Department for Environment Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Wheat Dwarf Virus

April 2015

Stage 1: Initiation

1. What is the name of the pest?

Wheat Dwarf Virus

Wheat Dwarf Virus (WDV), family *Geminiviridae,* genus *Mastrevirus*.

WDV has two distinct strains known as the wheat strain and barley strain. Genomic sequencing has shown a divergence of 16% between the Swedish barley and wheat strains (Kvarnheden *et al.* 2002), with many other studies from across the current distribution of *WDV* showing the existence of these distinct strains (Köklü *et al.* 2007, Kundu *et al.* 2009, Schubert *et al.* 2007). Though Schubert *et al.* (2007) proposed that the barley strain be re-classified as *Barley Dwarf Virus,* the sequence divergence is too small to meet the requirements for a distinct species as defined by the International Committee on the Taxonomy of Viruses and so it is still considered as a strain of *WDV* (Yan *et al.* 2012).

A third strain was described as occurring exclusively in oats and the tentative name *Oat Dwarf Virus* (*ODV*) was proposed (Schubert *et al.* 2007). This name was ratified in 2013 by the International Committee on the Taxonomy of Viruses (Adams *et al.* 2013) and *ODV* is now considered to be distinct from *WDV*. *Oat Dwarf Virus* is not considered further in this PRA.

2. What initiated this rapid PRA?

Entomologists at Fera were contacted about the finding of two adult *Psammotettix alienus* in Cambridgeshire, initially thought to be the first findings of this leafhopper species in the UK. This was identified as a vector of *WDV*, which was then added to the UK Plant Health Risk Register with a priority to complete a PRA to see if statutory action is justified.

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]?

Wheat Dwarf Virus 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 published records of *WDV* occurrence by country are summarised in Table 1. The UK record of *WDV* is discussed in more detail in section 6.

Within Africa, *WDV* has a disjointed distribution – only being reported in Tunisia and Zambia. In Zambia, a survey of viruses in irrigated wheat showed that the majority of symptomatic plants were co-infected with multiple viruses. *WDV* was observed to be in complexes involving up to six other cereal viruses (Kapooria & Ndunguru 2004). Co-infection of cereals with *WDV* and other viruses including *Barley Yellow Dwarf Virus* and *Cereal Yellow Dwarf Virus* have also been reported in Europe (Achon *et al.* 2006, Bukvayová *et al.* 2006) and in Turkey (Köklü 2004). Because symptoms of dwarfing and chlorosis can be caused by a range of viruses in cereals, as well as other biotic and abiotic factors such as drought and nutrient deficiency, it is not an unreasonable scenario that *WDV* has a much greater distribution that currently reported, and symptoms are mistaken for other causes in the field.

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

[2] https://www.eppo.int/QUARANTINE/quarantine.htm

Table 1: Distribution of *Wheat Dwarf Virus*	
North America:	No records
Central America:	No records
South America:	No records
Europe:	Austria (Schubert *et al.* 2014), Bulgaria (Bakardjieva *et al.* 2004), Czech Republic (Vacke & Cibulka 1999), Finland (Lemmetty & Huusela-Veistola 2005), France (Bendahmane *et al.* 1995), Germany (Schubert *et al.* 2007), Hungary (Tobias *et al.* 2011), Italy (Rubies Autonell *et al.* 1995), Poland (Jezewska 2001), Romania (Jilaveanu & Vacke 1995), Spain (Achon *et al.* 2006), Sweden (Lindblad & Waern 2002), Ukraine (Tobias *et al.* 2011), United Kingdom (Schubert *et al.* 2014)
Africa:	Tunisia (Najar *et al.* 2000), Zambia (Kapooria & Ndunguru 2004)
Asia:	China (Xie *et al.* 2007), Iran (Behjatnia *et al.* 2011), Syria (Ekzayez *et al.* 2014), Turkey (Ilbagi *et al.* 2003)
Oceania:	No records

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

There is only a single record of *WDV* (the wheat strain) in the UK from a wheat plant collected in Elveden in Suffolk in 2012 by a group looking to obtain strains of *WDV* from new locations for genomic analysis (Schubert *et al.* 2014). However, given that this record is from an area where *P. alienus* is known to occur, it is very likely that *WDV* is also established in the UK. Since the vector is thought to be rare, *WDV* is also probably occurring only at low levels – however this is highly uncertain. As noted in section 5, symptoms are similar to other dwarfing viruses such as *BYDV* which is relatively widespread in the UK, and thus cases of *WDV* may have been misdiagnosed. The status of the barley strain of *WDV* in the UK is unknown.

