Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Pepper vein yellows viruses (PeVYVs)

October 2018

Summary and conclusions of the rapid PRA

Pepper vein yellows viruses (PeVYV) are an emerging threat to pepper production worldwide. Where outbreaks have occurred, significant reduction in the value of the crop has been observed. PeVYVs are spread by two very common vectors in the UK, the aphids *Aphis gossypii* and *Myzus persicae.* As the host range includes *Solanum nigrum*, there is the potential for the viruses to establish in the UK outside of protected cultivation where most *Capsicum* spp. are grown. This PRA shows that PeVYVs are a significant threat to pepper production in the UK.

Risk of entry

The pathway of entry considered most likely is plants for planting of *Capsicum* species from Southern Europe. There is significant trade of *Capsicum* spp. from European countries where the virus has established, with no mitigations in place. Detecting the viruses in young plants during transit is also difficult. Plants for planting as a route for entry has been assessed as likely with high confidence. There is also a risk of entry through the import of infected fruit or cut flowers, but these are considered unlikely with medium confidence. As both vectors are widely distributed across Europe, natural spread is another possible route into the UK, though this has been assessed as unlikely, with medium confidence.

Risk of establishment

As *Capsicum* species are grown in protected cultivation in the UK, and the vectors are persistent problems within glasshouses, the risk of establishment in protected cultivation was determined to be very likely, with high confidence. The viruses are also known to infect *Solanum nigrum*, a common shrub in parts of the UK. Establishment outdoors has been assessed as likely, with medium confidence.

Economic, environmental and social impact

PeVYVs cause a reduction in the size, and significant discolouration, of infected fruit. For a high value crop like pepper, the symptoms can make the fruit unmarketable. Where outbreaks have occurred, the incidence of symptoms is typically very high. Large economic impacts have been observed in areas this virus has established, but these are in regions significantly hotter and with higher light intensity than the UK. Economic impacts to the UK have been assessed as medium, with medium confidence. Environmental impacts have been assessed as small, with low confidence. Social impacts have been assessed as very small, with high confidence.

Endangered area

All *Capsicum species* grown in protected cultivation in the UK are at risk of PeVYVs, as well as *S. nigrum* growing in the wider environment.

Risk management options

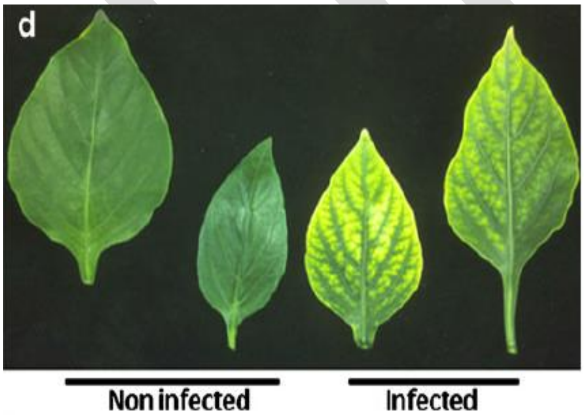
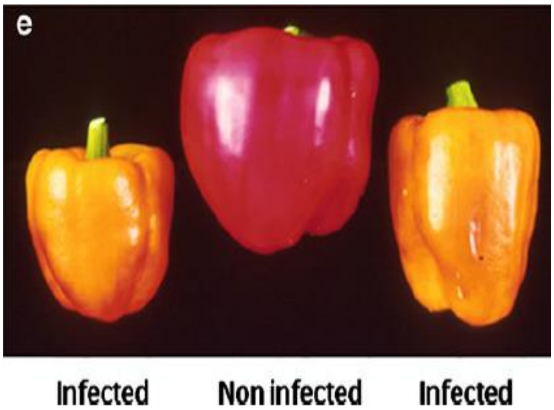
Exclusion is unlikely to be effective. The import of Solanaceae plants from third countries outside of Europe is prohibited, but the pathogen has already established in Greece, Italy and Spain. Requiring imported *Capsicum* plants for planting from countries with PeVYVs to be produced at a place of production free from the disease is a possibility.

Eradication is unlikely to be an effective means of controlling the spread of this pest. The ability of the viruses to persist outdoors on *S. nigrum*, and the very widespread nature of the vector makes eradication difficult. The destruction of infected plants within protected cultivation is sensible to prevent reinfection, but the risk of reinfection from an outdoor source would remain. Eradication of the vectors is essentially impossible. Measures that are currently being used for the control of other insect pests of pepper are likely to offer some control of infected vectors of PeVYV. There is limited research on resistance to PeVYV.

