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**United Kingdom Cereal Pathogen Virulence Survey  
2017 Annual Report**

# **United Kingdom Cereal Pathogen Virulence Survey**

## **2017 Annual Report**

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## 1. Summary

The UKCPVS monitors the populations of the important cereal pathogens *Puccinia striiformis* f.sp. *tritici* (*Pst*), causing wheat yellow rust, *Puccinia triticina* (*Pt*) causing wheat brown rust, *Blumeria graminis* f.sp. *tritici* (*Bgt*) causing wheat powdery mildew and *Blumeria graminis* f.sp. *hordei* (*Bgh*) causing barley powdery mildew.

### **Wheat yellow rust**

Since the incursion of the Warrior population in 2011, the UK *Puccinia striiformis* f.sp. *tritici* population has been changing, with the old UK population now entirely replaced by the new Warrior group. Results from the tests on isolates collected in 2016 showed new pathotype combinations not seen before. Whilst not unusual in this very diverse population, the new pathotypes were found during a year of high disease pressure that saw several Recommended List (RL) varieties rated as more susceptible. Adult plant trials with five key races revealed that the races Blue 7 (previously called the Invicta race) and Red 24 (a new race only identified in 2016) were most likely to have caused these changes. Many varieties were affected by these races and were often affected more by one than the other which would explain the localised differences in varietal performance both in 2016 and again during the 2017 field season.

### **Wheat Brown Rust**

Isolates collected in 2016 were tested on a new differential set which brings the UKCPVS into line with researchers from other countries. This will allow the direct comparison of results to identify common patterns. With the exception of eight resistance (*Lr*) genes, the virulence of isolates to most *Lr* genes was only monitored for the first time this year. Virulence frequencies for the eight previously monitored *Lr* genes differed slightly from 2015, however it is unclear at this stage whether these differences are genuine or if they are due to the use of new differentials. Further work is ongoing to investigate this. Variety tests at the seedling and adult plant stages were conducted, however discrepancies were observed between differential test results and control varieties. The cause of this difference will be investigated further, with the adaptation of methods to isolate from single pustules in future years.

### **Wheat Powdery Mildew**

Low to moderate levels of disease in 2016 led to modest numbers of samples of wheat powdery mildew being received by the UKCPVS. Virulence was seen for most of the differentials tested, with avirulence seen on Amigo and Shamrock. For the most part, the virulence frequencies compared well with previous years. Small changes in virulence frequencies were observed however there were no reports of mildew outbreaks during the

year and based on this information we suspect that this small population change is therefore unlikely to prove detrimental at the adult plant stage.

***Barley Powdery Mildew***

Very few samples were received by the UKCPVS of *Blumeria graminis* f.sp. *hordei*.

Virulence for all of the differentials was detected with the exception of Riviera. Although virulence for Riviera has not been detected this year, it has been detected in the past and has equally been undetected in other years. For the remaining genes there were some deviations from previous years, however these changes were not coupled with any unusual outbreaks and it is therefore unlikely that these changes will have a big effect on varietal performance at the adult plant stage.

## **2. Introduction**

### **2.1. General Introduction to the United Kingdom Cereal Pathogen Virulence Survey (UKCPVS)**

#### **2.1.1. Establishment of the survey**

Wheat production in the UK is threatened annually by a number of pests and diseases. In our cool maritime climate the foliar diseases Septoria leaf blotch and yellow (stripe) rust are easily found. Warmer summers have also led to the sighting of brown (leaf) rust at the end of the season which can be serious if left unchecked on susceptible varieties. Current methods of control are based principally on fungicidal inputs, however for the latter two diseases host resistance plays an important role due to the high levels offered in some UK wheat varieties. Host resistance to the rust fungi is however subject to change and should be monitored as part of a virulence survey due the ability of the pathogen to mutate and overcome some kinds of resistance. For this reason, the UK Cereal Pathogen Virulence Survey was established in 1967 following an unexpected outbreak of yellow rust on the previously resistant variety Rothwell Perdix.

#### **2.1.2. Targets of the Survey and Pipeline for Pathotyping**

##### **2.1.2.1. Targets**

Known originally as the Physiologic Race Survey of Cereal Pathogens, the survey was conducted by a group of organisations including NIAB. The list of target diseases was longer and included wheat yellow rust, wheat and barley mildew, barley brown rust, barley leaf scald (*Rhynchosporium*), barley net blotch, oat crown rust, oat leaf spot and oat mildew. Over time the list of target species has reduced but the principals still remain the same and in its 50<sup>th</sup> year the survey continues to provide information to growers, breeders and other interested parties on the population of these important pathogens. The survey currently limits its activities to monitoring the pathogens causing the diseases wheat yellow and brown rust and wheat and barley powdery mildew. A close eye is also kept on the incidence of barley yellow rust, which although rare currently, has been a problem in the past.

##### **2.1.2.2. Timescale of characterisation**

Once a sample is received by the survey the causal agent is multiplied and stored for further testing. At the end of July when all the samples have been received the list is scrutinised at least 25 samples are selected per disease for further characterisation using a differential test. The differential tests follow a worldwide standard procedure where the different isolates of rust or mildew are inoculated onto a set of different varieties ("differentials") whose

underlying resistance gene(s) are known. Other varieties carrying uncharacterised sources of resistance are also included in these tests. By assessing whether the isolate can cause disease on the individual varieties (termed as virulent) or not (termed avirulent) allows the isolate to be characterised and compared with isolates previously identified within the UKCPVS and also with colleagues elsewhere in the world. A new race is declared when virulence for a particular resistance gene, gene combination or variety is detected which has not been seen before in the UK.

