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Preventing a new invasive alien plant from entering and spreading in the Euro-Mediterranean region: the case study of *Parthenium hysterophorus*

S. Brunel[1], D. Panetta[2], G. Fried[3], D. Kriticos[4], R. Prasad[5], A. O. Lansink[6], A. Shabbir[7] and T. Yaacoby[8]

[1]*European and Mediterranean Plant Protection Organization, 21 boulevard Richard Lenoir, 75011, Paris, France; e-mail: brunel@eppo.fr*
[2]*Melbourne University, Parkville, Vic., Australia*
[3]*Laboratoire de la santé des végétaux, Station de Montpellier, Montpellier, France*
[4]*CSIRO Ecosystem Sciences, Canberra, Australia*
[5]*Directorate of Weed Science Research Centre, University of Agricultural Sciences, Bengaluru, India*
[6]*Wageningen University, Wageningen, Netherlands*
[7]*Department of Botany, University of the Punjab, Lahore, Pakistan*
[8]*Ministry of Agriculture and Rural Development, Plant Protection and Inspection Services, Israel*

Parthenium or famine weed (*Parthenium hysterophorus* L.) is an annual plant originating from the Americas, which is a major invasive alien plant in almost all continents. While the deleterious impacts of the species on agriculture, human and animal health have been well documented, information on the pathways of entry of the species is only occasionally mentioned in the literature. As this invasive alien plant is only recorded as established in Israel and Egypt within the Euro-Mediterranean region, the European and Mediterranean Plant Protection Organization identified *P. hysterophorus* as an emerging threat. EPPO therefore performed a Pest Risk Analysis on this species to assess the risk it represents and to consider appropriate management options. The EPPO Pest Risk Analysis main outputs are summarized in this article, indicating the probability of entry of the species via the different pathways within the EPPO region, its probabilities of establishment and spread, and the magnitude of its potential agricultural, environmental and social impacts.

Introduction

Parthenium (*Parthenium hysterophorus* L.) is an invasive alien plant that causes substantial impacts where it has been introduced, and has been named 'famine weed' in South Africa[1]. Parthenium is an inconspicuous annual plant of the Asteraceae family, growing up to 1.5–2 m, with a deep tap root, finely lobed leaves and small white flower heads. It is a pioneer species that can invade grazing land and degraded pastures, arable fields (especially summer crops), orchards, disturbed areas, natural grasslands, forests, railway tracks and roadsides, recreation areas, as well as river banks and floodplains (Navie *et al.*, 1996). In arable fields, Parthenium can also invade a large range of perennial crops (alfalfa, clover, banana, cardamom, ginger, coconut, areca nut, mango, citrus species, etc.) as well as annual crops (cotton, pineapple, rice, sorghum, tomato, sugarcane, onion, cucumber, watermelon, groundnut, tobacco, garlic, eggplant, beans, capsicum, maize, etc.). It induces yield losses to various crops which reaches 90% in Sorghum in Ethiopia when left uncontrolled (Tamado *et al.*, 2002). It can also be a very detrimental weed in a wide range of dryland crops, as well as pastures and natural or semi-natural habitats. Famine weed is not only detrimental to agriculture. It is also a very allergenic plant that causes respiratory allergies. In Bangalore in India, Parthenium was estimated to affect 7% of the population, and was reported to cause severe dermatitis (Srirama Rao *et al.*, 1991). This invasive alien plant also affects animal health, leading to reduction in milk yield, tainting as well as toxicity of milk after ingestion of the plant (Parsons & Cuthbertson, 1992; Karki, 2009).

Parthenium originates from the Americas, but has spread with human activities and is nowadays present in almost all continents: North and South America, Australia, Asia, as well as Africa. The Euro-Mediterranean region is nearly free from the species, as Parthenium is so far only recorded as established in Israel (Dafni & Heller, 1982) and in Egypt (Boulos & El-Hadidi, 1984). The plant has been detected in Belgium (Verloove, 2006) and Poland (Mirek *et al.*, 2002), but did not manage to establish, due most probably to too cold climatic conditions [See the EPPO Datasheet for additional information on the species (EPPO, 2014b)].

[1]In South-Africa, the name 'famine weed' has purposefully replaced the name 'parthenium' as it is easier to remember and carries the envisioned message that this is a highly undesirable alien invader (Sithole & Macdonald, 2013). In this article, both names are used.

How could Parthenium enter the territory of the Euro-Mediterranean region? Could it establish and spread in the region? Would its impact in the region be the same as observed in its introduced range? What is the risk it finally represents? What could be done to prevent its entry and spread? These are the questions addressed through the Pest Risk Analysis (PRA) of famine weed (EPPO, 2014a) which are summarized in this paper.