Key uncertainties and topics that would benefit from further investigation

- The impact that the lower light levels, temperatures and shorter day lengths in the UK have on symptom development, vector transmission and viral replication.
- Sources of natural resistance of *Capsicum* species to PeVYVs.
- Determination of the full host range of PeVYVs.

Images of the pest

<table>
<tr>
<td>Symptoms of PeVYV on infected leaves of C. frutescens.

</td>
<td>Symptoms of PeVYV on infected C. frutescens fruit.

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<td>Dombrovsky, 2010</td>
<td>Dombrovsky, 2010</td>
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*Permission to use the images in the public version is being sought.

Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EU) and the PRA scheme (UK or EPPO) to be used.

As an emerging disease there is limited information available that could address the uncertainties highlighted here, limiting the value of a more detailed PRA at this time. Should the virus cause more significant damage than expected or be found on a wider range of hosts, a more detailed PRA might be necessary.

No	✓				
Yes		PRA area: UK or EU		PRA scheme: UK or EPPO	

Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

There are three options for action against PeVYVs:

1) No statutory action taken against findings of the virus. Awareness raising amongst industry will still happen, with guidance on best management practices provided. No formal action will be taken on interceptions or findings of the virus.

2) Maintain the current position. This is to take statutory action on findings of PeVYV infected fruit or plants for planting, but without seeking a specific listing. This allows for flexibility in taking action without being tied to legislation. If statutory action proves too onerous this could be reviewed.

3) Further regulation. There is the possibility of the UK becoming a Protected Zone, with PeVYVs a Regulated Non-Quarantine Pest (RNQP). However, as plants for planting are not the only viable pathway this is unlikely to be effective in the long term. Requirements for pepper to be produced in a pest free site of production are possible, but would have limited effectiveness. As symptoms would not be present until later in the plants development, requirements would need to include measures which did not rely on visual inspection of the traded plants. Post entry quarantine is another possible option, but is difficult and may only be possible for small quantities of high value material.

Yes Statutory action	✓	No Statutory action	

Stage 1: Initiation

1. What is the name of the pest?

Pepper vein yellows viruses (PeVYVs), family *Luteoviridae*, genus *Polerovirus*.

In 1981, symptoms of vein yellowing and leaf roll were first observed in greenhouses in Okinawa, Japan, and later identified as a unique *Luteovirus* named *Pepper vein yellows virus* (PeVYV) (Yonaha *et al.*, 1995). A similar disease was observed in Israel in 1998, given the name of *Pepper yellows leaf curl virus* (PeYLCV) (Dombrovsky *et al.*, 2013). There have now been multiple findings of related *Polerovirus* species across the world causing yellowing, leaf curl symptoms and distortions of the fruit on *Capsicum* species. Three species isolated from Australia (Maina *et al.*, 2016), China (Liu *et al.*, 2016) and Spain (Fiallo-Olivé *et al.*, 2018) have now been sequenced and identified as related to PeVYV. Most recently, an emerging yellows disease of *Capsicum* in Greece led to the identification of another polerovirus causing similar symptoms, related to both PeVYV and PeYLCV called *Pepper yellows virus* (PYV) (Lotos *et al.*, 2017).

All six polerovirus species associated with yellowing and leaf curl in *Capsicum* species produce similar, if not identical, symptoms (Fiallo-Olivé *et al.*, 2018) and are all transmitted by the same two aphid species, *Aphis gossypii* and *Myzus persicae* in a persistent manner (Yonaha *et al.*, 1995). Current species demarcation criteria for the genus *Polerovirus* requires more than 10% difference in amino acid identity for any viral gene product (Fiallo-Olivé *et al.*, 2018). The polerovirus genome typically encodes 6 proteins P0 to P5, and 3A (Dombrovsky *et al.*, 2013, Yonaha *et al.*, 1995). An analysis of the five species from Australia, Japan, China, Israel and Spain identified greater than 10% divergence in the P0, and sometimes the P5 protein, between all 5 species, with greater that 90% similarity across all other open reading frames (Fiallo-Olivé *et al.*, 2018). As such, these viruses are considered highly similar, but still genetically distinct species. It has been proposed to rename the species cluster as ‘Pepper vein yellows virus 1’ PeVYV-1 to ‘PeVYV-5’ (or, putatively PeVYV-6 based on Lotos *et al*., 2017) (Fiallo-Olivé *et al.*, 2018).

