



Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for: *Peronospora sp. on Aquilegia*

September 2016

Summary and conclusions of the rapid PRA

This rapid PRA shows that a new species of *Peronospora* is causing a damaging downy mildew on *Aquilegia*, but the disease is already widespread in the UK, with limited control options available.

Risk of entry

Aquilegia downy mildew is only recorded from South Korea and the United Kingdom. There is a relatively small trade in plants and seeds from South Korea. It is possible the disease has a wider distribution than currently reported. If limited to South Korea, new introductions would be very unlikely, but since global distribution is uncertain, entry has been rated as unlikely with low confidence. The confidence in the rating is also impacted by the lack of knowledge on trade volumes or the amount of material that may enter in passenger baggage.

It is not known which pathway *Aquilegia* downy mildew entered the UK on.

Risk of establishment

Aquilegia downy mildew is already widespread in England and Wales and establishment outdoors across the UK is very likely, with high confidence.

Economic, environmental and social impact

No details of impacts have been reported from South Korea. Disease symptoms are severe on *Aquilegia* and plants may be killed by infection after one or two seasons. It is likely sales of *Aquilegia* will be negatively impacted by the disease, causing large economic impacts in that sector with high confidence. Loss of garden plants and a reduction in consumer choice will lead to social impacts which are rated as medium with medium confidence.

Aquilegia vulgaris is a native species, though also a common garden escapee. Impacts of the disease on wild populations have not yet been reported and it is highly uncertain what impacts may occur. Relatively few species are reliant on *Aquilegia* as a primary food source, but some of those species that are reliant are considered rare or notable in the UK and could be impacted if there is a large decrease in *Aquilegia* due to downy mildew disease. Environmental impacts are rated as small, with low confidence.

Endangered area

The endangered area is anywhere where *Aquilegia* is grown.

Risk management options

Since the disease is established and spreading rapidly, there are limited risk management options. Infested plants should be removed and destroyed, and re-planting of *Aquilegia* at the same site avoided since spores can survive in the soil for several years. Currently no chemical control options have been identified, and development of resistant varieties is likely to provide the best risk management option.

Key uncertainties and topics that would benefit from further investigation

Since *Aquilegia* downy mildew appears to be new to science, and is not formally described, there is an inherent uncertainty throughout the PRA. The following points are key uncertainties:

- Full global distribution of the pest
- How the pest was introduced to the UK
- If, like some other *Peronospora* species, *Aquilegia* downy mildew is transmitted by seed
- The potential environmental impacts should the disease spread to wild populations of *A. vulgaris*, especially on rare invertebrates for which *Aquilegia* is the primary food source.
- The level of resistance to the disease within *Aquilegia* species and varieties.

Images of the pest

Images of this pest can be found on the RHS website:

<https://www.rhs.org.uk/advice/profile?pid=866>

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.

No	<input checked="" type="checkbox"/>				
Yes	<input type="checkbox"/>	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?

Given the number of findings in both nurseries and gardens, the pest is clearly established in the UK and spreading rapidly. Therefore statutory action against findings would not be appropriate.

Yes
Statutory action

No
Statutory action

Stage 1: Initiation

1. What is the name of the pest?

Aquilegia downy mildew, *Peronospora* sp.

This appears to be a new species of *Peronospora* (Peronosporales: Peronosporaceae) and has not yet been fully described. It will be referred to as Aquilegia downy mildew throughout this PRA. It is the first known occurrence of downy mildew on *Aquilegia* (Denton *et al.*, 2015). Molecular analysis indicates UK isolates may be the same species as seen on *Semiaquilegia* in South Korea, as they have identical ITS (internal transcribed spacer) regions, which is the area of fungal genomes usually used for DNA barcoding (Denton *et al.*, 2015).

For the purposes of this PRA, it is assumed that the *Peronospora* species in South Korea on *Semiaquilegia* is the same species found in the UK on *Aquilegia*.

2. What initiated this rapid PRA?

This rapid PRA was initiated following several news reports of severe damage caused to *Aquilegia* by a new downy mildew disease.

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/EC¹) and in the lists of EPPO²?

