Department for Environment Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Rose rosette virus and its vector *Phyllocoptes fructiphilus*

December 2016

Summary and conclusions of the rapid PRA

This rapid PRA shows that *Rose rosette virus* (RRV) is a very damaging pest and can be lethal to many species of the genus *Rosa*. *Rose rosette virus* is spread by the microscopic mite *Phyllocoptes fructiphilus,* and has the potential to cause large economic, environmental and social impacts in the UK.

Risk of entry

The pathways of entry assessed were plants for planting and cut flowers of *Rosa*. Since trade in *Rosa* planting material between the UK/EU and North America is small, entry on plants for planting was rated as unlikely with medium confidence. There is also only limited trade in cut flowers, and, because of the short shelf life of this commodity and the fact that mites need living tissue to survive, the likelihood of transfer to living *Rosa* plants is considered to be very low and entry on this pathway very unlikely with high confidence.

Risk of establishment

The mite and virus are present in parts of North America with colder winters than the UK, and so survival of UK winters is considered very likely. Summers are hotter in the current distribution of the pest and its vector, and this may reduce the number of generations per

year of *P. fructiphilus*. Host species are abundant, and establishment outdoors is considered very likely with medium confidence, as the exact thermal requirements of the mites are not known. Though there are no reported cases of *P. fructiphilus* or RRV infesting protected crops, there appear to be no factors that would prevent this occurring and colonies have been established under glass for experimental purposes. Establishment under protection is rated as very likely with medium confidence.

Economic, environmental and social impact

RRV is a highly destructive virus of roses and infection kills the majority of rose hosts, with no proven resistant cultivars. Large collections of roses have been destroyed by the disease in the USA and impacts in the current range are rated as large with high confidence.

Potential economic impacts in the UK are large with medium confidence. Infected plants will be unmarketable, and there may be a reduction in demand for roses if the disease spreads. There will also be economic impacts associated with the removal and replacement of roses use in public landscaping. Businesses for which a rose garden may be a prominent feature, e.g. wedding venues and stately homes, may see reductions in visitors or bookings if the rose garden was destroyed by RRV. Two native rose species are known to be a host of RRV (*Rosa canina* and *R. rubiginosa*) though little is known about their relative susceptibility, and it is likely that other native *Rosa spp.* will also be susceptible to infection. Since *Rosa* species are very common hedgerow plants, and a valuable food source, wide scale death due to RRV infection could have large scale environmental impacts. Confidence is low because the susceptibility of the UK native species is unknown or not well documented. As *Rosa* are of significant cultural importance to the UK, as well as being very widely grown, potential social impacts are large with high confidence.

Endangered area

The whole of the UK is endangered by RRV with the greatest impacts likely in the south of England where higher summer temperatures could allow *P. fructiphilus* to complete more generations per year and thus lead to more rapid spread of the virus.

Risk management options

Exclusion is the best risk management option for the UK and regulation of the pest should be considered, with appropriate phytosanitary measures on the import of *Rosa* plants from North America. This could include sourcing plants only from pest free areas or certain pest free places of production if criteria that would help ensure disease freedom can be achieved.

If outbreaks are detected, early eradication may be possible if infested plants, and all host plants within 100 metres, are destroyed and intensive surveillance is carried out within a demarcated area.

In the USA, destruction of infested plants to prevent the spread of RRV is the main control measure utilised. Some growers use a regime of pesticide application to prevent infestation by *P. fructiphilus*, but there is little evidence that this is effective and, as mites are usually located in sheltered parts of the plant, sprays may not reach them.

Key uncertainties and topics that would benefit from further investigation

- The susceptibility of UK native species of *Rosa* spp.
- How temperature effects the development of the mite, *P. fructiphilus*, and if cooler UK summers compared to North America may lead to less generations per year and therefore reduce spread and impacts.
- The period for which infected ornamental *Rosa* remain symptomless – reports vary and information on the latency period has largely only been published for *R. multiflora*. This host has also been documented to temporarily revert to a symptomless state, and it is uncertain if this phenomenon may occur in ornamental *Rosa*

Images of the pest

<table>
<tr>
<td> 
</td>
<td> 
</td>
</tr>
<tr>
<td>A rose (Rosa spp. cv. ‘Colorific’) with RRV showing increased thorn production. Jennifer Olson, Oklahoma State University, Bugwood.org</td>
<td>Plant infested for several years (Rosa spp. cv. ‘Carefree marvel’) and now severely stunted. Jennifer Olson, Oklahoma State University, Bugwood.org</td>
</tr>
</table>

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.

The UK considers that regulation at EU level may be warranted, which will require a Europe wide assessment.

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

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

Rose rosette virus is highly destructive with the potential to cause large economic, environmental and social impacts if introduced to the UK. Statutory action against findings is justified, and regulation of the pest advised.

Yes Statutory action	✓	No Statutory action	

Stage 1: Initiation

1. What is the name of the pest?

Rose rosette virus (RRV)

Rose rosette virus was not characterised formally as the causal agent of rose rosette disease, which had been known since the 1940s, until 2011 (Laney *et al.*, 2011). The abbreviation RRV will be used throughout this PRA.

RRV is a member of the genus *Emaravirus*, the majority of which have been demonstrated to be vectored by eriophyid mites (Mielke-Ehret & Mühlbach, 2012).

The vector is *Phyllocoptes fructiphilus* Keifer. (Acari: Eriophyidae)

Phyllocoptes fructiphilus is the only known vector of RRV and does not have a common name.

2. What initiated this rapid PRA?

RRV was added to the UK Plant Health Risk Register in September 2016 after an increase in impacts of the disease in North America was noted during horizon scanning activities. As roses are of economic, environmental and social importance to the UK, a PRA was initiated to see if regulation of the pest was appropriate.

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]?

Neither *Rose rosette virus* nor *Phyllocoptes fructiphilus* are listed in the EC Plant Health Directive. RRV was added to the EPPO Alert list in June 2016 after the severity of the virus, and its spread in the USA, was noted (EPPO, 2016).

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0029:20100113:EN:PDF
[2] https://www.eppo.int/QUARANTINE/quarantine.htm

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

Both RRV and *P. fructiphilus* are only recorded from North America. It was first documented in California and Wyoming, and is now present in much of the Midwestern, Southern and Eastern United states (Hand, 2014). It is believed to be endemic to the eastern Rockies (both American and Canadian Rockies) where it occurs on the native *R. woodsii* (Martin, 2013)

The pest appears to still be spreading, for example only being found in Louisiana for the first time in 2015 (Morhan *et al.*, 2015), and it has been stated that RRV "will continue to spread into new areas providing the climates in those areas are conducive for supporting populations of eriophyid mites" (Windham *et al.*, 2016).

Table 1: Distribution of *Rose rosette virus* taken from (EPPO, 2016)	
North America:	Canada (Manitoba, Ontario), USA (Alabama, Arkansas, California, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Wisconsin, Wyoming)
Central America:	No records
South America:	No records
Europe:	No records
Africa:	No records
Asia:	No records
Oceania:	No records

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

RRV and *P. fructiphilus* are not known to occur in the UK, and nor have they been intercepted. There have been instances where roses showing symptoms similar to those caused by the virus have been reported, but no viruses were detected on samples submitted for testing, and other causes were assumed.

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?