For the purpose of this PRA all six species of pepper yellows disease causing poleroviruses will be considered together as the *Pepper vein yellows viruses* (PeVYVs). Symptoms, hosts and vectors are virtually indistinguishable between the species, and no difference in impacts or management strategies can yet be observed between the different species. Where differences between species are meaningful to draw out, in geographic origin for example, this has been done so.

The PeVYVs are a distinct species from the similarly named *Pepper yellow vein virus* (Fletcher *et al*., 1987). PeVYVs are also not the same as *Capsicum yellows virus*, caused by an Australian potato leafroll virus-like species (Gunn & Pares, 2008).

2. What initiated this rapid PRA?

Recent reports of damage to *Capsicum* plants in parts of Europe led the Dutch to publish a Quick Scan (rapid PRA) on PeVYV (which also included PeYLCV) (Dutch NPPO, 2016). After reviewing this information, PeVYV was added to the UK Plant Health Risk Register. The Plant Health Risk Group determined that a PRA would better assess the level of risk to the UK.

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

Stage 2: Risk Assessment

4. What is the pest's status in the EC Plant Health Directive (Council Directive 2000/29/EC[1]) and in the lists of EPPO[2]?

PeVYVs are not listed in the EC Plant Health Directive and are not recommended for regulation as a quarantine pests by EPPO, nor are they on the EPPO Alert List.

5. What is the pest's current geographical distribution?

PeVYVs have been found in 20 countries across 5 continents. A scattered distribution like this is likely indicative it is present in more countries, but no formal reports exist yet.

Table 1: Distribution of Pepper Vein Yellows Virus Species		
Region	**Country**	**Species**
North America:	USA (Alabi *et al.*, 2015)	PeVYV
Central America:	No reports	
South America:	No reports	

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0029:20100113:EN:PDF

[2] https://www.eppo.int/ACTIVITIES/quarantine_activities

Europe:	Greece (Lotos *et al.*, 2017), Italy (Tomassoli L, 2016), Spain (Villanueva *et al.*, 2013), Turkey (Buzkan *et al.*, 2013)	PeVYV, PeYV
Africa:	Ivory Coast (Antoine *et al.*, 2015), Mali (Knierim *et al.*, 2013), Republic of Benin (Afouda *et al.*, 2017), Sudan (Alfaro-Fernández *et al.*, 2014), Tunisia (Buzkan *et al.*, 2013)	PeVYV
Asia:	China (Zhang *et al.*, 2015), India (Knierim *et al.*, 2013), Indonesia (Knierim *et al.*, 2013), Israel (Dombrovsky *et al.*, 2013), Japan (Yonaha *et al.*, 1995), Pakistan (Ahmad *et al.*, 2017), Philippines (Knierim *et al.*, 2013), Thailand (Knierim *et al.*, 2013), Taiwan (Knierim *et al.*, 2013)	PeVYV, PeYLCV
Oceania:	Australia (Maina *et al.*, 2016)	PeVYV

6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA Area?

There have been no interceptions or outbreaks of PeVYVs in the UK.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

Table 2: Hosts of Pepper Vein Yellows Virus

Family	Species	Source	Reference	Species
Solanaceae	*Capsicum annum*	Natural	(Yonaha *et al.*, 1995)	PeVYV
Solanaceae	*Capsicum chinense*	Natural	(Tomassoli L, 2016)	PeVYV
Solanaceae	*Capsicum frutescens*	Natural	(Zhang *et al.*, 2015)	PeVYV

Solanaceae	*Capsicum baccatum*	Natural	(Murakami & Kawano, 2017)	PeVYV
Solanaceae	*Solanum nigrum*	Natural	(Alfaro-Fernández *et al.*, 2014)	PYV
Solanaceae	*Nicotiana tabacum**	Natural	(Wang *et al.*, 2017)	PeVYV
Amaranthaceae	*Chenopodium amaranticolor*	Experimental	Dombrovsky et al., (2013),	PYLCV
Cucurbitaceae	*Curcubita pepo*	Experimental	Dombrovsky *et al.* (2013)	PYLCV
Solanaceae	*Datura stramonium*	Experimental	Dombrovsky *et al.* (2013)	PYLCV
Amaranthaceae	*Gomphrena globose*[+]	Experimental	Dombrovsky *et al.* (2013)	PYLCV
Solanaceae	*Nicotiana clevelandii*	Experimental	Dombrovsky *et al.* (2013)	PYLCV
Solanaceae	*Nicotiana benthamiana*[+]	Experimental	Dombrovsky *et al.* (2013)	PYLCV
Solanaceae	*Petunia hybrida*	Experimental	Dombrovsky *et al.* (2013)	PYLCV
Solanaceae	*Physalis floridana*	Experimental	Dombrovsky *et al.* (2013)	PYLCV

* There are contrasting reports from the literature about this host. *Nicotiana tobacum* was not found to be a host by Yonaha, 1995.