As trade of plants and plant products and the movement of people accross countries and continents accelerate, pests, including invasive alien plants find their way to new territory by contaminating commodities and people's goods. Identifying emerging pests before they arrive, to prevent their entry and spread, is considered the most efficient and cost-effective option. Such a task is undertaken by National Plant Protection Oganizations (NPPOs) within countries. The free movement of goods is ensured by the World Trade Organization, and the Sanitary and Phytosanitary Agreements provide general principles for the trade of plants and plant products. The International Plant Protection Convention is the organization responsible for setting standards for its 181 (as of August 2014) member countries to provide guidance on how to implement these international recommendations. Pest Risk Analysis is an essential tool to protect countries' agriculture, environment, and human populations from the huge detrimental impacts of pests of plants and plants as pests (see the International Standard on Physonitary Measures n°11 on Pest Risk Analysis, IPPC, 2013).

A Pest Risk Analysis is a comprehensive document assessing the risk a species represents for a given area and justifying preventive measures that could be taken to prevent its entry and spread. To elaborate such a justification, the European and Mediterranean Plant Protection Organization (EPPO)[2] developed a scheme (the EPPO Decision-support scheme for quarantine pests, see EPPO, 2011) and organizes Expert Working Groups (EWGs) with experts knowledgeable about the pest under consideration, the crop or habitats affected, management measures and modelling. The outputs of the Pest Risk Analysis which was performed for Parthenium for the European and Mediterranean region, run by the EPPO, are presented in this article.

Probability of entry: how could Parthenium enter new countries?

How could the tiny seeds of Parthenium enter new countries? To answer this question, an enquiry had to be undertaken by analyzing records mentioning how the species is known to have entered new territories, as well as by evaluating probable new pathways, having an understanding of how international trade is organized. The international trade of plants and plant products represents a major pathway of entry for pests worldwide. Assessing the probability of entry for a species represents one of the most challenging parts of a PRA. The EPPO Expert Working Group for *Parthenium hysterophorus* gathered all available data on this issue, analysed all the steps for individual entry pathways, from the country of export to the country of import. This analysis concluded that Parthenium may likely enter as a contaminant of used machinery, of grain (seeds intended for processing or consumption and not for planting), of seeds (seeds for planting or intended for planting), of growing media adherent to plants for planting and of travellers. These pathways, and other less likely ones, are described below.

Parthenium may enter as a contaminant of used machinery

Historical records

The most likely pathway of entry for Parthenium is considered to be as a contaminant of used machinery (e.g. seeds lodged on the radiators and grills of automobiles or as seeds in soil attached in mud on machinery), in particular military equipment, agricultural machinery such as harvesters, and other vehicles (e.g. cars).

The species has a long story of introduction through contaminated military equipment. The first reported record (1955) of Parthenium in Australia was in Southern Queensland (Auld *et al.*, 1983), attributed to the movement of aircraft and machinery parts into Australia coming from the USA during the second World War (Parsons & Cuthbertson, 1992. In Ethiopia, it is believed that Parthenium had been introduced by army vehicles during the Ethiopian-Somalian war (Frew *et al.*, 1996; Tamado & Milberg, 2000). In Pakistan, it is suspected that Parthenium 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 (Khan, 2012).

Agricultural machinery is also a very important pathway, in particular with regard to movements of machinery at a continental level. Of the outbreaks of new Parthenium infestations on private properties in New South Wales in Australia, during the period 1982-2004, about 60% were attributable to the movement of contaminated grain harvesters (Blackmore & Johnson, 2010). In the Shandong Province in China, harvesters are also reported as a major pathway (Li & Gao, 2012).

Numerous references report vehicles as a pathway of introduction and spread (Li & Gao, 2012) (e.g. mining machinery, construction machinery, cars, etc.). The species was, for instance, considered to have entered Papua New Guinea through second-hand vehicles imported from Australia (Kawi & Orapa, 2010).

[2]The European and Mediterranean Plant Protection Organization (EPPO) is an intergovernmental organization under the International Plant Protection Convention (IPPC) responsible for cooperation in the European and Mediterranean region. See www.eppo.int.

Analysis of the pathway

In areas where it occurs, Parthenium is commonly present along roadsides, so seeds situated on fruiting plants or in soil could consequently easily become attached to machinery.