Pest is not listed in the EC Plant Health Directive and is not recommended for regulation as a quarantine pest by EPPO, nor is it on the EPPO Alert List.

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

The pest has only been recorded from the UK and South Korea (Denton *et al.*, 2015). Given species of *Aquilegia* are found throughout the Northern Hemisphere and *Semiaquilegia* in China, South Korea and Japan (Kubitzki *et al.*, 2013), it is likely this pest may be more widespread than currently reported.

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

Aquilegia downy mildew is established and widespread in England and Wales. Denton *et al.* 2015, report *Aquilegia* downy mildew from the following locations: Berkshire, Buckinghamshire, Cardiff, Derbyshire, Devon, Dorset, Essex, East Sussex, Hampshire, Hertfordshire, Isle of Wight, Kent, Lancashire, London, Norfolk, North Yorkshire, Oxfordshire, Somerset, South Yorkshire, Surrey, Swansea, West Midlands and Wiltshire.

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

² <https://www.eppo.int/QUARANTINE/quarantine.htm>

There are no published records from Scotland or Northern Ireland to date (September 2016).

It is not known when *Aquilegia* downy mildew was introduced to the UK. The first sample was submitted to Fera in 2011 (Fera, unpublished data) with the RHS receiving news of outbreaks from a number of gardens in 2013 (RHS, 2016). Carrie Thomas is the owner of the National Collection of *Aquilegia* and has been collating reports of the disease, with one London gardener reporting they may have had the disease since 2005 – 2007 (Thomas, 2015). It is not possible to confirm these early records.

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?

The only records to date are on *Aquilegia* and *Semiaquilegia*. *Aquilegia* species are distributed across the Northern Hemisphere, and *Semiaquilegia* is native to China and East Asia (Wiersema & León, 2016). Denton *et al.* 2016 describe the known host range as *Aquilegia vulgaris* and its hybrids, *A. alpine*, *A. flabellata*, *A. viridiflora* and *Semiaquilegia adoxoides*. Additional species of *Aquilegia* and *Semiaquilegia* may be susceptible; the host status of the related genus *Paraquilegia* is unknown.

Downy mildews of the genus *Peronospora* generally have narrow host ranges (Denton *et al.* 2015 and references there in). It is very unlikely *Aquilegia* downy mildew will infect hosts outside of the Ranunculaceae (buttercup) family to which *Aquilegia* and *Semiaquilegia* belong, and unlikely the pest can infect hosts other than *Aquilegia* and *Semiaquilegia* within the Ranunculaceae, except perhaps those that also lie within the subtribe Isopyrinae, of which none are of environmental or economic importance to the UK.

Aquilegia spp. are popular ornamental species in the UK and widely grown. *Semiaquilegia* is a less commonly grown ornamental.

In addition, European columbine, *A. vulgaris*, is considered a native wild flower in the UK, whose habitat is damp woodland and fens, though there have also been a number of garden escapes which may have mixed with the wild populations (Plantlife, 2010).

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?

The pathway of introduction of *Aquilegia* downy mildew into the UK is unknown.

If, outside of the UK, *Aquilegia* downy mildew is limited to South Korea then the risk of further introductions would appear low due to limited trade in plant material between the

UK and South Korea. However, it is likely that the pest is more widely distributed than currently reported.

Plants for Planting Excluding Seeds

Aquilegia downy mildew may be transported on the leaves of infected plants, but also on rhizomes as these have been demonstrated to be infected and may play a role in the overwintering of the pathogen (Denton *et al.*, 2015).

All plants for planting (including rhizomes) from 3rd countries must enter with a phytosanitary certificate and may be inspected upon landing. Inspection would not necessarily detect Aquilegia downy mildew if infection was recent, or on rhizomes where symptoms may be latent.