[+]PYLCV was identified, but the plant exhibited no symptoms.

Dombrovsky *et al.* (2013) indicate *Chenopodium amaranticolor, Curcubita pepo, Datura stramonium, Gomphrena globosa, Nicotiana clevelandii, Nicotiana benthamiana, Petunia hybrida* and *Physalis floridana* as experimental hosts. Several of these species saw viral replication, but no symptoms. No subsequent source that mentions these as hosts in the field has been found. Not all species of PeVYVs have been tested against all the hosts listed in this table, there might be species specific host preferences, or differences in impacts that are not clear yet.

Capsicum annum is the most economically important host in the UK, with over 90 Ha of glasshouse grown peppers planted in 2016 worth approximately £18.5 million (https://www.gov.uk/government/statistics/latest-horticulture-statistics). *Capsicum frutescens* is commonly grown domestically. *Solanum nigrum* is a common host in the UK environment. Some of the hosts identified as experimental only are also common in the UK, including *Datura stramonium, Petunia hybrid and Physalis floridana. Chenopodium amaranticolor* is also found in the wider environment with a scattered distribution and there is some production of *Curcubita pepo* species. These have only been found to be hosts in artificial inoculations at present, and are not the main focus of the PRA. Should impacts be observed from PeVYVs on these species, this might need to be reviewed. The observation that the viruses are capable of infecting non-solanaceous species in the Amaranthaceae and Cucurbitaceae families might also suggest that the host range of these viruses is larger than currently believed.

8. Summary of pest biology and/or lifecycle

PeVYVs are transmitted by aphids in a persistent, circulative manner (Fiallo-Olivé *et al*., 2018). When the aphid feeds on the phloem of an infected host, the virion enters the body through the alimentary canal, and crosses into the epithelia through receptor mediated cytosis without uncoating (Whitfield, 2015). After passing the epithelia the virions enter the hemocoel, and circulate to the salivary glands. The viruses do not replicate within the vector, so high levels of virus accumulation occur only after longer feeding periods or prolonged exposure to infected hosts (Whitfield, 2015). The viruses are not transmitted parthenogenically – a vector can only acquire the virus through feeding (Knierim *et al*., 2013). Information about viral spread and replication *in planta* has not been found for this pest.

Myzus persicae is a heteroecious species of aphid that alternates between winter and summer hosts. Preferred winter hosts are *Prunus* species, commonly peach where these are grown, but in the absence of the preferred host the aphid is known to overwinter as a mobile adult on various weed species and Brassicacea in the UK (CABI, 2018). The summer hosts of *M. persicae* are very numerous, covering more than 40 different plant families including *Capsicum frutescens.* Winged forms begin to migrate onto summer hosts from late April to early June, and peak numbers on summer hosts are typically found in July. Migration onto winter hosts occurs in late September and early October. *M. persicae* is relatively cold tolerant, and has demonstrated a high degree of suitability to the UK climate. In glasshouses, some *M. persciae* display an anholocyclic lifecycle, remaining on the same hosts year round in warmer environments.

Aphis gossypii has a similar lifecycle to *M. persicae*, being heteroecious in the wider environment and transferring between winter and summer hosts, but predominantly anholocyclic in glasshouses all year round (CABI, 2018). Winged forms tend to migrate between June and July annually. Like *M. persicae,* it has a very large host range of over 40 species (CABI, 2018).

9. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

Seed transmission:

There is no evidence that seed transmission of PeVYVs occurs (Yonaha *et al.*, 1995). Seed transmission has been ranked as very unlikely, with high confidence.

Seeds	Very unlikely	✓	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐				

Plants for planting:

The most likely route of entry for PeVYVs will be the transfer of infected hosts. The UK does import *Capsicum* seedlings from parts of Europe where PeVYVs have been established, including Spain (Villanueva *et al.*, 2013) and Italy (Tomassoli L *et al*., 2016).

Data from PHSI inspectors and nurseries were sought concerning the import of growing *Capsicum* plants from other EU member states. From this limited survey approximately 150,000 *Capsicum* seedlings were imported from the continent between August 2016 and August 2017 (E. Birchall, pers. comm., August 2017). Most of the trade in seedlings comes via the Netherlands, but it is difficult to determine the original source. Furthermore, from this dataset the import of 10,000 grafted *Capsicum* from Israel was observed, another region where PeVYVs are present (Dombrovsky *et al.*, 2013).