Phyllocoptes fructiphilus is able to infest and complete development on every species within the genus *Rosa*, except for *R. bracteata* (Macartney rose), but host range testing of this mite species on other members of the Rosaceae family have not found any other species on which it has been shown to develop (Skoracka *et al.*, 2010). *Rosa bracteata* can be infected with RRV via graft inoculation (Epstein & Hill, 1999).

RRV has been reported on a range of wild and cultivated rose species and varieties (EPPO, 2016). No comprehensive list of susceptible *Rosa* spp. has been published, but RRV has been seen in climbers, hybrid teas, floribundas, miniatures and antique rose species and varieties (Cloyd, 2013, Martin, 2013). A pest alert in Florida stated that "no rose variety is immune" (Baker *et al.*, 2014), and other sources also state that all cultivars are susceptible or potentially susceptible (Hand, 2014, Singh & Owings, 2014, Windham, 2014).

Rosa multiflora (multiflora rose) is particularly susceptible to the disease, with infection always being lethal. This species is invasive in North America, and RRV infection is so severe it was used as a biocontrol agent for multiflora rose (Epstein & Hill, 1999, Epstein *et al.*, 1997). The use of *R. multiflora* as a rootstock does not appear to affect the susceptibility of scions (Roebuck, 2001).

The Knock Out or knockout rose, reported to be the bestselling garden rose in the USA where it is favoured for its blooms and resistance to black spot (Bender, 2013, Frankel, 2015), is susceptible to RRV infection (Babu *et al.*, 2014).

The wood rose, *R. woodsii*, a native North American species, is reported to only show mild symptoms (Epstein & Hill, 1999).

The European species *R. rubiginosa* (sweet briar) is also reported as a host (Windham, 2014). *Rosa canina,* the dog rose, is another European native species which was reported as being "apparently" infected with RRV in North Platte, Nebraska (Allington *et al.*, 1968), but no details or symptoms were provided. This species is found in the USA and Canada, both as an ornamental and an invasive in some regions. It was rated as "susceptible" to RRV in biological control studies (the classes considered were: very susceptible, susceptible, tolerant and resistant) (Van Driesche & Team, 2002).

Some rose species appear to be resistant to RRV, based on observations from gardens and inoculation experiments. These include *R. acicularis, R. arkansana, R. blanda, R. carolina, R. palustris, R. setigera,* and *R. spinosissima* (EPPO, 2016, Epstein & Hill, 1999). Epstein *et al.* (1997) state that *Rosa* "Bonica" appears to be resistant to infection under field conditions, but the virus can be transmitted via grafting.

Hosts of importance the UK

Roses are very widely cultivated in the United Kingdom. Statistics on production of roses and value of the market have not been kept by Defra since 2004, when the industry was valued at £24 million. There are data on the export of roses, provisionally this was worth £2.36 million in 2015 (Defra basic horticultural statistics, 2015), but this includes re-exports and not all exports will have been produced in the UK.

Rosa rubiginosa is native to the UK (BRC, 2016b), as well as being grown as a hedging plant or for ornamental purposes. *Rosa canina* is also a widespread native species found in hedgerows. There are several other species of native *Rosa* in the British Isles: *Rosa agrestis* (small-leaved sweet briar), *R. arvensis* (field rose), *R. caesia* (northern dog-rose), *R. mollis* (soft downy-rose), *R. micrantha* (small-flowered sweet briar), *R. pimpinellifolia* (Burnet rose), *R. obtusifolia* (round-leaved dog-rose), *R. sherardii* (Sherard's downy-rose), *R. stylosa* (short-styled field rose) and *Rosa tomentosa* (harsh downy rose).

Information on the host status and susceptibility of other *Rosa* species native to the UK could not be found, but given the massive host range in North America including native species it is very likely the majority of these species can be infested by *P. fructiphilus* and infected by RRV.

Roses also have significant social value in the UK. The rose is one of the national emblems of England (Reif, 1992). Rose gardens are found across the country, many are open to the public as part of large tourist or amenity destinations. They are also widely grown in private gardens.

8. 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?

Though RRV can be transmitted via grafting, the most important pathway of spread appears to be via infectious *P. fructiphilus*, and so this entry section considers entry of both the virus and vector together.

Plants for Planting

The UK imports relatively small amounts of *Rosa* planting material from the USA and Canada. From January 2012 to September 2016 there was a single consignment of *Rosa* plants for planting imported from the USA, weight 6.4 kg (APHA, unpublished data).

Imports for the whole of the EU are also relatively low. All commodity codes associated with rose plants for planting were searched on Eurostat, but imports were only recorded under "roses, whether or not grafted" and totalled 12.3 tonnes between Jan 2015 – Sep 2016 (Eurostat data, extracted 28/10/2016). It is possible that some material imported into EU countries is then sold on to the UK as being EU in origin, and thus additional rose planting material from North America may be entering the UK.

In addition, some material may be imported via internet trading or through passenger baggage. It is very difficult to obtain any data on *Rosa* planting material imported via these pathways. Amateur rose breeding is a hobby in the UK and those with an interest in breeding new roses may therefore seek propagating material from abroad.

Under current plant health regulations, *Rosa* plants for planting can only be imported into the EU from non-European countries if they are dormant and free from leaves, flowers and fruits. However, this would not prevent the entry of RRV and its vector. *Phyllocoptes fructiphilus* are microscopic, and cannot be seen by the naked eye. They are also difficult to detect even when a hand lens is used (Hoy, 2013). Mated adult females, from which viable populations could develop, overwinter under bark or old bud scales and on living rose tissues (Hoy, 2013), and so could be associated with dormant plants, and would be impossible to detect if roses were inspected on landing. Being in the overwintering stages when plants are transported means the mites are likely to survive, and then emerge in the spring to begin reproducing. From there they could then spread to any nearby *Rosa.*

Symptomatic plants are very distinctive, and, due to witches' brooms, thickened stems and increased thorn production, these would be very likely to be detected if inspected on landing. Moreover such symptomatic plants are very unlikely to be moved in trade, as the disease would be considered to make them unmarketable. The period a plant may be infected without showing symptoms, known as the latent period, will affect the likelihood that infected plants may be traded. Recently infected *Rosa* are very unlikely to display symptoms, and early symptoms of rose rosette are largely confined to the leaves (Epstein & Hill, 1999), and so would not be detected on dormant plants. It is not clear from the literature what the latency period of RRV infection is, with reports greatly varying. There is also the potential in some *Rosa* sp. of symptomatic reversion for several years as described in the paragraph below. These reports are summarised in the following paragraphs.

Mature *R. multiflora* grafted with infected material in May 1998 only displayed symptoms in June 1999 (Tipping & Sindermann, 2000). Another paper also reported the development of typical symptoms "the following year" after grafting of diseased material onto the plant (Epstein & Hill, 1995). However, initial symptoms in one trial were noted in *R. multiflora* as early as 17 days after mite infestation (Hindal *et al.*, 1988).

Epstein & Hill (1999) reported that smaller plants rarely survive more than a year, single crowned plants survive 2 to 3 years and multi-crowned plants up to 5 years, suggesting initial symptom development may vary depending on the age of the infected *Rosa* material. *Rosa multiflora* has also been reported to "revert" to an asymptomatic state whilst remaining infected for 1 to 3 years (Windham *et al.*, 2016).