### 2.1.3. Key virulence changes over the years: Wheat Yellow Rust

Until very recently, changes in the pathogen populations were typically detected in only one or two locations at low levels. Depending on the prevalence of the host cultivar, the new races appeared in one year and then slowly increased until the following season where it was seen more widely. Eventually these new races would start to be more dispersed and therefore noted in virulence surveys of other European countries, such as France, Germany and Denmark. New races of wheat yellow rust for example have historically appeared in the UK on average every 3-4 years, with changes in the population appearing to be step wise mutations of current established isolates (Table 1).

Table 1: Key *Puccinia striiformis* f.sp. *tritici* (*Pst*, wheat yellow rust) race changes in the UK

Year	Variety	Key Resistance Gene Combination*
1988	Hornet	Yr6, Yr9
1994	Brigadier	Yr9, Yr17
1996	Madrigal	Yr6, Yr9, Yr17
2000	Robigus	Yr4, Yr9, Yr17, Yr32
2008	Solstice	Yr6, Yr9, Yr17, Yr32
2011	Warrior	Yr6, Yr7, Yr9, Yr17, Yr32, Spaldings Prolific
2014	Kranich	Avirulence for Yr4, Yr8, Avirulence for Spaldings Prolific
2015	Invicta	Yr6, Yr9, Yr17, Yr32, Evolution

\*Virulences noted for seedling tests only. The Invicta race has no impact on Evolution at the adult plant stage.

In 2011 a new race of yellow rust, the Warrior race, was identified that appeared to be similar to previous races, but with additional virulence for Yr7 and the variety Spaldings Prolific. It is important to note that virulence for Yr7 had been seen before, but not in combination with virulence to Yr6, Yr9, Yr17 and Yr32. There were however other pieces of evidence to suggest that the Warrior race was different to previous races, with abundant production of the sexual stage spores (teliospores) and multiple sightings of the new race



across Europe in the same year. Further molecular genotyping of the Warrior race has shown that this new race was a foreign incursion and not a mutation of the existing population (Hovmøller et al. 2016; A. J. Hubbard et al. 2015). The Warrior race was also characterised by its high population diversity, indicating that it was likely to be derived via sexual recombination, and not the asexual mutation that previously characterised the UK population (Ali et al. 2014; Hovmøller, Justesen, and Brown 2002). The population diversity identified in the Warrior race highlighted that the incursion was of multiple isolates, in effect a population, rather than a single isolate or race.

Since the arrival of the Warrior group of isolates in 2011, existing European populations have been replaced so that the population is now dominated by isolates classified as members of the Warrior group (Hovmøller et al. 2016; A. J. Hubbard et al. 2015). In 2015 the UKCPVS confirmed that an additional race had arrived in the UK, the Kranich race. The Kranich race is broadly related to the Warrior group and has arrived as another exotic incursion. It is not surprising that it has arrived here since the race was detected in northern Europe as early as 2011 and was also identified in Poland for the first time in 2014 (Hovmøller et al. 2016). The Kranich race is identified by a virulence profile of avirulence for *Yr4* and *Spaldings Prolific* and virulence for *Yr8* and *Ambition* and represents the first recent detection of virulence for *Yr8* in the UK since 1982 (Anon 1982).

Most recently, in 2015 the Invicta race was identified. Initial pathology tests on isolates of this race showed it to carry the same pathotype as the Solstice race from the old UK population. Subsequent genotypic analysis at the John Innes Centre clearly grouped these isolates into the “Blue” group of the Warrior population showing that it was different to the old Solstice race. A variety seedling test using this isolate highlighted that this isolate carried additional virulence to the variety *Evolution*, thus enabling the UKCPVS to improve the differential set to separate these isolates from any remaining isolates of the old UK Solstice race (Hubbard, Pritchard, and Holdgate 2016).

#### **2.1.3.1. Changes in naming of races**

With the recent race changes affecting the UK and across Europe, the UKCPVS has sought to redefine the naming system for new races. A meeting between virulence surveys from across Europe in 2016 failed to reach a consensus of how to deal with such a diverse pathogen population. In the UK a system has now been proposed to take into consideration the genetic data currently produced by the John Innes Centre as well as the pathotype data generated by the UKCPVS. The races are now assigned a colour to divide the races into

their genetic groups using the genotype data and then a number to divide the isolates according to the pathotype data. The colour group is based on that produced in the STRUCTURE programme used to analyse the data and the number is assigned sequentially. So for example, the race Blue 1 will have been discovered in advance of Blue 2. Using this system it will be possible to separate races that may otherwise look similar. This is clearly shown with the Invicta and Solstice races, where they are now re-named Blue 7 and Navy 9 respectively. During this renaming process, colleagues at the Global Rust Reference Centre also developed a new naming system which groups races into PstS groups (Ali et al. 2017). This system takes a broader approach to naming races so that individual races are not named, rather they are included into the broad groups and important races within the group are highlighted. Translation between the two systems is ongoing.