Although the volume and frequency of used vehicles being introduced from areas where the plant occurs to European and Mediterranean countries is considered to be moderate, used vehicles are traded through the internet across Europe and Africa, as well as other continents. Considering the persistence of the seed (which can be up to 8 years), seeds travelling as contaminants on used vehicles could remain viable for a long time. Apart from legislation on cleaning machinery in Israel (where the species already occurs) (State of Israel, treatments as required by the plant import regulations, 2009) and in Norway (Regulations of 1 December 2000 no. 1333 relating to plants and measures against pests), there are no inspection procedures in place for used machinery in EPPO countries. Once infested vehicles have entered a new country, they will drive on roads, sometimes nearby agricultural fields (in particular for agricultural equipment), or semi-natural areas, which represent suitable habitats for Parthenium to establish (Krishnamurthy *et al.*, 1977; Ramachandra Prasad *et al.*, 2010; Sushilkumar & Varshney, 2010).

As a consequence, given evidence of history of entry of Parthenium to new countries via machinery (Parsons & Cuthbertson, 1992; Tamado & Milberg, 2000), this pathway is considered to be moderately likely.

Parthenium may enter as a contaminant of grain[3]

Historical records

Movement of Parthenium throughout its introduced range has been strongly associated with cropping and the transport of agricultural products, in particular grain (Navie *et al.*, 1996; Fessehaie *et al.*, 2005; Blackmore & Johnson, 2010; Sushilkumar & Varshney, 2010; Adkins & Shabbir, 2014).

In India, Parthenium was first observed in Poona in 1956 (Rao, 1956), where it was most likely to have been introduced through large scale import of infested wheat and other cereals from the USA (Sushilkumar & Varshney, 2010) under a grant to counter food shortage. Through public distribution of these infested cereals, Parthenium has ultimately spread over 35 million ha of the Indian sub-continent (except to Western Ghats and snow covered areas of Northern and North–Eastern parts) through various spread pathways (Yaduraju *et al.*, 2005; Ramachandra Prasad *et al.*, 2010; Sushilkumar & Varshney, 2010). Parthenium may also have entered Maputo harbour in Mozambique through grain imports, possibly as food aid (Wise *et al.*, 2007). It is also suspected that Parthenium 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). In China, Tang (2012) suggests that the species was introduced as a contaminant of grain. Parthenium is considered to have entered Israel with grain from the USA for use as fish food in ponds (Dafni & Heller, 1982). In Belgium, the species is suspected to have entered as a contaminant of grain (Verloove, 2006).

Analysis of the pathway

In countries where Parthenium occurs, all cereal fields may be infested (wheat, sorghum, millet, oats, rye, barley, maize, etc.) (Adkins & Shabbir, 2014). As Parthenium 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 the same life cycle and their grain could be contaminated during harvest. The density of Parthenium could be maintained at low levels with the extensive use of herbicide in crops and of tillage and cultivation (Reddy & Bryson, 2005), as is observed in the USA. However, crop production conditions may be different in other countries where Parthenium occurs, and where climate would be more suitable to the plant. Indeed, high densities have been observed in sorghum fields in Ethiopia for instance (Tamado *et al.*, 2002). It appears that thousands of tonnes of wheat, sorghum, maize, oats, rye and millet are imported into EPPO countries and countries neighboring the EPPO region from countries where Parthenium occurs each year. The United States of America are the main exporters of cereals to the EPPO region, and exported for instance 101 440 tonnes of wheat to Morocco, 59 396 tonnes to Israel, 55 526 tonnes to Turkey in 2010 (FAOSTAT Website). The seeds of Parthenium are very small and there are no specific regulations on this species or on invasive alien plants having the same seed size for grain in EPPO countries. Seeds of Parthenium contaminating grain are therefore likely to remain undetected. The possibility of contaminating seeds transferring from grain commodities to suitable habitats for the plant depends upon the end use of the grain. When the grain is processed, the seeds of Parthenium are expected to be destroyed. However, contaminating seeds may escape during the transport of grain, or during storage and may then reach suitable habitats, following a process which has already been documented for numerous annual weeds, for example *Amaranthus palmeri* in Spain (Recasens & Conesa, 2011). Grain for processing is usually cleaned before being processed. If the product of this cleaning is released into the environment, seeds of Parthenium and of other invasive alien plants would transfer to suitable habitats. When infested grain is destined for animal feed, the seeds of Parthenium ingested by animals would be spread to suitable habitats (e.g. pastures).

In conclusion, entry of Parthenium is moderately likely to occur through contaminated grain.

[3]According to ISPM n°5, grain is defined as 'a commodity class for seeds intended for processing or consumption and not for planting'. Available at https://www.ippc.int/index.php.

Parthenium may enter as a contaminant of seed[4]

Historical records

Movement of Parthenium throughout its introduced range has been strongly associated with cropping and the transport of agricultural products, in particular seed (Navie *et al.*, 1996; Fessehaie *et al.*, 2005; Blackmore & Johnson, 2010; Sushilkumar & Varshney, 2010; Adkins & Shabbir, 2014).

The following seed have been suspected to be infested with Parthenium:

- 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, Environment, The Arts & Sport, Government of Northern Territory, 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).