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?

Wheat Dwarf Virus is split into two strains based on genetics and on host preference for either barley (*Hordeum vulgare*) or wheat (*Triticum aestivum*) (Schubert *et al.* 2007). Though this host preference is very strong, there are occasional reports of the barley strain being found in wheat and vice versa (Ramsell *et al.* 2009, Tobias *et al.* 2011). These are also the main two hosts that impacts are reported on. Vacke and Cibulka (1999) state that *Avena sativa* (oat) is a host for both wheat and barley strains of *WDV*, though with the classification of the oat strain of *WDV* as a separate virus in 2013 (*ODV*), it is not clear if oat is still a host for *WDV.* Other commercially grown cereals that *WDV* has been isolated from are: rye (*Secale cereale*), perennial rye-grass (*Lolium perenne*) and triticale (*x Triticosecale*) (Ramsell *et al.* 2008, Schubert *et al.* 2007).

The virus has also been isolated from various wild grasses, though at a much lower rate than other cereal viruses such as *Barley Yellow Dwarf Virus*, perhaps suggesting that wild grasses are not significant reservoirs of the *WDV*. For example Ramsell *et al.* 2008 only found that 8 out of 1098 plants of wild grasses tested positive for *WDV*. Confirmed hosts for *WDV* in wild grasses are: *Apera spica-venti* (loose silkybent grass), *Avena fatua* (wild oat), *A. sterillis,* (winter wild oat), *Bromus inermis* (smooth brome), *B. secalinus* (rye brome), *B. tectorum* (drooping brome), *Hordeum murinum* (wall barley), *Lagurus ovatus* (hare's tail grass), *Lolium multiflorum* (annual ryegrass), *L. temulentum* (darnel), *Poa annua* (annual meadow grass) and *P. pratensis* (smooth meadow grass) (Ramsell *et al.* 2008, Vacke & Cibulka 1999). The entire host range is unlikely to have been fully elucidated and there may be several asymptomatic hosts amongst wild grasses. For example triticale collected from near *WDV* infected winter wheat was positive for the presence of the virus, but displayed no clear symptoms (Ramsell *et al.* 2008).

Nygren *et al.* (2014) experimentally inoculated a range of wild and domesticated wheat species with *WDV* as part of studies into susceptibility. Various *Aegilops* (goatgrasses) were susceptible. Cultivated spelt wheat varieties (*Triticum spelta*) were capable of being infected by *WDV* but showed comparatively few symptoms and in some variable measures, including leaf and tiller number, performed better than the uninfected plants (Nygren *et al.* 2014).

Wheat and barley are grown extensively in the UK, with provisional figures indicating 16.6 million tonnes of wheat was produced in the UK in 2014 and 7 million tonnes of barely (Defra 2014).

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?

There is no evidence that *WDV* is seed borne or mechanically transmitted. The only known mechanism of spread is via infectious vectors, and, in nearly all instances, the vector reported is *P. alienus*.

Natural Spread

Natural spread refers to the movement of infectious vectors from outside of the PRA area, for example by arrival via flight from northern European countries. Currently only the wheat strain of *WDV* is known to be present in the UK, and such arrivals could enter and introduce the barley strain, or *Oat Dwarf Virus,* if these are absent from the UK. Though some leafhopper species are known long distance migrants, there appears to be no data indicating this is the case for *P. alienus*. Leafhoppers could also arrive as vagrants, blown by storms from Continental Europe, though the frequency of such occurrences is unknown. Entry by natural spread is rated as very unlikely, with low confidence due to a significant lack of data.

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

Plants for Planting

Both the vector and virus could enter via plants for planting – if *WDV* infected plants are imported, transfer to other grasses and economic hosts such as wheat will be limited unless they are exposed to UK populations of *P. alienus,* or the vector is also associated with the infected plant. Since the full host range of the vector is not known, it is possible that it or *WDV* could enter on ornamental grasses imported into the UK. The eggs of *P. alienus* would be very difficult, if not impossible, to spot during inspections as they are laid inside the leaf tissue (Alla *et al.* 2001). Nymphs and adults could also be associated with plants for planting. There are no reports of *WDV* in ornamental grass species, or of *P. alienus* being common in nurseries growing such plants. For this reason entry on plants for planting is rated as very unlikely, with medium confidence as the susceptibility of ornamental grasses is unknown, and they may be asymptomatic carriers of *WDV*.

