishment will occur despite competition from existing species, and/or despite natural enemies already present?

Highly likely

***Level of uncertainty*: low**

Competition

Interspecific competition is one of the major factors regulating the abundance of *P. hysterophorus*. Asha Kumari *et al*. (2010) considered that *P. hysterophorus* is a weak competitor. Nevertheless, allelopathic effects on various other plant species have been observed in laboratory experiments (Batish *et al*., 2002). In addition, chemicals contained in *P. hysterophorus* such as phenolics and sequiterpene, in addition to pollen allelopathy are supposed to have decreased growth of other vegetation such as *Lagascea mollis, Bidens pilosa, Sida acutangula*, etc. (Akter & Zuberi, 2009; Ramachandra Prasad *et al*., 2010b).

However, *P. hysterophorus* thrives under conditions of frequent disturbance, which tends to reduce the role of competition in vegetation dynamics (Grime, 1979).

In areas where the use of herbicides is not economical, one option to manage this weed is the use of competitive plants to suppress and displace it (Joshi, 1991; Kandasamy & Sankaran 1997; O'Donnell & Adkins, 2005; Khan *et al*., 2013; Sushilkumar, 2009; Shabbir *et al.,* 2013). Asha Kumari *et al*. (2010) showed for instance that plant species such as *Senna uniflora* and *Hyptis suaveolens* may be effective in managing *P. hysterophorus*. Although these sepcies are not native and not known to occur in the area of establishment, and the possible similar effects of other species are unknown.

In grazing areas, management of *P. hysterophorus* can be achieved by maintaining high levels of pasture grass growth to maximise competition against the weed. Pasture cover and composition are the key factors that influence the density of *P. hysterophorus* present in native pastures in Australia (Dhileepan & Strathie, 2009) and rangelands elsewhere (Ayele, 2007). *Stylosanthes hamata*, forage legume can be used to ground cover and gradually suppress *P. hysterophorus* in orchards, plantation crops, road sides, etc. (Ramachandra Prasad *et al*., 2010b).

Accordingly, the suitability of sites for *P. hysterophorus* within the area of potential establishment will vary markedly, both spatially and temporally.
However, competition is not expected to influence significantly the suitability of the area in any permanent sense.

Natural enemies
No natural enemies of *P. hysterophorus* are known to occur within the PRA area. While classical biological control has been effectively employed against this weed elsewhere in the world (Dhileepan & McFadyen, 2012), in the absence of intentionally introduced agents the distribution and abundance of *P. hysterophorus* in its exotic range have generally been determined by other factors, such as climate, soils and disturbance regimes (land use).
Epiblema strenuana is reported as an efficient biological control agent against *P. hysterophorus* (Florentine *et al*., 2005), and occurs in Israel (Yaacoby & Seplyarsky, 2011), but so far in a different area. The presence of this species may limit the establishment of *P. hysterophorus* in Israel, but this species is not known to occur in other EPPO countries.
If biological control agents against *Ambrosia artemisiifolia* would be released in Europe, some of them such as *Zygogramma bicolorata* could limit the establishment of *P. hysterophorus*.

The managed environment

3.14 - How favourable for establishment is the managed environment in the area of potential establishment?
Highly favourable
***Level of uncertainty*: low**
Roadside maintenance and construction works
P. hysterophorus can be expected to be well-adapted to the disturbance regimes of managed environments in the area of potential establishment. Since *P. hysterophorus* commonly spreads rapidly along roadsides, railways and canals wherever it occurs (Auld *et al*., 1983; Lakshmi & Srivinas, 2007), it is likely to spread along such infrastructure if not controlled. For example, it will benefit from roadside maintenance activities, such as grading and mowing. Some farmers in eastern Ethiopia believed that *P. hysterophorus* had been introduced during the course of road construction (Tamado & Milberg, 2002).

Agricultural practices
Irrigation increases the suitability of areas which would otherwise be too dry for the species to establish (southern Pakistan, India, etc.).
Elsewhere in the world, *P. hysterophorus* is a persistent weed of crops and pastures. Under typical management regimes of cropping, opportunities for establishment of *P. hysterophorus* will arise through disturbance imposed by cultivation.
P. hysterophorus is reported to grow luxuriantly in orchards in India due to the less frequent weeding practices in such ecosystems (Susilkumar, 2012). Tillage and cultivation and the extensive use of herbicide are considered to have limited the abundance of *P. hysterophorus* in the USA (Reddy & Bryson, 2005).
In pastures, gaps in vegetative cover (i.e. opportunities for establishment) will occur via activities of grazing animals, as well as through the effects of drought. The presence of disturbance created by cultivation would also increase the potential for establishment, especially when there is a fallow period in between crops.

Because the agricultural product contamination and infested machinery pathways are so effective for this weed (see 2.01a), it is expected that whatever the broad landscape scale distribution of these land uses, *P. hysterophorus* will colonise and establish in any sites to which these pathways lead.

Management practices commonly associated with agricultural production (e.g. irrigation, disturbances, use of vehicles) and corridor (e.g. roadside) maintenance in the potential area of establishmentcan are expected to have a very large influence on the suitability of the area for the establishment of *P. hysterophorus*. Though, the extensive use of herbicides would reduce this suitability.

3.15 - How likely is the pest to establish despite existing pest management practice?
Likely
***Level of uncertainty*: low**

P. hysterophorus is primarily controlled in cropping situations with the use of herbicides. Since a range of options are available in this context (see 6.01), it is likely that some of the herbicides currently used against broad-leaved weeds in the PRA area (European Union, 2007) would also control *P. hysterophorus*.
Reddy & Bryson (2005) consider that unfavourable temperate climatic condictions, extensive use of herbicide, tillage and cultivation practice and competition from other aggressive weeds may have restricted the invasiveness of *P. hysterophorus* in the USA.
However, no form of control is ever consistently 100% effective over large areas, so the weed could be expected to establish despite existing pest management practices. Furthermore, it could be expected to establish and thrive in unmanaged, neglected areas (e.g. vacant land, land destined for development), as it has done elsewhere in its exotic range.
P. hysterophorus is very common along the watercourses supplying water to farms, which watercourses are generally not well managed, and where *P. hysterophorus* could thrive.
In addition, the existence of herbicide resistant populations has been documented (see question 3.18).

3.17 - How likely are the reproductive strategy of the pest and the duration of its life cycle to aid establishment?

Very likely

Level of uncertainty: **low**

P. hysterophorus does not require specialised pollinators in order to reproduce, and under the most favourable conditions (warm, moist climates) can produce seeds very quickly, from 4 weeks (Jayachandra 1971; Trounce and Gray, 2004) to 6 weeks post emergence (Lewis *et al*., 1988; Parsons & Cuthbertson, 1992). Seed production of *P. hysterophorus* is prolific: a 4-year investigation of its reproductive output in two sites in Queensland, Australia, found that the weed produced up to 39,192 capitula (flower heads) per plant, corresponding to >156,768 seeds per plant. However, the majority of the plants (approximately 75%) produced between 11 and 1,000 capitula, with less than 0.3% producing more than 10,000 capitula or >40,000 seeds per plant (Dhileepan, 2012). *P. hysterophorus* when present in wastelands, along the roadsides and irrigated agriculture produce much more seeds (Shabbir, pers. comm., 2013). Different amounts of seeds can be produced by different biotypes, while capitula usually have 5 florets, southern China or Vietnamese populations have commonly 6-8 florets (seeds) per capitulum, and potentially more seeds (Shabbir, pers. comm., 2013).
Fatimah & Ahmad (2009) identified that the aggressiveness of the weed owes to its multiple generations in addition to its capacity to withstand a wide climatic range.

Seed viability is high, 85% or higher (Haseler 1976; Williams & Groves, 1980; Dubey & Pandey, 1988; Pandey & Dubey, 1988; Navie *et al*., 1998; Tamado *et al*., 2002b). Newly produced seeds have a relatively short period of dormancy (up to several months) (Picman & Picman, 1984; Navie *et al*., 1998; Tamado *et al*., 2002b) and subsequently do not have specialised germination requirements (Navie *et al*., 1996a).

Seeds of *P. hysterophorus* achieve dispersal through both natural means (e.g. wind and water) and a variety of human-mediated mechanisms (see 2.01a). Many of these dispersed seeds will germinate as soon as adequate moisture is available, but 70 % of the buried seed live for at least two years; half-life is estimated to 7 years (Navie *et al*., 1998). This is beneficial for both colonisation and persistence, since it means that germination may be delayed if environmental conditions are not immediately favourable.

In Australia, Navie *et al.* (2004) determined the size of the viable soil seed bank at two infested beef pasture sites and found it to range from 3,200 to 5,100 seed m^{-2} in a black, cracking clay soil with a low ground cover up to 20,500 to 44,700 seed m^{-2} in a sandy loam soil close to a creek. In these sites the *P. hysterophorus* seed bank accounted for 47 to 73% and 65 to 87%, respectively of the total seed bank present. Nguyen (2011) has recently reported that a *P. hysterophorus* seed bank still exists at these two field sites, but now, 10 years later both sites are in the range of 5,000 to 6,000 seed m^{-2}.

3.18 - Is the pest highly adaptable?

Highly adaptable

***Level of uncertainty*: low**

P. hysterophorus is present in at least 7 different Koppen-Geiger climate zones (Kottek *et al*., 2006), including Equatiorial fully humid (Af), Equatorial winter dry (Aw), Arid steppe hot (BSh), Temperate fully humid hot summer

(Cfa), Temperate fully humid warm summer (Cfb), Temperate summer dry hot summer (Csa), Temperate winter dry warm summer (Cwb).

It has some characteristics of plasticity, which are detailed below:

Life cycle

P. hysterophorus can germinate and complete its life cycle over a broad temperature range (see below) whenever sufficient moisture is available. Soil moisture is a major contributing factor to the duration of flowering (Navie *et al*., 1996a). Depending upon the availability of moisture, reproduction may occur as quickly as after 4 weeks (Jayachandra, 1971; Trounce and Gray, 2004) or after a number of months. In the latter case, plants are larger and many more seeds are produced.

Seeds

Seeds of *P. hysterophorus* from Australian populations germinate over a wide range of temperatures, exhibiting more than 20% germination where night temperatures are as low as 10°C or day temperatures as high as 36°C (Williams & Groves, 1980). However, germination is very sensitive to moisture availability, Williams & Groves (1980) showed that germination decreased from approximately 90% when soil was at field capacity, to 50% when soil moisture (SM) was reduced to -0.07 MPa and 0% when SM fell to -0.09 MPa. Germination can occur in a wide range of soil pH (from 2.5 to 10) but the optimum pH for germination is between 5.5 to 7.0 (Muniyappa & Krishnamurthy, 1977, cited in Kandasamy, 2005). Alkalinity may suppress weed growth, but seed production remains unaffected (De & Mukhopadhyay, 1983).

Herbicide resistance

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).

Different biotypes

Plants grown from seed collected in Argentina, Bolivia and Brazil showed differences in morphology, pollen colour, capitula size, development of axillary branches, size of disc flowers and petal size from *P. hysterophorus* collected in Australia. The sesquiterpene lactone, hymenin, which is present in plants from Argentina and Bolivia is different from the lactone, parthenin, identified from most samples collected in India and North and Central America (Dale, 1981). Two biotypes have been introduced into Australia as well. Although the differences in the 2 biotypes were not large, this may be the reason for the large difference in the relative invasiveness of these biotypes in the disturbed environments in Queensland (Navie *et al*., 1996a). In South Africa, although the species was present since 1880, it only appeared as invasive in the 1980s, and this may be due to the presence of 2 different biotypes as well (Wise *et al*., 2007).

Hybridization between different biotypes is expected to create new genotypes and to enhance their potential to adapt to new conditions (Tang *et al*., 2009).

It is considered that *P. hysterophorus* is highly adaptable.

3.19 - How widely has the pest established in new areas outside its original area of distribution? (specify the instances, if possible; note that if the original area is not known, answer the question only based on the countries/continents where it is known to occur)

Very widely

***Level of uncertainty*: low**

P. hysterophorus has spread to most tropical and sub-tropical areas of the world since the 1950s. Initial trans-continental spread was usually in grains from the USA delivered as food aid, and subsequent intra-country and intra-region spread has been via agricultural machinery and vehicles (Dhileepan & McFadyen, 2012). *P. hysterophorus* is now a major weed in India, Australia, Pakistan, Taiwan, China, Vietnam, Pacific Island countries, and countries of east and southern Africa, including Madagascar (Dhileepan & Strathie, 2009). It is predominantly a weed of agriculture in areas with a distinct wet/dry season climate, particularly where the wet season coincides with high temperatures (Dhileepan & McFadyen, 2012).

3.20 - The overall probability of establishment should be described.

High

***Level of uncertainty*: low**

Given access to suitable habitats via its most frequent pathways, it is highly likely that *P. hysterophorus* will establish within the Mediterranean part of the EPPO region (It already has established and persisted for about 25 years in Israel).

Within this area, large areas exist where there is a confluence of suitable climate, soils and land management regimes (including transport infrastructure). It is also likely that *P. hysterophorus* will establish in other areas within the EPPO region (e.g. areas with a cool- and cold-temperate climate).

Stage 2: Pest Risk Assessment Section B: Conclusion of introduction

c1 - Conclusion on the probability of introduction.

P. hysterophorus already has a limited occurrence within the EPPO region (in Israel). The probability of introduction of this species to the remainder of the EPPO region will be a function of the activity of pathways by which it has been introduced in many other parts of the world.

These include primarily movement as a contaminant of seed, of grain, of vehicles, etc. It is considered that in the absence of effective regulation of these pathways, it is only a matter of time before *P. hysterophorus* is introduced to the remainder of the suitable parts of the EPPO region, either secondarily from its current occurrence within Israel, or as a result of trade from other parts of the world (e.g. Africa, Australia, India) that it has invaded.

As a conclusion, the probability of introduction of *P. hysterophorus* to the remainder of the EPPO region is high.

Stage 2: Pest Risk Assessment Section B: Probability of spread

4.01 - What is the most likely rate of spread by natural means (in the PRA area)?

Medium rate of spread

***Level of uncertainty*: medium**

The propagule for *P. hysterophorus* is a cypsela with two appended sterile florets, which act as air sacs and increase both mobility in the air and flotation (Navie *et al.,* 1996a). Dispersal occurs locally by wind, but whirlwinds can carry seeds for considerable distances (Haseler, 1976). Dispersal by water is also important, as indicated by spread along waterways in central Queensland, Australia (Auld *et al*., 1983) and Mahaweli River in Sri Lanka (Jayasuriya, 2005). While *P. hysterophorus* may be dispersed small distances by wind, its spread by natural means is most likely to be water-mediated. The species also spreads naturally through irrigation canals, as observed in Pakistan (Anwar, 2012).

Cyclones play also an active role in spreading *P. hysterophorus*. In KwaZulu-Natal, *P. hysterophorus* became very abundant after the cyclone 'Demonia' hit this region from the east in 1986, causing widespread damage and creating ideal conditions for a pioneer like *P. hysterophorus* (Wise *et al*., 2007). Rare climatic events projected under future climatic scenarios may therefore be favourable for the spread of *P. hysterophorus*.
Flooding was reported to play a significant role in the spread of the species, with 25 out of 40 *P. hysterophorus* spread events related to flooding in rangelands in Ethiopia (Ayele, 2007). The extent of suitable habitat that is prone to flooding will be critical (Panetta & Cacho, 2012). Flooding events are known to occur in the Mediterranean area and in Europe, as shown in Figure 3. Similar information could not be retrieved for other Mediterranean countries.

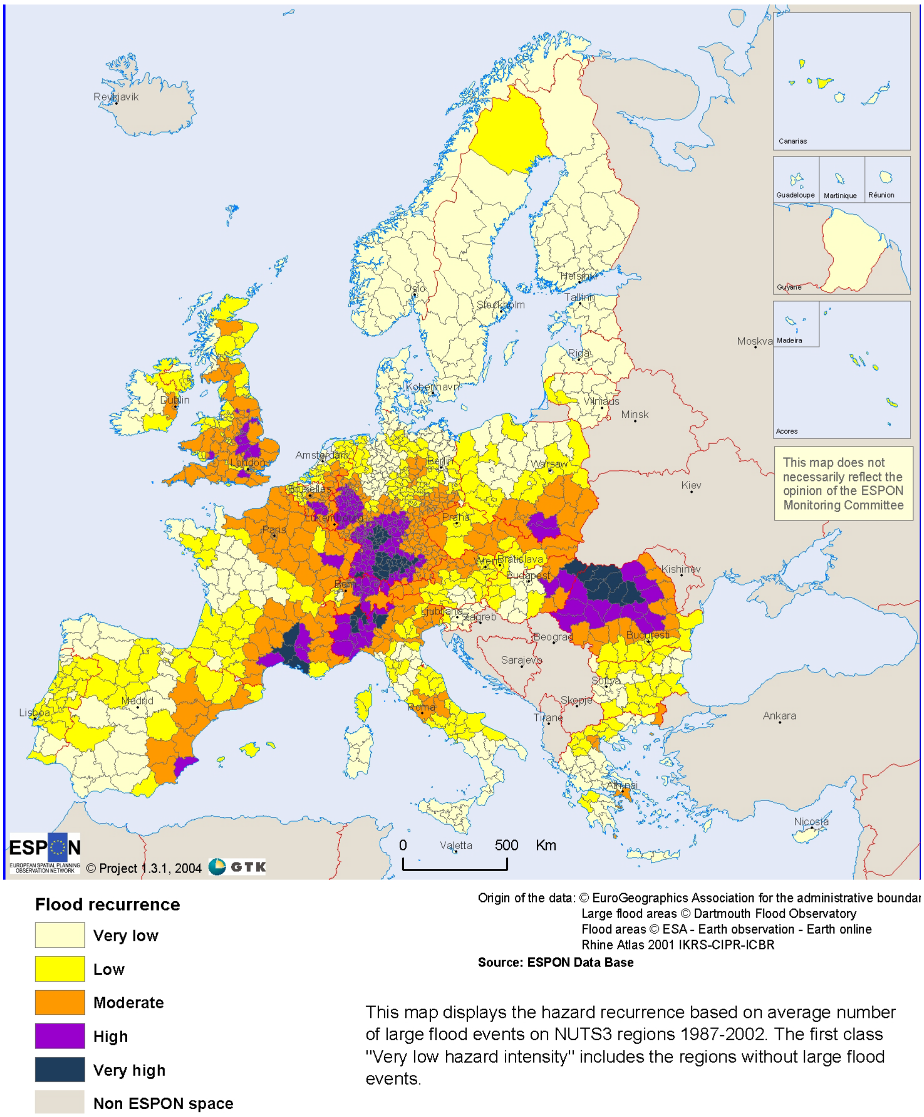


Figure 3: Flood occurences in Europe.

P. hysterophorus could also be spread by wild animals. In Australia, it is dispersed by feral pigs, wallabies and some birds (Grice, Undated). It is assumed that the feral pigs spread *P. hysterophorus* in Australia either by eating weeds or grass around it or by catching seeds on their fur. *P. hysterophorus* was consistently found growing along the tracks used by feral pigs in a property near Kilcoy, SE Queensland (personal communication with a local farmer, Mr Richard Wilkinson). Bores and birds could spread the species in the EPPO region.

4.02 - What is the most likely rate of spread by human assistance (in the PRA area)?

High rate of spread

***Level of uncertainty*: medium**

Spread by *P. hysterophorus* elsewhere in its introduced range has been largely human-mediated (see 2.01a). As a result, *P. hysterophorus* has spread rapidly following its introduction in Australia (Navie *et al*., 1996a), Ethiopia (Ayele, 2007), India (Pandey *et al*., 2003; Sushilkumar & Varshney, 2010), Pakistan (Javaid, 2007; Khan *et al*., 2012; Shabbir *et al*., 2012) and elsewhere.
The current distribution of *P. hysterophorus* in Israel actually followed a single introduction in 1980 of the weed, most likely through impure grains imported from the USA (Dafny & Heller, 1982).

Many spread pathways are reported, including as a contaminant of seed, of grain, on people, in farm yard manure or composts; construction materials; land filling; movement of soil (Ramachandra Prasad *et al*., 2010a), movement of vehicles, of fodder, of soil (see the entry section), and of pasture seed (Navie *et al*., 1996a), as a hicthhicker, etc. within a country.
People may also spread the plant for its flowers, as Sweddy (2011) reports that in Tanzania, flower sellers pick the freely available *P. hysterophorus* flowers which are then included in the rose flower bouquets, which spread the species. The plant as also been reported as a flower bouquet in India (Prof. Ramashandra Prasad, pers. comm., 2013) and in Pakistan (Marion Steir, pers. comm., 2014).
P. hysterophorus can also be spread through livestock, as it is thought to have entered Sri Lanka within or on goats accompanying an Indian military mission (Jayasurya, 2005). Beef cattle and sheep may also feed on *P. hysterophorus* in the dry season when there is little green grass available in pastures (Mr & Mrs David Chandellor, livestock farmers in South Central Queensland; Mr Bruce Boele, a shepherd in south west Queensland, pers. comm., 2013). Seed dispersal in mud adhering to the hooves of cattle and human feet has also been observed in Sri Lanka (Jayasuriya, 2005).

4.03 - Describe the overall rate of spread

High rate of spread

***Level of uncertainty*: medium**

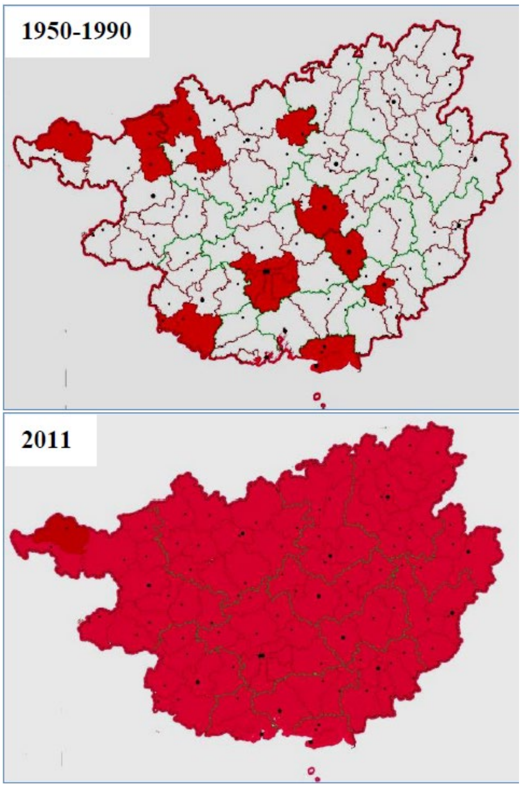
Generally, observations of spread have been qualitative. In the earliest quantitative examination of its rate of spread, Auld *et al*. (1983) reported that *P. hysterophorus* spread at an exponential rate in central Queensland during the 1970s. Agriculture & Resource Management Council of Australia & New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers (2001) reported that the core infestation in central Queensland had been estimated at 8.2 million hectares.
It is highly likely that these spread dynamics were replicated elsewhere in the species' introduced range. There can be a substantial lag phase in between the entry of the species and a period of rapid spread. In Pakistan, after 20 years of slow spread, *P. hysterophorus* has spread rapidly in the past 10 years into many districts of Punjab and Khyber Pukhtunkhwa Provinces (Shabbir *et al*., 2012). In South Africa, although *P. hysterophorus* was recorded in Kwazulu-natal as far back as 1880, it appears to have become a concern only since the 1980s. There was, as in Australia, 2 separate introductions in South Africa, with only the second one becoming invasive (Wise *et al*., 2007).
Sushilkumar & Varshney (2010) report that when initially introduced in India around 1955, the species was initially a problem in waste and vacant land, while reports of infestation in fields crops starts after 1980. Reports of the species in forest areas started to appear after 1990. It is estimated that 35 million hectares are infested with *P. hysterophorus* today. *P. hysterophorus* progression in India during different decades is provided in Table 3.

Period	Infestation (in million ha) in different land types			
	Barren, fallow, waste land, land under non agricultural use	Crop land	Forest land	Total infested
1955-1960	0.5	0	0	0.5
1961-1970	1.75	0.25	0	2
1971-1980	4.5	0.5	0	5
1981-1990	6	1	0	7
1991-2000	7.5	2	0.5	10
2001-2009	18.78	14.25	2	35

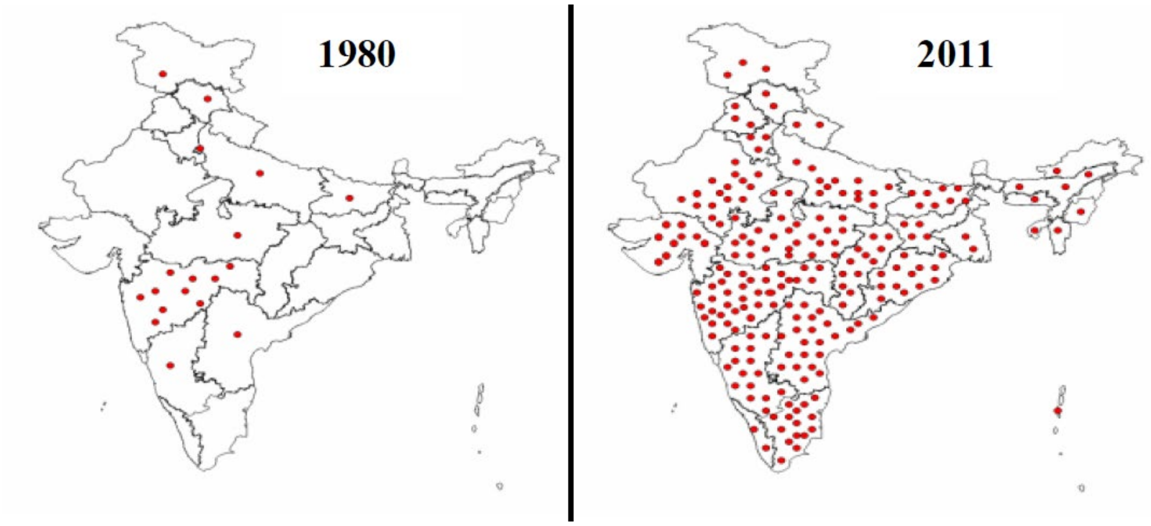
Table 3: Estimated infested area by *P. hysterophorus* in India during different decades since 1955, taken from Sushilkumar & Varshney, 2010.