In the early stages of infection, symptoms of the disease are difficult to detect and later stages might be misinterpreted as drought or nutrient deficiencies, making the identification of an infected host difficult. A search of Europhyt (16/10/2018) has not found any reported interceptions of PeVYVs within Europe, but not all interceptions of unlisted pests would be recorded.

There is also the possibility of the import of ornamental *S. nigrum* (Alfaro-Fernández et al., 2014*)*, though as a weed native to the UK the volume of trade is likely to be very low. Similarly, there is likely to be low levels of trade of the other currently experimental only hosts. As some of these saw viral replication, but remained asymptomatic under the test conditions, identification of infected material would be impossible without molecular testing. Plants for planting as a pathway for entry of PeVYVs has been assessed as likely, with high confidence.

Plants for planting	Very unlikely ☐	Unlikely ☐	Moderately likely ☐	Likely ☑	Very likely ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Natural Spread:

Natural spread in this case refers to the movement of an infected vector from outside of the PRA area into it and onto a suitable host. The viruses are vectored by two aphid species *Aphis gossypii* and *Myzus persicae.* Both of these species are widespread within the PRA area and Europe (CABI A, 2018). Vector availability is not considered a limiting factor in the spread of this virus.

PeVYVs are transmitted to the aphids in a persistent manner, but are not passed on parthenogenically (Dombrovsky *et al.*, 2013, Raccah *et al*., 2009). An aphid can only become infected if it is feeding on an infected host. This potentially limits the rate of spread – new generations must be raised on infected hosts. Further limiting the potential rate of natural spread is that the most significant hosts, *Capsicum* species, are predominantly grown commercially in protected cultivation. Although *Myzus persicae* is a significant problem for protected cultivation as well, the vector would have to feed on an infected host prior to movement into the protected cultivation, or be transported alongside an infected host, further limiting natural spread as a pathway for entry. Aphids are well documented to be able to move long distances through air currents and natural spread from the continent across the channel is possible (Hu *et al*., 2016, Parry *et al*., 2013).

Natural spread has been assessed as unlikely, with medium confidence. Should many wild hosts for this virus (i.e. *S. nigrum*) be found in the vicinity of protected pepper crops, the chances of a vector finding a suitable outdoor host prior to entering protected cultivation would be increased, resulting in a higher likelihood score. Should the viruses be found in neighbouring European countries France, Belgium and the Netherlands, the chances of natural spread as a pathway of entry to the UK becomes more likely.

Natural Spread	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Mechanical transmission:

There is no evidence that mechanical transmission of PeVYVs occurs (Yonaha *et al.*, 1995). Mechanical transmission has been ranked as very unlikely, with high confidence.

Mechanical transmission	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐

Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐

Fruits or vegetables:

Peppers are being imported into the UK in very high numbers from areas where PeVYVs have established in Europe, including Greece, Italy and Spain (Lotos, 2017; Tomassoli L, 2016; Villanueva, 2013). However, the vectors of this pest tend to feed on leaves and stems of the host plant, with very little feeding on fully developed fruit. If they did feed on the fruit, they would mostly be restricted to the calyx and pedicle. Furthermore, most fruit would be imported for consumption and the vectors would therefore have little opportunity to move into protected cultivation. Fruits or vegetables have been rated unlikely routes of entry, with medium confidence – a result of the high numbers of imported peppers and the possibility that some crops are in close proximity to pack houses which import peppers from Europe.

Fruits or Vegetables	Very unlikely	☐	Unlikely	✓	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

Cut flowers or branches:

The virus will persist in living cut flowers or branches from hosts it has infected. There is only a low level of import of cut flowers or branches of *Capsicum* species however. Similarly, only low levels of *S. nigrum* are likely to be imported, as it is a native weed to the UK. If further research identifies a wide range of flowering plants as hosts, the likelihood of entry through cut flowers or branches can be increased. Cut flowers or branches as a pathway for PeVYVs for entry has been assessed as unlikely with medium confidence, as the full host range of the virus is unknown.

Cut flowers or branches	Very unlikely	☐	Unlikely	✓	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

10. If the pest needs a vector, is it present in the UK/PRA area?

The aphid vectors *Myzus persicae* and *Aphis gossypii* are widespread in the UK, in both outdoor and protected cultivation (CABI, 2018). The presence of suitable vectors is not a limiting factor for the spread or establishment of PeVYVs.

11. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

Outdoor establishment:

PeVYVs are moderately likely to establish outdoors in the PRA area. Although its most significant hosts, *Capsicum* species, are mostly grown in protected cultivation with some domestic growth of chillies, *S. nigrum* is a common wild host in the UK. In Japan, wild populations of bird pepper are known to act as reservoirs for the PeVYVs and a source of introduction to commercially grown bell peppers (Murakami *et al*., 2017). The potential for a natural host of PeVYVs in the wider environment significantly increases the risk of establishment, and lowers the effectiveness of any containment or eradication measures taken.

S. nigrum is recorded across most of southern and central England and coastal regions of Wales, with a scattered distribution in northern England, Northern Ireland and Scotland (see Figure 1). *Datura stramonium, Petunia hybrid and Physalis floridana* have a more restricted distribution in the UK, but are still common. Should these be found to be hosts in field conditions the likelihood of PeVYVs establishing outdoors would be higher.

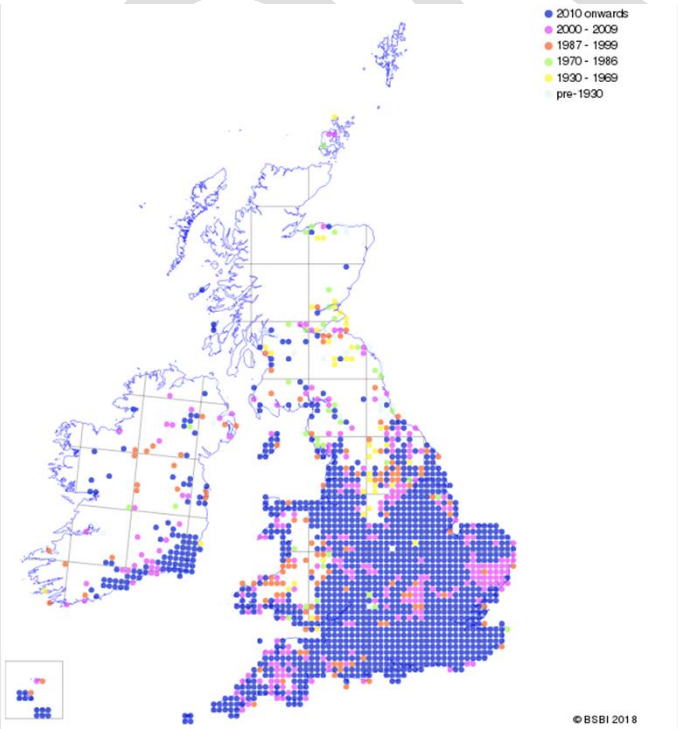

Figure 1 Distribution of *Solanum nigrum* in the UK. Image courtesy of BRC, taken from https://www.brc.ac.uk/plantatlas/plant/solanum-nigrum

As these are viruses, the UKs climate is unlikely to be a limiting factor in the establishment of this pest. It has been noted by Dombrovsky *et al.* (2010) that the yellowing symptoms on glasshouse grown plants were not observed in shaded parts of the greenhouse. This might suggest that light intensity is a significant factor in the development of symptoms, and could suggest that impacts might be reduced in the lower light growing conditions of the UK compared to regions within the virus's current distribution. This is highly uncertain, however, based only on a single source with no detailed studies on symptom development of infected plants under different light levels. Impacts of PeVYVs have only been seen in regions with a significantly hotter climate, higher light intensity and longer day lengths than the UK.

Outdoors	Very unlikely ☐	Unlikely ☐	Moderately likely ☐	Likely ☑	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Establishment in protected cultivation:

The majority of commercial peppers in the UK are grown under protected cultivation. *Myzus persicae* and *Aphis gossypii* are both significant pests in glasshouses in the UK and across Europe. If an infected host is transplanted into protected cultivation, or if an infected vector feeds on a host in protected cultivation, the virus is very likely to establish. Impacts have been observed in both field and protected cultivation in areas the viruses are present (Dombrovsky *et al*., 2010, Fiallo-Olivé *et al*., 2018). Crop breaks that occur in UK glasshouses over the winter might restrict establishment in the UK. Even with measures taken to control aphids, they remain a significant problem and a number of aphid borne diseases have established effectively in the UK under protected cultivation. The risk of establishment in protected cultivation has been assessed as very likely with high confidence.

Under Protection	Very unlikely ☐	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☑
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

12. How quickly could the pest spread in the UK/PRA area?

Both vectors are widespread across the UK, and diseases borne by them have typically spread across the country rapidly. Natural Spread has been assessed as quickly, with high confidence.