Analysis of the pathway

Different types of seed have different probabilities of being contaminated with seeds of Parthenium. 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 Parthenium seed, especially in certified or standard seed lots. Pasture seeds have a much higher probability of being contaminated, as the life cycle of Parthenium and produced pasture seeds coincide. In addition, Parthenium has been recorded as occurring in pastures in Australia (Navie *et al.*, 1996), India (Blackmore & Johnson, 2010; Sushilkumar & Varshney, 2010), etc. where it is able to reach high densities. For cereal seeds, the risk is considered to be higher for summer crops than for winter cereals, considering the phenology of the plant, although the species has been found in wheat fields at the time of harvest (see Fig. 1). Although management practices may limit the prevalence of Parthenium where seed is produced, in particular with the use of herbicides, these measures may not totally remove the weed from the fields and therefore from the commodity (Reddy & Bryson, 2005). Thousands of tonnes of seeds of field crops are imported into EPPO countries according to the International Seed Federation (see http://www.worldseed.org/isf/seed_statistics.html).

Seeds are very small, and as the species is not targetted by specific inspection procedures, these contaminants are very likely to remain unnoticed. Then, as seeds infested by Parthenium are intended for sowing, seeds will be planted in a field which represents a suitable habitat for the weed.

In conclusion, the entry of Parthenium is moderately likely to occur via pasture and cereal seeds (while it is unlikely to occur through vegetable seeds).

Fig. 1 Parthenium in a wheat field at the time of harvest in Pakistan (©Asad Shabbir).

Parthenium may enter as a contaminant of growing media adherent to plants for planting

Historical records

Parthenium has been observed as a contaminant of soil adherent to traded ornamental plants in Pakistan (Shabbir *et al.*, 2012). Parthenium 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).

Analysis of the pathway

Parthenium is able to form large stands in and around production areas, and there are reports of nurseries infested with this weed in countries where the species occurs. As the plant produces seeds in summer which are spread by wind and are viable for at least 8 years, it is likely that the growing medium of trees and potted plants can contain seeds of Parthenium. The risk for plants for planting produced in glasshouses is considered to be a little lower, as contamination of the growing media would only occur outdoors, not during the production of plants in glasshouses. Although the species could be quite easily controlled with targeted sprays of herbicides, it is usually uncommon to use phytosanitary products in nurseries in this way. This trade pathway is active, as according to AIPH (2008), fruits trees and shrubs are imported into the European Union from countries where Parthenium occurs, and these may have some growing media attached, potentially infested with seeds of Parthenium. Seeds (2 mm or less) are not visible in the growing media and they may remain undetected. As Parthenium is not regulated in EPPO countries, phytosanitary measures would not apply and seeds may be present in

[4]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'.

plants for planting with growing media attached coming from countries where it occurs. Such plants will be planted in suitable habitats for Parthenium. Indeed, ornamental plants would be planted in gardens or on roadsides and public areas. All of these habitats are suitable for the plant to establish and to transfer to further suitable habitats.

In conclusion, the entry of Parthenium is moderately likely to occur via growing medium adherent to plants for planting.

Parthenium may enter as a contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage

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

Analysis of the pathway
In infested areas, the soil of fields, gardens, roadsides, pastures, waste lands, etc. can be infested with high numbers of seeds of Parthenium. Seeds are <2 mm in length and could be present on travellers' foot wear, as well as in their clothes and luggage. The transportation of alien species via soil on international aircraft passengers' footwear has been demonstrated by McNeill *et al.* (2011). With an estimated 700 million people crossing international borders as tourists each year (McNeely, 2006), the probability of introducing Parthenium as a contaminant on travellers exists. Once in the country, footwear could spread the plant to roadsides, fallowlands, etc. which are suitable habitats for the species. The probability of transfer from infested clothes or luggage is nevertheless lower than for footwear.

As a conclusion, the entry of Parthenium as a contaminant of travellers and their luggage is considered as moderately likely.

Other pathways not considered as supporting entry of Parthenium

Parthenium as a contaminant of soil
In India, famine weed is seen spreading through transportation of soil for the purpose of filling roadsides and other purposes (Krishnamurthy *et al.*, 1977; Ramachandra Prasad *et al.*, 2010). In the infested areas, soil to be traded as a commodity is likely to be infested by seeds of Parthenium, as the plant occurs in high densities in a wide range of habitats where soil could be taken. Studies undertaken in Australia highlighted that the germinable soil seed bank comprised between 3 284 to 44 639 seeds per m² (Navie *et al.*, 2004). Seeds in soil will be able to germinate where the soil will be transported. However, considering that countries where Parthenium occurs are very distant from the EPPO countries, the trade of soil is expected to be almost nonexistent, and entry of Parthenium along this pathway is therefore considered as unlikely.