A study conducted in the Ethiopian rangelands ranked the different modes of spread of *P. hysterophorus*, and it appears that for 40 spread events, 25 were reported to be linked to flood, 12 to animal dung, 2 to wind and 1 to animal movement (Ayele, 2007). Natural spread therefore plays a crucial role, in particular through flooding.

The following map of spread of *P. hysterophorus* show how quickly spread can occur over large distances:



Spread of *P. hysterophorus* in Guangxi, China by 1950/90 and by 2011, taken from Tang (2012)



Spread of *P. hysterophorus* in India by 1980s and by 2011. Red dots showing a heavy occurrence in the state, taken from Sushilkumar (2012)

4.04 - What is your best estimate of the time needed for the pest to reach its maximum extent in the PRA area?

***Level of uncertainty*: high**

This estimate will depend largely upon the degree and effectiveness of intervention. However, some idea can be gained of unimpeded spread from the history of spread of *P. hysterophorus* elsewhere in its introduced range (see 4.02).

Assuming no coordinated efforts to slow the spread are put in place, the EWG estimated that *P. hytserophorus* may possibly reach its maximum extent in the EPPO region in 50 to 100 years. The species could nevertheless reach a substantial extent in 30 years.

4.05 - Based on your responses to questions 4.01, 4.02, and 4.04 while taking into account any current presence of the pest, what proportion of the area of potential establishment do you expect to have been invaded by the organism after 5 years?

***Level of uncertainty*: high**

The EWG estimated that considering the current distribution of *P. hysterophorus* in Israel, the proportion of the area of potential establishment is expected to be less than 1% as spread follows an exponential pattern and is expected to be slow at the start of the invasion process.

Stage 2: Pest Risk Assessment Section B: Eradication, containment of the pest and transient populations

5.01 - Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the area of potential establishment?

Likely

***Level of uncertainty*: low**

As for many weeds, eradication is possible if infestations are detected early, when they are very limited. However, *P. hysterophorus* has two features that increase difficulty of eradication. Firstly, it is an annual species that is capable of producing seeds relatively rapidly (approximately 4 weeks). Only if detected very early (<4 weeks), can young plants be controlled prior to reproduction. If plants are not detected and controlled quickly, they will add to the soil seed bank. Secondly, seeds in the soil seed bank may persist for several years (Navie *et al.*, 1998; Tamado *et al.*, 2002b). In older infestations the existence of a large seed bank, accumulated over time, will require repeated monitoring surveys, for at least 7 years.

Attempts at eradicating *P. hysterophorus* in Australia have been generally unsuccessful, although very small infestations have been eradicated in New South Wales and the Northern Territory (Blackmore & Johnson, 2010; other refs) and also in many parts of India (Sushilkumar & Varshney, 2010; Ramachandra Prasad *et al.*, 2010a). In 1977, *P. hysterophorus* was discovered in the Northern Territory along Elsey Creek in the Mataranka district and the infestation had spread 8 km downstream from the Roper Highway. This infestation was the subject of an intensive eradication program (through aerial and ground spraying and manual removal) and the weed was successfully eradicated from this area (Wingrave, 2010).

Eradication has also been attempted in Papua New Guinea, lasting for 5 years with the regular spraying of paraquat and glyphosate at the affected sites, where the plant had been introduced in 2001. In 2009, a quarantine survey indicated that no *P. hysterophorus* was found (Kawi & Orapa, 2010). The climatic situation in Papua New Guinea was unfavourable to *P. hysterophorus*, easing eradication actions.

It is concluded that eradication would only be a possibility for isolated and limited infestations where sustained resourcing could be anticipated. Therefore, it is likely that the species would survive an eradication programme, with a low level of uncertainty.

5.02 - Based on its biological characteristics, how likely is it that the pest will not be contained in case of an outbreak within the PRA area?

Likely

***Level of uncertainty*: medium**

Dispersal of *P. hysterophorus* occurs locally by wind, but whirlwinds can carry seeds for considerable distances (Haseler, 1976). Dispersal by water is also important, as indicated by spread along waterways in central Queensland, Australia (Auld *et al.*, 1983) as well as in India (Krishnamurthy *et al.*, 1977). In addition, long-distance dispersal occurs via movement of propagules on motor vehicles or machinery, on livestock, with crop, grain and pasture seed, in fodder, as a hitchhicker, or attached to clothes and feet (Navie *et al.*, 1996a). It is this capacity for human assisted spread that is the basis for the feasibility of containment for *P. hysterophorus*, since such pathways can be regulated (Panetta & Cacho, 2012; Panetta, 2012).

The strategic plan for *P. hysterophorus* in Australia (Australian Weeds Committee, 2012) comprises a comprehensive set of actions to be undertaken:

- Minimise the spread: maintain washdown and inspection facilities;
- Prevent weed seed spread: advise public of hygiene protocols, implement a system where competent commercial or government authorised inspectors certify that machinery is clean;
- Encourage development and adoption of codes of practice;
- Establish procedures for early detection: encourage la,dholders and other members of the community to report sightings; inspect major roads/highways during growing season;
- Maintain detailed records and reports on outbreaks through a database;

- Develop a system to define the core infestation areas and catalogue small or isolated outbreaks;
- Eradicate the weed from small or isolated outbreaks;
- Establish a monitoring system for controlled outbreaks: regularly reinspect outbreaks on private property; ensure follow-up control treatments;
- Ensure that the species is declared under relevant legislation.

Two studies have documented the capacity for containment of *P. hysterophorus* in Australia. In the first, Auld *et al*. (1983) showed a decrease in the rate of spread over time in a region of central Queensland where the weed had been subjected to a coordinated control program. More recently, Blackmore & Johnson (2010) have demonstrated the contribution of early detection and control of small infestations of *P. hysterophorus* in New South Wales (NSW) to the containment of the invasion of this weed to Queensland in the north. Of the infestations detected in NSW between 1982 and 2009, 73.6% were detected in roadside corridors or wash-down areas and 24.2% were found on private properties. Almost 94% of the probable pathways leading to outbreaks detected on private property between 1982 and 2004 were human related. Over 80% of the detections comprised 10 or fewer plants.
For what concerns ease of control, although the species showed resistance to some herbicides such as glyphosate, a recent research in Pakistan has demonstrated particular effectiveness of metribuzin and glyphosate in managing *P. hysterophorus* in degraded pasture, with all herbicides tested being more effective against rosette plants than those that had bolted (Khan *et al*., 2012).

Because *P. hysterophorus* has a distinctive appearance when flowering and occurs in pastures, crops and disturbed sites in readily accessible areas, there is considerable scope for detection of this weed through both active (structured) and passive (unstructured, involving opportunistic detections by informed individuals) surveillance. However, detection of the largest infestations on private property (Blackmore & Johnson, 2010) indicates the need for ongoing investment in public awareness programs to support timely detection through unstructured surveillance. In some cases, some landholders do not treat *P. hysterophorus* for fear of allergic reactions (Agriculture & Resource Management Council of Australia & New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers, 2001). This makes the containment of *P. hysterophorus* difficult.

Overall, the containment feasibility of *P. hysterophorus* is considered to be low, primarily owing to the potential for spread through flood events (Panetta & Cacho, 2012) (see Figure 3 in Q 5.01) as well as owing to the coordinate set of actions that need to be implemented. This may not apply to the current situation in the EPPO region, but may apply if the species would be introduced elsewhere in the region where flood occur (see Figure 3).

5.03 - Are transient populations likely to occur in the PRA area through natural migration or entry through man's activities (including intentional release into the environment) or spread from established populations?

Yes

***Level of uncertainty*: low**

There is very little evidence of transience in populations of *P. hysterophorus*. Propagules of this species may enter through either natural or human-mediated dispersal, perhaps occasionally in insufficient numbers to establish a persistent population.
A transient population has been observed in 1999 in Belgium (Verloove, 2006).
The CLIMEX projection transient population map shown in Appendix 2 identifies that transient populations could be supported over extensive areas of Northern Europe. Should it become established in its northern range limit, the species may spread both naturally and through human assistance into regions capable of supporting transient populations.

Stage 2: Pest Risk Assessment Section B: Assessment of potential economic consequences

6.01 - How great a negative effect does the pest have on crop yield and/or quality of cultivated plants or on control costs within its current area of distribution?

Major

***Level of uncertainty*: low**

Impact upon cropping

Crop losses are reported to be primarily through allelopathic effects over and above the ability of *P. hysterophorus* to compete for nutrients and moisture. The impacts of *P. hysterophorus* upon cropping systems may be both direct and indirect from a competition point of view (Lakshmi & Srinivas, 2007). Although Asha Kumari *et al*. (2010) consider that p. hysterophorus is a weak competitor and that allelopathy does not seem to play an effective role, Swaminathan *et al.* (1990) report that direct effects arise owing to allelopathy (allelopathogenicity) resulting from the release of a wide variety of substances, including caffeic, vannilic, chlorogenic and *p*-hydroxybenzoic acids, as well as sesquiterpene lactones such as parthenin, ambroxin and coronopilin. These substances variously inhibit the growth of a number of crops, thus causing yield reductions.

Indirect effects occur through interference with the reproduction of crop plants, as when pollen of *P. hysterophorus* is deposited upon floral stigmatic surfaces (Jayachandra, 1980), which prevents seed set with resulting losses in yields of up to 40% (Wise *et al*., 2007). In particular, *P. hysterophorus* pollen has been reported to be able to inhibit fruit set through allelopathy (in beans, eggplant, peppers, tomatoes and other plants (Sukhada & Jayachnadra, 1980 in Stamps, 2011) and grain filling of corn. Stands of *P. hysterophorus* are indeed reported to be able to produce an average of 316 million pollen grains per square foot (Sukhada & Jayachnadra, 1980 in Stamps, 2011). *P. hysterophorus* was also found to reduce chlorophyll content of heavily infested crops, probably owing to interference with porphyrin biosynthesis (Towers & Subba Rao, 1992). Although these indirect negative impacts on crop yield are considered to be significant, there are no quantitative data available.

Impacts upon cropping are detailed below by country.

Carribbean

In the Caribbean, where crop losses due to weeds average approximately 20%, *P. hysterophorus* is the fourth most serious weed, largely because of its resistance to the widely used herbicide paraquat (Hammerton, 1981, cited in Kandasamy, 2005).

India

In India, *P. hysterophorus* occurs in most states (e.g. Mahadevappa, 1997; Pandey & Dubey, 1989) and is a weed of high importance in cropping areas (Mahadevappa, 1997), inflicting yield losses of up to 40% in several dryland crops (Khosla & Sobti, 1981, cited in Kandasamy, 2005). In irrigated sorghum, the presence of *P. hysterophorus* reduced grain yield from 6.47 to 4.25 t/ha and decreased grain weight by almost 30% (Channappagoudar *et al.,* 1990). In India, yield losses from *P. hysterophorus* in upland rice has been reported as ranging from 41 to 100% and averaging 79% (Mathews & Sarkar, 2005).

Heavy deposition of *P. hysterophorus* pollen on the stigmatic surfaces of maize caused a 40% reduction in grain-fill. Hence, this weed may suppress the reproduction of other plants through deposition of pollen even when growing at some distance from them (Towers *et al.*, 1977).

Pakistan and Sri Lanka

P. hysterophorus also causes impacts in crops in Pakistan and Sri Lanka, but there are no quantitative impact studies available (Khan *et al*., 2013). In Pakistan, p. hysterophorus has also been recorded as a weed in *Gladiolus* fields (Riaz *et al*., 2009).

Ethiopia

In Ethiopia, sorghum grain yield was reduced between 40% and 90% if *P. hysterophorus* was not controlled (Tamado *et al*., 2002a).

P. hysterophorus is primarily a weed in sugarcane cropping areas and rangeland areas, and is ranked as the most serious weed by farmers (Tamado & Milberg, 2000; Firehun & Tamado, 2006). The yield of sorghum could be seriously depleted, peaking at 90% at a lowland site. Even at low density, the plant can have very high crop yield loss, as a mean of 69% sorghum grain yield loss was noted with only 3 *P. hysterophorus* plants per m² (Tamado *et al*., 2002a).

Kenya

Since *P. hysterophorus* was first reported in Kenya in 1975, it has rapidly spread throughout the country, affecting crops such as coffee (Njoroge, 1991).

South Africa

P. hysterophorus is a weed of sugarcane and banana plantations in South Africa (Dhileepan & McFadyen, 2012).

Role as reservoir for plant pests

As another indirect effect upon crop production, *P. hysterophorus* acts as a reservoir host for plant pathogens and insect pests of crop plants (Basappa, 2005; Govindappa *et al*., 2005; Prasada Rao *et al*., 2005; Lakshmi & Srinivas, 2007).

For example, it can act as a secondary host for the bacterial pathogen, *Xanthomonas campestris* pv. *phaseoli* which can transfer between this weed and the common bean (*Phaseolus vulgaris*) (Ovies & Larrinaga, 1988).

As regards viruses, *P. hysterophorus* has also been reported as a reservoir for *Groundnut bud necrosis virus* in India (Prasada Rao *et al*., 2005). A bacterial wilt pathogen has been recorded on *P. hysterophorus* in India (Kishun & Chan, 1988), as have *Tomato yellow leaf curl virus* (Govindappa *et al*., 2005) and *Tobacco streak virus* (TSV) (Prasad Rao *et al*., 2005). TSV is damaging host of many crops of economic importance, such as cotton, sunflower, mungbean, ground nut, etc. *P. hysterophorus* is a key host of TSV, which is considered to be the cause of sunflower necrosis disorder (Basappa, 2005). Pollen and thrips transferred from *P. hysterophorus* plants infected with TSV were able to transmit TSV to sunflower (Basappa, 2005). In 2005 sunflower necrosis disorder caused a 20% loss ($4.5 million) across the sunflower industry in central Queensland (Australian Weeds Committee, 2012). This virus can also be transmitted through seeds of *P. hysterophorus*. Sharmon *et al*. (2011) found that there was almost no change in the rate of TSV seed transmission when *P. hysterophorus* seed was stored for up to 24.5 months.

A wide range of fungal pathogens of crop plants, including species from the genera *Sclerotium*, *Myrothecium*, *Colletotrichum*, *Drechlera*, *Alternaria*, *Lasiodiplodia*, *Phoma*, *Curvularia*, *Erysiphe*, *Rhizoctonia*, *Sclerotinia*, *Syncephalastrum* and *Exerohilum* are known to infect *P. hysterophorus*, as have several phytoplasmas (Prasad Rao *et al*., 2005). *Candidatus phytoplasma asteris* has also been found to be infecting *P. hysterophorus* in India displaying symptoms of witches' broom disease (Somvanshi *et al*., 2006; Raj *et al*., 2008). *P. hysterophorus* is acting as a reservoir for these organisms.

As regards functioning as a reservoir for insect pests of crop plants, between cropping seasons *P. hysterophorus* acts as a host for the scarab beetle (*Pseudoheteronyx* sp.), which is a pest of sunflower in Central Queensland (Robertson & Kettle, 1994). Similarly, the agromyzid pest (*Liriomyza trifollii)* feeds and ovoposits on *P. hysterophorus* growing along roadsides in green pepper (*Capsicum annuum*) growing regions of Texas (Chandler & Chandler, 1988). In parts of India, *P. hysterophorus* is considered as favourable host for a spider mite (*Tetranychus urticae*) which is a serious pest of ladies finger, eggplant and many cucurbitaceous crops in eastern Uttar Pradesh (Singh *et al*., 2005). It is also a reservoir for solenopsis mealy bug (*Phenacoccus solenopsis)* in cotton (Singh *et al*., 2012), as well as solanum lealy bug (*Phenacoccus solani)* and grape vine mealy bug (*Maconellicoccus hirsutus*) (EPPO A2 pest), as observed in parts of Delhi (Saxena *et al*., 2010). In Delhi, Professor Ramashandra Prasad (pers. com., 2013) reports that insects namely *Achaea janata*, *Aphis gossypii*, *Earias vittella* (quarantine pest in Africa and America), *Ferrisia virgata*, *Helicoverpa armigera* (EPPO A2 List and listed in many regions), *Spilarctia oblique* and *Spodoptera litura* (EPPO A1 List, quarantine pest or listed as A1 in many regions) were observed on *P. hysterophorus*.

A few studies indicate the allelopathic impacts of *P. hysterophorus* towards forest trees and forest nurseries. For instance, *P. hysterophorus* is reported as a problem in forest nurseries in Madhya Pradesh (Sushilkumar, 2012). Some studies show its allelopathic impacts on trees such as *Acacia* spp., *Casuarina equisetifolia, Eucalyptus* spp., *Leucaena leucocephala*, etc. (Kholi & Rani, 1994 in Huy & Seghal, 2004). *P. hysterophorus* seedlings in pots have been found to have strong allelopathic effects to reduce significantly the germination rate of *Pinus roxburghii* seeds (Huy & Seghal, 2004).

<u>Impact upon pastures</u>

Australia

In Australia, in the 1990s, *P. hysterophorus* mainly occured in Queensland, affecting more than 170,000 km^2 of prime grazing country (Chippendale & Panetta, 1994) and it still has the potential to spread over a large part of the country (Doley, 1977). In 2012, *P. hysterophorus* affected 9.4% of Queensland, with the core area of infestation in central Queensland estimated to be 8.5 million hectares (Commonwealth of Australia, 2012).

Chippendale & Panetta, (1994) estimated that in 1990/91, in Queensland, *P. hysterophorus* reduced stocking rates by 4.7%. Chippendale & Panetta (1994) considered generally that *P. hysterophorus* is a serious problem in perennial grasslands in central Queensland as it impacts cattle production (see Q 6.10).

In central Queensland, Dhileepan (2007) reported substantial increases (40-50%) in grass production in sites and years where introduced biological control agents attained high densities. Shabbir *et al.* (2013) reported the strong suppressive ability of the native Kangaroo (*Themeda australis,* Poaceae) and bull Mitchell grasses (*Astrebla squarrosa,* Poaceae) against *P. hysterophorus*, decreasing the need to rely on non-native species.

India

P. hysterophorus reduces forage production in non-cropping areas of India from 10% (Jayachandra, 1971) to 90% (Nath, 1981). Vertak (1968) in Sushikumar & Varshney (2010) reports a loss of 90% in grazing land in the State of Maharashtra. No quantitative data on actual stock losses are available from India. In this country *P. hysterophorus* has encroached on cultivated and natural pastures where it can reduce grass forage by 10% of the normal yield (Jayachandra, 1971) while Nath (1988) reported a forage reduction of infested grassland by up to 90%.

Ethiopia

In the Ethiopian rangeland, Ayele (2007) undertook a study on the proportion of grasses, forbs and *P. hysterophorus* in 5 infestations levels (see Table X), and it appears that cover abundance value of the invasive plant greater than 30% might exert suppressive effects on other species which could contribute to a decline in species composition as the gradient levels of the infestation increases.

Infestation levels	**Grasses %**	**Grass biomass**	**Forbs %**	**Forb biomass**	**Legumes %**	**Parthenium %**	**Parthenium biomass**
None	62.72	407.8±12	30.65	167±7	6.63	0	0
Very Low	62.05	304.9±62	31.98	171±15	4.46	1.5	12
Low	55.93	248±28	24.77	192±23	5.03	14.27	111±36
Moderate	39.96	159±45	23.38	97±28	5.93	30.72	293±34
High	16.66	30±27	15.10	25±13	1.25	66.98	714±18

Table X: the proportion of grasses, forbs, legumes and *P. hysterophorus* in 5 infestion levels in rangelands in Ethiopia, with dry matter biomass production of grasses, forbs and Parthenium (g/m^2), taken from Ayele (2007).

This change in composition of species also involves a sharp decline of the diversity index, as well as reduction in forage production (Ayele, 2007).

<u>Impact on soil</u>

In Nepal, Karki (2009) performed studies on soil and identified that the sites invaded by *P. hysterophorus* had higher soil pH than the non-invaded areas (the pH at invaded sites was nearly neutral). There was no significant difference in soil N content between invaded and non invaded sites, though, change in soil N may require longer period of time. The C/N ratio was significantly lower at invaded sites. *P. hysterophorus* is also known to inhibit the growth and activity of nitrogen fixing (*Rhizobium* sp. and *Azotobacter* sp.) and nitrifying bacteria like *Nitrosomonas* sp. (Yaduraju *et al*., 2005). This may have an indirect effect on the producticity of crops.

<u>Control of *P. hysterophorus*</u>

Australia, South Africa and to some extent other countries such as India have used biological control as a measure for control of *P. hysterophorus*. Other control measures in crops, pastures and non cropping situations are detailed below.

Crops

Controlling *P. hysterophorus* in cropland requires selective herbicide use and/or crop rotations (DEEDI, 2011). A range of herbicides has been used to control *P. hysterophorus* in this context. In Queensland, atrazine, glyphosate and metsulfuron-methyl are employed in both crops and fallow situations (DEEDI, 2011). Other herbicides used in crops elsewhere include chlorobromuron, monuron, DSMA and 2,4-D in sorghum and maize (Dutta *et al*., 1976), DSMA in cowpea (*Vigna unguiculata*) (Dutta *et al*., 1976), and hexazinone, picloram and diuron in sugarcane (Anon., 1976; Anon., 1985).

Since *P. hysterophorus* is a major weed in horticultural crops, even more options are available for this land use. Examples include diquat, bromacil, diuron and glufosinate-ammonium in orchards (Gupta & Sharma, 1977; Crane *et al*., 2006), metribuzin in potato and tomato, and bromacil and diuron in grapes and pineapple (Gupta & Sharma, 1977). Bromoxynil, methazol and oxadiazon have given good control of *P. hysterophorus* in onions if applied when the weed was young and linuron has controlled *P. hysterophorus* in onion when applied post-emergence (Menges & Tamez, 1981). Diuron has successfully controlled *P. hysterophorus* in lucerne (*Medicago sativa*) (Zanbrana & Corona, 1973). Low rates of glyphosate have controlled *P. hysterophorus* in coffee (Njoroge, 1989). However, it should be noted that 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). Managing herbicide resistant populations would increase control costs of the species. The extent to which control of *P. hysterophorus* increases costs upon and beyond the control of other weeds is unknown and costs of the use of these chemical treatments is not available.

In Queensland *P. hysterophorus* is not considered to be a serious weed in winter cereal crops (Navie *et al*., 1996a), as long as it is controlled during a previous summer fallow period (Parsons & Cuthbertson, 1992).

Today, in central Queensland, cropping industries incur costs of AU$6 million per annum from additional herbicides and cultivation in order to control this weed (Australian Weeds Committee, 2012). Grain harvesters estimate that one clean down of their machinery costs about AUSD 2000, mostly due to the time required (1.5 days) (Agriculture & Resource Management Council of Australia & New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers, 2001).

In India, Sushilkumar & Varshney (2010) have estimated that Rs 182 million are required per year to control *P. hysterophorus* by manual labour (US$ 3.8 million), and Rs 119 million per year to manage this weed through chemical measures (US$ 2.49 million). The exchange rate of rupies to dollars in 2010 was 47.774 (http://www.irs.gov/Individuals/International-Taxpayers/Yearly-Average-Currency-Exchange-Rates).

Pastures

In Queensland, 2,4-D amine, 2,4-D + picloram, 2,4-D ester, metsulfuron-methyl, hexazinone and dicamba are employed to control *P. hysterophorus* in pastures (DEEDI, 2011). Dicamba is used to control the weed selectively in grass pastures. Mixtures of 2,4-D and atrazine have also been employed, whereby 2,4-D controls existing plants and atrazine provides long term residual activity (Parsons & Cuthbertson, 1982).

A recent research in Pakistan has demonstrated particular effectiveness of metribuzin and glyphosate in managing *P. hysterophorus* in degraded pasture, with all herbicides tested being more effective against rosette plants than those that had bolted (Khan *et al*., 2012).

It has been reported that *P. hysterophorus* is rarely a problem in pastures that are healthy and in good condition (Chamberlain & Willcocks, 1996 cited in O'Donnell & Adkins, 2005). As there is a negative relationship between invasion by *P. hysterophorus* and pasture vigour (Navie *et al*., 1996a), management of grazing pressure is an important component of the management of this weed. High grazing pressure increases both the likelihood of invasion by *P. hysterophorus* and the severity of existing infestations. Stocking rates must be carefully adjusted according to season and rainfall in order to maintain the dominance of pasture grasses (Navie *et al*., 1996a). However, grazing management is less effective as a tool to control *P. hysterophorus* in semi-arid rangelands (<500 mm annual rainfall), as vegetation tends to be relatively sparse and prone to weed invasion when rainfall is above average or following flood events (Australian Weeds Committee, 2012).