Natural Spread	Very slowly	☐	Slowly	☐	Moderate pace	☐	Quickly	✓	Very quickly	☐
Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐				

The viruses are spreading globally through trade (Fiallo-Olivé *et al*., 2018). The virus that was sequenced in Italy is not the same as the species found in Spain, suggesting that trade from two different regions was responsible for establishment in these areas (Tomassoli L *et al*., 2016). The transplanting of infected hosts into otherwise virus free glasshouses across the country would significantly increase the spread of these viruses across the UK. Although propagated pepper seedlings are likely to be of high quality, at the time of transplanting the seedlings will be too small to have manifested significant symptoms, lowering the likelihood an infected host could be identified before transplanting. With trade, spread has been assessed as very quickly, with high confidence.

With trade	Very slowly	☐	Slowly	☐	Moderate pace	☐	Quickly	☐	Very quickly	✓
Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐				

13. What is the pest's economic, environmental and social impact within its existing distribution?

Pepper vein yellows viruses are having significant impacts on pepper production within its current distribution. In the 2012 outbreak in Almeria, Spain, over 10,000 Ha of *C. annum* grown in protected cultivation were infected with the virus, with an incidence of up to 100% within glasshouses (Fiallo-Olivé *et al*., 2018). The symptoms included interveinal yellowing, upward leaf curling, and the abnormal ripening of the fruits, including off-colouring for the variety of pepper being produced (Villanueva, 2013). The marketability of infected fruit is significantly reduced. In the Italian outbreak of 2014 and 2015, disease incidence was reported as being lower (around 2%) amongst chillies grown for seed production (Tomassoli L *et al*., 2016). In Greece, PeVYV was not considered a limiting factor in pepper cultivation before 2013, but an outbreak in Crete in 2013 led to significant losses, with incidences in glasshouses between 40 and 60% (Lotos *et al*., 2017). It is unclear why symptoms were worse in that year.

Elsewhere in the Mediterranean region, PeVYVs have caused serious economic damage on *C. annum* and *C. frutescens* production in Israel since 1998 (Dombrovsky *et al*., 2013), and Turkey and Tunisia, with incidences above 70% in some regions (Buzkan *et al*., 2013).

Worldwide, there are similar records of very high incidences of the disease when an outbreak occurs. Incidence of PeVYVs in field grown peppers in Texas was reported as 75% in 2014 (Alabi *et al*., 2015) and 65% on field grown hot pepper (*C. annum*) in Pakistan in 2014 (Ahmad *et al*., 2017). The viruses have been a persistent issue in bell pepper production in Okinawa Japan since 1981, where the virus is also widespread in local populations of wild bird peppers (Murakami *et al*., 2017).

Because of the very high degree of infection seen when an outbreak occurs, and the loss of marketability of infected crops, impacts have been assessed as large, with high confidence. The virus does not cause host mortality.

Impacts	Very small	☐	Small	☐	Medium	☐	Large	☑	Very large	☐
Confidence	High Confidence	☑	Medium Confidence	☐	Low Confidence	☐				

14. What is the pest's potential to cause economic, environmental and social impacts in the UK/PRA area?

Pepper is an important glasshouse crop in the UK, worth approximately £18.5 million per year, all grown in protected cultivation. For pepper production, minor damage to the fruit, including discoloration, can make it unmarketable, so should the disease establish in the UK it is likely that significant impacts would be seen in glasshouse pepper production. Potentially limiting this is the effect of the UK's climate, specifically how linked to high light levels the manifestation of symptoms are. The current distribution suggests the viruses are only present in areas warmer than the UK, but these are also the regions that see the most pepper production and trade. Lower light intensity might affect both symptom development and the viral transmission rates. The observation that symptoms did not develop in shadier parts of glasshouses needs further investigation (Dombrovsky *et al*., 2010). As both vectors are already abundant in the UK, temperature is unlikely to limit vector spread or reproduction. Because of the significant risk to a crop of moderate importance, the economic impact to the UK has been assessed as medium, with medium uncertainty due to the possibility of reduced symptoms in the UK climate.

Economic Impacts	Very small ☐	Small ☐	Medium ✓	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ✓	Low Confidence ☐		

Environmental impacts of this viruses are expected to be relatively limited. Most of its hosts are *Capsicum* species, which are not native to the UK or found in the wider environment. It does, however, infect *S. nigrum*, which is common in the UK. The extent of damage the virus could cause on this species is unclear, with only a single reference referring to a single sample of *S. nigrum* being infected (Knierim *et al*., 2013). Because the full host range of this pest is not well studied, other wild hosts might be found. Environmental impacts have therefore been assessed as small on a precautionary basis, with low confidence.