Most studies appear to have been carried out on *R. multiflora,* with only very limited information available on latency in other species or cultivars. A mite transmission trial on the floribunda variety Julia Child (also known as Absolutely Fabulous) displayed the first symptoms 45 days post infestation with mites carrying RRV (Di Bello *et al.*, 2013), Dr George Philley, Texas A&M University quoted in Roebuck (2001) stated that "roses may

show symptoms in as little as 3 weeks after infection…or they can have an incubation period of up to a year or more”

Due to the limited trade in *Rosa* planting material from North America, and the fact that symptomatic plants are high distinctive, even in dormancy, **entry on plants for planting is considered unlikely, with low confidence.** Confidence is low because: a) there are no data on import of material via internet trading or passenger baggage and b) there is very limited knowledge on the latency period of RRV in hosts other than *R. multiflora*, which would affect the likelihood of the virus to be associated with asymptomatic imported material.

Cut Flowers

Mites such as *P. fructiphilus* are able to crawl or be blown by wind, and as a consequence cut flowers of infected roses could pose a risk of entry for RRV and its vectors (Hoy, 2013). As described in the plants for planting pathway, cut flowers would have to originate from bushes that had only recently been infected, as those that are symptomatic would not be marketable. As cut rose flowers have very high quality standards, they are also likely to be treated with high levels of pesticides some of which may be effective at limiting colonisation by *P. fructiphilus*.

In order for mites to transfer to living *Rosa* plants, any infested cut roses would need to be disposed of outside and in reasonable proximity to a *Rosa* plant. Transfer must occur before cut flowers begin to desiccate, as mites need living green tissue to survive (Cloyd, 2013). Many cut roses may be composted, and since rose is a common garden plant as well as widespread native, there is potential for transfer though this is considered very unlikely as once disposed of roses may no longer be able to support viable populations of mites. Some *Rosa* are kept indoors, presenting an opportunity for the mite to transfer whilst cut flowers are still fresh enough to support viable populations, but again this is considered an unlikely scenario. As described in section 11, mites are both windblown and spread by crawling – so for indoor transmission to occur cut roses would have to be kept directly next to an indoor rose plant.

Import data between January 2011 and October 2016 was extracted from Eurostat (28/10/2016). In the stated time period material under the commodity code “fresh cut roses and buds, of a kind suitable for bouquets or for ornamental purposes” has been imported directly into the UK from the USA once, with no imports recorded from Canada: 500 kg of fresh cut roses being imported in 2015. Across the EU, 4.1 tonnes of cut rose flowers have been imported between January 2011 and October 2016. As discussed in the plants for planting pathway, some US or Canadian material may be re-exported from EU countries to the UK.

Because of limited trade, the fact that symptomatic plants would be rejected for cut flower purposes and the limited ability of the mite to transfer from cut roses to growing plants, **entry is rated as very unlikely with high confidence.**

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

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

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

Yes, RRV requires *P. fructiphilus* as a vector, and as stated in section 6 this pest is not known to occur in the UK. There are no other known vectors of RRV; transmission trials have been carried out with other arthropods including spider mites, aphids, leafhoppers, plant hoppers and thrips but no transmission was seen (Allington *et al.*, 1968), and although no records of other eriophyoid mites which feed on Rosa being able to transmit RRV have been found, to date each of the emaraviruses described have only to have a single mite vector (Mielke-Ehret & Mühlbach, 2012).

In the UK, there are no credible records of Eriophyid mites on *Rosa* spp., but due to their complicated taxonomy and difficulty associated with identification to species level these mites are poorly studied and there may be species present on *Rosa* spp. in the UK that have yet to be collected or reported (Joe Ostoja-Starzewski, Fera Science Ltd, *Personal Communication* 01/11/2016).

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

Roses, both wild and cultivated, are widespread in the UK. The virus is likely to be able to survive wherever rose plants are grown – however, establishment of the mite vector may be more limited by the UK climate. RRV and its vector are recorded from regions of North America with colder winters than the UK, so winter survival of the vector is very likely. Summers are hotter in these regions than in the UK. Temperature affects how long it takes mites to reach adulthood (Hoy, 2013), and thus the number of generations per year. It is possible that the cooler summers in the UK will mean reduced mite populations compared to regions where RRV is found in North America (see sections 11 and 13).

Amrine (1996) reported that female *P. fructiphilus* live approximately 30 days and can lay about one egg per day. Egg hatch at 23°C takes 4.3 days. The protonymph and

deutonymph require 2 days each to develop and so, depending on temperature, egg to adult can occur in approximately one week (Hoy, 2013). Multiple generations are produced throughout the growing season until the weather turns cold in the autumn, though in regions where weather is mild development may occur into the winter months. Once the weather is cold enough, the females migrate to their overwintering sites under bark and old bud scales (Amrine, 1996, Hoy, 2013).

Larger populations of mites occur on plants showing symptoms of RRV compared to apparently healthy plants suggesting RRV infected plants may be more conducive to mite development due to the development of multiple new, tender shoots (Amrine, 1996, Hoy, 2013). There is no evidence that mites are more attracted to RRV infected plants. Mites appear to favour plants in full sun; greater populations are found on these compared to shaded *R. multiflora* (Jesse *et al.*, 2006).

Establishment outdoors is rated as very likely, with medium confidence, as the exact thermal requirements of the mite are not known.

Roses are also grown under protection in the UK, in particular those used for cut flower production. Since the mite can spread on contaminated tools, as well as by crawling between plants, if introduced on planting material it could establish in such protected environments. Attempts to establish *P. fructiphilus* cultures in a greenhouse was reported to fail, but it was not clear if this was due to the mites not surviving the conditions or the fact that the plants were also infested with spider mites (Allington *et al.*, 1968). Plants already infested with RRV and *P. fructiphilus* have been successfully transferred to glasshouse environments (Di *et al.*, 1990) and populations under glass have been established for experimental purposes (Di Bello *et al.*, 2016). The related *P. adalius* is also a problem on *Rosa* under glass in Poland (Druciarek *et al.*, 2014).

Establishment under protection is very likely; with medium confidence as no records of RRV or its vector infected protected rose production could be found.

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

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

Natural Spread

There is some difficulty in assessing natural spread as RRV has, in some instances, been deliberately introduced as a biocontrol agent against *R. multiflora* as well as potentially moving in trade of plants.

Most recent publications agree that *P. fructiphilus* can be dispersed on air currents, and natural spread of the mite occurs to plants downwind of those that are infested (Conner & Hagan, 2012, Hand, 2014, Roebuck, 2001). Amrine (1996) states that “mites are thought to disperse by actively entering the air column on warm, sunny days”. It is thought that the pest may have spread from Oklahoma to North Texas by springtime weather fronts, and mites have been reported to be common in some regions in air samples collected for spore and pollen counts, with peak abundance between June and September (Roebuck, 2001). It was likely to have been carried into the Fort Worth Botanic Garden on air currents (Steve Huddleston, Fort Worth Botanic Garden, *personal communication* 28/10/2016).

At one site in Maryland, an initial survey showed 10% of plants at a site to be have symptoms of RRV. In a follow up survey 12 months later, 50% of the plants were symptomatic – but the size of the infected site was not recorded. Over the four year period since RRV was first found in Maryland, many infected sites were found and the disease was described as spreading “rapidly” (Tipping & Sindermann, 2000).