While recommendations abound for the control of *P. hysterophorus*, very little information is available with regard to aggregated costs of control. Prior to 1994 it was estimated that about AU$1.8 million per annum was spent by producers and the government on the chemical control of *P. hysterophorus* in central Queensland, where the worst infestations of *P. hysterophorus* occurred (Chippendale & Panetta, 1994).

Non-cropping situations
P. hysterophorus occurs in a wide range of non-cropping situations (e.g, roadsides, rights-of-way, commercial and industrial land). Herbicides commonly employed to control this weed in these situations include 2,4-D amine, 2,4-D ester, 2,4-D + picloram, atrazine, dicamba, hexazinone, and metsulfuron-methyl (Parsons & Cuthberson, 1982; Brooks *et* al., 2004; DEEDI, 2011). Metribuzin and glyphosate are used in India (Kandasamy, 2005; Ramachandra Prasad *et al*., 2010a).
In Queensland, the cost of herbicide per hectare (i.e. not including cost of labour and machinery) for roadside control of *P. hysterophorus* in 2005 was: imazapyr (125 g a.i: $52.00), atrazine (3 kg a.i: $43.20), metsulfuron-methyl (4.2 g a.i: $2.28), imazapic (240 g a.i: $210.00), tebuthiuron (1 kg a.i: $48.50) and glyphosate (270 g a.i: $9.75) (Brooks, 2005).

Wise *et al*. (2007) summarize the economic costs of the options available for controlling *P. hysterophorus*, which are presented in table 1.

Control option	Description	Cost	Country
Mechanised, hand weeding and deep ploughing	Hand-weeding 100 plants per m² 40-140 days labour 10 days per ha	US$14 to US$42 per ha - US$45 per ha	India Ethiopia South Africa
Chemical 1 to 2 additional sprays (aerial or hand-spray) per cropping season	Atrazine-based mixtures at 3 L per ha Total cost of US$1 121 000 to aerially spray 17 542 km²	US$70 per ha US$0.64 per ha	South Africa & India Australia
Biological control with *Zygogramma bicolorata* and *Epiblema strenuana*.	Requires research and development Recurrent rearing, releasing & monitoring	(1991 US$) US$181 500 per year US$69 500 per year (2000-2006) US$138 900 per year (2007)	Australia South Africa
Preventing long distance dispersal	Wash-down facilities for vehicles; mandatory inspections; adoptions of codes of practice by agribusiness	US$4 667 000 per year to 6 426 000 per year.	Queensland and NSW, Australia

* 100 plants per square metre.
Table 1: The economic costs (2006 US$ unless otherwise stated) of the options available to control *P. hysterophorus*, taken from Wise *et al*. (2007).

<u>Losses in economic revenues</u>
In the Mpumalanga Province in South Africa, if *P. hysterophorus* would spread without control, small scale farmers would suffer a decline in total economic revenues of between 26 and 41%, which equates to an annual loss in total economic revenues to each small-scale farming in the region of between US$87 and US$136 per year. Commercial farmers' annual total economic revenues would decline by between US$38.818 and US$60.957 (Wise *et al*., 2007).
Wise *et al*. (2007) also estimated that in Mpumalanga, the potential economic impact per-unit-area of agricultural production ranges between US$30 and US$214 per ha for small-scale farmers and between US$38 and US$229 per ha for commercial farmers. Table 4 provides the loss in yields and in economic value for low altitude and high altitude crops, taken from Wise *et al*. (2007).

Land-use type	Potential revenue	Impact		Economic value of impact	
		Low altitude	High altitude	Low altitude	High altitude
Small-scale farmers					
Maize	208	55%	25%	115	52
Cattle	100	30%	30%	30	30

Other	388	55%	25%	214	97
Commerical farmers					
Maize	417	55%	25%	229	104
Cattle	126	30%	30%	38	38
Soya-beans	416.4	55%	25%	229	104.1
Planted pasture	222.4	30%	30%	66.7	66.7
Other	388.1	55%	25%	213.5	97

Table 4: per capita economic consequences (2006 US$ per year) of the biophysical impacts (% change in productivity) of *P. hysterophorus* on agricultural acitivites at 2 sites (low altitude and high altitude) within the Mpumalanga province, South Africa, taken from Wise *et al*. (2007).

6.02 - How great a negative effect is the pest likely to have on crop yield and/or quality of cultivated plants in the PRA area without any control measures?

Major

***Level of uncertainty*: medium**

Countries at risk are the following: Albania, Algeria, Azerbaijan, Bosnia & Herzegovina, Bulgaria, Cyprus, Croatia, Former Republic of Macedonia, France, Greece, Hungary, Israel, Italy, Jordan, Kazakhstan, Kyrgyzstan, Malta, Moldova, Morocco, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Tunisia, Turkey, Ukraine and Uzbekistan.

Other countries at lower risk: Austria, Germany

Crops

The EWG considered that there are little differences in the environmental conditions between areas where *P. hysterophorus* occurs and the EPPO areas suitable for the plant's establishment. Tamado *et al*. (2002a) reported yields losses on sorghum comprised between 40 and 90 % in Ethiopia without any control measures. The yield loss in summer crops in the EPPO countries at risk is therefore extrapolated to be major.

Vegetable

As there is little difference in the environmental conditions in between areas where *P. hysterophorus* occurs and the EPPO areas suitable for the plant's establishment, the impacts on vegetables (e.g., tomatoes, eggplants, chillies, etc.) are expected to be the same as in countries where *P. hysterophorus* occurs, and are extrapolated to be major.

Perennial crops

Orchards (stone fruits, cherries, olives, citrus species and other fruits) and vineyards (*Vitis vinefera*) are important crops in the EPPO countries at risk (i.e. Spain, Italy, and Morocco). *P. hysterophorus* could cause competition problems in the first years of planting and have a major indirect effect by affecting fruiting through pollen allelopathy (Akter & Zuberi, 2009; Ramachandra Prasad *et al*., 2010b).

Pastures

P. hysterophorus develops particularly well in overgrazed pastures, and in Mediterranean this commonly occurs. The impacts of *P. hysterophorus* in pastures in the EPPO countries at risk are expected to be similar as in other countries where the plant occurs (i.e. Queensland, India) and would be major.

6.03 - How great a negative effect is the pest likely to have on yield and/or quality of cultivated plants in the PRA area without any additional control measures?

Major

***Level of uncertainty*: high**

The EWG considered that there is a difference in between EPPO countries having intensive farming production systems, compared to extensive farming ones. It is expected that there would be a lesser use of herbicide in southern EPPO region.

P. hysterophorus can be managed with existing herbicides (paraquate, glufosinate ammonium, glyphosate, MCPA and fluroxypyr) with satisfying efficiacy, though resistance has been observed with the long term use of glyphosate

(Crane *et al*., 2006; Vila-Aiub *et al*., 2008).

Herbicide	Allowed in EU/other countries	Efficiency	Resistance
Paraquate	Y	Good (young seedlings)	Not known
Glufosinate amonium	y	Good (young seedlings)	Not known
Glyphosate	y	Good	Yes, could be like ambrosia
MCPA	y	Good	Not known
Fluroxypyr	y	Good	Not known

Table 1 of herbicides used in crops, whether they are allowed in the EU or other countries, their efficiency on *P. hysterophorus*, and possible resistance of *P. hysterophorus*.

Crops

In Queensland *P. hysterophorus* is not considered to be a serious weed in winter cereal (Navie *et al*., 1996a), as long it is controlled during a previous summer fallow period (Parsons & Cuthbertson, 1992). This is common practice.

The EWG considered that *P. hysterophorus*' management could be problematic in sunflower as it belongs to the same family. As a proxy, *P. hysterophorus* is close to *Ambrosia artemisiifolia* and classified within the same tribe (Helianthae) which is a threat in sunflower production. Due to poor control efficiency of herbicides for species botanically close to the crop, several weeds of this tribe are of increasing occurrences in sunflower (*Ambrosia artemisiifolia, Xanthium orientale*, Fried *et al*., 2009) and the same could therefore be expected for *P. hysterophorus*.

Considering the case of France, as crops sown in spring are considered the most at risk due to the germination date of *P. hysterophorus*, maize and sunflower are of particular concern. Maize covers around 2,8 millions ha in France mainly concentrated in the South-Western part and Atlantic regions of France (Agreste, 2010). The sunflower crops cover 0,6 million ha in France mainly in the South-West. This region is also one having the highest proportion of monocultures of maize (more than half of maize fields are under monoculture in this region) which would provide particularly favourable conditions considering germination timing of *P. hysterophorus.* Regarding control measures, 1.9 and 2.9 herbicide treatment are applied on average on sunflower and maize respectively (Agreste, 2013a). The treatment frequency index (TFI, the number of full dose applied) reaches on average 1.4 in sunflower, and 1.5 in maize (Agreste, 2013b). These levels are considered sufficient to reduce the density of arable weeds to an acceptable level.

Vegetables

The use of herbicides may be more limited in vegetables (although oxyfluorfen, oxadiazon, linuron, diflufenican, pendimethalin, rimsukfuron, flurochloridone, and others are being used in Israel) and there is no selective herbicide. The impacts of *P. hysterophorus* could therefore not be easily controlled and impacts are expected to be major without effective control methods, and may even affect the production of the following seasons.

Perennial crops

This concerns orchards (stone fruits, cherries, olives, citrus spp. and other fruits) and vineyards (*Vitis vinefera*).

The presence of *P. hysterophorus* in new orchards would affect control methods because of the inability to use herbicides in young tree plantations. In addition, competition for moisture and nutrient could occur with young trees, affecting future yields.

P. hysterophorus would also be a problem in intercropping production areas, in which the use of herbicide would not be used.

Impacts are also expected in medicinal plant production as the EWG considered that the species would be difficult to manage in mint, lavanda, and aromatic plants.

Pastures

There is usually no use of herbicides in pastures in the Mediterranean countries, though in Israel, herbicides such as mcpa, paraquate, diquate, chlorsulfuron are used against perenials in pastures. No use of herbicide would facilitate the spread of *P. hysterophorus* in pasture and could have an impact on the pasture's stocking rates and quality of forage. This is especially true in overgrazed pastures with gaps in vegetation that would be colonized and serve as sources to invade other parts of the pasture.

As a conclusion, the EWG considered that although some cultural practices may partly manage *P. hysterophorus* in crops, vegetables, perennial crops and pastures, the species' impacts are still expected to be major without any additional control measures, in particular in pastures. *P. hysterophorus* has also exhibited resistance to glyphosate, and the decrease in the use of herbicides in Europe would make the management of this weed even more difficult. Furthermore, the species can still have impacts through pollen contamination and through acting as a reservoir for pest organisms (in particular in sunflowers).

6.04 - How great a negative effect is the pest likely to have on yield and/or quality of cultivated plants in the PRA area when all potential measures legally available to the producer are applied, without phytosanitary measures?

Moderate

***Level of uncertainty*: high**

Depending on the countries' production, the impacts may be moderate for countries relying on pastural and vegetable production (e.g. Morocco, Spain) or minor (for intensive crop producing countries such as France).
Level of uncertainty: high

There will be gaps in management, crops for which there is no measure, but as long as herbicides will be available to control it, the negative effects would be lowered.
The species is quite easy to identify.

Crops
As in Australia, as long the species is controlled with herbicides and cultural methods, *P. hysterophorus* should only have minor impacts. The EWG considered that in India as well, if available management methods would be applied consistently, the negative impacts would be minor as well.

Vegetables
In Pakistan, vegetables are the most affected crops as *P. hysterophorus* establishes in between rows, and yield losses are noted (Shabbir, pers. com., 2013). Competition for nutrients and space leads to lower biomass and yield reduction in vegetables.
The management methods available in vegetables are limited (tillage, reduced use of herbicide, rotation, manual control, mulching) and this is particularly true in organic vegetable production. The efforts dedicated to manage the plant will be high, but the farmers may develop allergy to the species.
The negative impacts on yield and or quality of cultivated plants are expected to be moderate.

Pastures
In Australia, although the species has been efficiently managed in pastures, and 11 biological control agents have been released, the impacts of *P. hysterophorus* are still considered as moderate, and this represents a good approximation of what the situation could be in the European countries at risk.
The situation may be different in North African countries of the EPPO region where fewer management measures are being implemented. Negative effects there could be more substantial, unless all measures available would be used there too.
As a n exampke, two-third to three-quarters of pastures in Provence have between 0.5 and 1 livestock/ha in French mediterannean area (République Française, Ministère de l'agriculture, de l'agroalimentaire et de la forêt http://agriculture.gouv.fr/IMG/pdf/Paca2.pdf), most of the pastures are conducted with extensive practices with for example a mean of 0.35 livestock units/ha in the region Languedoc-Roussillon (Chambre d'agriculture Languedoc-Roussillon, http://www.languedocroussillon.chambagri.fr/languedoc-roussillon/lagriculture-lr/lelevage-en-lr.html). Although overgrazing could occur locally, there are no large overgrazed areas in France. The situation is different in the southern part of Mediterranean where the increase of livestock (+4%/year for sheeps) and the decrease in rainfall causes overgrazing, for example in some areas of Morocco (Mahyou et al., 2010)

Perennial crops
When using all available control methods, the impacts on orchards are only expected to be minor, and would mainly

occur in the first years of the planting of the orchard.

In forests as well as in glasshouses, the EWG considered that the impacts would be minor.

6.05 - How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area in the absence of phytosanitary measures?

Overall the increase in production costs is expected to be minor, except for vegetable, for which they would be moderate.

Level of uncertainty: **medium**

Crops

The existing control measures are expected to control *P. hysterophorus*. The EWG suggested that higher rates of chemicals, or more expensive chemical may be used. The production and control costs are expected to be minimal, except for sunflower where may be no effective herbicide, as it is the case for the closely related species *Ambrosia artemisiifolia*.

Vegetables

Labor intensive measures would need to be employed, in particular in systems using only a small amount of herbicides to control *P. hysterophorus*. Farmers may develop allergies to the species, which would lead to additional labor costs. The production costs are expected to be moderate (though, there would be social costs for farmers being allergic to the species).

Pastures

In natural pastures, there may no additional control costs as measures are not utilized. The only effective management tool is the regulation of grazing pressure which could result in additional costs, but this may also result in more sustainable use of the resource in the long terme.

Perennial crops

Production costs would only occur in the initial years of planting of the orchard, and these would be minor.

Field hedges

If *P. hysterophorus* would be a reservoir for quarantine pests in the countries at risk, farmers would have to manage it on field hedges. This is estimated to represent a minor cost.

As phytosanitary measures are not taken into account, the cleaning of agriculture vehicles is not taken into account here. The health of agricultural workers will be affected primarly as has occurred frequently elsewhere in its introduced range and this is an impact upon the cost of production. Nevertheless, if *P. hysterophorus* would have impacts on general human health (see question 6.11), there would be pressure from the public on farmers to control the species.

6.06 - Based on the total market, i.e. the size of the domestic market plus any export market, for the plants and plant product(s) at risk, what will be the likely impact of a loss in export markets, e.g. as a result of trading partners imposing export bans from the PRA area?

Minimal

Level of uncertainty: **medium**

P. hysterophorus is a quarantine pest in Tasmania: Summary table of Tasmanian Quarantine Pest Declarations since January 2006 - December 2012: http://www.dpiw.tas.gov.au/internnsf/Attachments/LBUN-934U5Z/$FILE/TasPestDecLists_7Dec2012.pdf. In Queensland, is declared Class 2 pest under the quarantine legislation (http://www.daff.qld.gov.au/plants/weeds-pest-animals-ants/weeds/a-z-listing-of-weeds/photo-guide-to-weeds/parthenium-weed) and is also a weed of National Significance (WONS) in Australia.

In South Africa, *P. hysterophorus* is regulated as well (CARA 2002 – Category 1 'Invader plants must be removed & destroyed immediately. No trade in these plants', http://www.invasives.org.za/invasive-species/item/295-parthenium-weed%7Cparthenium-hysterophorus.html).

It is also reported as listed as a noxious weed by the governments of Kenya and Puerto Rico (http://edis.ifas.ufl.edu/ep448).

Area freedom would be important for the production of seeds.

The species is not a declared quarantine pest in many countries, the EPPO countries at risk do not export large amounts of the potentially infested commodites to these countries. The impact on the loss of export market is considered to be minimal.

6.07 - To what extent will direct impacts be borne by producers?

Major extent

***Level of uncertainty:* low**

A broad range of commodities are affected, and the possibilities for substitutes are limited.
Alternative use of grain for animal consumption would decrease the spread of the plant and would be recommended.
There is no way to influence the price because farmers are individually too small to influence the market price.
The possibility for storage is limited for the commodities that may be infested.
As a conclusion, it is estimated that the direct impacts would be borne by the producers to a major extent.

Environmental impact

6.08.0A - Do you consider that the question on the environmental impact caused by the pest within its current area of invasion can be answered? (Read the note)

Yes
Data on environmental impacts are available from several invaded countries, in particular Australia, Ethiopia, India, Nepal and Pakistan.

Negative impact on native biodiversity

Note: **The word "native" in "native species" or "native biodiversity" throughout Questions 6.08 and 6.09 should be understood in a broad sense, i.e. it should also include species that have been naturalised for centuries and that play an important role in the ecosystems or local cultural heritage, such as walnut (Juglans) or chestnut (Castanea) in Europe. The assessor may also include other, more recently introduced beneficial organisms such as exotic plants that play a role in ecosystem services, e.g. plants used against erosion.**

6.08.01 - To what extent does the plant cause a decline in native species populations and changes in communities of native species?

Low to medium extent

***Level of uncertainty:* medium**

P. hysterophorus is an environmental weed that can impact upon native grasslands, the understorey of open woodlands and along rivers and floodplains (Chippendale & Panetta, 1994). McFayden (1992) has reported a total habitat change in Australian grassland, open woodlands, river banks and floodplains caused by *P. hysterophorus*. Where it is well-established, *P. hysterophorus* tends to become dominant in the soil seed bank (Huy & Seghal, 2004; Navie *et al*., 2004; Ayele, 2007). If disturbance is sufficiently frequent, it will dominate above-ground vegetation as well (Navie *et al*., 2004). This is commonly associated with marked declines in species richness, aboveground biomass and evenness and (accordingly) to diversity indices (Sridhara *et al*., 2005; Ayele, 2007 in rangeland in Ethiopia; Nigatu *et al*., 2010 in grazing land in Ethiopia; Nguyen *et al*., 2010 in pastures in Queensland; Belgeri *et al*., 2012; Fensham, 1999, in Agriculture & Resource Management Council of Australia & New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers, 2001). Nguyen *et al*. (2010) observed that the diversity of a pasture plant community in Queensland was found to be significantly reduced by *P. hysterophorus*, even at low densities (i.e. 2 plants per m²).
However, from a conservation perspective, the nature of the changes to diversity may vary. *P. hysterophorus* invasion has been associated with both decreases and increases in the abundance of native plant species. For example, in Nepal *P. hysterophorus* displaced some native grass species, but was associated with increases in others, as well as increases in some native woody species (Timsina *et al*., 2011). In parts of Karnataka, India, *P. hysterophorus* invasion has replaced native weed flora including grasses (Ramachandra Prasad *et al*., 2010a&b). In Punjab in Pakistan, parthenium showed 90-100% prevalence in different surveyed areas, replacing the local flora (Javaid & Riaz, 2012).

Huy & Seghal (2004) have conducted a quantitative analysis of the species diversity in *Pinus roxburghii* forest in Solan in India. They highlighted that in *Pinus roxburghii* forests, the invasion of parthenium had significantly affected the species diversity, structure and quality of the ground vegetation. There was indeed a significant impact on herbs, but not on shrubs. Parthenium seedlings in pots have also been found to have strong allelopathic effects to reduce significantly the germination rate of *Pinus roxburghii* seeds. In the Upper Bari Doab region of Punjab in India, Kumar & Soodan (2006) also measured a significant decrease in plant species diversity in the open vegetation of Khiala Khurd.

In the Serengeti – Masai mara ecosystem in Africa which hosts 70 large mammal species and some 500 different birds in highly diverse habitats, *P. hysterophorus* is considered as one of the most serious emerging threats to the ecosystem. The implications for wildlife conservation in the Serengeti ecosystem are potentially extremely serious. The movement of thousands of grazing animals means that the grasslands are often highly disturbed, making it easy for *P. hysterophorus* to invade. The displacement of palatable species means that, in time, the available food for animals will rapidly diminish (UICN Website http://cms.iucn.org/?uNewsID=6511).
Similarly, the severe infestation of *P. hysterophorus* has reduced the availability of palatable grasses to herbivores in Van Vihar National Park in Bhopal in Madhya Pradesh (Sushilkumar, 2012). Parthenium, in addition to other invasive alien plants, threatened the palatable vegetation availability to elephants (Sushilkumar, 2012).

As always, care must be taken to differentiate between situations in which an invasive species *causes* a decline in native species populations (i.e. acting as a 'driver' of change), as opposed to responding positively to the action of other factors that negatively affect native species populations (i.e. acting as a 'passenger' of change) (MacDougall & Turkington, 2005). For instance, a high level of disturbance may both reduce the abundance of native species and create openings for colonisation by an opportunistic plant such as *P. hysterophorus*. The role that overgrazing plays in the invasion and dominance of native grasslands by *P. hysterophorus* was described by Fensham (1999), who documented the invasion and proliferation of this weed in four different native grasslands in central Queensland. In areas that are regularly flooded, *P. hysterophorus* is difficult to manage because grasses and vegetation are killed as a result of submersion, and competition is thereby markedly reduced if not eliminated (Navie *et al*., 1996a).
The EWG considered that at least some of the biodiversity declines observed may have been due to grazing pressure rather than to the presence of *P. hysterophorus per se*. The impact on the native species populations is therefore considered to be low to medium.

6.08.02 - To what extent does the plant hybridize with native species?

Low extent

***Level of uncertainty*: low**

The genus *Parthenium* includes 17 species, all native to tropical America (Dhileepan & McFadyen, 2012). There is no evidence of hybridisation of *P. hysterophorus* with any native species in its exotic range.

Alteration of ecosystem patterns and processes

6.08.03 - To what extent does the plant cause physical modifications of habitats (e.g. changes to the hydrology, significant increase of water turbidity, light interception, alteration of river banks, changes in fire regime, etc.)?

Low extent

***Level of uncertainty*: medium**

Where *P. hysterophorus* is dominant, it will reduce light intensity. However, introducing *P. hysterophorus* to ecosystems would not alter their light regime significantly. No study could be found on the effects of *P. hysterophorus* on habitat modification.

6.08.04 - To what extent does the plant cause changes to nutrient cycling and availability (e.g. significant changes in nutrient pools in topsoils or in water)?

Low to medium extent

***Level of uncertainty*: high**

In Nepalese grassland communities, invasion by *P. hysterophorus* was associated with higher levels of soil organic matter and higher soil nitrogen, potassium and phosphorus (Timsina *et al*., 2011). Dogra & Sood (2012) found significantly higher amounts of nutrients (especially N, P and K) in soils invaded by *P. hysterophorus*. *P. hysterophorus* may have a range of impacts on soil nutrients dynamics, but the circumstances under which these occur are largely unknown.

P. hysterophorus is also known to inhibit the growth and activity of nitrogen fixing (*Rhizobium* sp. and *Azotobacter* sp.) and nitrying bacteria like *Nitrosomonas* sp. (Yaduraju *et al*., 2005).

Timsina (2007) found that soil pH changed from acidic towards neutral due to invasion of *P. hysterophorus* in grasslands in Central Nepal.

6.08.05 - To what extent does the plant cause modifications of natural successions (e.g. acceleration or temporary freezing of successions)?

Low extent

***Level of uncertainty*: medium**

P. hysterophorus could conceivably affect succession through allelopathic effects. However, in this regard it is important to consider the findings of Belz *et al*. (2009), who reported that at least one major allelochemical constituent of the plant (parthenin) did not persist for long periods in soil and that degradation was accelerated in heavier soils and under conditions of high temperature and moisture availability.

Shabbir & Bajwa (2006) reported that the population of many native plants growing in the wastelands of Islamabad were rapidly declining because of the aggressive colonization by *P. hysterophorus* and a transition phase of competition or succession was in progress, in association with the invasive *Lantana camara*, although *L. camara* is considered to have a greater effect upon successions than *P. hysterophorus*, because *L. camara* is a perennial.

However, as no information is available on modification of natural successions of natural or semi natural habitats, such impact is considered as low, with a medium uncertainty.

6.08.06 - To what extent does the plant disrupt trophic and mutualistic interactions (e.g. through the alteration of pollinator visitations - leading to a decrease in the reproductive success of native species-, allelopathic interactions, strong reduction of phytophagous or saprophagous communities, etc.)?