Assuming the pathogen originates in East Asia, then trade in susceptible plants is very likely to be small, but there are no data on commodity volumes. Because of limited trade, if disease is limited to South Korea new entries would be very unlikely. However, because of the new and emerging nature of this pathogen, and given that *Aquilegia* and *Semiaquilegia* have more extensive ranges than South Korea, the pest may be under reported and have a wider global distribution. For this reason, entry on plants for planting has been rated as unlikely, with low confidence. Contributing factors to the low confidence score are the lack of data on current distribution, an absence of data on import volumes of hosts and potential hosts from South Korea and uncertainty over the possibility that material may be imported via passenger baggage, as described for seeds below, and is either a) not declared at the border or b) declared, accompanied by the correct paperwork (a phytosanitary certificate) but not subject to inspection as the APHA do not inspect plants from passenger baggage in the majority of circumstances.

Seeds

The second pathway is seeds. Several *Peronospora* downy mildews have been demonstrated to be transmitted by seed including those infecting basil (*Ocimum basilicum*) (Garibaldi *et al.*, 2004), spinach (*Spinacia oleracea*) (Inaba *et al.*, 1983) and sunflower (*Helianthus*) (Cohen & Sackston, 1974). Seed transmission has not been demonstrated for Aquilegia downy mildew, though DNA from the pathogen has been isolated from seeds (Denton *et al.*, 2015). Early results from seed transmission trials have indicated that oospores were only detected in seed washings “at a relatively low rate”, and in a seed infection trial no signs or symptoms of sporulation were seen on plants (Jennings, 2016).

There are no plant health requirements on seeds of *Aquilegia* or *Semiaquilegia* and as such they can be imported into the UK from any country. Passengers may also bring back seeds from holidays etc. for personal use. It is not known how many seeds may have been imported from South Korea, the only other nation where Aquilegia downy mildew is known to occur, but it is assumed movement is very low. Entry on this pathway is very unlikely, with low confidence, as commodity volumes are unknown and the ability of the pathogen to be transmitted by seed unconfirmed.

Plants for Planting Very unlikely Unlikely Moderately likely Likely Very likely

Confidence High Confidence Medium Confidence Low Confidence

Seeds 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?

The pest does not require a vector.

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

Aquilegia downy mildew is already established outdoors in the UK, so establishment is rated as very likely with high confidence.

Aquilegia plants are not usually grown under protection, and so establishment under protection is very unlikely with high confidence.

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?

There are no studies on the natural spread of *Aquilegia* downy mildew, so ratings are based on the spread of related species. *Peronospora tabacina* causes blue mould of tobacco, and in cool, wet conditions with effective wind conditions, epidemics can quickly occur on a continental scale (Main *et al.*, 2001). Downy mildew of basil, *P. belbahrii*, is also

spread by airborne spores, and the oospores or resting spores can survive approximately 5 – 10 years. A UK PRA on this species rated potential natural spread as very quickly, though this was taking into account the abundance of potential hosts in the wider environment (Webb *et al.*, 2012). As *Aquilegia* and *Semiaquilegia* are the only known hosts, natural spread may be limited by the lower densities of host species in the wider environment compared to hosts of *P. belbahrii*. However, it is very likely they can be spread by wind under favourable conditions, and that oospores may survive in the soil for long periods (5 plus years). Natural spread is rated as quickly, taking into account the spread of similar species, with medium confidence as there are no specific studies on spread of *Aquilegia* downy mildew. Given the number of sites *Aquilegia* downy mildew has been recorded on from England and Wales, and the fact it has been observed on plants sold at nurseries (Denton *et al.*, 2015, Jennings, 2016), it is evident that *Aquilegia* downy mildew can spread with trade very quickly, with high confidence.

<i>Natural Spread</i>	Very slowly <input type="checkbox"/>	Slowly <input type="checkbox"/>	Moderate pace <input type="checkbox"/>	Quickly <input checked="" type="checkbox"/>	Very quickly <input type="checkbox"/>
<i>Confidence</i>	High Confidence <input type="checkbox"/>	Medium Confidence <input checked="" type="checkbox"/>	Low Confidence <input type="checkbox"/>		
<i>With trade</i>	Very slowly <input type="checkbox"/>	Slowly <input type="checkbox"/>	Moderate pace <input type="checkbox"/>	Quickly <input type="checkbox"/>	Very quickly <input checked="" type="checkbox"/>
<i>Confidence</i>	High Confidence <input checked="" type="checkbox"/>	Medium Confidence <input type="checkbox"/>	Low Confidence <input type="checkbox"/>		

12. What is the pest’s economic, environmental or social impact within its existing distribution and its potential future impact?