A long term study was carried to monitor spread within invasive populations of *R. multiflora* at a site in Indiana. *Rosa multiflora* was present over 1000 acres at an initial average density of 1200 plants per acre. In May 1987 30% of plants were symptomatic, by October 56%, October 1988 78% were symptomatic, October 1989 87% and by the end of the study in October 1990 93% were symptomatic (Amrine, 1996).

There are some publications on RRV and *P. fructiphilus* which demonstrate only a very slow rate of natural spread, and do not support dispersal on wind currents. Epstein *et al.* (1997), in an experiment to establish the potential of RRV as a biocontrol agent of *R. multiflora,* inoculated experimental plots of *R. multiflora* by grafting with symptomatic tissue from naturally infected plants. Experimental plots of ornamental and multiflora roses were then established at various distances from the inoculated plots, to assess the risk of spread of RRV from deliberately infected *R. multiflora*. In this experiment, no plants 100 m or more from the infected RRV plants developed symptoms, infection was detected in plots 20 metres from the RRV infected plants (Epstein *et al.*, 1997). In this study spore traps were also utilised to try to detect airborne movement of *P. fructiphilus*, but none were detected, and it was hypothesised that the mites probably “walked” between rose plants. Monitored experimental plots were also stated to have no obvious downwind directional bias, with development of disease occurring most often in adjacent plants, and incidence increased most quickly in full sun (Epstein & Hill, 1995).

Some publications also hypothesise that infectious mites may hitchhike on other insects, such as aphids (Cloyd, 2013, Hand, 2014, Roebuck, 2001). However this mode of spread has not been conclusively proven for *P. fructiphilus*.

Natural spread in the USA has been aided by the widespread and invasive *R. multiflora*, which is widely considered highly susceptible to the virus (Hand, 2014, Martin, 2013), and mite populations have been recorded to be 14 times higher on symptomatic *R. multiflora* compared to apparently healthy plants, indicating that infected plants with their multiple tender stems offer a better substrate for the development of *P. fructiphilus* (Amrine, 1996, Hoy, 2013). *Rosa multiflora* is grown as an ornamental in the UK, but is also a naturalised garden escapee (BRC, 2016a). It is unlikely to play as important a role in the natural spread of the pest as seen in North America, however there are many other widespread native rose species in the UK which could play a similar role. As stated in section 7, *R. canina* is a known susceptible host and is very widespread in the UK (see figure 1). This, and other native rose species, are often used or found in hedging as well.

The rate of natural spread will also be influenced by the number of generations per year *P. fructiphilus* has under UK conditions. The exact temperature requirements for the pest are unknown, though it is stated that temperature affects how quickly the lifecycle is completed and that reproduction ceases with cooler weather (Hoy, 2013), so potentially the mite may also begin to overwinter early in the UK compared to some regions of North America.

Natural spread is rated as occurring at a moderate pace, with medium confidence. Areas sheltered from wind may only see very slow to slow spread of the mite and disease, but strong air currents may lead to occasional long distance spread. Depending on their susceptibility to mite and viral infection, native roses may also provide natural bridges to allow spread of RRV and *P. fructipilus* to new areas. Cooler UK summers may mean *P. fructiphilus* produces fewer generations per year, and the vector may also begin overwintering sooner than in the USA, reducing natural spread.

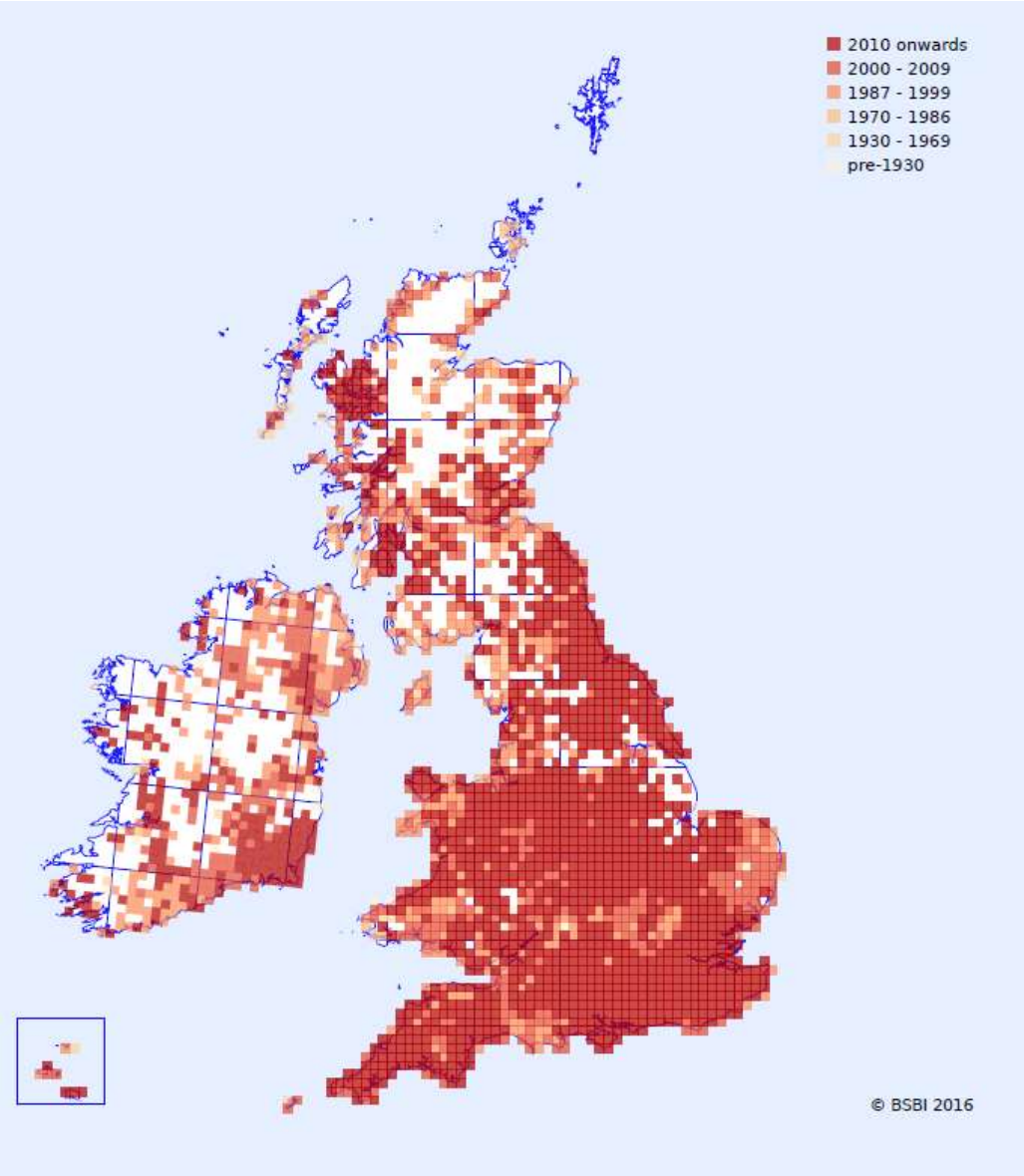

Figure 1: Distribution of *Rosa canina* (dog-rose) in the British Isles based on presence/absence in a 10 km grid square. Data extracted from the BSBI online atlas, 28/10/2016.