Parthenium as a hitchhiker on fruits, vegetables, timber and packing material
Parthenium is thought to have entered Sri Lanka as seeds contaminating mustard imported from India, and as seeds contaminating condiments from India (Jayasuriya, 2005). Parthenium has also been reported as a contaminant on packing material (Parsons & Cuthbertson, 1992). Any commodity could potentially be infested with seeds spread through wind. However, this remains quite unlikely.

Parthenium as a contaminant of livestock
Parthenium is thought to have entered Sri Lanka within or on goats accompanying an Indian military mission (Jayasuriya, 2005). Beef cattle and sheep may also feed on famine weed in the dry season when there is little green grass available in pastures (Chandellor, pers. comm., 2013) and be therefore carrying seeds of the plant in their guts. Within a country, livestock represents an important pathway for spread. The transport of livestock (goats, cattle, sheep) from one country to another may also be a pathway of entry of the species. However, entry of the pest through livestock is not within the competency of Plant Protection Organizations. The entry of Parthenium as a contaminant of livestock would need to be assessed and managed with the collaboration of Animal Health authorities.

Natural spread
The propagule of Parthenium is a cypsela with two appended sterile florets, which act as air sacs and increase both mobility in the air and flotation in water (Navie *et al.*, 1996). 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 (Auld *et al.*, 1983) and in many parts of India (Ramachandra Prasad *et al.*, 2010a). Parthenium can also be spread by wild animals. In Australia, it is dispersed by feral pigs, wallabies and some birds (Grice, Undated). Entry through open borders are reported, as for instance the entry in Nepal through India (Shabbir & Adkins, 2010), and in China through Vietnam (Shabbir & Adkins, 2010). In general, however, this represents a spread (rather than an entry) pathway and will be considered under the next section. Considering the situation in the EPPO region, the risk that the weed would spread by natural means from Israel to other countries within the PRA is considered to be negligible.

Other pathways have been noted, such as with manure and compost, in bouquets (Sweddy, 2011), but as for natural spread, these will be considered in the following section as these pathways are considered to support spread within a country, rather than movement of the species between countries.

As this section has demontrated that pathways of entry for Parthenium exist, the probability that the species can establish and spread in the EPPO countries needs to be considered.

Where can Parthenium establish and spread in the Euro-Mediterranean region?

Not all plant species that enter a new territory establish and spread. To establish, a species needs to be introduced into a suitable habitat that also has suitable climatic and abiotic conditions. All these environmental conditions are met for Parthenium to establish in at least the warmest parts of the Euro-Mediterranean region.

Habitat suitability

Famine weed is a pioneer species that can invade grazing land, cultivated areas (annual crops, permanent crops, fruit trees and berry plantations, natural forests and plantations, non irrigated arable land, olive groves, permanently irrigated arable land, vineyards, glasshouses) and in particular summer crops (which are the most at risk due to the phenology of the species), as well as disturbed areas, roadsides, construction sites, recreation areas, green urban areas, river banks, estuaries, floodplains and natural grasslands (see EPPO, 2014b). These habitats are widely present in the entire EPPO region.

Climatic suitability

Parthenium is reported to have a maximum photosynthetic response at temperatures between 25 and 30°C (Doley, 1977). The plant 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 Parthenium which has been reviewed in the framework of the EPPO Pest Risk Analysis. According to this projection (which includes an irrigation scenario), the whole Mediterranean Basin is at risk, as well as the warmest parts of the temperate area in France, Hungary, Moldova, Russia, the Ukraine, etc. as shown in Fig. 2. The highest risk is considered to exist in Algeria, Israel, Jordan, Morocco, Spain, Tunisia and Turkey.

The EWG also ran a climate change scenario (not shown here), highlighting that the risks from Parthenium could extend poleward over longer periods. Within the EPPO region, many countries that are currently incapable of supporting established populations of Parthenium may become climatically suitable in the future due primarily to rising temperatures. This includes countries such as Austria, Belgium, the Czech Republic, Germany, the Netherlands, the United Kindgom and Baltic States.

Other abiotic factors do not represent limitating factors, as Parthenium can grow on a wide variety of soils (Dale, 1981; Navie *et al.*, 1996) and will find suitable soils in the EPPO region for its establihsment.

Probability of spread of Parthenium

As mentioned in the probability of entry section, seeds of Parthenium can be naturally dispersed through water, wind, and animals. Rare climatic events would also represent opportunities for the species to spread. These could include cyclones, as observed in South Africa in 1986 (Wise *et al.*, 2007), or flooding, as observed in Ethiopia (Ayele, 2007) or in Maharshtra (Krishnamurthy *et al.*, 1977).