#### **2.1.4. Key virulence changes over the years: Wheat Brown Rust**

Surveillance of the *Puccinia triticina* (formerly *P. recondita*) population in the UK began a little later than surveys for the other cereal diseases, beginning in 1973 with samples collected from 1972. Colleagues at the Welsh Plant Breeding Station (now Institute of Biological, Environmental and Rural Sciences at the University of Aberystwyth) managed the survey of this pathogen until 2006 when the survey was transferred to NIAB. In the early stages of this programme there was very little known or developed in the way of differential sets, and the initial screening of isolates was conducted using a selection of winter and spring wheat varieties from the Recommended List of that year along with some research lines from a Septoria leaf blotch resistance screen. From here, nine varieties were selected that were able to differentiate between the isolates and included current differentials Maris Halberd and Sappo. Like today, wheat brown rust is less important than wheat yellow rust, and at the start of the survey, there were only limited options for resistant varieties, for example Clement, which carried the gene *Lr26* (also referred to as WBR1). Official ratings of resistance to wheat brown rust were not introduced onto the Recommended List (RL) until 1977. Dominant races of *P. triticina* tend to match commonly deployed host resistance genes. For example, use of the resistance gene *Lr1* in the variety Glasgow led to the emergence of the Glasgow race in 2005 which carried virulence for this resistance gene (Table 2). Once the acreage of varieties carrying these resistance genes reduces, the frequency of finding these isolates reduces. A recent example is virulence for *Lr24*. The two varieties carrying this resistance gene (Warrior and Stigg) are no longer widely grown and the population has therefore mirrored this and the frequency of detection continues to decline. The most recent change to the population saw the population overcome the

moderate resistance in the variety Crusoe in 2014. The causal race is still under investigation by the UKCPVS.

Table 2: Key wheat brown rust changes in the UK since the start of the survey

Year	Variety	Key Resistance Gene Combination
1973*	Sappo	<i>Lr20</i> (WBR3)
1973*	Maris Halberd	<i>Lr20</i> (WBR4)
1974*	Maris Fundin	<i>Lr17b</i> (WBR2)
1976	Maris Huntsman	WBR5 (APR)
1977	Clement	<i>Lr26</i> (WBR1)
1977	Sterna	<i>Lr3a</i> (WBR7)
1978	Maris Ranger	WBR8
1980	Avalon	WBR9
1982	Gamin	WBR6
1991	Slejpner	<i>Lr26</i> + APR
1993	Spark	Not specified
1994	Flame	Not specified
1995	Chablis	<i>Lr3a</i> + ?
1999	Rialto	<i>Lr17b</i> , <i>Lr26</i> + APR
2005	Glasgow	<i>Lr1</i>
2005	Claire	<i>Lr3a</i> , <i>Lr17b</i> , <i>Lr20</i> , <i>Lr26</i> , APR
2006	Robigus	<i>Lr28</i>
2006	Multiple <i>Lr37</i> varieties	<i>Lr1</i> , <i>Lr3a</i> , <i>Lr17b</i> , <i>Lr26</i> , <i>Lr37</i>
2011	Stigg	<i>Lr24</i>
2014	Crusoe	<i>Under investigation</i>

\* Tested for the first time, virulence may have been present in previous years.  
APR = Adult plant resistance

## 2.2. Aims and Objectives

The principal aim of the project is to detect new races of economically important pathogens for UK growers to provide an early warning system that will aid effective disease management. To achieve this, the UKCPVS currently monitors the populations of the fungi causing wheat yellow rust and brown rust and wheat and barley powdery mildew. A subset of the isolates collected will be characterised to identify any new races. The reactions of the current RL varieties and candidates will be assessed using some of the newest isolates at both the seedling and adult plant stages to establish future risks of disease outbreaks.

### **3. Materials and methods**

#### **3.1. Wheat Yellow Rust and Wheat Brown Rust**

##### **3.1.1. Collection of samples and preparation of isolates**

Infected wheat leaves were received from growers, agronomists and trials operators of RL trials. Spores from the infected samples were transferred on to plants of the universally susceptible variety Victo (wheat yellow rust) or Armada (wheat brown rust). Plants were grown under controlled environment conditions on Burkard isolation benches until fresh sporulation was evident. Spores were collected and used to re-infect further pots of the susceptible varieties until enough spores were available to inoculate a differential test.

##### **3.1.2. Characterisation of isolates using differential tests**

Seedlings of the differential set were inoculated with spores from the new isolates, using a complete set of differential varieties for each isolate under test. The differentials used and the resistance genes they carry are listed in Table 3 and Table 10. Approximately 14 days post inoculation the tests were scored using a 0-4 scale which was then converted into an average infection type score (a.i.t.). A score of 0-2.3 indicates an incompatible (avirulent) reaction, a score of 2.4-2.6 represents a borderline reaction and should be treated with caution as it is difficult to be certain whether the reaction is one of virulence or avirulence, and scores of 2.7 – 4.0 indicate a compatible reaction and the isolate is virulent on that differential.

##### **3.1.3. Characterisation of isolates using adult plant trials**

Varieties from the current RL, RL candidate varieties and selected control varieties were hand sown in tussock plots for evaluation under field conditions to selected isolates. Each trial consisted of two replicates and one trial was used for each of the isolates under test. Prior to inoculation, natural infection was eliminated as far as possible by the use of a seed treatment and follow-up foliar fungicide applications up to and including a T1 application. Plots were directly inoculated as soon as eventual leaf 2 was fully emerged and then re-inoculated at 2-3 day intervals. The wheat yellow rust trials were inoculated seven times and the wheat brown rust trials were inoculated six times. Assessments were made at the onset of disease development on the upper leaves until senescence.