Economic Impacts

Symptoms of *Aquilegia* downy mildew can be severe. Development of symptoms is described by Denton *et al.* (2015). Briefly, chlorotic lesions are formed initially on leaves, darkening with time before the typical ‘down’ caused by spore production forms. Lesions can become necrotic and secondary infection may occur. *Aquilegia* downy mildew can also cause systemic (i.e. throughout the plant) infections – in addition to foliar symptoms described above, plants are stunted with curled leaves and distorted flowers. Death of infected plants may occur in one to two seasons. It is uncertain what percentage of infected plants is killed by the disease, especially as some growers may choose to remove and destroy plants in the first season symptoms are seen.

Economic impacts will occur due to symptoms making plants unsaleable. As the disease continues to spread and more people become aware of it, it is likely that sales of *Aquilegia* will decrease unless resistant varieties are identified, as individuals are unlikely to be willing to purchase a species which will inevitably suffer disease and potentially die. A

severe outbreak of *Impatiens* downy mildew, caused by the related *P. obducens*, led to very poor performance of plants, meaning major retailers did not stock *Impatiens* in 2012 (Anon, 2012). The reduction in sales in the USA due to *P. obducens* has also been documented (Getter & Behe, 2013, Shamus, 2015).

The economic impacts on this sector are rated as large, with high confidence, due to the significant amount of damage seen and the apparent lack of resistant varieties available.

Environmental Impacts

There are no published reports of disease in wild populations of the native *A. vulgaris*, but it is not unreasonable to expect that natural spread may eventually reach such populations, especially as *Aquilegia* is a common garden escapee. Truly wild populations may be confused with garden escapes (Plantlife, 2010), so it is difficult to determine if truly wild populations still exist.

If wild populations of *A. vulgaris* were killed by *Aquilegia* downy mildew as has occurred in garden plants, environmental impacts could occur. Certain species of invertebrate use *Aquilegia* as their primary or only host, both in the wider environment and within gardens, though relatively few compared to other native plants. The Biological Records Centre list 11 species of invertebrate associated with *A. vulgaris* (BRC, 2016), though only five of these utilise either only *Aquilegia* or *Aquilegia* and one or two other species. The BRC checklist includes a record for *Pristiphora alnivora*, a sawfly, but the 2014 UK checklist states this to be a misidentification of *P. rufipes* (Liston et al., 2014).

Ophiomyia aquilegiana a stem mining fly (Agromyzidae) that has a very limited distribution in the UK only having been recorded from Huntingdonshire and Cambridgeshire, though it has an additional host of *Thalictrum flavum* (Pitkin et al., 2016a). Nevertheless, the limited distribution of *O. aquilegiana* could make it very vulnerable to loss of populations of *A. vulgaris* to *Aquilegia* downy mildew. *Phytomyza krygeri* is another fly from the family Agromyzidae whose larvae feed on the seed capsules of *Aquilegia* (Spencer, 2013), and this appears to be the only host it utilises. There appear to be few records of this species in Great Britain, though it is widespread elsewhere in Europe (Pitkin et al., 2016b). It is possible it is under recorded in the UK, and it is difficult to predict how negatively populations of *P. krygeri* would be affected by *Aquilegia* downy mildew. This species was only reported from Britain for the first time in 1957 (De V. Graham, 1967), and so may be an introduction, but equally it could have previously gone unnoticed. A leaf miner, *Phytomyza minuscula*, can be considered a pest of *Aquilegia* and also *Thalictrum* species (Alford, 2012). This species appears to be more widespread in the UK and thus may be at less risk than other invertebrates strongly associated with *Aquilegia*. *Phytomyza aquilegiae* is largely associated with *Aquilegia* and *Thalictrum*, though BRC (2016) also include an entry for "other species". Another leaf miner, this species can be considered a pest and damaging when severe infestations occur (Alford, 2012). It is common in the south of England (Spencer, 1972), and its ability to utilise other host plants may reduce any impacts on this species.