Environ - mental Impacts	Very small ☐	Small ✓	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ✓		

Chilli peppers are commonly grown domestically in the UK, so some social impacts would be seen should the virus become widespread. There are no other significant social impacts that might be observed with these virus at present. Social impacts have been assessed as small, with high confidence.

Social Impacts	Very small ☐	Small ✓	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ✓	Medium Confidence ☐	Low Confidence ☐		

15. What is the pest's potential as a vector of plant pathogens?

N/A: These are viruses and not capable of vectoring other pathogens.

16. What is the area endangered by the pest?

All peppers produced in protected cultivation are at risk from PeVYVs. *Solanum nigrum* in the wider environment is also threatened. As the full host range is not well understood at present, it's possible that other environmentally and economically important hosts are also under threat from PeVYVs.

Stage 3: Pest Risk Management

17. What are the risk management options for the UK/PRA area?

The aim of risk management measures would be to prevent the entry and establishment of PeVYVs in commercial pepper production in the UK.

Exclusion:

Exclusion, via the introduction of legislation against PeVYVs may be possible, but given how widespread the vectors are it would be difficult. The import of Solanaceae plants from third countries outside of the Euro-Mediterranean area is prohibited in Annex IIIA of Council Directive 2000/29/EC. However the pathogen has already established in Greece, Italy and Spain, which reduces the chance of continued exclusion of the pest as there is already moderate trade in *Capsicum* seedlings from these regions. Intra-EU trade already involves plant passporting and monitoring agreements, but requirements which would need to be met as part of the passporting arrangements could be introduced.

Detection of symptomatic plants for planting would be possible on more mature plants where symptoms are visible, but plants are usually traded as young plants, when symptoms are unlikely to be visible. Screening for the vector is unlikely to be effective, as both aphid vectors are extremely widespread, and there is no way of knowing if they are carrying PeVYVs without a molecular test. At present, no action would be taken against findings of the vectors of this pathogen. For countries without the viruses, there is the possibility for a pest free area, but the scattered, uncertain distribution and widespread nature of the vectors make this an unreliable option.

Requiring imported *Capsicum* plants for planting to be produced at a place of production free from the disease is a possibility. However, as symptoms would not be present until later in the plants development, requirements would need to include measures which did not rely on visual inspection of the traded plants. For example, plants should have been produced on a place of production where no symptoms of PeVYVs have been observed in the last year or plants could be grown on a site with complete physical isolation to prevent aphid vector introducing the virus into the production site. Post entry quarantine is another possible option, but is difficult and may only be possible for small quantities of high value material, and as pepper seedlings are imported in large batches for immediate introduction into production sites is likely to be very disruptive.

Eradication & Containment:

Eradication may be possible on sites where there is a crop break but it is possible that infected aphids would be able to over winter. *M. persicae* can overwinter in a mobile stage typically on weeds, and could persist through the crop break. The destruction of infected plants within protected cultivation is sensible to prevent reinfection of the following crop, but even with eradication of infected hosts the virus remains a persistent problem in some areas (Murakami, 2017). Eradication of the vectors is impossible. Both aphid species are persistent threats to protected cultivation despite intervention to control their numbers. If a vector acquires the disease and spreads it to wild *S. nigrum* in the wider environment, eradication would not be practical. Similarly, containment is unlikely to be a long term solution to the problem should the vector spread PeVYVs to the wider environment.

Non-statutory Controls

It is possible that infection on a site could be supressed by chemical, biological and cultural (mass trapping, removal of waste etc.) control of aphids and removal of infected plants. Removal of *Solanum nigrum* from the area surrounding glasshouses could reduce the build-up of a reservoir of infection in the environment. There will often be a crop break over winter in pepper production which could reduce the vector population, but as the vector can overwinter on hosts in the wider environment, the benefits of the crop break might be limited.

Insecticides employed against aphids, of which *M. persicae* is a common target, accounted for 75% of insecticide usage on peppers, of which 561 hectares were treated in 2015 (Garthwaite *et al.,* 2015). Current pesticide applications are likely to be effective at limiting numbers of the vectors, but even with chemical intervention they remain a persistent problem. There is limited research on identifying natural sources of resistance to PeVYVs, and no clear picture of current crop varieties that exhibit resistance to the pest has emerged.

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