#### **3.1.4. Characterisation of isolates using variety seedlings**

The isolates under evaluation in the field trials were also used in parallel experiments under controlled environment conditions to assess the seedling reaction of the varieties used in the adult plant tests. These tests were inoculated in the same way as previous differential tests, and assessment was carried out using the same average infection type scoring system.

### **3.2. Wheat and Barley Powdery Mildew**

#### **3.2.1. Collection of samples and preparation of isolates**

Infected leaves were received from growers, agronomists and trials operators for the RL trials. Individual pustules taken from the infected samples were mounted on agar and when sporulation was seen the pustules were transferred onto fresh detached leaf sections using the universally susceptible varieties Cerco (wheat mildew) and Golden Promise (barley mildew). Subsequent transfers onto new detached leaves were conducted to maintain the isolate.

Where sample numbers were low, 'mobile trap nurseries' were also deployed. Pots of Cerco and Golden Promise were sown in controlled environment rooms and then given to NIAB staff living near arable areas to place in their gardens for up to 14 days, and then returned to the lab where individual pustules were harvested and maintained as normal.

#### **3.2.2. Characterisation of isolates using differential tests**

Seedlings of the differential set were inoculated with spores from the new isolates. The differentials used and the resistance genes they carry are listed in Table 16 and Table 18. Each differential was represented by 4 detached leaf sections, giving four replicates. This was to ensure the maximum amount of information obtained using the small amount of spores available. Approximately 14 days post inoculation the detached leaves were scored using a 0-4 scale. The score for each of the four detached leaf sections was then averaged to give the final score for each differential. A score of 0-2.5 indicates an incompatible (avirulent reaction) and a score of 2.75-4 indicates a compatible reaction and the isolate was virulent on that differential.

#### **3.2.3. Characterisation of isolates using adult plant field trials**

No adult plant field trials were carried out as part of the UKCPVS mildew survey.

## 4. Results and Discussion

### 4.1. Wheat Yellow Rust

#### 4.1.1. Samples Received

In 2016 the UKCVPS received 340 samples of wheat yellow rust from 29 different counties across the UK (Figure 1).



Figure 1: Map of the UK with the number of samples of wheat yellow rust received in 2016 from the different counties. Two samples were from an unknown location.

There was a very high pressure from the disease throughout the season, starting in autumn 2015 where mild conditions allowed the disease to move swiftly through crops which were generally susceptible at the seedling stage. In early 2016, the UKCPVS received many reports from growers and agronomists concerned by levels of disease seen in the variety Reflection. Previous results from the UKCPVS in 2016 showed that this variety was known to be susceptible at the seedling stage to some races (Hubbard, Pritchard, and Holdgate 2016) and the moderate resistance rating of this variety suggested it may be within the expected levels. However, as the season progressed, much higher levels of disease were

seen on this and other varieties, such as Britannia, Myriad, Leeds and Zulu, prompting a large number of samples to be sent to the survey from across the UK. In total, samples were received from 80 different varieties consisting of current and past RL varieties, spreader plots and other breeding lines. The full sample register is provided in Appendix 1. It is important to note that the host varieties in the sample register have not all been confirmed and it is entirely possible that a sample listed as coming from a resistant variety may turn out to be from another more susceptible variety. For this reason the sample register is included as an indicator of what was received but should not be used to infer any breakdowns in resistance or changes in rating at this stage.

#### **4.1.2. Pathotyping of isolates**

##### **4.1.2.1. Virulence for individual resistance genes and varieties**

Thirty seven isolates were selected for further pathotyping (Table 3). The isolates were selected based on their county of origin and the resistance rating of the host. Given the extensive reports received during the season of higher than expected levels of yellow rust on some varieties, several samples from these varieties were also included for analysis. Isolates were assessed for their reactions on a differential set and their reactions, expressed as an average infection type (a.i.t.), were recorded. Isolates were classified as virulent if the a.i.t. score was 2.7 or above. Scores between 2.4 and 2.7 were considered borderline. Using these scores it was possible to combine the scores for reactions to different resistance genes to infer a pathotype for each of the isolates (Table 4). No new virulences to individual genes were detected in the isolates collected in 2016 using the differentials tested at the seedling stage and frequency of virulence to the individual resistance genes remained relatively stable for known resistance genes in comparison to previous years (Table 5). Virulence for *Yr7* was at a similar level to that found in 2014. This was slightly unexpected as it was thought that the Invicta race (Blue 7) could be behind some of the changes seen in the field during the summer of 2016. Had this been the case the frequency would have been expected to remain similar to or lower than the 2015 frequency. Virulence for *Rendezvous* was at a much higher level than in recent years. This could be explained by the presence of the Blue 7 race; however the lower frequency of virulence for *Yr7* suggests that this may not provide a full explanation. In some of the tests unusual results were reported, for example in the isolate 16/289, where unexpected virulence combinations were seen. In this example, virulence for *Yr8* was seen, which would indicate the Kranich race, however, virulence for

Table 3: Average infection type (a.i.t.) scores for the 37 selected isolates against the UKCPVS differential set. Yellow shading indicates a compatible reaction; orange shading indicates a borderline reaction. Compatible interactions classify the isolate as virulent against a particular resistance gene or variety. Numbers next to the differential variety names indicate the known resistance genes carried by the variety. \* = missing data.