Low to medium extent

***Level of uncertainty*: high**

One of the major detrimental effects of *P. hysterophorus*, and a potentially important contributor to its aggressiveness, is its allelopathic effects on other plants (Navie *et al.*, 1996a). Water soluble phenolics and sesquiterpene lactones, mainly parthenin, have been found in the roots, stems, leaves, inflorescences, achenes and pollen of *P. hysterophorus* (Kanchan & Jayachandra, 1979, 1980a; Jarvis *et al.*, 1985; Patil & Hegde, 1988; Pandey *et al*., 1993). There is evidence that these chemicals exhibit an inhibitory effect on both germination and growth of a range of plants, including pasture grasses, cereals, vegetables, trees and other weeds (Nath, 1981; Srivastava *et al.*, 1985; Mersie & Singh, 1987, 1988; Swaminathan *et al.*, 1990; Batish *et al.*, 2002; Singh *et al.*, 2003; Bajwa *et al.*, 2004; Huy & Seghal, 2004; Wakjira *et al.*, 2009; Shabbir & Javaid, 2010; Dogra & Sood, 2012). Growth and nodulation of legumes is also inhibited by *P. hysterophorus* (Kanchan & Jayachandra, 1981; Dayama, 1986). Pollen from *P. hysterophorus* can reduce the chlorophyll content of the leaves in which it comes in contact and can interfere with pollination and fruit set of other species (Kanchan & Jayachandra, 1980b).

There is evidence that allelopathic effects of *P. hysterophorus* are not confined to other higher plants, extending to a wide range of organisms. For example, Megharaj *et al*. (1987) reported that beneficial soil algae were inhibited by powdered dried leaves, inflorescences and roots of *P. hysterophorus*. Similarly, inhibition of the growth of nitrogen-fixing bacteria by leaf material of *P. hysterophorus* was observed by Kanchan & Jayachandra (1981). Luke (1976) concluded that root exudates of *P. hysterophorus* can influence the composition of soil microflora, based upon observations of the suppression of fungal species in the rhizosphere of this weed.

A cautionary note with regard to allelopathic effects arising from *P. hysterophorus* was sounded by Belz *et al*. (2009), who conducted a detailed study of the degradation of parthenin. They found that this allelochemical was degraded rapidly under most conditions, but degradation was delayed in sterilised soils and at lower soil moisture. Degradation was particularly rapid on soils with high clay content (hence a high cation exchanges capacity). These are just the soils that are most favourable to *P. hysterophorus*, i.e. those on which the weed would potentially attain the highest densities and biomass under suitable climate and land management regimes.

The EWG considered that the effective ecosystem level impacts of allelopathic componds are highly uncertain.

Conservation impacts

6.08.07 - To what extent does the plant occur in habitats of high conservation value (includes all officially protected nature conservation habitats)?

Medium extent

***Level of uncertainty*: medium**

P. hysterophorus is recorded as invasive in grasslands (Nigatu *et al.*, 2010) and rangelands (open woodland, comprised of an acacia overstory with a grassland understory) (Ayele, 2007) in Ethiopia and native grasslands in Australia (Navie *et al.*, 2004; Belgeri *et al*., 2012) and Nepal (Timsina *et al*., 2011). In all of these studies, the invaded habitats were subjected to grazing.

In Queensland, *P. hysterophorus* is present in 23 reserves and 2 listed wetlands (Agriculture & Resource Management Council of Australia & New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers, 2001), and is considered one of the greatest threats to biodiversity in the Einasleigh Uplands bioregion (CRC Weed Management, 2003).

In Nepal it is becoming a serious weed in protected areas such as Chitwan National Park, a home of the rare Asian one-horned rhinoceros. Of great concern is the recent report of the weed in the Masai Mara - Serengeti ecosystem, Kenya/Tanzania which is home to an estimated 2 million wildebeest that depend upon this ecosystem for their survival (Anonymous, 2010) (see question 6.08.01).

P. hysterophorus has been shown to change the floristic diversity in protected areas and natural forests in India. Pandey & Saini (2002) describe a loss of 69-94% of species in forest gaps and forest margins in India where *P. hysterophorus* is present.

Dhileepan (2009) reports that *P. hysterophorus* has been found in various forests and nature reserves in Ethiopia, India, Pakistan, South Africa and Zimbabwe (see Table 2). In South Africa, *P. hysterophorus* has been reported in unspecified habitats of several of the national parks in Mpumalanga (e.g., Kruger National Park) and KwaZulu–Natal (e.g., Ndumo, Tembe and Hluhluwe-iMfolozi parks) provinces (Dhileepan & McFadyen, 2012).

An overview of the national parks/reserves where *P. hysterophorus* occurs is provided in Table 5.

Country	**Region/State/Province**	**National park/reserve**
India	Orissa	Kaziranga National Park
	Karnataka	Bandipur National Park
	Chandigarh	Sukhna Wildlife Sanctuary
	Uttaranchal	Mothronwala Swamp Rajaji National Park Jim Corbett National Park
	Rajasthan	Keoladeo National Park
	Tamil Nadu	Mudumalai Wildlife Sanctuary Nilgiri Bioreserve
	Kerala	Chinnar Wildlife Sanctuary
Australia	Queensland	Albinia National Park Mazeppa National Park
South Africa	Mpumalanga province	Kruger National Park
	KwaZulu-Natal	Ndumo Park Tembe Park Hluhluwe-iMfolozi Park
Swaziland	Lebombo mountain	Lebombo Conservancy
	Northeastern Swaziland	Mbuluzi Game Reserve Mlawula Nature Reserve
Zimbabwe	Bulawayo	Chipangali Wildlife Sanctuary
Ethiopia	Oromia	Awash National Park

Pakistan	Punjab	Chhanga Manga Forest

Table 5: *P. hysterophorus* incidence in national parks and forests, taken from Dhillepan, 2009.

6.08.08 - To what extent does the plant threaten rare or vulnerable species (includes all species classified as rare, vulnerable or endangered in official national or regional lists within the PRA area)?

Low extent

***Level of uncertainty*: medium**

Except on the soils most favourable for the species and under suitable climatic conditions, *P. hysterophorus* is not likely to attain high densities in the absence of high levels of disturbance (Dale, 1981). Such disturbance regimes are in themselves likely to be the proximal threatening factor to rare or vulnerable species.

6.08 How important is the environmental impact by the pest within it current area of invasions?

Moderate

***Level of uncertainty*: medium**

6.09.0a - Taking into account the responses to the relevant questions (on hosts and habitats, climatic conditions, abiotic factors, management methods) in the establishment section, are the conditions in the PRA area sufficiently similar to those in the area of invasion to expect a similar level of impact?

Yes

***Level of uncertainty:* high**

Most impacts would appear in tropical and subtropical rangelands.

The tropical grassland ecosystems and their associated wildlife (see table 5) are not found in the EPPO countries at risk and therefore.

However, natural and semi-natural ecosytems which are similar to the rangelands of Ethiopia and Northern Pakistan and India are present in the countries at risk of the EPPO region in the Mediterranean area.

6.09.0b - Does the same native species or community, or the same threatened ecosystem services, occur in the PRA area and, if not, is it known whether the native species or communities, or ecosystem service in the PRA area are similarly and significantly susceptible?

Yes

***Level of uncertainty*: medium**

The following list summarizes the main habitats according to the EUNIS habitat classification scheme that could be threatened by *P. hysterophorus* (see Appendix 1 for further details):

B1	Coastal dunes and sandy shores
C3	Littoral zone of inland surface waterbodies
E1	Dry grasslands
E2	Mesic grasslands
E3	Seasonally wet and wet grasslands
E5	Woodland fringes and clearings and tall forbs stands
E7	Sparsely wooded grasslands
F3	Temperate and Mediterranean-montane scrub
F9	Riverine and fen scrubs
G5	Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice
I1	Arable land and market gardens
I2	Cultivated areas of gardens and parks
J1	Buildings of cities, towns and villages
J2	Low density buildings
J3	Extractive industrial sites
J4	Transport networks and other constructed hard-surfaced areas
J6	Waste deposit

6.09 - How important is the environmental impact likely to be in the PRA area?

Minor to moderate

***Level of uncertainty*: medium**

Except on the soils most favourable for the species and under suitable climatic conditions, *P. hysterophorus* is unlikely to attain high densities in the absence of high levels of disturbance. Such disturbance regimes are in themselves likely to be the proximal threatening factor to rare or vulnerable species. If it occurs at relatively low densities, *P. hysterophorus* is unlikely to have a consequent effect upon nutrient cycling.

6.10 - How important is social damage caused by the pest within its current area of distribution?

Major

***Level of uncertainty*: low**

One of the most detrimental effects of *P. hysterophorus* is the human health hazard that it poses, which has been noted in India and Australia (Sharma & Sethuraman, 2007). Sushilkumar & Varshney (2010) reported that approximately Rs 8800 million (the exchange rate of rupies to dollars in 2010 was 47.774 http://www.irs.gov/Individuals/International-Taxpayers/Yearly-Average-Currency-Exchange-Rates) were spent annually for the treatment of medical problems arising from exposure to *P. hysterophorus.*

Humans who have continued exposure to *P. hysterophorus* can develop allergic eczematous contact dermatitis (Navie *et al*., 1996a) (see Figure 4). Patients with severe dermatitis suffer fatigue and weight loss and deaths have occurred in severely affected people (Lonkar *et al*. 1974). Hundreds of cases of *P. hysterophorus* dermatitis have been reported in India (Subba Rao *et al*., 1977), as well as elsewhere (Towers & Mitchell, 1983; Warshaw & Zug, 1996; Khan *et al*., 2011). Kololgi *et al*. (1997) mention that due to its chronicity (and when no cure is provided to the patient), reports of committing suicide are available in India and abroad. Sushilkumar (2012) also reports that some people have died as a result of allergies to *P. hysterophorus*, but no further detail is provided.

The pollen of the plant is also allergenic. On examination, it was concluded that the chances of getting sensitised to *P. hysterophorus* are 50% in case of regular exposure by direct contact, leading to allergic rhinitis resulting from exposure to the species' pollen. Allergic responses increase with the degree of exposure to *P. hysterophorus*. McFadyen (1995) reported that in Australia, after 1-10 years of exposure to *P. hysterophorus* some 10-20% of the human population will develop severe allergic reactions. In Queensland, 73% of person sampled were presenting a positive allergy risk to *P. hysterophorus* (Goldsworthy & Austin, 2009). Pollen of *P. hysterophorus* is a major cause of rhinitis in Bangalore, India, with 7% of the human population affected and 40% sensitive to the pollen (Srirama Rao *et al.*, 1991). The figures in allergies caused by *P. hysterophorus* are expected to be higher in developing countries rather than in developed ones because mechanical control (hand-wedding) is likely to be the predominant control method, particularly in rural, subsistence-farming areas (Wise *et al*., 2007).

Cross-sensitivity with other plants, particularly other members of the Asteraceae, may occur, causing patients to react to plants to which they previously had not been sensitive (Rodriguez *et al*., 1977). For example, *P. hysterophorus* and *Xanthium strumarium* have shown a high rate of cross-sensitivity in Indian patients (Pasricha *et al*., 1990). Furthermore, cross-sensitivity (in both directions) has been demonstrated between *P. hysterophorus* and ragweeds (*Ambrosia* spp.) in both American and Indian patients (Towers & Subba Rao, 1992; Sriramarao P & Rao PV, 1993). As *Ambrosia artemisiifolia* is already a major allergenic problem in Europe, the cross-sensitivity with *P. hysterophorus* would amplify the allergies.

Alhammadi (2010) report in Yemen many cases of allergy due to consumption of honey from bees which fed on the flowers in Hajah.


Figure 4: Contact Dermatitis to *P. hysterophorus* (http://www.mmc.tn.gov.in/Department/OCD/services.html)

Impact upon domestic animals

P. hysterophorus is usually avoided by stock, as it is toxic, but where it forms almost pure stands, animals may consume significant quantities of it (Navie *et al*., 1996a). Fisher (1996) in Sushilkumar & Varshney (2010) indicate that *P. hysterophorus* was found to cause clinical signs in animals, such as salivation, onset of diarrhoea, anorexia, pruritus, alopecia and dermatitis on the face, muzzle, neck, eyes, thorax, abdomen and brisket region in calves. Stock animals, especially horses, suffer from allergic skin reaction while grazing infested paddocks (Dhileepan, 2009)

Serious impacts upon the health of livestock in *P. hysterophorus*-infested areas have been reported from India (Lakshmi & Srivinas, 2007). Buffaloes in India are more susceptible than cattle, but no figures are available on buffalo poisoning in this country (Wise *et al*., 2007). Free-ranging cattle and buffalo generally graze this weed only sparingly, but goats readily consume it. In artificial feeding trials, buffalo calves (n=16) that ate *P. hysterophorus* alone or in various fodder mixtures fared poorly. Almost 70% of these animals developed severe dermatitis and toxic symptoms, dying within 8-30 days (Lakshmi & Srivinas, 2007). Diets containing 10-50% of *P. hysterophorus* can kill cattle and buffaloes within 30 days (Narasimhan *et al.*, 1977a; Narasimhan *et al.*, 1977b; More *et al*., 1982). By the end of a six-week period all bull calves (n=3) that were fed a diet of 5% *P. hysterophorus* had died (Narasimhan *et al.*, 1980). Loss of hair and skin pigmentation, as well as dermatitis and diarrhoea have been reported in domestic stock (Narasimhan *et al.*, 1977b), as have degenerative changes in both the liver and kidneys of buffalo (Amhed *et al.*, 1988) and sheep (Rajkumar *et al.*, 1988).

Sheep appear to consume *P. hysterophorus* more readily than other animals and seem to be more resistant to its toxic effects (Navie *et al*., 1996a), but taints have been detected in the meat of sheep fed a diet of 30% *P. hysterophorus* (Tudor *et al.*, 1982). Both milk and meat of cattle, buffalo and sheep that have fed upon *P. hysterophorus* may become tainted (Tudor *et al.*, 1982 ; Towers & Subba Rao, 1992). Reductions in milk quantity have been reported as an early consequence of weed ingestion in dairy cattle in Pakistan (Shabbir A., pers. comm., 2013). Cattle may pass the toxic principle to their milk (Parson & Cuthbertson, 1992 in Department of Natural Resources, the Art and Sport, 2010). In Nepal, 11% farmers at Bharatpur and 36% of the Hetauda reported that their milk had bitter taste or taint and had faced rejection of their milk at their market (Karki, 2009).

Impact on beef production

In Queensland, *P. hysterophorus* reduces cattle production by as much as AU$16.5 m annually in the early 1980s, owing to reduced stock numbers and liveweight gains, as well as additional production and control costs. *P. hysterophorus* also reduces stock production. McFayden (1992) provided a rough estimate of stocking rate reductions in *P. hysterophorus* infested land in Queensland. The reductions varied between 25% for light to medium infestations to 80% for heavy infestations. A later, and more thorough, economic analysis in the mid 1990s estimated that *P. hysterophorus* would cost the Australian beef industry AU$109 million per annum in the absence of control (Adamson, 1996). The presence of *P. hysterophorus* has caused a need for establishing improved pastures (in order to replace degraded, *P. hysterophorus*-infested natural grasslands; Fensham, 1999) and the production of extra cultivated forage, both of which have added to the cost of beef production (Navie *et al*., 1996a).

Other social impacts

Tang (2012) reports traffic obstruction when *P. hysterophorus* grows on roadside in Guangxi (China).

Dense patches of the plant would create a negative visual effect (Department of Primary Industries, Government of Victoria (2011). Although the species would not impact directly recreational activities, its human health impact may have deleterious consequence on the frequentation of certain areas.

6.11 - How important is the social damage likely to be in the PRA area?

Major

***Level of uncertainty*: medium**

Human health impact

Social damage arising from the presence of *P. hysterophorus* in the PRA may be similar as what is observed in its current area of distribution, unless the weed does not reach sufficient densities to have a significant impact (or there is evidence that human populations differ in terms of their susceptibility, which is unlikely).

Cross-sensitivity (in both directions) has been demonstrated between *P. hysterophorus* and ragweeds (*Ambrosia* spp.) in both American and Indian patients (Towers & Subba Rao, 1992; Sriramarao P & Rao PV, 1993). As European populations are sensitized to *Ambrosia artemissifolia*, it is likely that they would also be sentitive to *P. hysterophorus*.

Southern EPPO countries' populations may be in closer contact with the plant as there is less mechanisation, health problems may be more frequent than in European EPPO countries at risk.

P. hysterophorus could conceivably attain relatively high densities in disturbed sites (e.g. vacant lots and wasteland) that are in the vicinity of high human population numbers. Severity of symptoms appears to be more intense in the Indian population than elsewhere. A hypothesis to explain this is that in India a greater percentage of the population may be living in close proximity of the weed.

Livestock impact

As sheep and goat production are important in countries at risk (e.g. Spain, Morocco), the impacts on animal production are expected to be as high as in other countries where impacts are reported.

In the French Mediterranean regions (Languedoc-Roussillon & Provence), there are 850 633 sheeps and 48 855 goats (according to the agricultural survey of 2010 undertaken by Agreste available at http://agreste.agriculture.gouv.fr/recensement-agricole-2010/resultats-donnees-chiffrees/). The Camargue area and more precisely the 'Plaine de Crau' concentrate most of the livestock in the endangered area (see Figure 5 and 6). The county of Arles and Eyguières have a mean number of sheeps by farm of 535.9 and 1049.9 which is much higher than the national mean of 99.6.

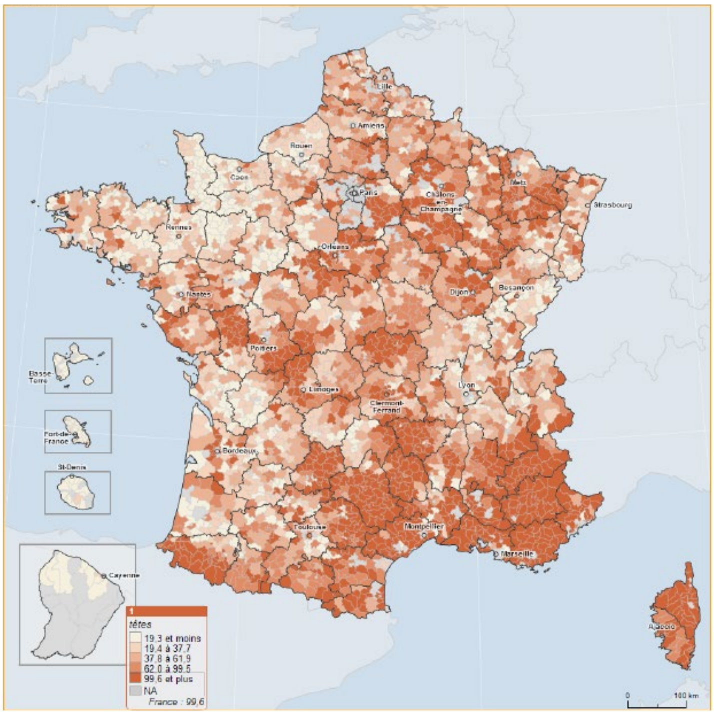


Figure 5: Average number of sheep per farm in 2010 in France. Source: Agreste, resencement agricole 2010 et estimations.

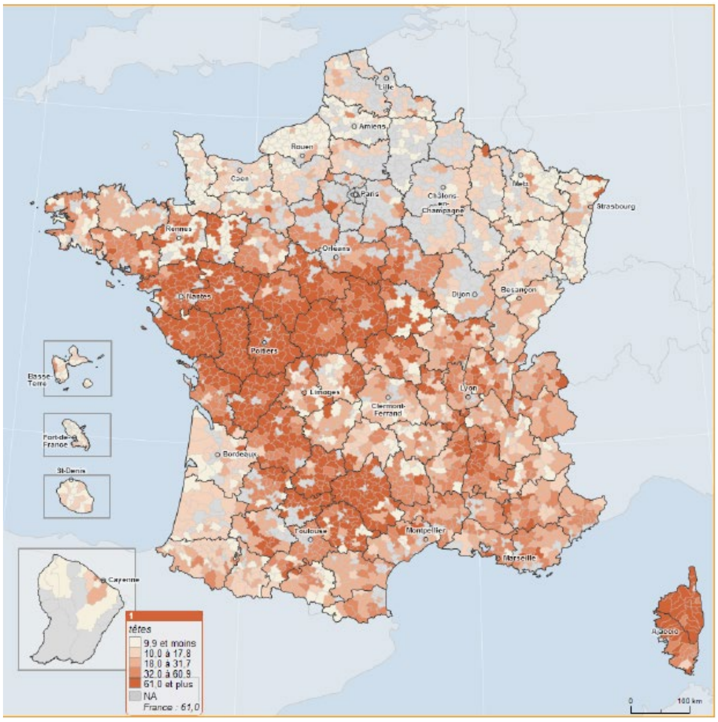


Figure 6: Average number of goat per farm in 2010 in France. Source: Agreste, resencement agricole 2010 et estimations.

As your responses to question 6.04 and 6.05 were "major" or "massive" or any of the responses to questions 6.06, 6.09 and 6.11 is "major" or "massive" or "very likely" or "certain", and the answers given to these questions do not have a high level of uncertainty, questions 6.12 to 6.14 are skiped.

6.15a - Describe the overall economic impact

Major

***Level of uncertainty*: medium**

Major social impacts
Moderate to major agricultural impacts
Moderate environmental impacts
P. hysterophorus is a unique case in that agricultural and social impacts cannot be entirely separated. The health of agricultural workers will be affected primarily as has occurred frequently elsewhere in its introduced range and this is an impact upon the cost of production. Impacts upon livestock production are likely to be significant as well and represent an additional impact on agriculture.

Table 6 provides a summary of ecosystem services that may be affected by *P. hysterophorus.*
This assessment is made for the endangered area (see Q 3.11) including the Mediterranean basin and the warmest parts of the temperate EPPO region. The different categories of ecosystem services have been taken from the Economics of Ecosystems & Biodiversity website, and from the EFSA guidance on the environmental risk assessment of plant pests (EFSA, 2011). For each ecosystem service, an assessment on a 5 grid scale (minimal, minor, moderate, major, massive) is provided, with an assessment of uncertainty (low, medium, high) and a justification. The overall impacts of *P. hysterophorus* on ecosystem services are considered to be major.

Provisioning services		
Food	Major Low uncertainty	*P. hysterophorus* is a serious problem in pastures (see Q. 6.01) and reduces livestock production. It also competes with cultivated crops (e. g. cereals, orchards, vegetables) causing important yield reduction.
Raw materials (fibres, wood, biofuels, ornamental resources).	Minimal Medium uncertainty	No impacts have been reported on raw materials.
Biochemical, natural medicines, etc.	Minor High uncertainty	*P. hysterophorus* has no recorded impacts on biochemical and natural medicines, although by outcompeting other species in grasslands and other natural or semi-natural ecosystems, the plant may be detrimental to natural medicines. On the other hand, *P. hysterophorus* is used as a medicinal plant used in India against dysentery and for its properties as antitumor. It is also externally used in the Caribbean and in Central America against skin disorders (Oudhia, 2014).
Fresh water	Minimal Low uncertainty	No impacts have been reported on global hydrological cycle.
Regulating services		
Air quality regulation	Minimal Medium uncertainty	Although the pollen of *P. hystyerophorus* is highly allergenic with its presence in the air greatly reduces air quality (see Q. 6.10), this cannot be taken into account as such in the evaluation of ecosystem services.
Climate regulation	Minor High uncertainty	No impacts on climate regulation have been explicitly reported. The species may lower the formation of shrub or tree communities, thus impeding the capture of CO2, changing the land use and potentially impacting the locally temperatures and precipitations.
Water regulation and cycling	Minimal Low uncertainty	No impacts on water regulation are reported.
Soil formation	Minor Medium uncertainty	No direct impact on soil formation have been reported, though, if the species outcompets other species including through allelopathy, this may have effects on soil formation.
Erosion regulation	Minimal Low uncertainty	No impacts on erosion regulation are reported.

Nutrient cycling	Minor to moderate Medium uncertainty	If *P. hysterophorus* attains high densities, it may have an impact on nutrient cycling (see Q 6.08.04).
Photosynthesis and primary production	Minor to moderate Medium uncertainty	Pollen from *P. hysterophorus* can reduce the chlorophyll content of the leaves in which it comes in contact (see Q. 6.08.01).
Pest and disease regulation	Major Low uncertainty	*P. hysterophorus* is a reservoir for many pests (see Q. 6.01).
Pollination	Major Low uncertainty	Pollen from *P. hysterophorus* can interfere with pollination and fruit set of other species, both wild and cultivated (see Q. 6.01 and 6.08.06).
Habitat or supporting services		
Habitats for species	Moderate Low uncertainty	*P. hysterophorus* has been recorded in protected areas which contain unique habitats and species (see Q. 6.08.07 and 6.08.01). More generally, the plant is able to outcompete other species (see Q 6.08.01).
Maintenance of genetic diversity	Minor Medium uncertainty	The plant is able to outcompete other species (see Q 6.08.01), though it is not reported to threaten rare species (see Q 6.08.08).
Cultural services		
Recreation and mental and physical health	Major to massive Low uncertainty	*P. hysterophorus* occurs in recreation areas. Although the species would not impact directly recreational activities, its human health impact may have deleterious consequence on the frequentation of certain areas (see Q. 6.10). Its human health impacts through dermatitis and respiratory allergies have led to the death or to the suicide of people (see Q. 6.10).
Tourism	Minor to moderate Medium uncertainty	*P. hysterophorus* may occur in touristic areas. Although the species would not impact directly touristic activities, its human health impact may have deleterious consequence on the frequentation of touristic sites (see Q. 6.10).
Aesthetic appreciation and inspiration for culture, art and design	Minor Medium uncertainty	Dense patches of the plant would create a negative visual effect (see Q. 6.10).
Spiritual experience and sense of place	Minimal High uncertainty	No information is available on this point.