Plants for planting	Very unlikely ✓	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐

Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐

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

There is only a single record of *WDV* in the UK, collected from a field in Suffolk in 2012, however as discussed in section 6 it may be present more widely at low levels. A suitable vector (*P. alienus*) is present in the UK (more details are in section 10) and records exist from East Anglia including Suffolk. Potential hosts of *WDV* are abundant – cereals are grown widely across the UK and the virus can survive in wild grasses fed on by *P. alienus* in instances where domesticated hosts are not present. Thus establishment is rated as very likely, with high confidence.

Hosts of *WDV* are not normally grown under protection, and the vectors are not usually present there, thus establishment under protection is rated as 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	☐				

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

The finding of *P. alienus* in Cambridgeshire in September 2014 was initially thought to be the first finding of this species in the UK. However the updated checklist of leafhoppers of the UK and Ireland published in 2015 accredits historical records of *P. striatus* to *P. alienus* (Wilson *et al.* 2015). It has previously been noted that the distribution of *P. striatus* is uncertain due to taxonomic confusion (Kirby 1992). It is thus assumed that all previous records of *P. striatus* in the UK are *P. alienus*. As such, this species appears to be established but very rare. Several were collected in North Cambridgeshire between 2010 and 2013, but when the same sites were studied in 2014 no *P.* alienus were found (Peter Kirby *pers. comm.* 30.03.2015). The 1992 review of scarce and threatened Hemiptera of the UK by Kirby stated it had only been recorded from Freckenham in Suffolk, and was a very rare UK species. In addition to the Cambridgeshire records, an image taken in Jersey appears to be *P. alienus* (Ransom 2014). The complete distribution of this species in the

UK remains highly uncertain. The species was described from the UK in 1969, though there is an additional old pre-1930s record (Kirby 1992). *Psammotettix* is a difficult genus to distinguish, and this species may have previously been overlooked, as such *P. alienus* is likely to be a native but rare and notable species. If introduced, it has been present for over forty years.

The other recorded *WDV* vector is the related *P. provincialis* (Ekzayez et al. 2014), which is not recorded as present in the UK. There is no evidence that other *Psammotettix* or unrelated phloem feeding leafhoppers can act as a vector of *WDV*, but presence of additional *WDV* vectors in the UK cannot be fully discounted.

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

Wheat Dwarf Virus is spread in a semi-persistent manner by *P. alienus* – that is the virus enters the salivary glands of the leafhopper but does not replicate within it and so unless further acquisition feeding occurs viral load diminishes over time. Adult leafhoppers can become capable of transmitting *WDV* as quickly as 5 minutes after acquisition feeding (Wang *et al.* 2014), though the amount of time it remains viruliferous is less clear. Field studies have shown that primary infection of winter barley and wheat occurs by adults migrating into fields and feeding on newly emerged plants in the autumn, adults are then killed by a period of cold and the species overwinters as an egg and in spring/summer secondary spread of the virus occurs via nymphs and adults (Lindblad & Arenö 2002, Lindblad & Sigvald 2004, Manurung *et al.* 2004).

There are no data on how far adult *P. alienus* will fly and thus potentially spread *WDV* to new areas. Spread potential also depends on the population levels of *P. alienus* year to year. This species appears to be rare in the UK, with no apparent records outside of East Anglia and Jersey, and any spread is likely to be very local rather than long distance. Natural spread is rated as very slowly, with medium confidence, as the flight potential of the vector is not fully understood.

The hosts of *WDV* and the vector *P. alienus* are not usually traded as plants for planting, and spread with trade is rated as very slowly with high confidence.

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?

As discussed in section 5, reports of *WDV* in mixed infections with other viruses – including those that also cause dwarfing – are common. As a consequence, this adds a significant level of uncertainty to the assessment of the impacts caused by this virus. Even in instances where *WDV* is reported to be the main cause of yield loss, it is not always clear if samples were tested for the presence of other viruses. It has also been reported that frost damage is greater in some cultivars of wheat infected with *WDV* (Širlova *et al.* 2005), so that other biotic and abiotic factors may contribute to the impacts seen. Conversely, epidemics of *Barley Yellow Dwarf Virus* or other viruses may be exacerbated by the undetected presence of *WDV*.