Longicaudus trirhodus is an aphid which migrates from *Rosa* spp. to *Aquilegia* and *Thalictrum* (Blackman & Eastop, 2008). There is little data on this species in the UK making it very difficult to judge the effect a decline of *Aquilegia* associated with the downy mildew will have on *L. trirhodus* populations.

Environmental impacts are rated as small, with low confidence. The small rating, with low confidence, reflects the fact that it is hard to ascertain if truly wild populations of *A. vulgaris* still exist, due to this species being a common garden escapee, and the fact relatively few invertebrates are reliant on *Aquilegia* as a host. The low confidence rating is also due to the fact it is unknown how the disease may impact wild populations, since there appear to be no records in the wider environment. It is highly uncertain how notable invertebrates reliant on *Aquilegia* may be impacted if the local populations of *Aquilegia* are infected by downy mildew. It is likely that some cultivation of more resistant varieties of *Aquilegia*, once identified, will continue in gardens, which could act as a food source for these invertebrates.

Social Impacts

Aquilegia downy mildew can be very damaging and kill plants. Because the spores are very likely to be able to survive in the soil for many years, this also means plants cannot be replaced with the same species without disease being likely to occur again. Since *Aquilegia* are widely planted in private gardens and may also be planted in public gardens and parks, widespread disease will lead to social impacts, especially for those who may have significant collections of *Aquilegia*, as has been seen at the British national collection (Thomas, 2014). The popularity of the species is reflected in the press attention the disease has garnered (Lacey, 2016, McCann, 2015, Rachael, 2015). Many individuals, or those in charge of public plantings, may choose to no longer grow the plants. Social impacts have been rated as medium, with medium confidence as there are no data on how widely planted *Aquilegia* may be in public parks and gardens.

<i>Economic Impacts</i>	Very small <input type="checkbox"/>	Small <input type="checkbox"/>	Medium <input type="checkbox"/>	Large <input checked="" type="checkbox"/>	Very large <input type="checkbox"/>
<i>Confidence</i>	High Confidence <input checked="" type="checkbox"/>	Medium Confidence <input type="checkbox"/>	Low Confidence <input type="checkbox"/>		
<i>Environmental Impacts</i>	Very small <input type="checkbox"/>	Small <input checked="" type="checkbox"/>	Medium <input type="checkbox"/>	Large <input type="checkbox"/>	Very large <input type="checkbox"/>
<i>Confidence</i>	High Confidence <input type="checkbox"/>	Medium Confidence <input type="checkbox"/>	Low Confidence <input checked="" type="checkbox"/>		
<i>Social Impacts</i>	Very small <input type="checkbox"/>	Small <input type="checkbox"/>	Medium <input checked="" type="checkbox"/>	Large <input type="checkbox"/>	Very large <input type="checkbox"/>
<i>Confidence</i>	High Confidence <input type="checkbox"/>	Medium Confidence <input checked="" type="checkbox"/>	Low Confidence <input type="checkbox"/>		

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

Peronospora spp. are not vectors of plant pathogens.

14. What is the area endangered by the pest?

Given how widespread *Aquilegia* downy mildew now appears to be in the UK, all areas where *Aquilegia* is grown are endangered by the pest.

Stage 3: Pest Risk Management

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

As the pest is established and widespread in England and Wales, exclusion, eradication or containment are not viable options. Though records have not yet emerged from Scotland and Northern Ireland, the pest is moving in trade and also spreading quickly naturally and it is very likely to have already arrived, or is expected to arrive shortly, in these regions.

Cultural control methods are the only viable risk management option. There may be some fungicides with activity against *Aquilegia* downy mildew, but this is an area that has not yet been investigated. The RHS recommends the removal of infected plants as soon as possible, disposing of them appropriately by burning or deep burial (RHS, 2016). This will aid in reducing inoculum levels and spread to other hosts. Soil may contain viable spores, and so new hosts should not be planted in affected areas for at least a year (RHS, 2016).

The breeding of resistant cultivars is likely to be the best control option for *Aquilegia* downy mildew.

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