Isolate code	Host	1	1	2	3a, 4a	3b,4b	4,Su	5	6	2,6	2,6,25	7	7,22,23	6,7	7,17	8	8,19	9	2,9,25	10	15	17	17	17	24	2,25	25,Sd	27	27	32	25,32	Sp	Sp	Ro	So	Wa	St		Am						
		Avocet Yr1	Chinese 166	Kalyansona	Vilmorin 23	Hybrid 46	Suwon Omar	Avocet Yr5	Avocet Yr6	Heines Kolben	Heines Peko	AV x Yr 7 NIL	Lee	Cadenza	Apache	Av x Yr8 NIL	Compair	Avocet Yr9	Clement	Moro	AVS x yr15	VPM 1	Rendezvous	AV x Yr17	Avocet Yr24	Heines VII	Strubes Dickkopf	Opata	Avocet Yr27	Av x Yr32	Carstens V	Avocet Sp	Spaldings Prolific	Robigus	Solstice	Warrior	KWS Sterling	Claire	Ambition	Crusoe	Avocet S	Vuka	Kranich	Evolution	
16/009	Reflection	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	2.9	3.0	2.9	0.0	0.0	4.0	3.0	0.0	0.0	3.0	3.0	3.5	0.0	3.0	3.0	-	3.0	2.9	3.0	3.0	3.0	3.0	3.0	3.0	2.1	2.1	2.0	1.8	0.0	3.0	3.5	0.1	0.1
16/013	Revelation	*	3.0	3.0	3.0	3.0	*	0.0	3.0	3.0	3.0	2.2	3.0	3.0	2.1	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.0	3.0	0.0	3.0	3.0	2.9	3.0	3.0	3.0	3.0	3.5	3.5	3.0	2.1	1.6	3.0	1.9	0.0	3.0	4.0	0.1	2.4	
16/019	KWS Target	4.0	3.0	4.0	4.0	3.0	3.0	0.0	4.0	4.0	3.0	4.0	3.0	3.0	2.9	0.0	0.0	3.2	3.0	0.0	0.0	3.2	3.0	3.5	0.0	4.0	3.0	2.8	3.5	3.0	3.0	3.5	4.0	4.0	3.8	3.0	2.6	4.0	2.1	0.0	3.2	3.5	0.0	*	
16/035	Reflection	4.0	4.0	4.0	4.0	3.0	1.5	0.0	3.2	4.0	4.0	3.0	3.0	3.2	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.5	0.0	3.1	3.0	3.0	4.0	4.0	3.1	3.0	3.0	4.0	3.5	2.7	2.7	3.0	2.9	0.0	3.3	4.0	0.4	*	
16/048	Myriad	3.0	3.1	3.1	4.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	2.4	0.0	0.0	3.0	3.0	0.0	0.0	4.0	3.0	3.0	0.0	4.0	4.0	2.3	3.0	4.0	3.0	3.0	3.0	4.0	4.0	2.8	2.0	4.0	3.0	0.0	4.0	4.0	0.0	*	
16/052	Breeding Line	3.0	3.0	4.0	4.0	3.0	-	0.0	3.0	3.0	3.0	3.0	3.0	3.2	3.0	0.2	0.0	3.2	3.0	0.0	0.0	3.1	2.8	3.0	0.0	3.5	3.0	2.0	3.1	4.0	3.0	4.0	3.0	4.0	3.0	2.9	3.0	3.0	2.8	0.3	3.4	4.0	1.2	*	
16/108	Invicta	3.5	3.0	3.5	3.0	3.0	3.0	0.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	4.0	3.0	0.0	0.0	3.1	3.0	3.0	0.0	4.0	3.1	3.0	4.0	3.0	3.5	3.0	4.0	4.0	4.0	2.2	2.0	3.5	2.9	0.0	3.5	4.0	0.2	*	
16/109	Monterey	3.0	3.5	4.0	4.0	3.0	3.0	0.0	3.5	3.0	3.0	3.1	3.0	3.0	3.0	0.2	0.0	3.1	3.1	0.0	0.0	3.5	3.0	3.2	0.0	3.5	3.0	3.0	3.1	3.0	3.0	3.2	3.5	3.5	4.0	2.5	3.0	3.0	2.8	0.0	3.0	4.0	0.0	*	
16/131	Amplify	3.0	3.0	3.0	3.5	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.9	3.0	0.0	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.5	2.9	3.0	3.0	3.0	0.0	3.0	4.0	1.8	*	
16/135	Cordiale	3.0	3.0	4.0	3.5	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.9	3.0	0.0	3.0	3.0	2.0	3.0	3.5	3.0	3.5	3.0	4.0	3.3	2.2	3.0	3.0	2.9	0.0	4.0	4.0	0.0	*	