Table 6: summary table of the impacts of *P. hysterophorus* on ecosystem services.

6.15b - With reference to the area of potential establishment identified in Q3.08, identify the area which at highest risk from economic, environmental and social impacts. Summarize the impact and indicate how these may change in future.

Major

***Level of uncertainty*: medium**

The Mediterranean Basin appears to be the area of highest risk. Densily populated areas are particularly at risk, so are pastures and rural vegetables production areas.

The species may increase its range to Northern Europe with climate change.

Stage 2: Pest Risk Assessment Section B: Degree of uncertainty and Conclusion of the pest risk assessment

c2 - Degree of uncertainty: list sources of uncertainty

The overall level of uncertainty is assessed to be medium.

- The current distribution in the EPPO region (the species may be unreported in some EPPO countries as for instance in the Mediterranean countries);
- The time for arrival and potential rate of spread of the species in the EPPO region;
- The effect of allelopathy on other species in the environment and on crops;
- The pollen effect on other species fruit production, such as in olives or grapes in EPPO countries;
- The densities the species could attain in the EPPO region;
- Uncertainty of occurrence in irrigated stone fruits fields (apple, pear, etc);
- Uncertainty of behaviour in different soils;
- Relationship between *P. hysterophorus* frequency and abundance and health effects;
- To what extent conventional methods would manage the species in the EPPO region.

c3 - Conclusion of the pest risk assessment

The species is considered to have major social impacts through human and animal health impacts, and moderate agricultural and environmental impacts. The pest qualifies as a quarantine pest.

The importance of pathways is ordered as follows:

- Contaminant of used machinery

Moderately likely
Level of uncertainty: low

- Contaminant of grain

Moderately likely
Level of uncertainty: low

- Contaminant of seed

Moderately likely for pasture and cereal seeds, unlikely for vegetable seeds
Level of uncertainty: medium

- Contaminant of growing media attached to plants for planting

Moderatley likely
Level of uncertainty: medium

- Contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage

Moderately likely
Level of uncertainty: high

- Contaminant of soil

Unlikely
Level of uncertainty: medium

- Hitchhiker on fruits, vegetables, timber, packaging material, etc.

Unlikely

Level of uncertainty: high

Stage 3: Pest Risk Management

7.01 - Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?

No

Benefits arising from the pathways that could potentially introduce *P. hysterophorus* do not outweigh the potential impact arising through its accidental introduction. High spread probability and potentially major social and economic impacts are considered a non-acceptable risk.

7.02 - Is natural spread one of the pathways?

Yes

P. hysterophorus is dispersed by wind, and to a much greater extent, by water elsewhere in its introduced range.

7.03 - Is the pest already entering the PRA area by natural spread or likely to enter in the immediate future?
The answer to question 4.01 was: Medium rate of spread by natural means

No

P. hysterophorus already occurs within the PRA area in Israel. Additional primary introductions to the PRA area through natural spread in the immediate future are unlikely considering that Israel is quite distant from other EPPO countries.
Natural spread is not the major pathway as human-mediated pathways predominate in the spread of *P. hysterophorus* elsewhere in its introduced range (Panetta, 2012; Panetta & Cacho, 2012). However, control measures in the area of distribution in collaboration with the NPPOs concerned could reduce natural spread.

Pathway 1: Contaminant of used machinery

7.06 - Is the pathway that is being considered a commodity of plants and plant products?

No

7.07 - Is the pathway that is being considered the entry with human travellers?

No

7.08 - Is the pathway being considered contaminated machinery or means of transport?

Yes

Possible measures: cleaning or disinfection of machinery/vehicles
Such cleaning has already been undertaken in Australia for agricultural machinery. Some measures are being taken for import into Israel (see Q. 2.04 of the pathway on used machinery).
Cleaning should also concern military equipment, and possibly vehicles.

7.29 - Are there effective actions that could be taken in the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts?

Yes

Level of uncertainty: low

Surveillance and rapid action including eradication and containment of the plant would lower the intensity of infestations.
Possible measures: internal surveillance and/or eradication or containment campaign.

7.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Q.	Standalone	System Approach	Possible Measure	Uncertainty

7.08		X	**cleaning or disinfection of machinery/vehicles**	**Low**
7.29		X	**internal surveillance and/or eradication or containment campaign**	**Low**

7.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

No

***Level of uncertainty*: low**

Cleaning or disinfection need to be accompanied with surveillance, the 2 measures need to be combined.

7.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

Yes

***Level of uncertainty:* low**

Cleaning or disinfection of machinery/vehicles and internal surveillance and/or eradication or containment campaign need to be combined.

7.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

***Level of uncertainty*: low**

Such measures are in place in countries such as Israel and Norway and do not interfere with international trade.

7.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

***Level of uncertainty*: low**

Additional costs are expected for the countries where the pest is absent (cleaning of entering machinery and surveillance), but they are cost-effective owing to the risk that *P. hysterophorus* represent. Cleaning or disinfection of used machinery will also prevent other pests.

7.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes

The following measures should be combined:

- cleaning or disinfection of machinery/vehicles
- internal surveillance and/or eradication or containment campaign.

Pathway 2: Contaminant of grain

7.06 - Is the pathway that is being considered a commodity of plants and plant products?

Yes

Grain is a plant product.

7.09 - If the pest is a plant, is it the commodity itself?

No

7.10 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

No

***Level of uncertainty*: low**

The EU legislation does not include measures which could be effective against *P. hysterophorus* (EU, 2000).
In Turkey, no plant species are regulated (Uludag, pers. com., 2014).
The situation for other EPPO countries is not known.

7.13 - Can the pest be reliably detected by visual inspection at the place of production?

Yes in combination with other measures

***Level of uncertainty:* medium**

P. hysterophorus is usually taller than vegetables and crops and has a distinctive appearance, particularly when flowering, and is therefore easily recognizable (see Appendix 3). Though, seeds are not easy to detect.
Possible measure therefore includes visual inspection at the place of production.

7.14 - Can the pest be reliably detected by testing at the place of production?

No

***Level of uncertainty:* low**

Testing is not relevant for seeds of *P. hysterophorus*.

7.15 - Can infestation of the commodity be reliably prevented by treatment of the crop?

Yes in combination with other measures

***Level of uncertainty*: high**

Tillage and cultivation and the extensive use of herbicide are considered to have limited the abundance of *P. hysterophorus* in the USA (Reddy & Bryson, 2005). Although management practices, in particular the use of herbicides, are limiting the prevalence of *P. hysterophorus*, they may not totally remove the species from the fields and therefore from the commodity, as indicated by control percentages by different herbicides (Reddy & Bryson, 2005). This remains a valuable measure to be used in combination with other measures.
Possible measure: specified treatment of the crop.

7.16 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?

No, not relevant for plants as pests.

***Level of uncertainty:* low**

7.17 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

No

***Level of uncertainty:* low**

There is no possible physical isolation for growing grain.

7.18 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

No

***Level of uncertainty*: medium**

The life cycle of *P. hysterophorus* coincides with the cultivated grain ones. Spring cereals and maize have the same life cycle, and seeds of *P. hysterophorus* could be mature at the time of harvest. Winter cereals may be affected as well.

7.19 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

Yes

***Level of uncertainty*: medium**

A combination of measures could be implemented: tillage, control of the fields to check the presence of *P. hysterophorus*, herbicide treatments, post-harvesting cleaning of the grain.

Possible measure: certification scheme

7.20 - Based on your answer to question 4.01 select the possible measures based on the capacity for natural spread.

***Level of uncertainty*: medium**

Low to moderate rate of natural spread	**pest-free place of production or pest free area**

7.21 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes

***Level of uncertainty*: medium**

Although requiring intensive efforts, a pest-free place of production could be ensured through surveillance, advice and information to producers, cleaning of machinery, ensuring that other commodities entering the area are not infested (hay, etc.).

7.22 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage?

No

***Level of uncertainty*: low**

The seed of *P. hysterophorus* is very small, measuring a few millimetres. Visual inspection at the time of export or during transport is therefore not an adequate measure.

7.23 - Can the pest be reliably detected by testing of the commodity (e.g. for pest plant, seeds in a consignment)?

Yes

***Level of uncertainty*: high**

Commodities of grain could be sampled and checked for seeds of contaminants including seeds of *P. hysterophorus*. This is technically feasible, though not very realistic.

7.24 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

No

***Level of uncertainty*: low**

Destruction of the seeds would destroy the commodity.

7.25 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?

No

***Level of uncertainty*: low**

This question is not relevant for this pathway.

7.26 - Can infestation of the consignment be reliably prevented by handling and packing methods?

No

***Level of uncertainty*: low**

Seed contaminant can be present in the whole grain consignment and handling or packing methods would not prevent the infestation.

7.27 - Can the pest be reliably detected during post-entry quarantine?

No

Level of uncertainty: **low**

This measure is neither practical nor realistic for grain consignment.

7.28 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

Yes

***Level of uncertainty*: high**

If grain is crushed or transformed the seeds of *P. hysterophorus* would be destroyed, lowering the risk of escape of the weed. However, the plant could be spread in the environment during the transport of the grain, though the probability if low. Grain for processing is usually cleaned before being processed. If the product of this cleaning is released into the environment, seeds of *P. hysterophorus* and of other invasive alien plants may transfer. It should be ensured that the oucome of such cleaning is destroyed and not damped. The end use of grain to be crushed lowers the risk.

When infested grain is destined to animal feed, the seeds of *P. hysterophorus* ingested by animals could be spread to suitable habitats (e.g. pastures). In the EU, millet (grains of *Panicum miliaceum*) and sorghum (grains of *Sorghum bicolor*) are not directly fed to animals. Other possibly infested cereals such as wheat or barley are expected to be fed to animals. This end use presents a high risk.

Possible measure: import under special licence/permit and specified restrictions.
However, there would remain uncertainty that the end use initially planned is the one actually in use for the commodity.

7.29 - Are there effective actions that could be taken in the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts?

Yes

***Level of uncertainty*: low**

Surveillance and rapid action including eradication and containment of the plant would lower the intensity of infestations.
Possible measures: internal surveillance and/or eradication or containment campaign.

7.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Q.	Standalone	System Approach	Possible Measure	Uncertainty
7.13		X	visual inspection at the place of production	Medium
7.15		X	specified treatment of the crop	High
7.19	X		possible measure: certification scheme	Medium
7.20	X		pest free place of production and pest-free area	Medium
7.23		X	testing of the commodity	High

7.28	X		**import under special licence/permit and specified restrictions**	**High**
7.29		X	**internal surveillance and/or eradication or containment campaign**	**Low**

7.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

No

Level of uncertainty: low

Most of the measures taken as stand alone measures, with the possible exception of sourcing consignments from pest-free place of production and pest-free areas, would not reduce the risk of introduction of *P. hysterophorus* to an acceptable level and need to be combined in a systems approach.

Import under special licence/permit and specified restrictions would destroy the contaminant and would represent an acceptable level of risk as an individual measure.

7.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

Yes

Level of uncertainty: low

Visual inspection at the place of production, specified treatment, testing of the commodity and surveillance in the country of import of the crop could be included in a systems approach.

7.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

Level of uncertainty: low

The measures/combinations thereof may impose additional costs to trade (compared to the absence of the imposition of measures), but are classical phytosanitary measures that should not interfere with international trade.

7.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Level of uncertainty: low

Additional costs are expected for the countries where the pest is present (phytosanitary certification, official control measures, establishment and maintenance of pest-free areas and places of production). These are considered to be cost-effective for the importing country compared with the risk that the species represents (i.e. no costs would be incurred).

7.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes

- Grain production in pest-free areas
- Grain production in pest-free places of production

Place of production freedom should consist of a combination of the following individual measures:

- Visual inspection at the place of production
- Specified treatment of the crop
- Testing of the commodity
- Internal surveillance and/or eradication or containment campaign

Other measures consist in:

- Certification scheme

- Import under special licence/permit and specified restrictions (for grain which is aimed to be crushed or transformed).

Pathway 3: Contaminant of seed (pasture and cereal seed)

7.06 - Is the pathway that is being considered a commodity of plants and plant products?

Yes

Seeds are a plant product.

7.09 - If the pest is a plant, is it the commodity itself?

No

7.10 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

No

***Level of uncertainty*: low**

The EU legislation does not include measures which could be effective against *P. hysterophorus* (EU, 2000) in seed.
There is no measure on plants in Turkey (Uludag, pers. com., 2014).
The situation for other EPPO countries is not known.

7.13 - Can the pest be reliably detected by visual inspection at the place of production?

Yes in combination with other measures

***Level of uncertainty:* medium**

P. hysterophorus develops quite fast in the field.
For fodder seed production, the species could easily go unnoticed in production sites.
P. hysterophorus is usually taller than vegetables and crops and has a distinctive appearance, particularly when flowering, and is therefore easily recognizable (see Appendix 3), except maybe in look-alike plants such as *Fagopyrum esculentum.*
Possible measure therefore is visual inspection at the place of production.

7.14 - Can the pest be reliably detected by testing at the place of production?

No

***Level of uncertainty*: low**

Testing is not relevant for seeds of *P. hysterophorus*.

7.15 - Can infestation of the commodity be reliably prevented by treatment of the crop?

Yes in combination with other measures

***Level of uncertainty*: high**

Tillage and cultivation and the extensive use of herbicide are considered to have limited the abundance of *P. hysterophorus* in the USA (Reddy & Bryson, 2005). Although management practices are limiting the prevalence of *P. hysterophorus*, in particular with the use of herbicides, they may not totally remove the species from the fields and therefore from the commodity, as indicated by control percentages by different herbicides (Reddy & Bryson, 2005). This remains a valuable measure to be used in combination with other measures.
Possible measure: specified treatment of the crop.

7.16 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?

No, not relevant for plants as pests.

***Level of uncertainty*: low**

7.17 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

Yes

***Level of uncertainty*: low**

Pastures and cereals for seeds cannot be grown in specified conditions.
Such measures are only possible for vegetables.

Vegetables can be grown in screened glasshouses, ensuring that they are free from *P. hysterophorus* and in sterilized growing media free from seeds of the weed.

7.18 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

No

***Level of uncertainty*: medium**

The life cycle of *P. hysterophorus* would coincide with the one of pastures species and cereals.
The risk in vegetables would be lower.

7.19 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

Yes

***Level of uncertainty*: medium**

A combination of measures could be implemented: tillage, inspection of the fields to check the presence of *P. hysterophorus*, herbicide treatments, post-harvesting cleaning of the seed. Certification schemes are already in place for seed. However, *P. hysterophorus* is not listed as a quarantine or noxious pest and may currently escape vigilance.
Possible measure: certification scheme

7.20 - Based on your answer to question 4.01 select the possible measures based on the capacity for natural spread.

***Level of uncertainty*: medium**

Low to moderate rate of natural spread	**pest-free place of production or pest free area**

7.21 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes

***Level of uncertainty*: medium**

Although requiring intensive efforts, a pest-free place of production could be ensured through surveillance and surveys, advice and information to producers, cleaning of machinery, ensuring that other commodities entering the area are not infested (hay, etc.).

7.22 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage?

No

***Level of uncertainty*: low**

The seed of *P. hysterophorus* is very small, though in a consignment of seeds, it could be spotted and removed, but this needs to be done through testing.

7.23 - Can the pest be reliably detected by testing of the commodity (e.g. for pest plant, seeds in a consignment)?

Yes

***Level of uncertainty*: high**

Seeds could be sampled and checked for the detection of seeds of *P. hysterophorus*.

7.24 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

No

***Level of uncertainty*: low**

Destruction of the seeds of *P. hysterophorus* would destroy the consignment[2].

7.25 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?

No

***Level of uncertainty*: low**

This question is not relevant for this pathway.

7.26 - Can infestation of the consignment be reliably prevented by handling and packing methods?

No

***Level of uncertainty*: low**

Handling and packing methods of seed lots would not prevent contamination.

7.27 - Can the pest be reliably detected during post-entry quarantine?

No

***Level of uncertainty*: low**

This measure is neither practical nor realistic for grain consignment.

7.28 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

No

***Level of uncertainty*: low**

Seeds are intended to be planted in fields, providing the ideal situations for *P. hysterophorus* to germinate and further escape.

7.29 - Are there effective actions that could be taken in the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts?

Yes

***Level of uncertainty*: low**

Surveillance and rapid action including eradication and containment of the plant would lower the intensity of infestations.

Possible measures: internal surveillance and/or eradication or containment campaign.

7.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Q.	Standalone	System Approach	Possible Measure	Uncertainty
7.13		X	visual inspection at the place of production	Medium
7.15		X	specified treatment of the crop	High
7.17		X	growing the crop in specified conditions (for vegetables)	Low
7.19	X		possible measure: certification scheme	Medium
7.20	X		pest free place of production and pest-free area	Medium
7.23		X	testing of the commodity	High
7.29		X	internal surveillance and/or eradication or containment campaign	Low

7.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

No

***Level of uncertainty*: low**

Most of the measures taken singly, with the possible exception of sourcing consignments from a pest-free place of production and pest-free areas and certification scheme (which represent a system approach), would not reduce the risk of introduction of *P. hysterophorus* to an acceptable level and need to be combined in a system approach.

7.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

Yes

***Level of uncertainty:* low**

Visual inspection, specified treatment, testing of the commodity and surveillance in the country of import of the crop could be included in a systems approach. This is nevertheless what is already been undertaken with certification schemes for seed lots.

7.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

***Level of uncertainty*: low**

The measures/combinations thereof may impose additional costs to trade (compared to the absence of the imposition of measures), but are classical phytosanitary measures that should not interfere with international trade. Certification schemes for seeds are already in place.

7.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

***Level of uncertainty*: low**

Additional costs are expected for the countries where the pest is present (phytosanitary certification, official control measures, establishment and maintenance of pest-free areas and places of production). These are considered to be cost-effective for the importing country compared with the risk that the species represents (i.e. no costs would be incurred).

7.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes

- Seeds production in pest-free areas
- Seeds production in pest-free places of production

Place of production freedom should consist of a combination of the following individual measures:

- visual inspection at the place of production
- specified treatment of the crop
- testing of the commodity
- internal surveillance and/or eradication or containment campaign

Other measure:

- Certification schemes for seeds

Pathway 4: Contaminant of growing media adherent to plants for planting

7.06 - Is the pathway that is being considered a commodity of plants and plant products?

Yes

7.09 - If the pest is a plant, is it the commodity itself?

No

7.10 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

No

***Level of uncertainty*: low**

General measures for plants for planting with growing media attached from non-European countries exist in the EU but are not specific enough to prevent the introduction of *P. hysterophorus.*

The current requirements of the EU Plant Health Directive do not cover specifically seeds in growing media. Though, the Directive 2000/29 (European Union, 2010) requires that plants for planting coming from Turkey, Belarus, Georgia,, Moldova, Russia, Ukraine, and other non European countries other than Algeria, Egypt, Israel, Libya, Malta, Morocco, and Tunisia be at the time of planting: free from soil and organic matter or were subject to appropriate heat treatment or fumigation against pests (thermic treatment or fumigation, which may be efficient against seeds of *P. hysterophorus*).

In Turkey, no plant species are regulated (Uludag, pers. com., 2014). In Russia, introduction of plants with soil is restricted.

Seeds (2 mm or less) are not visible in the growing media and they may remain undetected.

In EU, as *P. hysterophorus* is not considered a pest, phytosanitary measures would not apply and seeds of the pest may be present in plants for planting accompanied with growing media coming from countries where it occurs.

7.13 - Can the pest be reliably detected by visual inspection at the place of production?

Yes in combinaison with other measures

***Level of uncertainty*: high**

Seeds are no more than 2 mm in diameter and will be mixed with soil and will remain unnoticed. However, if a place of production is infested, seeds would have germinated and as the plant can easily be recognized, it could be detected. Though, seeds could also be carried by wind on growing media and go unnoticed.

Possible measure: visual inspection at the place of production

7.14 - Can the pest be reliably detected by testing at the place of production?

No

***Level of uncertainty*: low**

Testing of seeds in soil is not relevant.

7.15 - Can infestation of the commodity be reliably prevented by treatment of the crop

Yes in combinaison with other measures

***Level of uncertainty*: medium**

Some mechanical and chemical management methods exist. Nevertheless, the plant produces many little seeds (2 mm in diameter) that can remain viable a few years (7 years). This method needs to be combined with other management measures.

7.16 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?

No, not relevant for plants as pests.

***Level of uncertainty*: low**

7.17 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

Yes

***Level of uncertainty*: low**

Vegetables and plants for planting can be grown in screened glasshouses, ensuring that they are free from *P. hysterophorus* and in sterilized growing media free from seeds of the weed.

7.18 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

No

***Level of uncertainty*: medium**

Plants for planting may be grown all year long, and *P. hysterophorus* could germinate when conditions are suitable.

7.19 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

Yes

***Level of uncertainty*: medium**

A combination of measures could be implemented: visual inspection of the nursery, herbicide treatments, growing the plant in glasshouses and in sterilized growing media.

Possible measure: certification scheme

7.20 - Based on your answer to question 4.01 select the possible measures based on the capacity for natural spread.

***Level of uncertainty*: medium**

Low to moderate rate of natural spread	**pest-free place of production or pest free area**

7.21 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?

Yes

***Level of uncertainty*: medium**

Although requiring intensive efforts, pest-free place of production could be ensured through surveillance and surveys, advice and information to producers, cleaning of machinery, ensuring that other commodities entering the area are not infested (hay, etc.).

7.22 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage?

No

***Level of uncertainty*: low**

The seed of *P. hysterophorus* is very small and cannot be detected in growing media attached to plants for planting.

7.23 - Can the pest be reliably detected by testing of the commodity (e.g. for pest plant, seeds in a consignment)?

No

***Level of uncertainty*: low**

Testing of contaminating seeds in soil is not possible.

7.24 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

No

***Level of uncertainty*: low**

Destruction of the contaminant seeds would destroy as well the plants for planting.

7.25 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?

Yes

***Level of uncertainty*: low**

Plants for planting exported without soil do not represent a risk.
Possible measure: removal of growing media from consignment.

7.26 - Can infestation of the consignment be reliably prevented by handling and packing methods?

No

***Level of uncertainty*: low**

As long as growing media is infested, handling and packing methods would not lower the risk.

7.27 - Can the pest be reliably detected during post-entry quarantine?

No

***Level of uncertainty*: low**

Seeds would germinate in the growing media after a few weeks, but may also remain dormant months or years. However, this is not considered a realistic measure.

7.28 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

No

***Level of uncertainty*: low**

The risk would be lowered for plants for planting planted in glasshouses, but there is no way to ensure such end use, and of the treatment of *P. hysterophorus* that would be done if it were to be present in a glasshouse.

7.29 - Are there effective actions that could be taken in the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts?

Yes

***Level of uncertainty*: low**

Surveillance and rapid action including eradication and containment of the plant would lower the intensity of infestations.
Possible measures: internal surveillance and/or eradication or containment campaign.

7.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Q.	Standalone	System Approach	Possible Measure	Uncertainty
7.13		X	visual inspection at the place of production	High
7.15		X	specified treatment of the crop	Medium
7.17		X	growing the crop in specified conditions (for vegetables)	Low
7.19	X		possible measure: certification scheme	Medium
7.20	X		pest free place of production and pest-free area	Medium
7.25	X		removal of growing medium from consignment	Low
7.29		X	internal surveillance and/or eradication or	Low

			containment campaign	

7.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

No

***Level of uncertainty*: low**

Most of the measures taken as stand-alone measure, with the possible exception of sourcing consignments from pest-free place of production and pest-free areas and certification scheme (which represent a systems approach) and the removal of the growing medium from consignments, would not reduce the risk of introduction of *P. hysterophorus* to an acceptable level and need to be combined in a systems approach.

7.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

Yes

***Level of uncertainty:* low**

Visual inspection at the place of production, specified treatment, growing the plants for planting in glasshouses and in sterilized growing media and surveillance in the country of import could be included in a systems approach.

7.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

***Level of uncertainty*: low**

The measures/combinations thereof may impose additional costs to trade (compared to the absence of the imposition of measures), but are classical Plant Health measures that should not interfere with international trade.

7.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

***Level of uncertainty*: low**

Additional costs are expected for the countries where the pest is present (phytosanitary certification, official control measures, establishment and maintenance of pest-free areas and places of production). These are considered to be cost-effective for the importing country compared with the risk that the species represents (i.e. no costs would be incurred).

7.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes

- Plants for planting production in pest-free areas
- Plants for planting production in pest-free places of production

Place of production freedom should consist of a combination of the following individual measures:

- visual inspection at the place of production
- specified treatment
- growing in glasshouses and in sterilized soil
- internal surveillance and/or eradication or containment campaign

Other measures:

- Certification schemes for plants for planting
- Removal of the growing medium from plants for planting

Pathway 5: Contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage

7.06 - Is the pathway that is being considered a commodity of plants and plant products?

No

7.07 - Is the pathway that is being considered the entry with human travellers?

Yes

***Level of uncertainty*: low**

Possible measures: publicity to enhance public awareness on pest risks, fines or incentives. Treatments may also be possible.

7.29 - Are there effective actions that could be taken in the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts?

Yes

***Level of uncertainty*: low**

Surveillance and rapid action including eradication and containment of the plant would lower the intensity of infestations.

Possible measures: internal surveillance and/or eradication or containment campaign.