Spread with trade

Generally, symptoms of RRV are distinct and would make plants unmarketable, so obviously infected plants are very unlikely to move in trade. As discussed in the entry section, there is a latency period where plants will be infected but not yet symptomatic, and these could then be moved in trade.

Rosa multiflora is used extensively as a rootstock, and if infected rootstocks are inadvertently used the virus can then spread to the scion (Martin, 2013).

It is suspected that the microscopic mites may also move on pruning shears, gloves or similar equipment (Singh & Owings, 2014). If these are not properly disinfected by

gardening companies between jobs, then spread to new sites along this pathway may occur, but this scenario has not been conclusively demonstrated (Martin, 2013).

Spread with trade is rated as quickly, with low confidence as it will be strongly influenced by the latent period of the virus which for most rose cultivars and species is unknown, and there is relatively little evidence concerning spread in trade in North America.

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

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

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

Disease Development and Symptoms

Expression of symptoms may vary depending on the age, cultivar or stage of growth of the infected rose plant (Cloyd, 2013). In *R. multiflora,* Rose Rosette Disease is described as occurring in three stages by Epstein & Hill (1999):

1. In stage 1 symptoms are largely foliar, with leaves showing reddening as well as deformation such as elongation or crinkling. Shoots of affected canes are light pink to deep magenta and generally appear vigorous, though maybe more succulent than unaffected canes. Flowers are reduced and may be distorted.

2. Stage 2 is also known as the early rosette stage. Leaves will continue to be red in appearance and distorted. Lateral buds break dormancy and begin to grow – which is the start of typical witches' brooming. Petioles are shortened giving a rosette appearance to symptomatic shoots. Flower formation is rare. Epstein & Hill (1997) states that at this stage light frosts (-2°C or lower) will result in visible damage to the affected leaves.

3. Stage 3 infected plants show intense rosetting, reduced leaves often hair-like and red in colour, witches' brooming with weak apical growth and canes are chlorotic. Plants at this stage will seldom survive the winter.

If symptoms initially appear on a single cane, this can be pruned out and the rest of the plant may then go on to survive in an estimated 50% of cases (Roebuck, 2001), so in some cases the virus may take time before it becomes systematic within the plant. As well as loss of cold tolerance, infected roses may also be more susceptible to fungal diseases

such as powdery mildew (Cloyd, 2013). Most sources indicate infected roses die within 2 – 5 years.

Impact

RRV is recorded as having negative impacts on rose production in the USA. Since the only effective control option is destruction of the plants, significant losses can be incurred if it enters a production site. There are actually very little specific data on monetary losses caused by RRV. This may be related to that fact that for many years, incidence in cultivated roses appeared to be sporadic. It is only in recent years the disease has begun to appear more consistently on cultivated roses (Sheridan, 2014).

In Alabama, containerised rose production is largely reported as affected (Conner & Hagan, 2012). The University of Kentucky reported that losses can occur in home and commercial landscapes, nurseries and botanical gardens (Ward & Kaiser, 2012). One rose production business in North Texas reported at a 2015 conference they had seen a 25% reduction in gross revenue as a result of the disease (recording of presentation available online: https://www.youtube.com/watch?v=2YUoSOxKnCw&list=PLRyqQJrldHJE0T-4XVZjYUlxfSJNH7fTu&index=5) The situation in the USA has been described as “an epidemic”, with impacts particularly bad in northern Texas (Bahari, 2015). In Collin County, Texas, the Rose Rosette Eradication Alliance was established to help spread word and reduce incidence of the disease at a community level (Cook, 2015). Both Knock Out roses and Drift roses, some of the most popular roses in the USA, are susceptible and are being significantly impacted by RRV (Bender, 2013, Sheridan, 2014). The seriousness of the impacts seen in the USA led to the USDA funding a $4.6 million dollar project to help devise solutions to combatting the disease (UDaily, 2014).

The Fort Worth botanic garden was forced to remove all roses, including from its specialist rose garden, due to RRV (Fort Worth Botanic Garden, 2016). Cranford Rose Garden at the Brooklyn Botanic Garden had to destroy many beds of roses within the garden and it underwent significant restoration (Brooklyn Botanic Garden, 2016). In 2014 it was reported that around two-thirds of the 3000 roses at the Tulsa Rose Garden were infected with RRV, leaving empty beds in what was considered an iconic public area of the city and the garden has decreased in popularity as a site for weddings (Aspinwall, 2014). The garden usually held an evening of wine and roses each year, which was cancelled in 2016 due to the state the disease had left the garden in with weeds taking over many of the now empty beds (Fox 23 News, 2016).

An outbreak in Manassas, Virginia, reportedly led to the destruction of 20 old rose gardens (Shaner, 2006). Southlake, Texas, was reported to be removing and replacing 5400 rosebushes in medians (central reservations) and parks due to RRV at an estimated cost of $500 000 (Bahari, 2015). A news article reported in North Texas the destruction of 1200 roses from a business park, and 300 at a church, with the use of roses in landscaping apparently now decreasing and some owners destroying roses assuming that disease is inevitable (Holloway, 2015).

There are numerous other examples of botanic gardens and public parks which have had rose gardens or collections destroyed or significantly depleted by RRV.

Impacts in the current distribution are rated as large, with high confidence.

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

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

Economic, environmental and social impacts will all be affected by the number of generations per year produced by the mite – as larger populations of mites could lead to increased natural spread and thus greater impacts. It is uncertain how many generations per year the mite may have in the UK climate, because data on the temperature requirements for *P. fructiphilus* are lacking.

Economic Impacts

Economic impacts can be incurred in three ways:

Firstly, diseased plants in nurseries or propagators will be unmarketable and will have to be destroyed. The UK has a number of commercial rose growers, and there is considerable interest in rose breeding in the UK, both at a professional and amateur level. The breeding of a new rose variety can take around ten years (Fine Gardening, 2016), and the naming of a new rose via professional growers can cost between £5000 - £50000 (Royal National Rose Society, 2016). The presence of RRV in trials for new roses would have serious economic impacts for those breeders.

Secondly, if the disease spreads, the popularity of roses is very likely to decrease as individuals will be unwilling to invest in plants which may be killed by RRV. This has been seen previously with diseases of ornamentals, such as *Impatiens* downy mildew caused by *P. obducens.* Severe outbreaks leading to poor quality plants led to a reduction in demand in the USA (Getter & Behe, 2013, Shamus, 2015), and in the UK in one bad season availability of *Impatiens* was severely reduced due to quality issues with infected plants (Anon, 2012).

Thirdly, there will economic impacts associated with having to remove and replace any rose plants used in public landscaping or gardens open as a business. Roses are widespread and rose gardens are popular. Gardens open to the public as a business may see a reduction in visitors, or bookings for events such as weddings, if a rose garden that is a prominent feature of their business is destroyed by RRV.

Given the high levels of damage caused by RRV, and the widespread planting of roses in the UK in public settings which may have to be removed, destroyed and replaced,

potential economic impacts in the UK are rated as large, with medium confidence, as it is uncertain how the UK climate will affect the spread of the pest and thus its ability to cause impacts.

Environmental Impacts

As the susceptibility of most native UK *Rosa* species is not known, there is considerable uncertainty concerning the potential environmental impacts. It is very likely that a proportion of the UK native *Rosa* will be highly susceptible e.g. killed by RRV infection. It is known the widespread *R. canina* is a susceptible species, though information about infected *R. canina* being killed by RRV was not included in publications.