16/144	KWS Gator	2.9	3.0	4.0	4.0	3.0	3.0	0.0	3.0	3.2	3.0	3.5	3.5	3.0	2.2	0.0	0.0	3.0	2.9	0.0	0.0	4.0	2.9	3.0	0.0	4.0	3.9	3.0	4.0	4.0	3.2	4.0	4.0	3.3	3.0	2.4	1.4	3.0	2.9	0.0	3.5	4.0	0.3	*	
16/158	KWS Kerrin	*	3.0	3.1	3.0	3.0	3.0	0.0	2.8	3.0	3.0	3.0	1.7	0.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.9	3.0	0.0	3.0	3.0	3.0	0.0	3.5	3.0	0.0	0.0	3.5	3.0	0.0	0.0	3.0	2.0	0.0	3.0	4.0	0.1	3.0	
16/174	RGT Illustrious	3.0	3.0	3.0	3.1	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	2.2	0.0	0.0	4.0	3.0	0.0	0.0	3.0	3.0	3.0	0.0	3.1	3.0	2.8	3.0	4.0	3.5	3.0	3.5	4.0	4.0	2.8	2.8	3.0	3.0	0.3	3.0	4.0	0.1	*	
16/184	Zulu	3.0	3.0	3.5	3.5	3.0	3.0	0.0	2.8	3.0	3.0	2.0	0.3	0.2	0.1	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.0	0.0	3.0	3.0	2.4	0.0	3.0	3.0	0.2	0.0	3.0	3.0	1.4	0.0	3.0	0.0	0.3	3.0	3.0	1.0	*	
16/187	Cordiale	3.1	3.1	3.2	3.2	3.0	2.5	0.0	3.0	3.2	3.0	3.1	3.0	3.0	2.5	0.0	0.0	3.1	3.0	0.0	0.0	3.2	3.0	3.0	0.0	4.0	3.2	2.7	3.0	3.0	3.1	3.1	2.4	3.3	3.0	2.1	0.0	3.0	3.0	0.0	3.0	3.5	1.1	*	
16/189	Spyder	3.0	3.0	3.1	3.0	3.0	3.0	0.0	3.0	3.0	3.0	2.0	0.1	0.0	0.0	1.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.0	0.0	3.0	3.5	2.0	0.3	3.0	3.1	0.2	0.0	4.0	3.0	1.9	0.0	3.0	2.1	2.0	3.0	4.0	0.0	*	
16/199	Scout	3.0	3.0	3.0	3.0	3.0	2.8	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.9	3.0	0.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	4.0	3.5	2.0	0.6	3.0	3.0	0.2	3.5	3.5	0.0	*	
16/204	Icon	3.0	3.0	3.5	3.5	2.0	3.0	0.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	3.2	3.1	0.0	0.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.5	3.0	3.0	3.0	3.0	3.5	3.0	2.5	2.8	3.0	3.0	0.0	4.0	4.0	0.3	*	
16/205	KWS Croft	3.0	3.0	4.0	3.5	3.0	3.0	0.0	3.0	3.0	3.0	3.0	2.8	2.8	2.9	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.9	3.0	0.0	3.0	2.9	2.9	3.0	3.0	3.0	3.0	3.0	4.0	3.0	2.0	1.5	3.0	2.6	0.0	3.0	3.5	1.4	*	
16/208	RGT Marlborough	3.0	3.1	3.0	3.0	3.0	3.0	0.0	3.0	4.0	3.0	3.0	0.4	0.0	0.0	0.0	0.0	4.0	3.1	0.0	0.0	4.0	3.0	3.0	0.0	3.0	3.5	-	1.2	3.2	3.0	0.4	0.6	3.0	3.0	0.4	1.8	3.0	0.6	0.0	3.1	4.0	0.0	3.0	
16/225	Relay	3.0	3.1	3.1	3.5	3.0	3.0	0.0	2.9	3.0	3.0	3.0	2.7	3.0	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.3	3.5	0.0	3.0	3.0	3.0	3.5	3.0	3.0	3.2	4.0	4.0	3.5	2.3	1.4	3.0	2.5	0.0	4.0	4.0	0.0	*	
16/227	Evolution	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	2.8	2.0	2.9	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.1	2.3	3.0	0.0	3.0	3.0	3.0	3.1	3.0	3.0	3.0	3.0	4.0	3.0	2.0	2.7	3.0	2.9	2.0	3.5	3.5	1.3	*	
16/230	KWS Gator	3.0	3.0	3.0	3.0	3.0	2.5	0.0	3.0	3.0	3.0	3.0	2.0	3.0	2.9	0.0	0.2	3.0	3.0	0.0	0.0	3.1	2.1	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.4	2.1	3.0	3.0	0.0	3.0	3.0	0.6	*