7.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Q.	Standalone	System Approach	Possible Measure	Uncertainty
7.07		X	publicity to enhance public awareness on pest risks, fines or incentives. Treatments may also be possible.	Low
7.29		X	internal surveillance and/or eradication or containment campaign	Low

7.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

No

***Level of uncertainty*: low**

Inspection of travellers and their luggage is not considered a feasible option as seeds are very small, rendering the inspection of people unfeasible.

7.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

Yes in combinaison with measures

***Level of uncertainty:* low**

Publicity needs to be accompanied with surveillance.

7.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

***Level of uncertainty*: low**

Such measures are in place in countries such as the USA or Australia. They allow to prevent the entry of other pests than the one targeted, and do not interfere with trade.

7.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

***Level of uncertainty*: low**

Additional costs are expected for the countries, but they are cost-effective owing to the risk that *P. hysterophorus* represents and they will be effective for other pests as well.

7.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

Yes

The following measures should be combined:

- publicity to enhance public awareness on pest risks.
- internal surveillance and/or eradication or containment campaign.

7.38 - Have all major pathways been analyzed (for a pest-initiated analysis)?

Yes

7.41 - Consider the relative importance of the pathways identified in the conclusion to the entry section of the pest risk assessment

Contaminant of used machinery: Moderately likely
Level of uncertainty: low

Contaminant of grain: Moderately likely
Level of uncertainty: low

Contaminant of seed: Moderately likely
Level of uncertainty: medium

Contaminant of growing media adherent to plants for planting: Moderatley likely
Level of uncertainty: medium

Contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage: Moderately likely
Level of uncertainty: high

7.45 - Conclusions of the Pest Risk Management stage.

List all potential management options and indicate their effectiveness.
Uncertainties should be identified.

Pathways	Estimated probability of entry and uncertainties	Measures
Contaminant of used machinery	Moderately likely Low uncertainty	• cleaning or disinfection of machinery/vehicles AND • internal surveillance and/or eradication or containment campaign.
Contaminant of grain	Moderately likely Low uncertainty Uncertainty lies in:	• PC, and if appropriate RC • Grain production in pest-free areas OR • Grain production in pest-free places of production Place of production freedom should consist of a

	- whether treatment of the crop would effectively manage the species. - Whether the import under specified restrictions would effectively be respected	combination of the following individual measures: - Visual inspection at the place of production AND - Specified treatment of the crop AND - Testing of the commodity AND - Internal surveillance and/or eradication or containment campaign OR • Import under special licence/permit and specified restrictions (for grain which is aimed to be crushed or transformed) OR • Certification scheme
Contaminant of seed:	Moderately likely Medium uncertainty Uncertainty lies in whether treatment of the crop would effectively manage the species.	• PC, and if appropriate RC • Seeds production in pest-free areas OR • Seeds production in pest-free places of production Place of production freedom should consist of a combination of the following individual measures: - visual inspection at the place of production AND - specified treatment of the crop AND - testing of the commodity AND - internal surveillance and/or eradication or containment campaign OR • Certification schemes for seeds
Contaminant of growing media adherent to plants for planting	Moderately likely Medium uncertainty Uncertainty lies in whether production techniques of plants for planting would effectively manage the species.	• PC, and if appropriate RC • Plants for planting production in pest-free areas OR • Plants for planting production in pest-free places of production • Place of production freedom should consist of a combination of the following individual measures: - visual inspection at the place of production • AND - specified treatment • AND - growing in glasshouses and in sterilized soil • AND - internal surveillance and/or eradication or

		containment campaign OR • Removal of the growing medium from plants for planting OR • Certification schemes for plants for planting
Contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage:	Moderately likely High uncertainty	• Publicity to enhance public awareness on pest risks. AND • internal surveillance and/or eradication or containment campaign.

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Appendix 1 - EUNIS Habitat where *Parthenium hysterophorus* could establish

The following list summarizes the main habitats in which *P. hysterophoprus* could occur in the EPPO region, according to the EUNIS habitats classification:
http://eunis.eea.europa.eu/habitats-code-browser.jsp?

B : Coastal habitats
B1 : Coastal dunes and sandy shores
B1.6 : Coastal dune scrub
In India, *P. hysterophorus* is found in areas adjacent to coastal dunes where the soil is not saline and in finer grain soils. Similar habitats in the EPPO region, i.e. coastal dune scrub could also be colonized.

C : Inland surface waters
C3 : Littoral zone of inland surface waterbodies
C3.5 : Periodically inundated shores with pioneer and ephemeral vegetation

E : Grasslands and lands dominated by forbs, mosses or lichens

E1 : Dry grasslands
E1.1 : Inland sand and rock with open vegetation

- ⊞ E1.11 : Euro-Siberian rock debris swards
- ▣ E1.12 : Euro-Siberian pioneer calcareous sand swards

P. hysterophorus is unlikely to colonize Siberian ecosystem due to climatic contraints.

E1.2 : Perennial calcareous grassland and basic steppes
This habitat is considered to be suitable for *P. hysterophorus*, but no further detail can be provided.

E1.3 : Mediterranean xeric grassland
E1.31 : West Mediterranean xeric grassland
E1.32 : Southwestern Mediterranean perennial pastures
E1.33 : East Mediterranean xeric grassland
P. hysterophorus is an annual that is adapted to seasonal droughts conditions.

E1.4 : Mediterranean tall-grass and [Artemisia] steppes
P. hysterophorus is a weak competitor and may not be able to colonize Mediterranean tall-grass and steppes unless they are disturbed.

E1.5 : Mediterranean-montane grassland

E1.6 : Subnitrophilous annual grassland

E1.9 : Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland

E1.A : Open Mediterranean dry acid and neutral grassland
E1.A1 : Mediterranean annual deep-sand communities
E1.A2 : Supra-Mediterranean perennial siliceous grasslands
E1.A3 : Rhône riverine dunes
E1.A4 : Southern Iberian inland dunes
E1.A5 : Irano-Anatolian inland dunes

E1.C : Dry mediterranean lands with unpalatable non-vernal herbaceous vegetation

E1.C1 : [Asphodelus] fields
E1.C2 : Thistle fields
E1.C3 : [Phlomis] brushes
E1.C4 : [Ferula] stands
E1.D : Unmanaged xeric grassland
E1.E : Trampled xeric grasslands with annuals

- E1.D : Unmanaged xeric grassland
- E1.E : Trampled xeric grasslands with annuals

- E2 : Mesic grasslands

- ⊟ E2.1 : Permanent mesotrophic pastures and aftermath-grazed meadows
- E2.12 : Ditch-broken pastures
- E2.13 : Abandoned pastures

E2.2 : Low and medium altitude hay meadows
Only meadows which are situated in climatic suitable areas could be colonized.

E2.3 : Mountain hay meadows
Only meadows which are situated in climatic suitable areas could be colonized.

E2.4 : Iberian summer pastures (vallicares)

E2.5 : Meadows of the steppe zone

E2.6 : Agriculturally-improved, re-seeded and heavily fertilised grassland, including sports fields and grass lawns
▣ E2.61 : Dry or moist agriculturally-improved grassland
▣ E2.62 : Wet agriculturally-improved grassland, often with drainage ditches

- E2.7 : Unmanaged mesic grassland
- ▣ E2.8 : Trampled mesophilous grasslands with annuals

E3 : Seasonally wet and wet grasslands

- ⊞ E3.1 : Mediterranean tall humid grassland
- ▣ E3.2 : Mediterranean short humid grassland
- ⊞ E3.3 : Sub-mediterranean humid meadows
- ⊞ E3.4 : Moist or wet eutrophic and mesotrophic grassland
- ⊞ E3.5 : Moist or wet oligotrophic grassland

E5 : Woodland fringes and clearings and tall forb stands
E5.1 : Anthropogenic herb stands
E5.2 : Thermophile woodland fringes

E7 : Sparsely wooded grasslands

▣ E7.1 : Atlantic parkland
▣ E7.2 : Sub-continental parkland
▣ E7.3 : Dehesa

F : Heathland, scrub and tundra
F3 : Temperate and mediterranean-montane scrub

⊞ F3.1 : Temperate thickets and scrub
⊞ F3.2 : Submediterranean deciduous thickets and brushes

F9 : Riverine and fen scrubs
F9.1 : Riverine scrub
⊞ F9.2 : [Salix] carr and fen scrub
⊞ F9.3 : Southern riparian galleries and thickets
FB : Shrub plantations

▣ FB.1 : Shrub plantations for whole-plant harvesting
⊞ FB.2 : Shrub plantations for leaf or branch harvest
⊞ FB.3 : Shrub plantations for ornamental purposes or for fruit, other than vineyards
⊞ FB.4 : Vineyards

G : Woodland, forest and other wooded land
G5 : Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice
All categories are considered to be suitable for P. hysterophorus.

- ▣ G5.1 : Lines of trees
- ▣ G5.2 : Small broadleaved deciduous anthropogenic woodlands
- ▣ G5.3 : Small broadleaved evergreen anthropogenic woodlands
- ▣ G5.4 : Small coniferous anthropogenic woodlands
- ▣ G5.5 : Small mixed broadleaved and coniferous anthropogenic woodlands
- ⊟ G5.6 : Early-stage natural and semi-natural woodlands and regrowth
  - ▣ G5.61 : Deciduous scrub woodland
  - ▣ G5.62 : Mixed scrub woodland
  - ▣ G5.63 : Coniferous scrub woodland
  - ▣ G5.64 : Raised bog pre-woods
- ⊟ G5.7 : Coppice and early-stage plantations
  - ▣ G5.71 : Coppice
  - ▣ G5.72 : Early-stage broadleaved deciduous plantations
  - ▣ G5.73 : Early-stage broadleaved evergreen plantations
  - ▣ G5.74 : Early-stage coniferous plantations
  - ▣ G5.75 : Early-stage mixed broadleaved and coniferous plantations
  - ▣ G5.76 : Trees planted for early whole-tree harvesting
- ⊟ G5.8 : Recently felled areas
  - ▣ G5.81 : Recently felled areas, formerly broadleaved trees
  - ▣ G5.82 : Recently felled areas, formerly coniferous trees
  - ▣ G5.83 : Recently felled areas, formerly mixed broadleaved and coniferous trees
  - ⊞ G5.84 : Herbaceous clearings
  - ▣ G5.85 : Shrubby clearings

I : Regularly or recently cultivated agricultural, horticultural and domestic habitats
I1 : Arable land and market gardens
I1.1 : Intensive unmixed crops
I1.11 : Large-scale intensive unmixed crops (>25ha)
I1.12 : Medium-scale intensive unmixed crops (1-25ha)
I1.13 : Small-scale intensive unmixed crops (<1ha)
I1.2 : Mixed crops of market gardens and horticulture
I1.21 : Large-scale market gardens and horticulture
I1.22 : Small-scale market gardens and horticulture, including allotments
I1.3 : Arable land with unmixed crops grown by low-intensity agricultural methods
1.4 : Inundated or inundatable croplands, including rice fields
I1.5 : Bare tilled, fallow or recently abandoned arable land
I1.51 : Bare tilled land

I1.52 : Fallow un-inundated fields with annual weed communities
I1.53 : Fallow un-inundated fields with annual and perennial weed communities
I2 : Cultivated areas of gardens and parks
I2.1 : Large-scale ornamental garden areas
⊞ I2.2 : Small-scale ornamental and domestic garden areas
I2.3 : Recently abandoned garden areas

J : Constructed, industrial and other artificial habitats
J1 : Buildings of cities, towns and villages
P. hysterophorus may grow in the surroundings of buidlings of cities, towns and villages.

J2 : Low density buildings
J2.1 : Scattered residential buildings
J2.2 : Rural public buildings
J2.3 : Rural industrial and commercial sites still in active use
J2.4 : Agricultural constructions
J2.5 : Constructed boundaries
J2.6 : Disused rural constructions
J2.7 : Rural construction and demolition sites

J3 : Extractive industrial sites
J3.3 : Recently abandoned above-ground spaces of extractive industrial sites

J4 : Transport networks and other constructed hard-surfaced areas
J4.1 : Disused road, rail and other constructed hard-surfaced areas
J4.2 : Road networks
J4.3 : Rail networks
▣ J4.4 : Airport runways and aprons
▣ J4.5 : Hard-surfaced areas of ports
▣ J4.6 : Pavements and recreation areas
▣ J4.7 : Constructed parts of cemeteries

J6 : Waste deposits
J6.1 : Waste resulting from building construction or demolition
J6.2 : Household waste and landfill sites
J6.3 : Non-agricultural organic waste
J6.4 : Agricultural and horticultural waste
J6.5 : Industrial waste

X : Habitat complexes
P. hysterophorus may colonize habitat complexes situated in climatically suitable areas.
X01 : Estuaries
X06 : Crops shaded by trees
▣ X07 : Intensively-farmed crops interspersed with strips of natural and/or semi-natural vegetation
▣ X09 : Pasture woods (with a tree layer overlying pasture)
▣ X10 : Mosaic landscapes with a woodland element (bocages)
▣ X11 : Large parks
▣ X13 : Land sparsely wooded with broadleaved deciduous trees
▣ X14 : Land sparsely wooded with broadleaved evergreen trees
▣ X15 : Land sparsely wooded with coniferous trees
▣ X16 : Land sparsely wooded with mixed broadleaved and coniferous trees
▣ X18 : Wooded steppe
▣ X20 : Treeline ecotones
▣ X22 : Small city centre non-domestic gardens

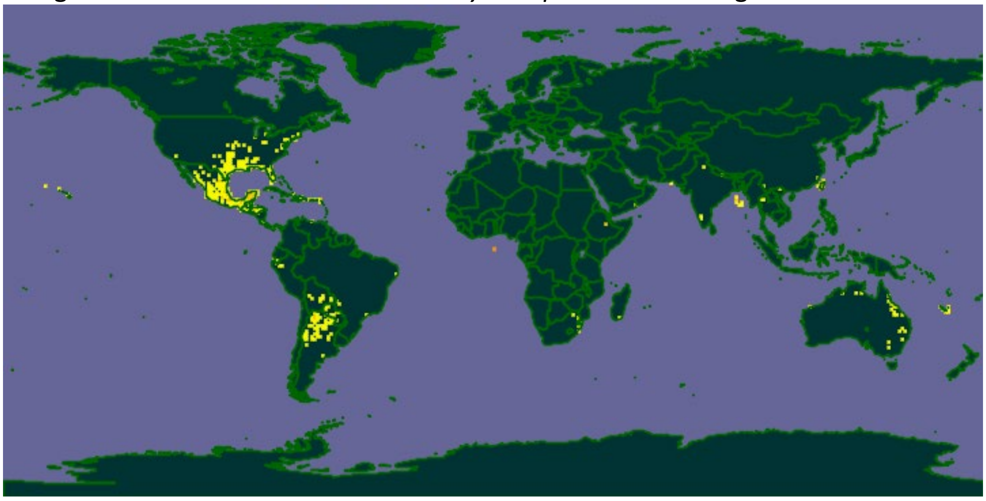
- ▣ X23 : Large non-domestic gardens
- ▣ X24 : Domestic gardens of city and town centres
- ▣ X25 : Domestic gardens of villages and urban peripheries
- ▣ X27 : Machair complexes

Appendix 2- Climatic projection for *Parthenium hysterophorus*

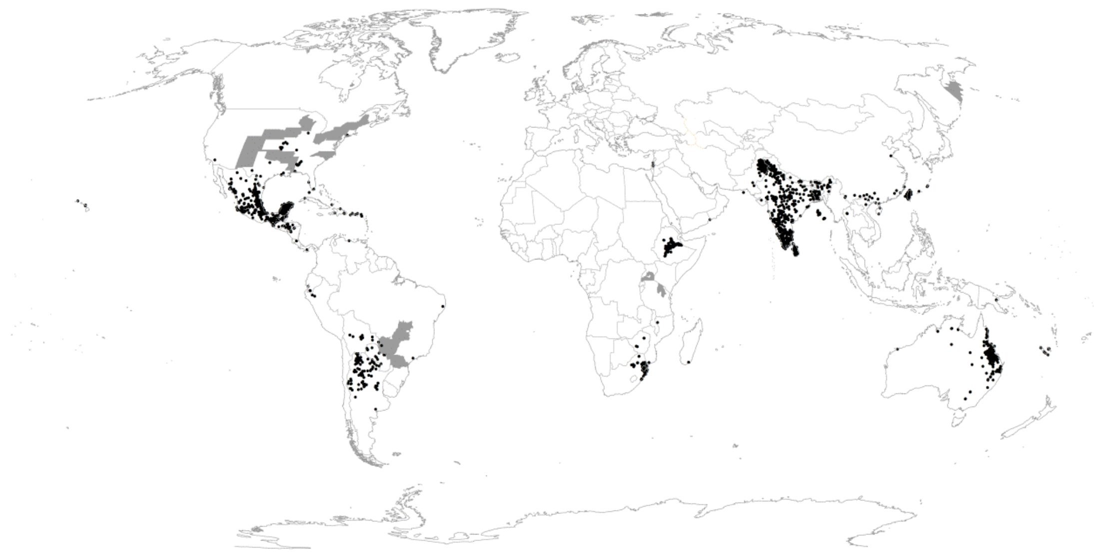
1. Collection of data for *Parthenium hysterophorus* distribution

Existing distribution maps for *P. hysterophorus* have been collected and are restituted below. See Question 1.07 for details and references on *P. hysterophorus* distribution.

The global distribution of *Parthenium hysterophorus* according to GBIF is as shown below:

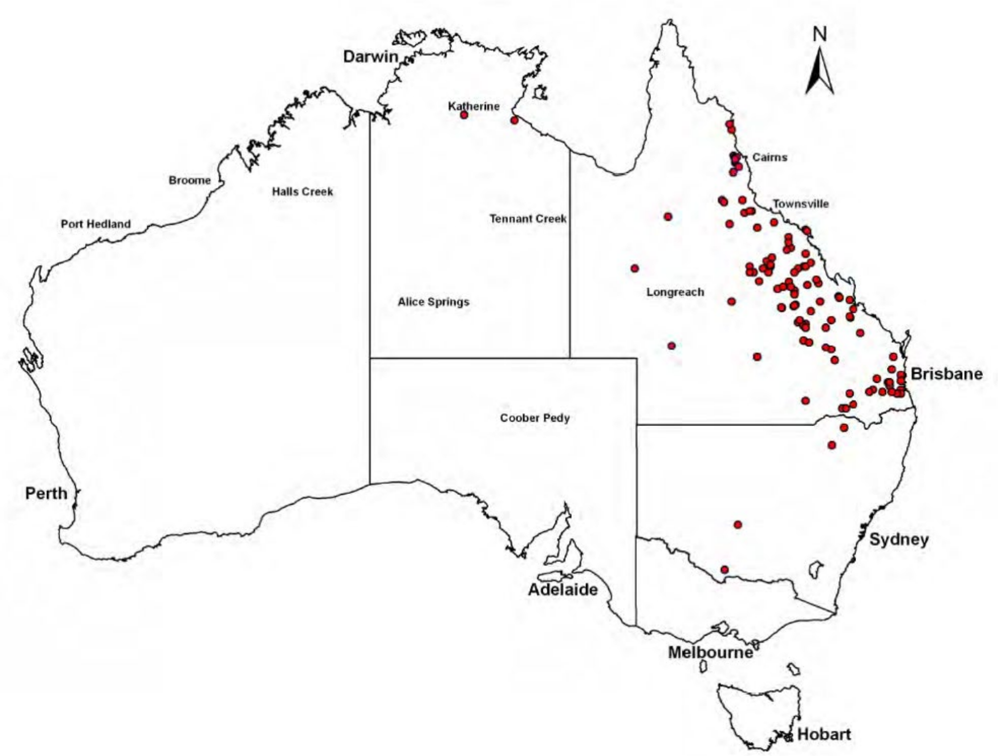


World distribution of *Parthenium hysterophorus* according to GBIF. The map is incomplete for data in Israel, Egypt, Oman and Yemen and India, where the species is distributed to many parts except Western Ghats, snow covered areas of North and North-Eastern regions.



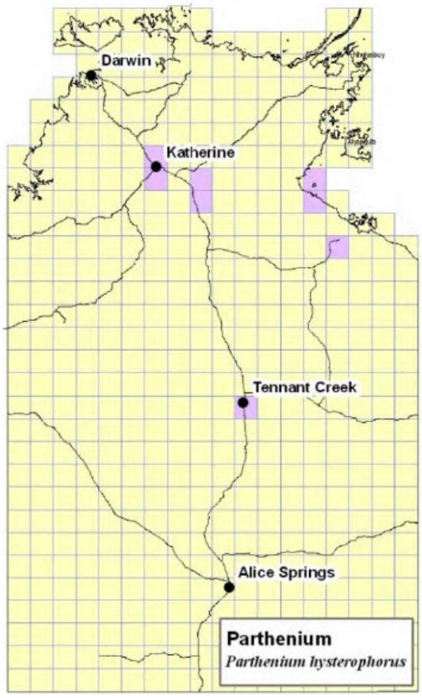
Known global distribution of Parthenium hysterophorus. Source Global Biodiversity Information Facility (www.gbif.org), Clark & Lotter (2011), Dhileepan (2009); Shabbir *et al*., 2012 Department of Natural Resources, the Art and Sport, 2010, assembled by Darren Kriticos. Black dots represent distribution points were *P. hysterophorus* is known to be established, grey areas represent sub-regions were the species in known to be established.

Australia



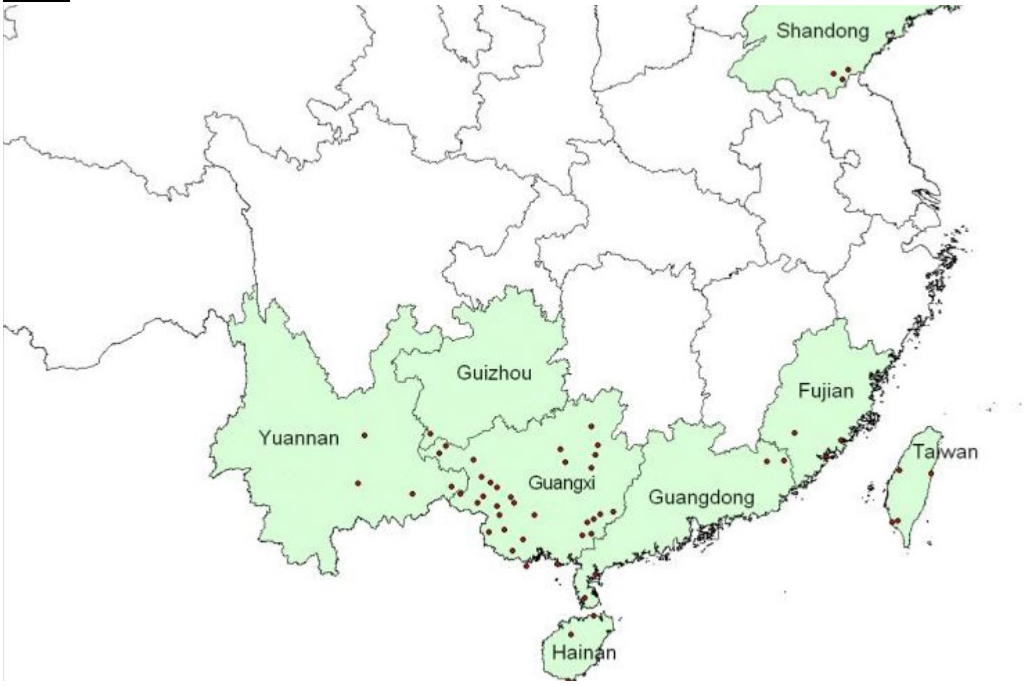
Current distribution of *Parthenium hysterophorus* in Australia (Data source: AVH 2010). Map source: Chejara V K, NT Weed Management Branch, 201. Taken from Department of Natural Resources, the Art art and Sport (2010).

Australia – Northern Territory



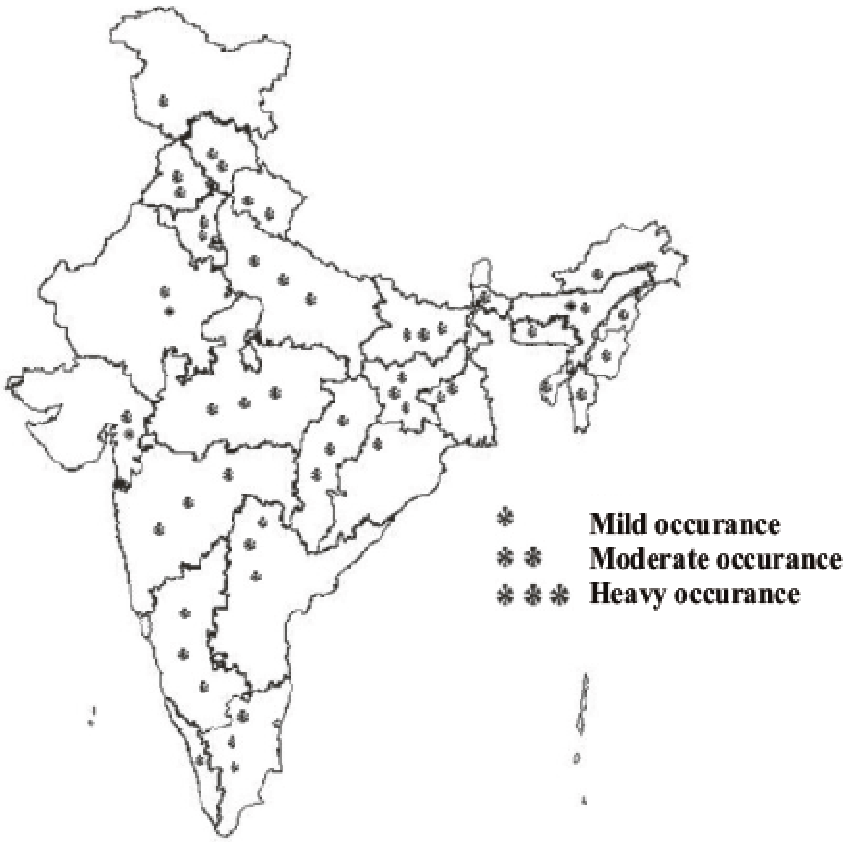
Distribution of *P. hysterophorus* in the Northern Territory. The cells highlighted with pink colour represent the areas under eradication and monitoring program. Map source: Hickey P, NT Weed Management Branch, 2010. Taken from Department of Natural Resources, the Art and Sport (2010).