Typical symptoms of *WDV* on cereals are dwarfing, yellowing of leaves and suppressed heading (Manurung *et al.* 2004). Some of the highly susceptible Czech cultivars tested failed to head at all and could be killed by the infection (Vacke & Cibulka 2000). Root formation is also inhibited (Ilbagi *et al.* 2003).

Though widespread, *WDV* tends only to cause major losses in yield during epidemic years – and the timing and incidence of such epidemics varies across its known distribution. It has been proposed that epidemics are caused by a combination of favourable conditions leading to high numbers of vectors with the use of cereal varieties with a high susceptibility to *WDV*. In central Sweden, fifty years occurred between epidemics of *WDV* that led to substantial losses (Lindblad & Waern 2002). Two years after the 1997 epidemic in field surveys of winter wheat in Central Sweden, no *WDV* was detected (Lindblad & Sigvald 2004). The virus was first detected in Austria in 2004, no serious impacts of *WDV* were seen until 2012 when a "severe" outbreak occurred (Huss *et al.* 2013, Schubert *et al.* 2014). In Saxony-Anhalt, Germany the incidence of *WDV* in barley is reported to differ greatly from year to year and even field to field (Manurung *et al.* 2004), and in the Czech Republic *WDV* is described as having "local epidemics in some years" (Širlova *et al.* 2005). Tobias et al. (2011) reported that in the last 10 years *WDV* has been the most frequently isolated virus of cereals in Hungary.

In such epidemic years yield losses in affected fields can be substantial. An outbreak in winter wheat in Finland saw a yield loss of between 20-40%, though in some fields this was as high as 100% (Lemmetty & Huusela-Veistola 2005). During an epidemic year in Sweden, an average yield loss of 35% (with maximum loss of 90%) was recorded (Lindblad & Waern 2002). The same study also reported that early sown fields suffered the largest yield losses; this is thought to be because it increases the risk of infection with *WDV* in the autumn when plants are most susceptible and possibly the earlier emergence of plants increase the number of eggs laid by the vector. Greenhouse trials confirmed that winter wheat plants were very susceptible to *WDV* until stem elongation, when susceptibility rapidly decreased (Lindblad & Sigvald 2004).

Substantial differences in tolerance of various wheat cultivars have been reported. Incidence and disease severity of WDV during an outbreak in Sweden was significantly higher in cv. Kosack, the most commonly grown cultivar, than in other cultivars (Lindblad & Waern 2002). Partial resistance to *WDV* was found in two Hungarian cultivars – though plants were capable of being infected in the lab, it was at significantly lower frequency than the susceptible cultivars tested, and accumulation of viral DNA was also lower in these cultivars (Benkovics *et al.* 2010). Studies done on Czech cultivars showed they could be split into three groups based on symptoms, however all varieties showed dwarfing and significant yield loss, no resistant cultivars were found. (Širlova *et al.* 2005, Vacke & Cibulka 2000). No resistant plants were identified. It seems that the resistance/tolerance of cultivars grown can have significant effects on the impact of *WDV.*

To summarise, a great number of factors appear to influence the impact *WDV* may have in a given season or even on a given farm, and these include vector abundance and period of activity, variety susceptibility, climate and sowing date. In the majority of countries, epidemics are only occasional though yield losses can be severe when they occur. Impact of *WDV* is rated as medium, with low confidence as *WDV* is often present with other viruses, and may also be far more widespread than currently reported and misdiagnosed as other viruses.

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?

The vector of *WDV* appears to be rare and local in the UK. The first record of *WDV* is from 2012 but it is assumed to have been present for significantly longer with disease incidence kept at low levels due to the scarcity of the vector. It is possible that some instances of *WDV* in the UK have been previously miss-diagnosed as the relatively widespread *BYVD*, because symptoms and damage are so similar – or may have been present in a mixed infection as seen on the continent but not tested for. In addition, the limited distribution and apparent low population levels of the vector will severely limit the incidence of this disease reducing impacts. As a consequence, economic impact is rated as small. Confidence associated with this rating is low. The reasons that epidemic years occur on the continent are not clear, though vector abundance and variety susceptibility appear to play an important role. The susceptibility of UK varieties of cereals to *WDV* is entirely unknown. There is also no clear reason why *P. alienus* is a rare species in the UK compared to the continent and it is possible that changes in climate or agricultural practises in the future may lead to changes in the population dynamics of *P. alienus*, leading to damaging levels of the virus to be transmitted.