Countryside hedgerows are considered a priority habitat and many are protected by law in England and Wales (The Hedgerow Regulations 1997). A survey of woody species found in hedgerows on farmers land showed that *Rosa* spp. occurred in more than 50% of the farms surveyed (Britt *et al.*, 2011). *Rosa canina* is a common *Rosa* spp. within hedgerows, and produces rosehips which provide a food source for a variety of taxa (Croxton & Sparks, 2004). *Rosa* spp. are so common in hedgerows that this would aid in the spread of RRV with the mites moving on both air currents and by crawling. Any species susceptible will be killed by RRV, leading to significant impacts on the biodiversity of that habitat.

There are a wide range of invertebrate species which are reliant on *Rosa* spp., and in some cases a specific species within the genus. For example the gall forming wasp *Diplolepis spinosissimae* is a specialist on *R. spinosissima* (Plantard et al., 1998) and Robin's pin cushion is a well-known gall caused by *Diplolepis rosae* on native species of *Rosa* (Kent Wildlife Trust, 2016). It is not within the scope of this rapid PRA to fully review species dependent on *Rosa*. Various *Rosa* species are also recommended as flowers for pollinators (RHS, 2016).

Potential environmental impacts in the UK are large with medium confidence. RRV is known to kill *Rosa* spp. and therefore has the potential to be fatal to all native *Rosa* species in the UK. The loss of *Rosa* spp. from hedgerows and other habitats would have major impacts on biodiversity due to species that are reliant on rose as a food source. Confidence is medium because the susceptibility of some native *Rosa* is unknown.

Social Impacts

Roses and rose gardens are very popular in the UK, and of cultural importance. The rose is one of the national emblems of England and is used, for example, as the symbol of the English rugby (England Rugby, 2016). *Rosa spinosissima* is also known as Scots rose and is considered a symbol of Scotland (National Records of Scotland, 2016).

Rose gardens may be destinations for tourism, or used as event venues for weddings etc. Individuals who have significant memories associated with particular rose gardens may suffer distress if these are affected by RRV because, as has been seen in the USA, RRV has potential to entirely destroy collections of roses as well as kill those grown in private gardens.

Rose hips are also a source of food collected by foragers, and rose-hip syrup (high in vitamin C) is used as a traditional remedy to keep cold viruses at bay (Fearneley-Whittingstall, 2006).

Potential social impacts in the UK are rated as large, with high confidence.

Economic Impacts	Very small	☐	Small	☐	Medium	☐	Large	☑	Very large ☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐			
Environ - mental Impacts	Very small	☐	Small	☐	Medium	☐	Large	☑	Very large ☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐			
Social Impacts	Very small	☐	Small	☐	Medium	☐	Large	☑	Very large ☐
Confidence	High Confidence	☑	Medium Confidence	☐	Low Confidence	☐			

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

This PRA considers the risk from *P. fructiphilus,* the vector of RRV. *Phyllocoptes fructiphilus* is not known to vector any other plant pathogens, and neither is RRV a vector.

15. What is the area endangered by the pest?

The whole of the UK is endangered by the pest, but those regions with the hottest summers in the south of England are likely to suffer the greatest impacts due to the potential for greater *P. fructiphilus* populations.

Stage 3: Pest Risk Management

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

Exclusion

Exclusion is the best risk management option for the UK, and regulation of the pest should be considered. In order to help mitigate against the risk of introduction, phytosanitary measures on rose plants (covering both plants for planting and cut flowers) could be considered.

Rosa plants, originating from the United States or Canada, should originate from a designated pest free area for *Rose rosette virus* and its vector *Phyllocoptes fructiphilus*.

Plants originating from a pest free place of production, where no visual symptoms of the disease have been seen at the site or in its immediate vicinity, could also be considered. However *R. multiflora,* which is a common and invasive species in the USA, has been reported to “revert” to an asymptomatic state whilst remaining infected for 1 to 3 years (Amrine, 1996, Windham *et al.*, 2016). As a consequence, up to 4 years of visual freedom of symptoms at the site and immediate vicinity may be required to ensure the area is free of RRV. An alternative would require that the immediate vicinity be free of *R. multiflora*.

No cases of RRV occurring on plants being produced under protection could be found, and so an alternative measure could be to allow the import of *Rosa* plants that have been grown under complete physical protection throughout their whole lives. The vector is microscopic, and thus could theoretically enter protected areas on wind currents through open vents. In addition it could move into glasshouses on contaminated tools and gloves, so additional measures such as visual freedom of symptoms for the last two cycles of complete vegetation could also be considered.

Eradication and Containment

If outbreaks of RRV are caught early, than eradication may be possible. *Rosa* spp. are highly valued garden and amenity plants, and symptoms of RRV are distinctive. If public awareness is high enough (e.g. via pest alerts or communication via stakeholder groups), early detection of outbreaks should be possible.

Symptomatic plants should be destroyed by burning or deep burial, the whole plant including the roots must be removed, to prevent regeneration from suckers as the virus may be present in the roots (Hand, 2014). As described in section 11, mites can travel on air currents and crawl on plants. When conditions for the build-up of large mite populations occur then the risk of spread is greater. *Rosa* plants may remain asymptomatic for some time, and so all *Rosa* spp. (including any wild species) within 100 metres of an infected plant should also be destroyed as recommended by Martin (2013). Surveys of *Rosa* plants in late spring and summer should be carried out over a 2 km area (designated as a demarcated area) each year for at least 3 years to ensure the virus has been eradicated. No *Rosa* spp. should be moved out of the demarcated area until eradication has been declared, unless they have been grown throughout their lives under complete physical protection and treated to eliminate the vector.

Non-Statutory Controls

Regular inspection throughout the growing season with destruction of symptomatic plants appears to be the only effective control measure for RRV. Removal of *Rosa* plants adjacent to the infected plant is also recommended (Hoy, 2013). Staff at the Beall Family Rose Garden, University of Tennessee, inspect plants several times a week for symptoms and rogue out symptomatic plants as soon as possible. The gardens have lost 2 – 4 % of

roses each year, but RRV has never spread to roses adjacent to those discovered to be infected (Windham, 2014). Infected rose plants need to be destroyed appropriately, by burning or bagging and sent for deep burial, to ensure mites do not transfer to other hosts.

At production sites in the USA, it is recommended that the immediate vicinity be free of *R. multiflora* due to its high susceptibility to the mite and virus (Bolques *et al.*, 2014, Conner & Hagan, 2012, Hand, 2014), however *R. multiflora* is not as widespread in the UK and other roses used in hedging may need to be removed – though this could have environmental or social consequences.

As the mite is likely to be windblown, natural barriers that shelter *Rosa* spp. can also help prevent against infestation – in the USA, *Miscanthus sinensis* has been used successfully as a natural barrier (Windham, 2014). Spacing of plants so that they do not touch each other (to prevent mites crawling plant to plant) may also reduce disease incidence (Hand, 2014). There is evidence that mites may move on contaminated tools or gloves, so clean equipment should be used for pruning (Singh & Owings, 2014)

Though pesticide products are available against mites such as *P. fructiphilus*, there are little data to support these as being effective or a practical management option, especially as mites tend to shelter in crevices where it is difficult for products to reach (Cloyd, 2013, Hand, 2014, Roebuck, 2001). However use of pesticides effective against mites during the growing season is still recommended by some publications (Amrine, 1996, Baker *et al.*, 2014, Singh & Owings, 2014). AmericanHort (a group of professional growers) recommend using three chemicals in rotation (Abemectin, Fenpyroximate and Spiromesoifen), every 5 – 7 days, from bud break throughout the growing season – and that growers who use this regime report significantly reduced incidence of RRV (AmericanHort, 2013), but given the approvals for these chemicals this treatment regime will not be available to growers and treatment options for amateur growers will be significantly reduced.