China



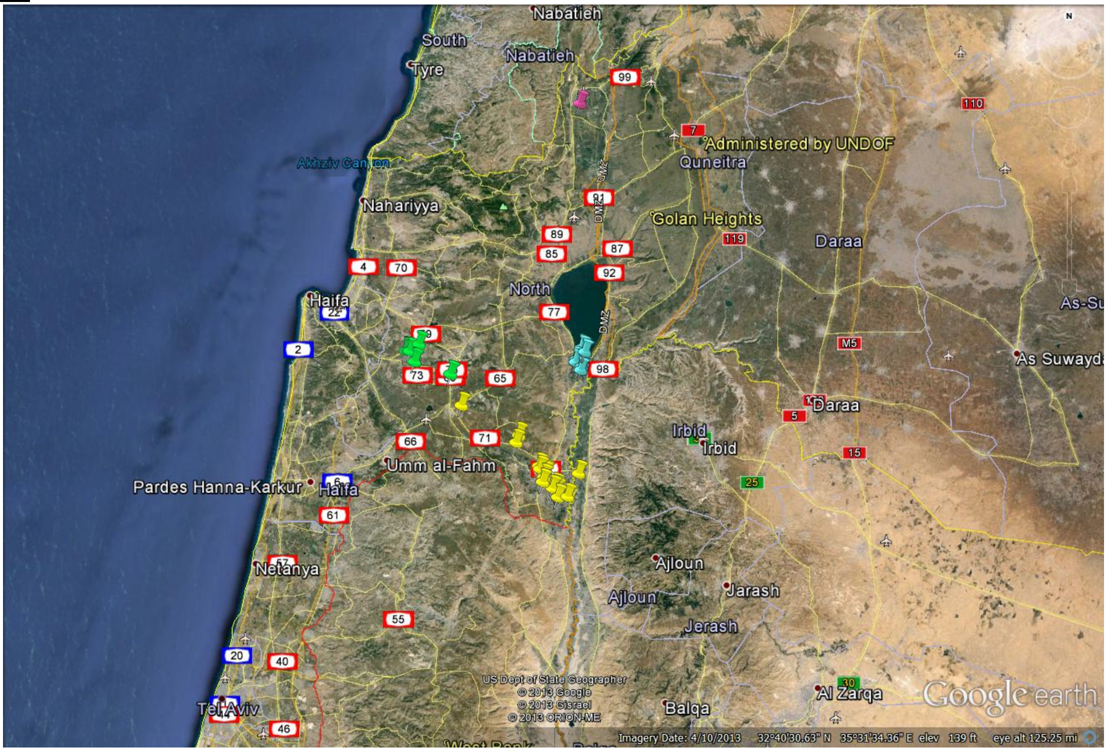
Distribution of *P. hysterophorus* in China in 2010, by Dr SQ Tang, taken from Shabbir & Adkins, 2010.

India



Present status of spread of *P. hysterophorus* in different states of India, taken from Sushilkumar & Varshney, 2010.

Israel

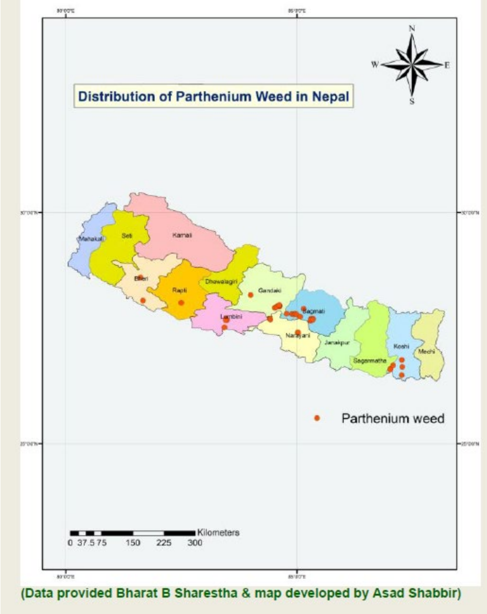


Distribution records of *P. hysterophorus* in Israel. Map provided by Tuvia Yaacoby, PPI, Israel.

Mexico

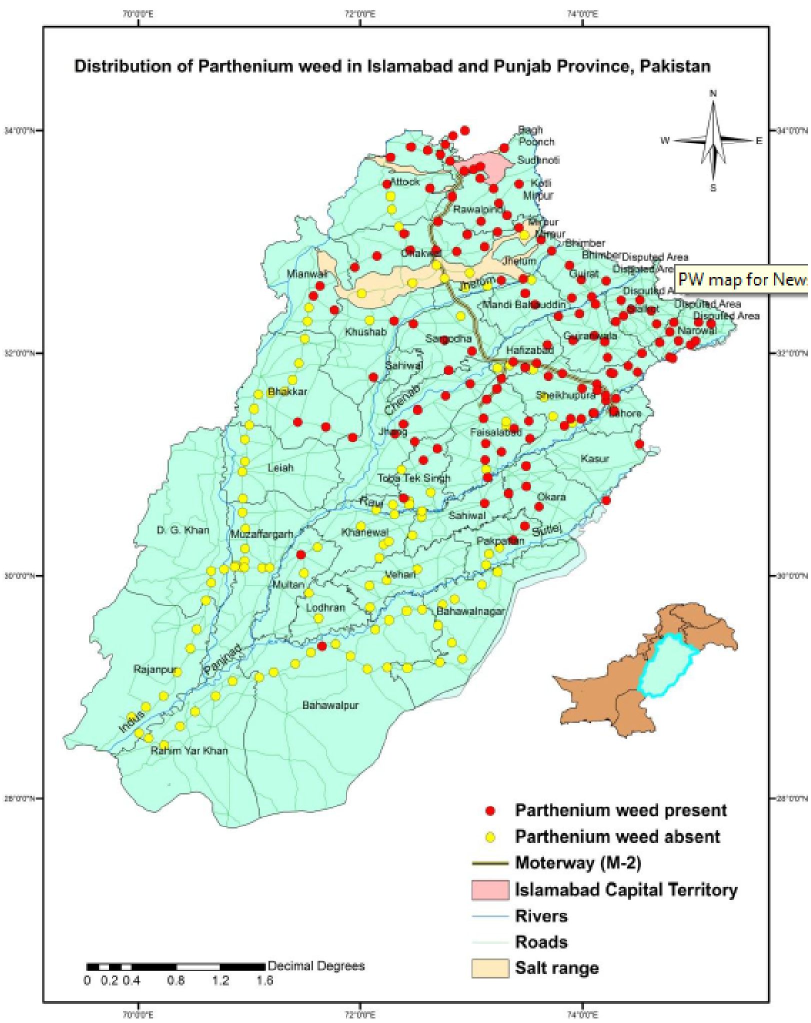
Distribution of *P. hysterophorus* in Mexico, taken from Shabbir & Adkins, 2010.

Nepal



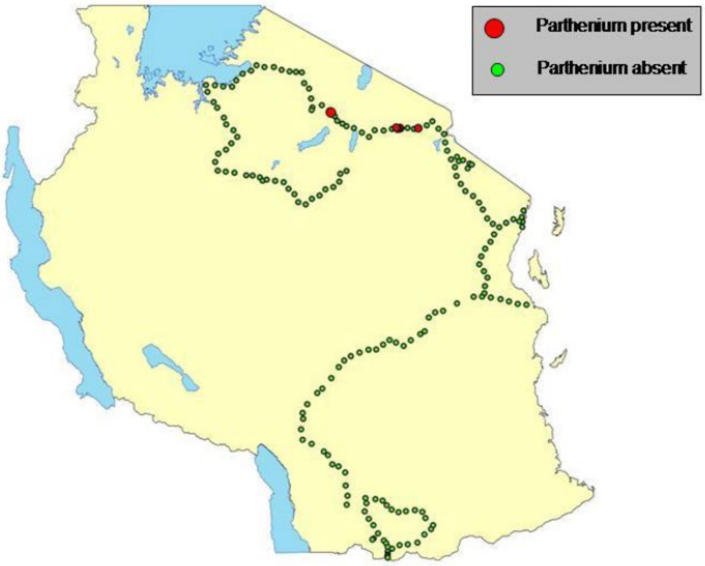
Distribution of *P. hysterophorus* in Nepal.
Data provided by Bharat B Sharestha and map developed by Asad Shabbir.

Pakistan – Punjab Province



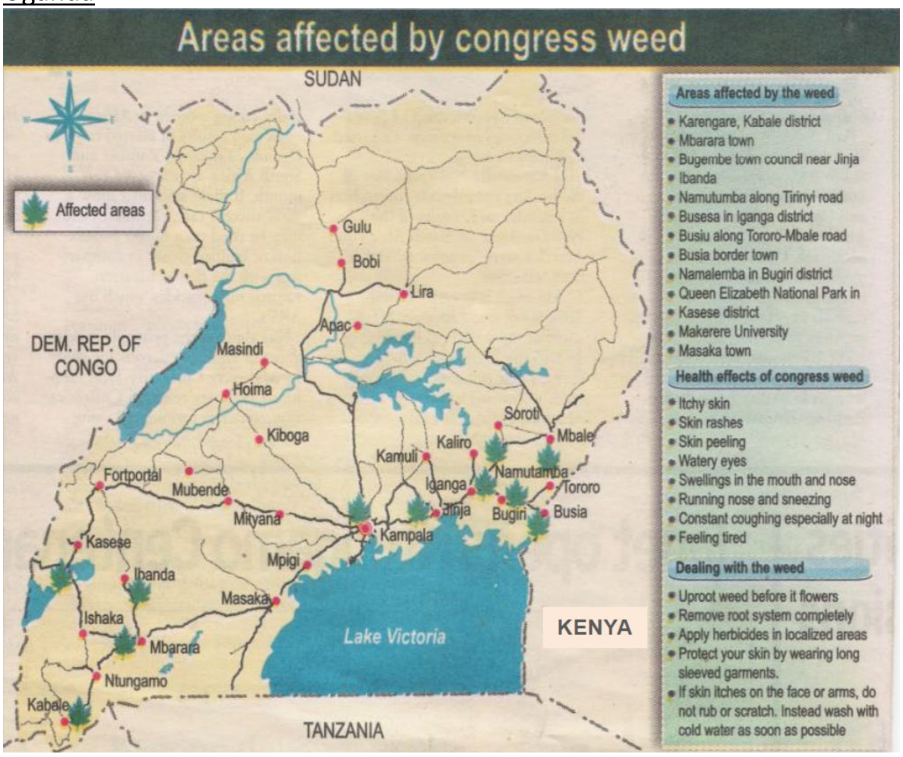
Distribution of *P. hysterophorus* is Islamabad and Punjab Province, Pakistan, map developped by Asad Shabbir in 2010.

Tanzania



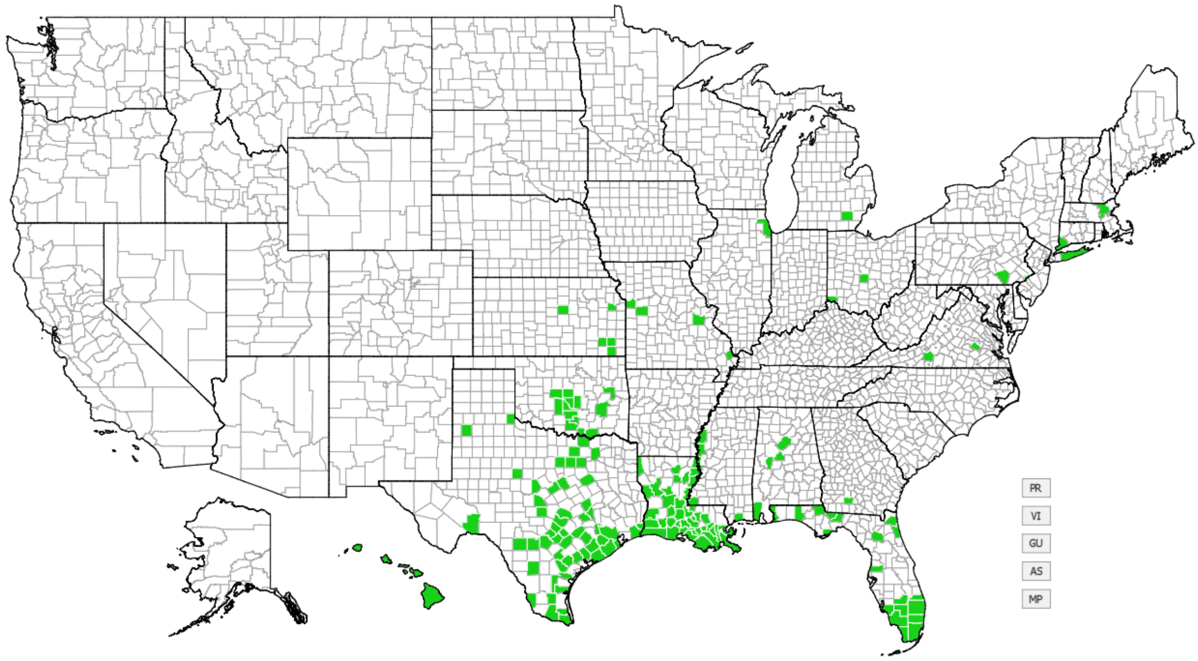
Distribution of *P. hysterophorus* in Tanzania (Clark & Lotter, 2011).

Uganda



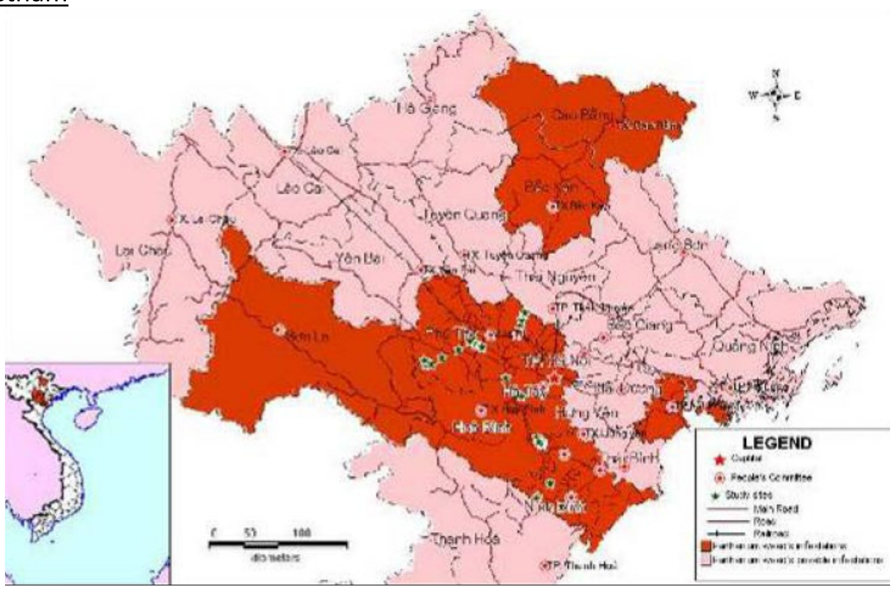
Distribution of *P. hysterophorus* in Uganda (IPM-CRSP, 2010).

United States of America



Distribution map of *Parthenium hysterophorus* in the USA at the County level.
EDDMapS (2014) Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed August 20, 2014.

Vietnam



Distribution of *P. hysterophorus* in Vietnam, as determined by mapping and a litterature search. Taken from Shabbir (2010).

2. Climatic projection of the potential distribution of *P. hysterophorus* with CLIMEX

A climatic projection of the potential distribution of *P. hysterophorus* was elaborated during the Expert Working Group with CLIMEX V3 (see Sutherst *et al.*, 2007) to refit the model of McConnachie *et al*. (2010).
The detailed analysis of this climatic projection, including consideration of transient populations, climate change and aggregation of climatic and habitat maps are available in Kriticos *et al*. (in preparation). The main parameters of the climatic projection are provided below and in Table 1.

CLIMEX calculates a weekly Growth Index (GI_W) that describes the species population response to temperature and soil moisture through the Temperature (TI) and Soil Moisture (MI) indices respectively. GI_W is integrated annually to calculate the Annual Growth Index (GI_A). Stress indices (hot, cold, wet, dry) are factors that limit a species' ability to persist at a particular location. Individual stress values are combined to create the total Stress Index (SI), and when combined with the Annual Growth Index (GI_A) CLIMEX calculates the Ecoclimatic index (EI). The EI is a measure of the overall suitability of a location for species persistence year-round (the larger the value the more suitable).

Temperature Index
Williams and Groves (1980) found an optimal temperature regime for *P. hysterophorous* of 25 °C night/30 °C day.

Cold stress
The cold stress threshold and rate parameters were relaxed to allow *P. hysterophorou*s to persist in the known, northern locations in the USA and northern India. In doing so, the extreme cold records in China and northern Pakistan and India also became suitable. Williams and Groves (1980:50) noted that plants that were frosted at -6 °C suffered "…leaf damage, leading to complete senescence and lateral floret development ceased". Using -7.5 as a damaging cold stress threshold (TTCS), the stress accumulation rate of -0.01 $week^{-1}$ fitted all but one of the coldest locality records in the northern hemisphere. The single record in the Himalayas is found in a region of extremely dissected topography, and the altitude and temperature are so extremely different to the next closest location records that this is likely to be a case of mismatch in gecoding precision or the climate data. In Argentina, a number of location records for *P. hysterophorous* in the GBIF database were found in locations that were apparently too cold or too dry for persistence, and for the dry records, did not appear to fall in irrigation areas defined in the irrigation areas database of Siebert *et al.,* (2005). Searching Google Earth using the locality description of these records revealed that they were incorrectly geocoded, and were found at lower elevation, wetter locations.

Dry Stress
The dry stress accumulation rate was increased to make the most extreme western Queensland records barely climatically unsuitable. This had the consequence of making some of the records in Pakistan and India unsuitable in the absence of irrigation.

Wet Stress
Parthenium hysterophorous is reportedly sensitive to shading (Wiliams & Groves, 1980). This observation under experimental conditions is likely to be reflected in reduced performance under shaded conditions and during periods of extended cloudiness associated with prolonged rainfall. Thus, some form of wet stress is likely to be indicated. In its native range in South America, there is an extremely large area around the Amazon Basin where the CLIMEX model indicates potential for growth and persistence, but where there are no known records. It was possible to make this wet habitat unsuitable using wet stress, improving the model specificity in this area. However, when this level of wet stress was applied, all of Bangladesh also became unsuitable. Bangladesh is covered in location records for *P. hysterophorous*. This paradox can perhaps be explained by the fact that the natural vegetation of Bangladesh would be similar to that of the Amazon Basin. In the absence of the intense agricultural disturbance regime in Bangladesh, we might expect that *P. hysterophorous* would be outcompeted by the native vegetation.

Climate data
The model was fitted initially using the 0.5 degree CliMond CM30_1975H_WO_V1.1 dataset, and subsequently refined with the CM10_1975H_WO_V1.1 (Kriticos *et al.*, 2012). The CliMond 10' results for 2070 of the A2 SRES climate change scenario run on the CSIRO Mk 3 GCM (CM10_2070_CS_A2_WO_V1.1) was chosen because it

represented a reasonably extreme scenario that would highlight the sensitivity of the invasion potential for *P. hysterophorous*.

Irrigation

The employed irrigation scenario applied provided 2.5 mm day^{-1} as a top-up to natural rainfall. That is, in any week in which average daily precipitation did not meet this threshold, the difference was assumed to be added to the rainfall inputs to the soil moisture model. The irrigation scenario was run on the global CM10_1975H_WO_V1.1 dataset.

Composite Risk Mapping

The irrigation area map from Siebert *et al*. (2005) was used to select within each climate cell, which of the natural and irrigated CLIMEX model results to use in a composite risk map. For each 10' cell, if the irrigation area was greater than 0, the irrigation scenario results were included, otherwise the natural rainfall scenario value was used.

Climate change

The CliMond 10' results for 2070 of the A2 SRES climate change scenario run on the CSIRO Mk 3 GCM (CM10_2070_CS_A2_WO_V1.1) was chosen because it represented a reasonably extreme scenario that would highlight the sensitivity of the invasion potential for *P. hysterophorus*.

Table 1 CLIMEX model parameters for *Parthenium hysterophorus*

Parameter	**Description**	***Values***	***Units***
Moisture			
SM0	Lower soil moisture threshold	0.10	
SM1	Lower optimal soil moisture	0.3	
SM2	Upper optimal soil moisture	0.8	
SM3	Upper soil moisture threshold	1.2	
Temperature			
DV0	Lower temperature threshold	6	°C
DV1	Lower optimal temperature	22	°C
DV2	Upper optimal temperature	32	°C
DV3	Upper temperature threshold	39	°C
Cold stress			
TTCS	Cold stress temperature threshold	-7.5	°C
THCS	Cold stress accumulation rate	-0.01	Week^{-1}
Heat stress			
TTHS	Heat stress temperature threshold	40	°C
THHS	Heat stress accumulation rate	0.001	Week^{-1}
Dry stress			
SMSD	Soil moisture dry stress threshold	0.10	
HDS	Dry stress accumulation rate	-0.025	Week^{-1}
Threshold Annual Heat Sum			
PDD	Annual heat sum threshold	2 000	°C days

Results

The modelled potential distribution of *P. hysterophorous* is very extensive, stretching from equatorial areas, through to warm temperate and Mediterranean climates (Figure 1). In its native range in the Americas, its modelled potential range extends into wet tropical areas, from which there are no recorded observations. Its potential range in the USA is anchored by a few northern records. Extensive records in Asia in similarly cool conditions support the assumption that the plant can tolerate such cold conditions. In South America, the modelled potential range extends into colder regions than the recorded distribution (Figure 1).

The effect of irrigation only increases the suitable range of the species in a few marginal innerland locations (e.g. Algeria, Egypt,), but the limits of the range remain globally similar (Figure 3).

According to the CLIMEX projection performed during the EWG, the countries at risk are the following:
Albania, Algeria, Azerbaijan, Bosnia & Herzegovina, Bulgaria, Cyprus, Croatia, Former Republic of Macedonia, France, Greece, Hungary, Israel, Italy, Jordan, Kazakhstan, Kyrgyzstan, Malta, Moldova, Morocco, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Tunisia, Turkey, Ukraine and Uzbekistan, as shown in Figure 1.
The highest risk is considered to be in Algeria, Israel, Jordan, Morocco, Spain, Tunisia and Turkey.
Glasshouses all over the EPPO region are suitable as well for the establishment of *P. hysterophorus*. Though, weeds can easily be managed in glasshouses.