Isolate code	Host																																												
		Avocet Yr1	Chinese 166	Kalyansona	Vilmorin 23	Hybrid 46	Suwon Omar	Avocet Yr5	Avocet Yr6	Heines Kolben	Heines Peko	AV x Yr 7 NIL	Lee	Cadenza	Apache	Av x Yr8 NIL	Compair	Avocet Yr9	Clement	Moro	AVS x yr15	VPM 1	Rendezvous	AV x Yr17	Avocet Yr24	Heines VII	Strubes Dickkopf	Opata	Avocet Yr27	Av x Yr32	Carstens V	Avocet Sp	Spaldings Prolific	Robigus	Solstice	Warrior	KWS Sterling	Claire	Ambition	Crusoe	Avocet S	Vuka	Kranich	Evolution	
16/242	RGT Conversion	3.0	3.1	3.1	3.0	3.0	-	0.0	2.8	3.0	2.9	3.0	0.4	0.0	0.0	0.1	0.0	3.0	3.0	0.0	0.0	3.0	3.5	3.0	0.0	3.0	4.0	-	0.0	4.0	4.0	0.1	0.0	3.5	3.0	2.1	0.3	3.0	1.7	0.0	3.0	4.0	0.0	3.0	
16/245	KWS Barrel	3.0	3.1	4.0	4.0	3.0	3.0	0.0	3.1	3.0	3.0	3.0	3.0	3.0	2.3	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.2	3.0	0.0	3.4	3.1	3.0	3.0	4.0	3.2	3.0	3.0	3.4	3.0	3.0	3.0	3.0	3.0	1.1	3.0	4.0	2.0	*	
16/260	Spyder	3.0	3.0	3.0	3.0	3.0	3.0	0.0	2.9	3.0	3.0	3.0	0.3	0.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.0	0.0	3.0	3.0	-	0.0	3.0	3.0	0.0	0.1	3.0	3.0	1.1	0.0	3.0	0.8	0.0	3.0	4.0	0.2	3.0	
16/262	KWS Silverstone	3.2	3.1	3.5	3.5	3.0	3.0	0.0	3.0	4.0	3.0	3.0	2.0	0.1	0.0	0.0	0.0	4.0	3.0	0.0	0.0	3.0	3.0	3.0	0.3	3.0	3.0	-	0.0	3.0	4.0	0.1	0.0	3.0	3.0	0.8	0.0	3.0	0.3	0.0	3.5	3.5	0.4	3.0	
16/271	JB Diego	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	2.5	3.0	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	1.6	3.0	2.9	0.0	3.0	4.0	2.0	*	
16/277	Hereford	3.1	3.0	3.0	3.0	3.0	3.0	0.0	4.0	3.3	3.0	2.2	0.1	0.1	0.0	0.0	0.0	3.0	3.1	0.0	0.0	3.3	3.0	3.0	0.0	3.0	4.0	3.0	3.0	4.0	4.0	3.0	2.9	4.0	4.0	2.8	0.0	4.0	2.9	0.0	3.1	3.5	0.0	*	
16/286	Invicta	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	2.6	3.0	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.7	3.0	0.0	3.1	3.1	3.0	3.5	3.5	3.0	3.0	3.0	4.0	3.0	2.8	2.1	4.0	2.7	0.0	3.0	3.5	0.5	*	
16/288	Deben	3.0	3.0	3.1	3.1	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.1	3.0	3.0	0.0	3.0	3.0	2.5	3.5	3.5	3.0	3.5	3.0	3.5	3.0	2.0	1.8	3.0	3.0	0.0	3.0	3.5	2.6	*	
16/289	Apache	3.0	3.0	3.0	3.0	2.0	3.0	0.0	4.0	3.0	3.0	3.0	3.0	3.0	2.8	3.0	1.0	3.0	3.0	0.0	0.0	3.0	3.0	4.0	0.0	3.0	3.0	2.9	3.0	3.0	3.0	3.2	3.2	4.0	3.0	3.1	3.0	3.0	3.0	0.8	4.0	3.0	3.0	*	
16/290	KWS Target	3.0	3.1	3.5	4.0	3.0	-	0.0	3.5	4.0	4.0	3.0	3.0	3.0	3.0	0.0	0.0	4.0	3.0	0.0	0.0	4.0	3.0	3.5	0.0	3.5	3.4	3.0	4.0	4.0	3.0	4.0	3.1	4.0	4.0	2.8	2.0	3.0	2.8	0.0	4.0	4.0	0.6	*	
16/292	LGW110	3.0	2.0	3.0	3.0	3.0	3.0	0.0	3.0	2.9	2.0	2.0	2.0	3.0	2.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.8	3.0	0.0	3.0	3.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0	2.7	3.0	3.0	2.9	3.0	3.0	3.0	3.0	3.0	*	
16/293	KWS Cashel	3.0	3.0	4.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	2.3	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.2	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	3.0	3.0	0.0	3.0	4.0	0.0	*	
16/299	KWS Kerrin	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	1.9	1.8	0.1	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.0	1.0	3.0	3.0	1.9	3.0	3.0	3.0	3.0	3.0	3.5	3.0	1.9	1.1	3.0	2.3	0.0	3.0	3.5	1.7	*	
16/332	RGT Westminster	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.1	3.1	3.0	3.0	3.0	2.7	1.9	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.5	0.0	3.0	3.0	-	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.4	0.1	2.8	2.2	0.3	3.5	4.0	0.9	0.3