17. References

Allington W, Staples R & Viehmeyer G (1968): Transmission of rose rosette virus by the eriophyid mite Phyllocoptes fructiphilus. *Journal of Economic Entomology* **61**, 1137-1140.

AmericanHort (2013) Rose Rosette Disease Chemical Control. AmericanHort, USA. Available at: http://americanhort.theknowledgecenter.com/Library/Americanhort/docs/Government%20Relations/Pest%20Disease%20Alerts/RRD_Chemical_Control.pdf (accessed 02/11/2016.

Amrine J (1996): *Phyllocoptes fructiphilus* and biological control of multiflora rose. *World Crop Pests* **6**, 741-749.

Anon (2012) Busy lizzies take summer off after mildew outbreak. In *The Telegraph*. Telegraph media group, UK.

Aspinwall C (2014) Tulsa Rose Garden walloped by mite-borne disease. TulsaWorld, Tulsa, USA. Available at: http://www.tulsaworld.com/news/local/tulsa-rose-garden-walloped-by-mite-borne-disease/article_4f8452f4-a8e0-5d6d-8c65-e775b1c6138e.html (accessed 26/10/2016.

Babu B, Dankers H, Newberry E, Baker C, Schubert T, Knox G & Paret M (2014): First Report of Rose rosette virus Associated with Rose Rosette Disease Infecting Knockout Roses in Florida. *Plant disease* **98**, 1449-1449.

Bahari S (2015) 'Rose rosette is an epidemic, and North Texas is the epicenter'. Star-Telegram, Fort Worth, Texas. Available at: http://www.star-telegram.com/news/local/community/fort-worth/article27534709.html (accessed 02/11/2016.

Baker C, Schubert T, Srivastava P, Paret M & Babu B (2014) Rose Rosette Disease (Rose Rosette Virus) Found in Florida. Florida Department of Agriculture and Consumer Services, Florida, USA. Available at: http://www.freshfromflorida.com/content/download/35585/832827/rose_rosette_disease.pdf (accessed 26/10/2016.

Bender S (2013) Is Knockout Rose Down for the Count? Time Inc. Lifestyle Group, USA. Available at: http://thedailysouth.southernliving.com/2013/04/21/is-knockout-rose-down-for-the-count/ (accessed 26/10/2016.

Bolques A, Paret M, Knox G, Babu B, Dankers H, Schubert T, Baker C & Orwat M (2014): Rose Rosette Disease in Florida. *Proceedings of the Florida State Horticultural Society* **127**, 165-166.

BRC (2016a) Rosa multiflora (Many-flowered Rose). Biological Records Centre, UK. Available at: http://www.brc.ac.uk/plantatlas/index.php?q=node/4025 (accessed 02/11/2016.

BRC (2016b) Rosa rubiginosa (Sweet-briar). Biological Records Centre, UK. Available at: https://www.brc.ac.uk/plantatlas/index.php?q=plant/rosa-rubiginosa (accessed 26/10/2016.

Britt C, Tuffnell N, Kirkham F, Roberts A & Sparks T (2011) Hedgerow Management: A Survey of Land Managers' and Contractors' Practices and Attitudes, UK, p. 144.

Brooklyn Botanic Garden (2016) Cranford Rose Garden. Brooklyn Botanic Garden, New York, USA. Available at: http://www.bbg.org/collections/gardens/rose_garden (accessed 26/10/2016.

Cloyd RA (2013) Rose Rosette Disease. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Kansas. Available at: http://www.bookstore.ksre.ksu.edu/pubs/mf2974.pdf (accessed 26/10/2016.

Conner K & Hagan A (2012) Rose rosette disease in Alabama. In *Alabama IPM Communicator*. Alabama State University, Alabama, USA, pp. 9-11.

Cook G (2015) Alliance formed to prevent spread of plant virus. AllenAmerican, Texas, USA. Available at: http://starlocalmedia.com/allenamerican/news/alliance-formed-to-prevent-spread-of-plant-virus/article_1f98fdb6-bd3b-11e4-a2fb-8b40d5515191.html (accessed 03/11/2016.

Croxton P & Sparks T (2004): Timing of berry depletion rates of three common hedgerow shrubs. *Agriculture, ecosystems & environment* **104**, 663-666.

Di Bello P, Ho T & Tzanetakis I (2013) Identification of the Rose rosette disease agent. In *VI International Symposium on Rose Research and Cultivation 1064*, pp. 295-298.

Di Bello PL, Thekke-Veetil T, Druciarek T & Tzanetakis I (2016) Resistance to Rose Rosette Virus and Transmission Attributes. preprints. Available at: http://www.preprints.org/manuscript/201610.0119/v1 (accessed 03/11/2016.

Di R, Hill J & Epstein A (1990): Double-stranded RNA associated with the rose rosette disease of multiflora rose. *Plant disease* **74**, 56-58.

Druciarek T, Lewandowski M & Kozak M (2014): Demographic parameters of Phyllocoptes adalius (Acari: Eriophyoidea) and influence of insemination on female fecundity and longevity. *Experimental and Applied Acarology* **63**, 349-360.

England Rugby (2016) Why a Rose? England Rugby, England. Available at: http://www.englandrugby.com/twickenham/world-rugby-museum/rugby-history/why-a-rose/# (accessed 01/11/2016.

EPPO (2016) *Rose Rosette Virus* (*Emaravirus*). EPPO, Paris, France. Available at: https://www.eppo.int/QUARANTINE/Alert_List/viruses/RRV000.htm (accessed 25/10/2016.

Epstein A & Hill J (1995): The Biology of Rose Rosette Disease: A Mite-associated Disease of Uncertain Aetiology. *Journal of Phytopathology* **143**, 353-360.

Epstein A & Hill J (1999): Status of rose rosette disease as a biological control for multiflora rose. *Plant disease* **83**, 92-101.

Epstein A, Hill J & Nutter Jr F (1997): Augmentation of rose rosette disease for biocontrol of multiflora rose (Rosa multiflora). *Weed science*, 172-178.

Fearneley-Whittingstall H (2006) Rosehip syrup. The Guardian. Available at: https://www.theguardian.com/lifeandstyle/2006/oct/21/recipes.dessert (accessed 01/11/2016.

Fine Gardening (2016) What Goes Into Breeding New Roses. The Taunton Press, Inc, UK. Available at: http://www.finegardening.com/what-goes-breeding-new-roses (accessed 13/12/2016.

Fort Worth Botanic Garden (2016) The Rose Garden. Fort Worth Botanic Garden, Texas, USA. Available at: http://www.fwbg.org/gardens/#/the-rose-garden/ (accessed 26/10/2016.

Fox 23 News (2016) 2016 Evening of Wine and Roses canceled at Tulsa Rose Garden. Fox 23, USA. Available at: http://www.fox23.com/news/2016-evening-of-wine-and-roses-canceled-at-tulsa-rose-garden/417279247 (accessed 26/10/2016.