Though *WDV* infects wild grasses, in its current distribution there are no reported environmental impacts. Environmental impacts are rated as very small with high confidence. There are also no reported social impacts, and this too is rated very small 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?

Wheat Dwarf Virus is not a vector of other pathogens.

15. What is the area endangered by the pest?

Winter wheat and barley production in East Anglia, where the vector is known to be present, is at greatest risk. In particular where crops are sown early and emergence occurs before the vector is killed by winter temperatures.

Stage 3: Pest Risk Management

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

The virus is likely to have been present in the UK for some time since *P. alienus* is likely to a native species, and thus exclusion and eradication are not feasible.

There are some actions that could be taken by growers that may reduce impacts of the pest. Chemical insecticides could be used to target the vector in autumn when winter wheat and barley emerge. This is when primary infection occurs via adults feeding. The majority of winter wheat and barley are subject to an autumn spray to control aphids, and the most common formulations used being pyrethroid based (Garthwaite *et al.* 2012), and would likely be effective on leafhopper vectors as well. Spraying may be required again in spring when nymphs and adults cause secondary spread of the virus. Early sown crops (beginning of September) are particularly at risk, because young plants are exposed to the leafhoppers for longer whilst they are still highly susceptible to the virus. The use of resistant or tolerant varieties could reduce impacts; however the resistance status of the cultivars of wheat and barley grown in the UK is entirely unknown. Stubble and volunteer cereal plants can act as overwintering material for infectious vectors, and their removal could reduce the leafhopper populations and thus reduce *WDV* infection rates in newly sown crops (Manurung *et al.* 2004). The current recommendations for cultural control for *BYVD* are similar: ploughing at least three weeks before drilling and destruction/burying of stubble in order to reduce populations of the aphid vectors, in addition sometimes sowing is delayed until mid-October in high risk areas (HGCA 2015). Where such measures are practised in the UK it is also likely to reduce impacts of *WDV*.

17. Summary and conclusions of the rapid PRA

Provide an overall summary and conclusions and then short text on each section:

This rapid PRA shows that *Wheat Dwarf Virus* is an occasionally damaging virus of cereals in Europe, transmitted by the leafhopper *P. alienus*. Both the virus and vector appear to be in the UK at low levels with no records of significant impacts recorded.

Risk of entry

Further introductions *WDV* are unlikely, as the known host plants are not traded and there is no evidence that *P. alienus* flies long distances and thus could arrive infectious from the continent.

Risk of establishment

The virus is likely to already be established in the UK. Establishment under protection is very unlikely as hosts are not usually grown under protection.

Economic, environmental and social impact

Though impacts in the current distribution are rated as medium, predicted economic impacts in the UK are rated as small due to the low abundance of the vector. However there is considerable uncertainty, as this assumes the virus has been present in the UK for considerable time and causing minimal impacts. There are no apparent environmental and social impacts are these are rated as very small with high confidence.

Endangered area

Early sown winter barley and wheat in East Anglia where the vector is known to be present.

Risk management options

Certain cultural measures to reduce leafhopper populations, and the use of resistant varieties if available, could reduce the impacts of *WDV.*

Key uncertainties and topics that would benefit from further investigation

The distribution of vector and virus in the UK is highly uncertain. Though there is only a single report of *WDV*, it is possible that it is relatively widespread in the UK and being mistaken for viruses such as *BYVD*. The genus *Psammotettix* is also difficult to identify, and this species too may be more widespread than currently reported. Monitoring the distribution and population density of *P. alienus* would help provide an early warning of possible greater impacts from *WDV* in the future. The degree of resistance or tolerance to *WDV* in wheat and barley cultivars grown in the UK is also unknown.

18. 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	✓				
Yes		PRA area: UK or EU		PRA scheme: UK or EPPO	

19. Images of the pest

Symptoms of *WDV* in a susceptible wheat variety Clever (left) compared to a healthy plant. Taken from Sirlova *et al.*, 2004.

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

Both the virus and vector appear to already be present in the UK at low levels, and as such statutory action would not be appropriate.

Yes Statutory action	☐	No Statutory action	☑

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