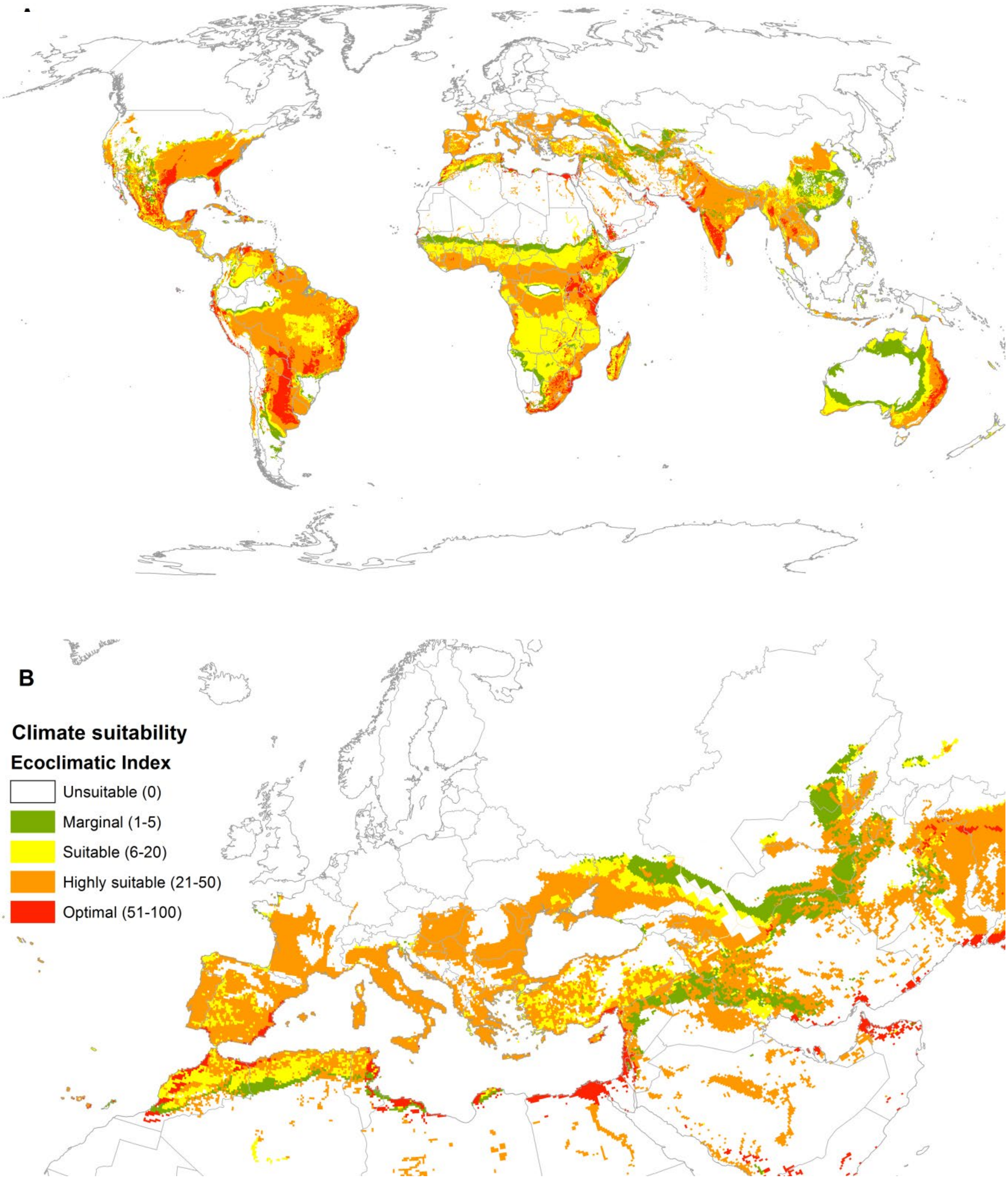


Figure 1. Climate suitability for *Parthenium hysterophorous* modelled using CLIMEX with the CM10_1975H_WO_V1.1 climate dataset (Kriticos *et al*., 2012), including the effect of irrigation (Siebert *et al*., 2005). (A) Global and (B) Europe and North Africa.

The climatically suitable area for *P. hysterophorus* without irrigation scenario is shown in Figure 2. The area at risk is quite similar, but extends with irrigation in Northern Africa.

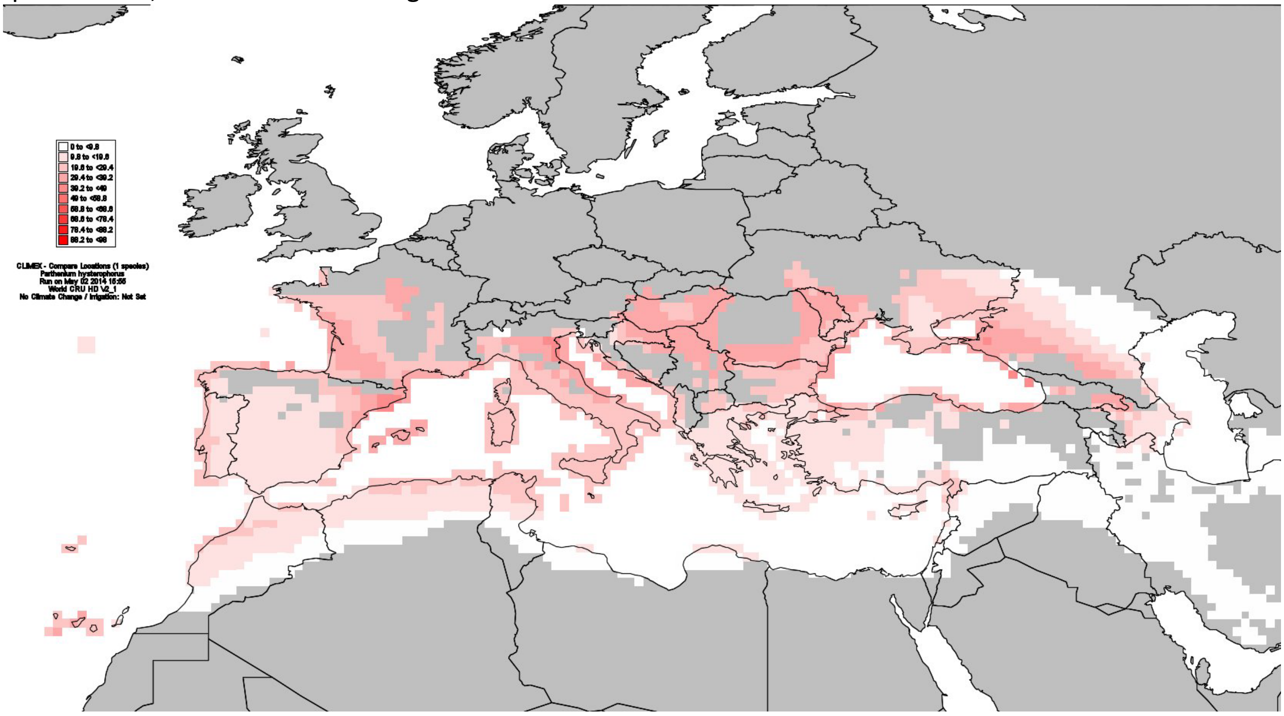


Figure 2. Climate suitability for *Parthenium hysterophorous* modelled using CLIMEX with the CM10_1975H_WO_V1.1 climate dataset (Kriticos *et al*., 2012), without irrigation scenario, in Europe and North-Africa.

Under the climate change scenario explored here, the modelled pest risks from *P. hysterophorus* extend poleward compared with the current climate risks (Figure 3). Within the EPPO region, many countries that are incapable of supporting established populations of *P. hysterophorus* may become at risk of becoming climatically suitable in the future due primarily to rising temperatures (Austria, Belarus, Belgium, the Czech Republic, Germany, Estonia, Latvia, Lithuania, the Netherlands, Poland, Slovenia, the United Kingdom, as well as larger parts of Bosnia and Herzegovina, Hungary, Kazakhstan, Moldova, Russia, Slovakia, Switzerland, Turkey, Ukraine, the southern coast of Sweden).

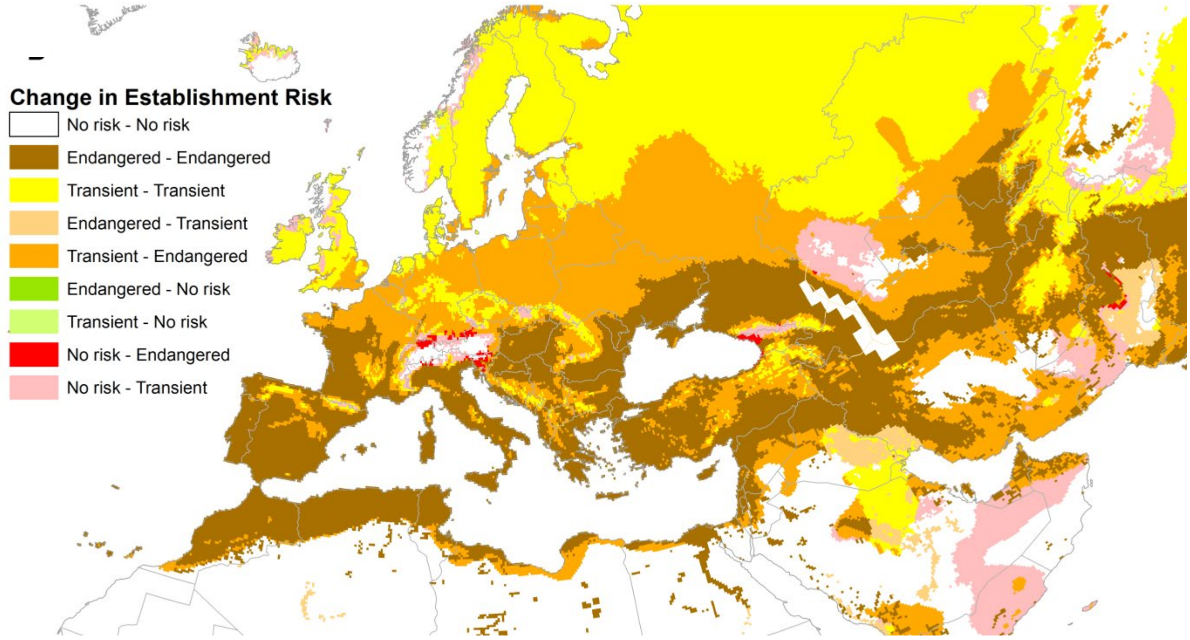


Figure 3. Future climatic establishment risk scenario simulated using the CM10_2070_CS_A2_V1.1 climate scenario.

3. Generated GBIF model for *Parthenium hysterophorus*

A GBIF niche model was generated for *Parthenium hysterophorus* taking into account all parameters, on the basis of the GBIF World distribution of the species.
The niche model indicates almost the whole of the EPPO region – except Scandinavia and Russai – are suitable for the establishment of the species (see Figure 4).
Such automatically generated model is very approximative.

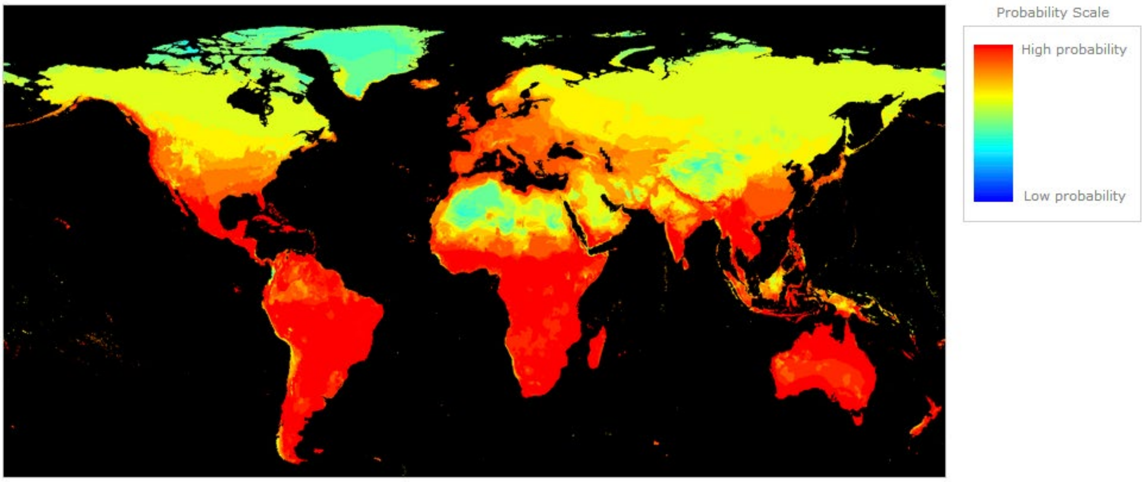


Figure 4. Generated GBIF niche model taking into account all parameters, on the basis of the GBIF World distribution of *Parthenium hysterophorus*.

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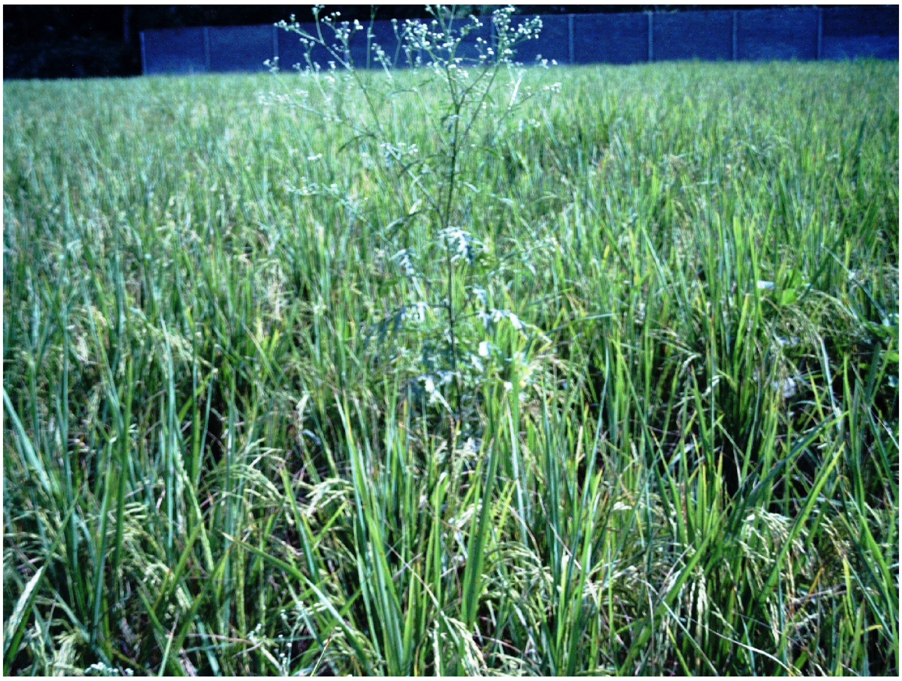
Appendix 3 - Pictures of fields infested with *Parthenium hysterophorus*

Parthenium hysterophorus in maize field in Pakistan ©Asad Shabbir



Parthenium hysterophorus in rice field in Pakistan ©Asad Shabbir

Parthenium hysterophorus in sorghum field in Pakistan ©Asad Shabbir

Parthenium hysterophorus in raddish field in India ©T.V. Ramachandra Prasad

Parthenium hysterophorus in potato field in India ©T.V. Ramachandra Prasad

Parthenium hysterophorus in front of a glasshousein India ©T.V. Ramachandra Prasad

Invasion of *Parthenium hysterophorus* in pastures in Queensland (http://www.getfarming.com.au).

Appendix 4 - Figures for pathway analysis of grain

Wheat

Wheat exports from countries where *Parthenium hysterophorus* occurs to EPPO countries or neighbouring EPPO countries are provided by FAOSTAT, for 2010 in tonnes (http://faostat.fao.org/site/537/DesktopDefault.aspx?PageID=537):

reporter	Algeria	Belgium	Egypt	France	French Polynesia	Germany	Israel	Italy	Jordan	Lebanon	Liberia	Malta	Morocco	Netherlands	Poland	Portugal	Spain	Sweden	Switzerland	Tunisia	Turkey
Argentina		254	10859			34	48												538		
Australia	7579	55	150946		182			46245		1129		7	10610								
Brazil			16033			2		1						1		27			1	7358	
Chile																		6			
Ecuador																	1				
India						7		1						2							
Israel								6							84	16			1		
Kenya																					
Mexico	5253							41675												12627	2973
Peru								5									30				
United States of America	42089	32533	433407	64		8692	59396	140147	16177	14029	3153		101440	2604		18920	70664		5	29504	55526

No imports were recorded from China, Ethiopia, Jamaica, Nepal, Nicaragua, Pakistan, South Africa, Sri lanka, Trinidad and Tobago, Uganda and United Republic of Tanzania.

The United States of America represent the largest and first exporter of wheat in EPPO countries, in particular in Egypt (433 407 tonnes imported in 2010, in Italy (140 147 tonnes), in Morocco (101 440 tonnes), in Israel (59 396 tonnes), in Turkey (55 526 tonnes), in Algeria (42 089 tonnes), in Tunisia (29 504), which are all Mediterranean countries which may be at risk.

Australia exports as well wheat to some EPPO countries: 46 245 tonnes to Italy, 15046 tonnes to Egypt, 10 610 tonnes to Morocco and 7 579 tonnes to Algeria.

Mexico exports as well wheat to EPPO countries: 41675 tonnes to Italy, 12627 tonnes to Tunisia, 5253 tonnes to Algeria and 2973 tonnes to Turkey.

Sorghum

Sorghum exports from countries where *Parthenium hysterophorus* occurs to EPPO countries or neighbouring EPPO countries are provided by FAOSTAT, for 2010 in tonnes (http://faostat.fao.org/site/537/DesktopDefault.aspx?PageID=537):

reporter	Algeria	Austria	Belgium	Cyprus	Denmark	Egypt	France	Germany	Israel	Italy	Jordan	Morocco	Netherlands	Norway	Portugal	Spain	Sweden	Turkey	Ukraine	United Kingdom
Argentina							1	12012					1318	1774						
Australia			80			61					17				55					21
Chile					6			70												
China								2									15			
Ethiopia			76						2											150
India						1352			10		316		132	3	102			130		18
Pakistan											4									
South Africa								3				76								
United States of America	280	486		6		75	1283	6	16646	1355	31	26308	70			38267			140	

No imports were recorded from Bolivia, Brazil, Kenya, Mexico, Nicaragua, Uganda and United Republic of Tanzania.

The United States of America remain the main exporter of sorghum to EPPO countries, in particular to Spain (38267 tonnes exported in 2010), Morocco (26 308 tonnes) and Israel (16 646 tonnes).

Argentina exports to northern EPPO countries, which lowers the risk of establishment of *P. hysterophorus*: 12 012 tonnes exported to Germany, 1 774 tonnes to Norway, 1 318 tonnes to the Netherlands, etc.

To a lower extent, India also exports sorghum to the following countries: Egypt (1 352 tonnes exported in 2010), Jordan (316 tonnes). South Africa exported 76 tonnes to Morocco. Ethiopia, where huge impacts on sorghum are recorded, exported a minimal amount of 2 tonnes to Israel in 2010.

Maize

Maize exports from countries where *Parthenium hysterophorus* occurs to EPPO countries or neighbouring EPPO countries are provided by FAOSTAT, for 2010 in tonnes (http://faostat.fao.org/site/537/DesktopDefault.aspx?PageID=537):

reporter	Algeria	Austria	Belarus	Belgium	Croatia	Cyprus	Czech Republic	Denmark	Egypt	Estonia	Finland	France	Greece	Hungary	Israel	Italy	Jordan	Latvia
Argentina	3398 70		9	128 4	13 9	61	68 9	150 5	2236 92			174 1	108 4	14	211 18	173 4	136 12	33
Bolivia (Plurinatio																		

reporter	Lebanon	Lithuania	Malta	Montenego	Morocco	Netherlands	Norway	Poland	Portugal	Romania	Russian Federation	Serbia	Slovakia	Slovenia	Spain	Sweden	wwitzerland	The former Yugoslav Republic of Macedonia	Tunisia	Turkey	Ukraine	United Kingdom
Argentina	509 1	33		40	1415 07	264 06	43 0	742 7	347	742	368	12	9	9	2164 2		13 4	53	531 3	713 8	18 1	330 78
Bolivia (Plurinatio															20							

nal State of)																																								
Brazil	63498							1071	62321			1117			9992	2691							186847	64163			80845						154138		4		15697			5963
Chile		827										15307		1287		240								2456				9			7		409					97		1
Ecuador																5																	1							
Ethiopia																	569																							2518
India									106								167		18					64									2							232
Israel																1	11004																						3	1
Kenya																								25																139
Madagascar												110																												
Mauritius												5																												
Mexico		11							5			151		12		8														0								2		1
Nepal																																								29
Pakistan																																								12
Peru				12								170				317								103	1								7469	1	33					
South Africa									141			224			18	7222								11			5803						5452		0					321
Uganda															2																									0
United Republic of Tanzania																																								46
United States of America	10819	4215		426	119	42	173	575	674805	29	64	11128	3802	633	83795	3824	10794	386	38299		37		41450	1196	516	1027	4842	1138	3778	15			19961	938	169		41382	3788	250	4000

No imports were recorded from Australia, Belize, China, Nicaragua, Sri Lanka, Trinidad and Tobago, Venezuela, Zimbabwe.

Concerning the imports of maize, the United States of America remain the major importer. Argentina, Brazil and South Africa are exporters as well.

Millet

Millet exports from countries where *Parthenium hysterophorus* occurs to EPPO countries or neighbouring EPPO countries are provided by FAOSTAT, for 2010 in tonnes (http://faostat.fao.org/site/537/DesktopDefault.aspx?PageID=537):

reporter	Algeria	Belgium	Czech Republic	Denmark	Egypt	Finland	France	Germany	Greece	Israel	Italy	Jordan	Malta	Morocco	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	Tunisia	Turkey	United Kingdom

Argentina		338						85							58			8		56			
Australia		332					225				189				12		26	30					5
Brazil																							
China		31	12	26			365	466		94	210		2		290		111	53	22			8	257
Ethiopia										6													
India	99	648			1825			278	7	86	679	9		364	252	1	81	77		1	509	3	486
Pakistan																1							
Uganda																							4
United States of America		203				5	131	834		95	268	111			768	105	31						1327

No imports were recorded from Kenya, South Africa, Trinidad and Tobago, Sri Lanka and United Republic of Tanzania.

The imports of Millet in the EPPO region are spread over 4 major exporters: the United States of America, Australia, Brazil and India. Nevertheless, the amounts imported remain low and the largest volumes are rather imported to temperate countries such as Germany, the Netherlands. In 2010, it is to be noted that India exported 1825 tonnes of Millet to Egypt, 679 tonnes to Italy, and 364 tonnes to Morocco.

Rye

reporter	**element**	**years**	**items**	**Israel**
Australia	Export	2010	Rye	
Chile	Export	2010	Rye	
India	Export	2010	Rye	
Kenya	Export	2010	Rye	346
United States of America	Export	2010	Rye	

In 2010, Rye has only been exported to Israel from Kenya.

Oats

reporter	**years**	**items**	**Belgium**	**Egypt**	**France**	**Germany**	**Israel**	**Italy**	**Lebanon**	**Netherlands**	**Portugal**	**Spain**	**United Kingdom**
Argentina	2010	Oats			90			28					
Australia	2010	Oats				30			11				7
Brazil	2010	Oats	27		250			160		9	57	15	
Chile	2010	Oats			114								
Ecuador	2010	Oats										186	

Ethiopia	2010	Oats					28						
Jamaica	2010	Oats											2
Peru	2010	Oats						11					
South Africa	2010	Oats											1
Trinidad and Tobago	2010	Oats											
United States of America	2010	Oats		83									

No imports were recorded from China, India, Mexico, Nicaragua, Pakistan and Trinidad and Tobago.

Oats is not a much imported commodity in EPPO countries. Though Brazil remains the major exporter with 250 tonnes exported to France in 2010 and 160 tonnes to France.

Appendix 5 – Additional information on impacts of *P. hysterophorus* on human health

The contact allergy with *P. hysterophorus* can be developed from repeated contact with the weed or its disseminated parts, and can be perpetuated in sensitive individuals by airborne pieces of dried plant material (airborne contact dermatitis; Sharma & Sethuraman, 2007), such as trichomes (Towers & Mitchell, 1983). Trichomes contain the highest concentrations of sesquiterpene lactones and are present on stems, the undersides of leaves and in the flowering heads of this weed (Warshaw & Zug, 1996; Lakshmi & Srinivas, 2007).

Humans who have continued exposure to *P. hysterophorus* can develop allergic eczematous contact dermatitis (Navie *et al*., 1996a). Parthenin is the causative agent of this reaction and is one of the very reactive toxic class of compounds known as sesquiterpene lactones. Flower heads of *P. hysterophorus* can contain up to 8% of their dry weight as sesquiterpene lactones, with parthenin being the major component (Rodriguez *et al*., 1976). When parthenin enters the dermis. An antigen and antibody reaction then cause phyto dermatitis. Such reactions appear over portions of the body exposed to the sun, and the hypersensitivity reaction creates a contact irritant dermatitis (Kololgi *et al*., 1997). Inhalation of pollen can cause allergic rhinitis that can develop into bronchitis or asthma if pollen enters the respiratory tract (Towers & Subba Rao, 1992).

The economic impact of *P. hysterophorus* on human health in Mpumalanga was estimated at US$13.5 per year and US$27.1 per year for each of the expected 15% of the small-scale and commercial farms that would be affected, respectively. This is a conservative estimate as it assumes only a single worker is affected per farm, that only 3 days per year are lost due to ill-health, and that no medical costs are incurred. This is significantly lower than the AU$500 per person per year estimated for Australian workers, where it is reported that 5 days per person per season is the average number of days lost and the average daily wage rate is AU$100. The per capita medical costs due to *P. hysterophorus* in affected areas in Australia is AU$6.90 (Wise et *al*., 2007).

Males appear to be differentially affected, possibly due to a higher exposure (Sharma & Sethuraman, 2007; Parson & Cuthbertson, 1992; Khan *et al*., 2011), but Indian women and children also work in fields (Lakshmi & Srinivas, 2007). Hayfever, asthma and dermatitis can be caused by dust and debris from the plant, including its pollen (McFadyen, 1995). Seasonal variation in dermatitis is initially observed, with symptoms arising during the growing season and disappearing during winter (Shenoi & Srinivas, 1997). After several years, however, persistent dermatitis develops (Lakshmi & Srinivas, 2007; Sharma & Sethuraman, 2007). *P. hysterophorus* appeared to be the leading cause of extensive eczematous eruption in patients over 40 years old (Khan *et al*., 2011).
There is no effective treatment for these allergies other than to leave the area (Wise *et al*., 2007). In Queensland, sensitized individuals have had to change residence and leave employment as a result of dermatitis caused by *P. hysterophorus* (Burry & Kloot, 1982). Similarly in India, Kaushal Verma (2010) has suggested shifting the person suffering from *P. hysterophorus* induced allergy to an area free from the plant in order to avoid recurrence of the disease. A survey conducted in this state indicated that 10% of workers in the infested region had developed visible skin allergies to *P. hysterophorus* (Chippendale & Panetta, 1994).

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