Frankel TC (2015) By any other name, the Knock Out rose would be just as sturdy. The Washington Post, Washington DC. Available at: https://www.washingtonpost.com/business/economy/by-any-other-name-the-knock-

out-rose-would-be-just-as-sturdy/2015/07/15/ff31635e-2713-11e5-aae2-6c4f59b050aa_story.html (accessed 26/10/2016.

Getter KL & Behe BK (2013): Consumer willingness to purchase Impatiens walleriana alternatives. *HortScience* **48**, 1370-1377.

Hand F (2014) Controlling Rose Rosette Disease. In *The Buckeye*. Ohio Nursery & Landscape Association, Ohio, USA, pp. 37-40.

Hindal DF, Amrine JW, Williams RL & Stasny TA (1988): Rose rosette disease on multiflora rose (Rosa multiflora) in Indiana and Kentucky. *Weed Technology*, 442-444.

Holloway K (2015) Deadly virus is killing rosebushes in North Texas. Dallas News, Texas, USA. Available at: http://www.dallasnews.com/life/gardening/2015/02/18/deadly-virus-is-killing-rosebushes-in-north-texas (accessed 02/11/2016.

Hoy M (2013) common name: eriophyid mite vector of Rose Rosette Disease (RRD)

scientific name: Phyllocoptes fructiphilus Keifer (Arachnida: Acari: Eriophyidae). University of Florida, Florida, USA. Available at: http://entnemdept.ufl.edu/creatures/ORN/ph_fructiphilus.htm (accessed 28/10/2016.

Jesse LC, Moloney KA & Obrycki JJ (2006): Abundance of arthropods on the branch tips of the invasive plant, Rosa multiflora (Rosaceae). *Weed biology and management* **6**, 204-211.

Kent Wildlife Trust (2016) Robin's Pincushion. Kent Wildlife Trust, UK. Available at: http://www.kentwildlifetrust.org.uk/species/robins-pincushion (accessed 09/11/2016.

Laney AG, Keller KE, Martin RR & Tzanetakis IE (2011): A discovery 70 years in the making: characterization of the Rose rosette virus. *Journal of General Virology* **92**, 1727-1732.

Martin CW (2013): Rose Rosette Disease and the Impacts on Propagation©. *Proceedings of the International Plant Propagators Society-2013 1055*, 319-321.

Mielke-Ehret N & Mühlbach H-P (2012): Emaravirus: a novel genus of multipartite, negative strand RNA plant viruses. *Viruses* **4**, 1515-1536.

Morhan J, Singh R & Owings AD (2015) Rose rosette disease confirmed in Louisiana. Louisiana State University, Bossier citty, Louisiana. Available at: http://www.lsuagcenter.com/portals/communications/news/news_archive/2015/november/headline_news/rose-rosette-disease-confirmed-in-louisiana (accessed 02/11/2016.

National Records of Scotland (2016) White Rose of Scotland (Scots Rose, Burnet Rose). National Records of Scotland. Available at: http://www.nrscotland.gov.uk/research/archivists-garden/index-by-plant-name/white-rose-of-scotland-scots-rose-burnet-rose (accessed 01/11/2016.

Plantard O, Rasplus J-Y, Mondor G, Le Clainche I & Solignac M (1998): Wolbachia–induced thelytoky in the rose gallwasp Diplolepis spinosissimae (Giraud)(Hymenoptera: Cynipidae), and its consequences on the genetic structure

of its host. *Proceedings of the Royal Society of London B: Biological Sciences* **265**, 1075-1080.

Reif D (1992) *The Role of Horticulture in Human Well-Being and Social Development: A National Symposium*. Timber Press.

RHS (2016) RHS Perfect for Polllinators Plant List. RHS, UK. Available at: https://www.rhs.org.uk/science/pdf/conservation-and-biodiversity/wildlife/rhs_pollinators_plantlist (accessed 13/12/2016.

Roebuck F (2001) Watch Out for Rose Rosette. American Rose Society, Shreveport, LA. Available at: http://www.rose.org/wp-content/uploads/2011/03/Rose-Rosette.pdf (accessed 26/10/2016.

Royal National Rose Society (2016) Naming a Rose. The Royal National Rose Society, UK. Available at: http://www.rnrs.org.uk/about-us/naming-a-rose/ (accessed 13/12/2016.

Shamus K (2015) Impatiens are back in Michigan gardens. Detroit Free Press, Detroit. Available at: http://www.freep.com/story/life/2015/05/14/impatiens-back/27305531/ (accessed 09/08/2016.

Shaner C (2006) Rose Rosette Disease. Shenandoah Rose Society, Virginia, USA. Available at: http://www.shenandoahrosesociety.org/sitebuildercontent/sitebuilderfiles/roserosettedisease.pdf (accessed 02/11/2016.

Sheridan M (2014) Dread garden disease knocking out Knock Out roses. USA Today, USA. Available at: http://www.usatoday.com/story/news/nation/2014/04/10/rose-rosette-disease/7566221/ (accessed 02/11/2016.

Singh R & Owings A (2014) Rose Rosette Disease. Lousiana State University, Louisiana, USA. Available at: http://www.lsuagcenter.com/nr/rdonlyres/074a1a97-65a9-4770-9049-059e2a74d5dd/98105/pub3355rosettediseasefinal.pdf (accessed 26/10/2016.

Skoracka A, Smith L, Oldfield G, Cristofaro M & Amrine JW (2010): Host-plant specificity and specialization in eriophyoid mites and their importance for the use of eriophyoid mites as biocontrol agents of weeds. *Experimental and Applied Acarology* **51**, 93-113.

Tipping P & Sindermann A (2000): Natural and augmented spread of rose rosette disease of multiflora rose in Maryland. *Plant disease* **84**, 1344-1344.

UDaily (2014) Battling RRD. University of Delaware, Delaware, USA. Available at: http://www1.udel.edu/udaily/2015/oct/rose-rosette-disease-102014.html (accessed 02/11/2016.

Van Driesche R & Team USFHTE (2002) *Biological control of invasive plants in the eastern United States*. U.S. Dept. of Agriculture, Forest Service, Forest Health Technology Enterprise Team.

Ward NA & Kaiser CA (2012) Rose Rosette Disrease. University of Kentucky Cooperative Extension Service, Kentucky, USA. Available at:

http://www2.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-OR-W-16.pdf (accessed 02/11/2016.

Windham M (2014) Unravelling Rose Rosette©. In *Proceedings of the 2014 Annual Meeting of the International Plant Propagators Society 1085*, pp. 409-413.

Windham M, Windham A & Hale F (2016) Observations on Rose Rosette Disease. The University of Tennessee. Available at: http://www.newenglandgrows.org/pdfs/ho_WindhamRoseRosette.pdf (accessed 31/10/2016.

Name of Pest Risk Analysts(s)

Melanie Tuffen

This publication is available at https://secure.fera.defra.gov.uk/phiw/riskRegister/plant-health/pest-risk-analysis-consultations.cfm

Any enquiries regarding this publication should be sent to us at

The Chief Plant Health Officer

Department for Environment, Food and Rural Affairs

Room 11G32

Sand Hutton

York

YO41 1LZ

Email: plantpestsrisks@defra.gsi.gov.uk