However, the highest spread potential of famine weed remains through human activities. Indeed, many spread pathways are reported, including as a contaminant of seeds, of grain, on people, of livestock, of farm yard manure or composts, of construction materials, of land filling, in movement of vehicles, of fodder, of soil, as bouquets, etc. within a country (see the EPPO PRA, EPPO, 2014b). Overall, Parthenium is considered to have a high potential rate of spread.

In addition, due to the thousands of seeds each plant can produce very rapidly and which remain viable for several years, eradication and containment of the species will prove difficult and have often been unsuccessful elsewhere.

Detrimental agricultural, environmental and social impacts of the species

To qualify as a 'pest', a species needs to have detrimental economic, social and environmental impacts. Parthenium qualifies for this, considering its huge detrimental impacts on agriculture, human and animal health.

Impacts on crops

Famine weed aggressively colonises disturbed sites and causes major negative impacts on pastures and on a wide array of crops. Crop losses are reported to be primarily through allelopathic effects (Lakshmi & Srinivas, 2007), over and above the ability of Parthenium to compete for nutrients and moisture. The impacts of famine weed upon cropping systems may be both direct and indirect from a competition point of view (Lakshmi & Srinivas, 2007). In India, it has been observed that Parthenium can cause yield losses of up to 40% in agricultural crops (Khosla & Sobti, 1981; cited in Kandasamy, 2005).

Indirect competition related effects occur through interference with the reproduction of crop plants, e.g. when pollen of Parthenium 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, Parthenium pollen has been reported to be able to inhibit fruit set through allelopathy in beans, eggplant, peppers, tomatoes and other plants (Sukhada & Jayachandra, 1980; in Stamps, 2011) and grain filling of corn.

Famine weed also causes major impacts on pastures. In Queensland (Australia), the species has invaded 170 000 km² of high quality grazing areas and losses to the cattle industry have been estimated at 22 million AUS per

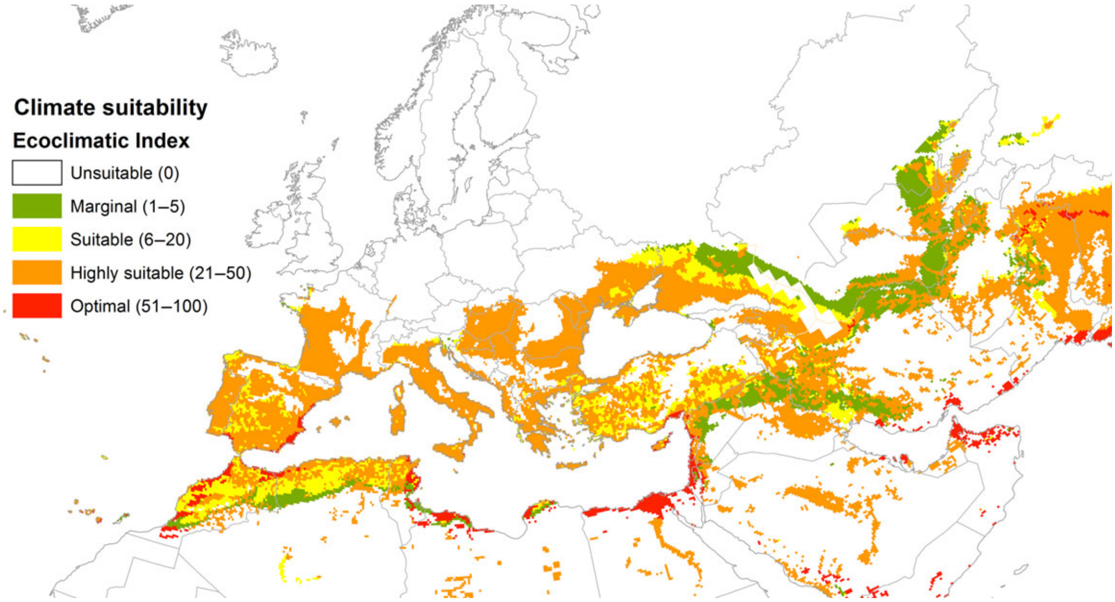

Fig. 2 Climatic suitability for *Parthenium hysterophorous* modelled using CLIMEX with the CM10_1975H_WO_V1.1 climate dataset (Kriticos *et al.*, 2012), including the effect of irrigation (Siebert *et al.*, 2005) in Europe and North Africa.

year in control costs and loss of pasture (Chippendale & Panetta, 1994).

As another indirect effect upon crop production, Parthenium 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).

The overall potential impact of Parthenium in the EPPO in areas where it could establish is assessed as major.

Impacts on the environment, human health and livestock

Infestations of Parthenium can also degrade natural ecosystems, in particular by changing soil properties (Timsina *et al.*, 2011), and outcompete native species, but this has been observed in tropical and subtropical rangelands. In Euro-Mediterranean habitats though, the environmental impact is only assessed as minor to moderate as generally, Parthenium would be unlikely to attain high densities.

However, the human health impacts of the plant are major. Humans who have continued exposure to Parthenium can develop allergic eczematous contact dermatitis (Navie *et al.*, 1996). Patients with severe dermatitis suffer fatigue and weight loss, ultimately leading to deaths of severely affected people (Lonkar *et al.*, 1974). The pollen of the plant is also allergenic. McFadyen (1995) reported that in Queensland, after 1–10 years of exposure to Parthenium, some 10-20% of the human population develop severe allergic reactions. Pollen of Parthenium 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). 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.*, 1976). In the EPPO region where *Ambrosia artemisiifolia* is already a major health problem, allergies may be even more serious for sensitized persons and affect a larger proportion of the population if famine weed enters and spreads. Such human health impacts would be dramatic, particularly in North African rural communities potentially in regular contact with the plant, but with limited access to medications.

Parthenium also has negative impacts on animal health. Because the plant contains sesquiterpenes and phenolics, it is toxic to cattle. Serious impacts upon the health of livestock in Parthenium-infested areas have been reported from India (Lakshmi & Srinivas, 2007). In addition, meat and milk produced from livestock that has eaten the weed can be tainted (Towers & Subba Rao, 1992).

As a conclusion of the EPPO PRA, Parthenium qualifies as a quarantine pest and is recommended for regulation in the EPPO region. What actions can be taken to prevent the entry and spread of this species?

What can be done to counter this pest?

Parthenium represents a major risk to the Euro-Mediterranean region, but its current distribution in this region is still very limited. An effective set of actions needs to be implemented including: preventive phytosanitary measures, eradication and containment plans to be drawn up and ready to be implemented in case of an outbreak, and communication campaigns towards civil servants, farmers and the general public.

Preventive measures on potentially contaminated commodities

Specific measures need to be implemented on the different entry pathways.

Parthenium as a contaminant of used machinery
One important pathway of introduction of the species is as a contaminant of used machinery (agricultural machinery, military equipment, vehicles) (IPPC, 2014). No measures are in place for the cleaning and disinfection of machinery in EPPO countries, except in Israel and in Norway. Cleaning and disinfection of used machinery are highly recommended to prevent the entry of Famine weed as well as other pests that may find their way through this pathway. The International Plant Protection Organization is currently drafting a Standard on 'International movement of used vehicles, machinery and equipment', providing guidance on how to treat, how to set up facilities and waste disposal, and how to check procedures.

Parthenium as a contaminant of grain, seeds, and growing medium adherent to plants for planting
Preventing the entry of Parthenium as a contaminant of grain, seeds and plants for planting consists of classical phytosanitary measures which include:

- Requirements from the importing country that the commodities (i.e., grain, seeds and plants for planting) be produced in areas free of Parthenium; or
- Requirements from the importing country that these commodities be produced in places where production freedom from Parthenium would have been ensured through a set of measures consisting of all the following: visual inspection (to determine whether the pest is present or not), specific treatments of the crops (most usually chemical treatments), testing of the commodities at borders during inspections, and the setting up of internal surveillance, eradication and containment plans ready to be implemented in case of an outbreak. These measures could also be organized in the framework of a certification scheme for grain, seeds and plants for planting.

Parthenium as a contaminant of travellers (tourists, migrants, etc.) and their clothes, shoes and luggage
The entry of Parthenium as a contaminant of travellers, in particular as seeds in mud adherent to shoes is not negligible. However, travellers, migrants and their belonging cannot be inspected for tiny seeds of this plant. The only possible measure for this pathway consists in informing travellers about the risk Parthenium represents, asking them to clean their shoes and belongings as much as possible. Such communication campaigns need to be complemented with an internal surveillance and rapid action plan in the EPPO countries at risk.

Surveillance, eradication and containment plans against Parthenium to be ready in countries at risk

EPPO provides its member countries with Standards on the monitoring, eradication and containment of pests in its PM 9 series. General recommendations contained in the forthcoming Standard for Parthenium are provided here.

To conduct surveillance, staff of organizations in charge of the monitoring of the species should be trained to recognize the plant even when occurring in small populations. This may include staff of NPPOs, nature conservation managers as well as botanists, agronomists, farmers, etc. As this plant grows in a wide range of habitats and has direct impacts on people's health, citizen science projects may be implemented to encourage landholders and other citizens to report sightings of Parthenium. Monitoring should concentrate on areas that are climatically suitable and most vulnerable to colonization (cultivated fields, pastures, managed areas, roadsides, etc.).

The eradication programme for Parthenium in the case of recently detected populations (including an incursion) is based on the delimitation of the invaded area and the application of measures to both eradicate and prevent further spread of the pest. Eradication measures include chemical, manual and mechanical methods.

The containment programme for Parthenium in the case of established populations is based on the application of measures to prevent further spread of the pest in the country or to neighbouring countries. Potential measures, in addition to the ones that can be used for eradication, are integrated cultural control through the use of suppressive plants and smother crops, as well as biological management through the use of biological control agents (Shabbir *et al.*, 2013).

Professionals (e.g. NPPOs, farmers) should be informed about the threat to agriculture and human health and about preventive measures.

Communication to civil servants, farmers and the general public

Communication and citizen science campaigns are particularly appropriate for Parthenium in the European and Mediterranean countries at risk as they can raise awareness and increase monitoring efforts. Indeed, the huge agricultural and human health impacts of this species will directly be detrimental to populations. Although NPPOs and farmers are dedicating extensive efforts to control and prevent the entry and spread of plant pests and pests as plants, success is invisible and the general public is usually not aware of these efforts. Communication has been identified as a new and necessary terrain to be invested by Plant Protection Organizations (Brunel, 2014). Parthenium is an excellent case study to raise awareness on invasive alien plants, their impacts and management measures, as well as to increase surveillance on this specific species through citizen science surveys. International cooperation and exchange of information is also essential. The International Parthenium weed Network is an online network that has contributed significantly in exchanging information, providing its members with access to various online resources such as identification kits, best management practice guides and regular e-newsletters (Adkins & Shabbir, 2014). Civil servants involved in agriculture and land maintenance (roads, pastures, waterways management) and farmers are the primary target audience to be informed. Similar communication and training programmes have been organized in North Africa to provide information on the recognition, impacts and management of *Solanum elaeagnifolium* through the FAO Farm Schools Experience (Mekki *et al.*, 2010). This network of farmers and trainers need to be made use of for Parthenium.

A wider communication campaign involving the media and citizen projects such as reporting sightings of Parthenium through phone or internet applications (as is for instance already done with farmers in the Indian Ocean through the project WIKWIO[5]) would also represent an innovative and useful initiative.

The early management of this plant could represent a fantastic opportunity of communication on pests and of cooperation between EPPO, the Near East Plant Protection Organization (NEPPO), Governments and farmers.

Prévenir l'introduction et la dissémination d'une nouvelle plante exotique envahissante dans la région euro-méditerranéenne: étude du cas de *Parthenium hysterophorus*

Parthenium hysterophorus L. est une plante annuelle originaire des Amériques et une plante exotique envahissante majeure sur presque tous les continents. Les effets délétères de cette espèce sur l'agriculture, et la santé animale et humaine sont bien documentés, mais la littérature donne peu d'informations sur les filières d'entrée de cette espèce. Dans la région euro-méditerranéenne, cette plante n'est signalée comme étant établie qu'en Israël et en Egypte, et l'Organisation Européenne et Méditerranéenne pour la Protection des Plantes a identifié *P. hysterophorus* comme une menace émergente. L'OEPP a par conséquent réalisé une analyse du risque phytosanitaire pour évaluer le risque que cette espèce représente et pour déterminer des options de gestion appropriées.

Предотвращение проникновения и распространения в Евро-Средиземноморском регионе нового инвазивного чужеродного растения на примере изучения *Parthenium hysterophorus*

Parthenium или гваюла (сорняк голода) (*Parthenium hysterophorus* L.) является однолетним растением, происходящим из Америки, которое является серьезным инвазивным чужеродным растением почти на всех континентах. В то время как вредные воздействия различных видов сорняков на сельскохозяйственное производство, на здоровье человека и животных хорошо документированы, информация о путях проникновения различных их видов редко появляется в литературе. Поскольку это инвазивное чужеродное растение было только что зарегистрировано в пределах Евро-Средиземноморского региона в качестве акклиматизировавшегося в Израиле и Египте, ЕОКЗР определила *P. hysterophorus* как новую возникающую угрозу. Поэтому ЕОКЗР провела Анализ фитосанитарного риска для этого вида с тем, чтобы оценить риск, который он представляет, и предусмотреть соответствующие варианты управления риском. Основные результаты АФР обобщаются в данной статье и указывают на вероятность проникновения этого вида различными путями в регион ЕОКЗР, на вероятность его акклиматизации и распространения, а также на масштабы потенциальных сельскохозяйственных, экологических и социальных воздействий.

[5]Weed Identification and Knowledge in the Western Indian Ocean http://portal.wikwio.org/.

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