Table 4: Pathotypes of the 2016 wheat yellow rust isolates based on the differential test results in Table 3. Yellow shading indicates virulence of an isolate for a particular resistance gene or variety; orange shading with parentheses indicates a borderline reaction.

Isolate code	Host	Genetic Group <sup>1</sup>	Race number <sup>2</sup>	Virulence Profile <sup>3</sup>																										
				1	2	3	4	5	6	7	8	9	10	15	17	24	25	27	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ap	Cr	Ev
16/009	Reflection	Red	5	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca			Ap		
16/013	Revelation	Red	8	1	2	3	4		6	7		9			17		25		32		Sp	Ro	So		Ca					(Ev)
16/019	KWS Target	Red	23	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	(St)		Ap		*
16/035	Reflection	Red	24	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St		Ap		*
16/048	Myriad	Pink (Path) <sup>4</sup>	13	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca			(Ap)		*
16/052	Breeding Line	Assume Red <sup>5</sup>	24	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St		Ap		*
16/108	Invicta	Red	5	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca			Ap		*
16/109	Monterey	Red	11	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	(Wa)	Ca	St		Ap		*
16/131	Amplify	Red	24	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St		Ap		*
16/135	Cordiale	Red (Path)	11	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca	St		Ap		*
16/144	KWS Gator	Red	21	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	(Wa)	Ca					*
16/158	KWS Kerrin	Blue (Path)	6	1	2	3	4		6	7		9			17		25		32	Re		Ro	So							Ev
16/174	RGT Illustrious	Red	14	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St				*
16/184	Zulu	Blue	1	1	2	3	4		6			9			17		25		32	Re		Ro	So							*
16/187	Cordiale	Red (Path)	21	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca			(Ap)		*
16/189	Spyder	Blue	1	1	2	3	4		6			9			17		25		32	Re		Ro	So							*
16/199	Scout	Red	5	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca			Ap		*
16/204	Icon	Red	11	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	(Wa)	Ca	St		Ap		*
16/205	KWS Croft	Red	5	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca			Ap		*
16/208	RGT Marlborough	Blue	7	1	2	3	4		6	7		9			17		25		32	Re		Ro	So							Ev
16/225	Relay	Red	3	1	2	3	4		6	7		9			17		25		32		Sp	Ro	So		Ca			Ap		*
16/227	Evolution	Blue	11	1	2	3	4		6	7		9			17		25		32		Sp	Ro	So		Ca	St		Ap		*
16/230	KWS Gator	Red (Path)	3	1	2	3	4		6	7		9			17		25		32		Sp	Ro	So	(Wa)	Ca			Ap		*
16/242	RGT Conversion	Blue (Path)	7	1	2	3	4		6	7		9			17		25		32	Re		Ro	So							Ev
16/245	KWS Barrel	Blue	8	1	2	3	4		6	7		9			17		25		32		Sp	Ro	So	Wa	Ca	St				*
16/260	Spyder	Blue	7	1	2	3	4		6	7		9			17		25		32	Re		Ro	So							Ev
16/262	KWS Silverstone	Blue	7	1	2	3	4		6	7		9			17	?	25		32	Re		Ro	So							Ev
16/271	JB Diego	Red	5	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca			Ap		*
16/277	Hereford	Blue	10	1	2	3	4		6			9			17		25		32	Re	Sp	Ro	So	Wa						*
16/286	Invicta	Red	23	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca			Ap		*
16/288	Deben	Red (Path)	5	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca		(Kr)	Ap		*
16/289	Apache	Red	Mix	1	2	3	4		6	7	8	9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ap		*
16/290	KWS Target	Red	23	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca			Ap		*
16/292	LGW110	Pink	14	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St	Kr		Cr	*
16/293	KWS Cashel	Red	14	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St				*
16/299	KWS Kerrin	Blue	9	1	2	3	4		6	7		9			17	?	25		32	Re	Sp	Ro	So							*
16/332	RGT Westminster	Red (Path)	5	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca			Ap		

<sup>1</sup> Genetic group assigned using data from Diane Saunders, John Innes Centre as part of the BBSRC and AHDB funded IPA “Using field pathogenomics to study wheat yellow rust dispersal and population dynamics at a national and international scale”

<sup>2</sup> Race number assigned by the UKCPVS using pathotype data in Table 3.

<sup>3</sup> Numbers refer to previously designated Yr genes, Re = Rendezvous, Sp = Spaldings Prolific, Ro = Robigus, So = Solstice, Wa = Warrior, Am = Ambition, Ca = Cadenza, St = KWS Sterling, Kr = Kranich, Ap = Apache, Cr = Crusoe, Ev = Evolution.

<sup>4</sup> No genotype data available, groups tentatively assigned using pathotype data.

<sup>5</sup> No genotype data available, group assigned based on similar isolates

Table 5: Frequency of detection of isolates carrying virulence to the different yellow rust resistance genes and varieties over the past five years. \* = missing data.

Virulence For Resistance Gene or Variety	Percentage of Isolates Identified with Virulence for Gene or Variety				
	2012	2013	2014	2015	2016
Yr1	100	100	100	100	100
Yr2	100	100	100	97	100
Yr3	100	100	96	100	100
Yr4	100	100	96	97	100
Yr5	*	0	0	0	0
Yr6	100	100	100	100	100
Yr7	100	92	92	76	92
Yr8	0	0	4	3	3
Yr9	100	100	100	100	100
Yr10	*	0	0	0	0
Yr15	0	0	0	0	0
Yr17	100	100	100	97	100
Yr24	*	0	0	0	0
Yr25		92	100	100	100
Yr32	100	100	100	100	100
Rendezvous	25	48	12	38	86
Spaldings Prolific	79	80	88	72	81
Robigus	100	100	100	100	100
Solstice	100	100	85	90	100
Warrior	61	28	23	3	35
Cadenza	79	80	73	55	76
KWS Sterling	29	44	8	24	32
Kranich	*	*	4	7	5
Apache	*	76	65	52	54
Crusoe	0	4	0	0	3
Evolution	*	*	*	*	14
<b>Total Number of Isolates</b>	<b>28</b>	<b>25</b>	<b>26</b>	<b>29</b>	<b>37</b>

Spaldings Prolific and Yr4 were also detected, which are atypical for the Kranich race. Further tests were done on this and similar isolates and it was apparent that there was often more than one race present in a single sample (data not shown). Virulence frequencies for the individual resistance genes and varieties should therefore be interpreted with caution as virulence/avirulence for some differentials may have been masked if there was more than one race present.

#### 4.1.2.2. Virulence frequencies for pathotype groups

Most of the isolates were assigned to different genetic groups using data from the Field Pathogenomics project (Diane Saunders, *pers. comm.*, Table 4). In some cases this information was missing and genetic groups were assigned based on pathotype data or similarity to other isolates. Considering the population by genetic group, the frequencies of isolates found in each group remained similar to that found in 2015 (Table 6). Data is presented for 45 isolates rather than 37 as this broad grouping considers the re-isolations, where multiple races were identified, as well as the original data.

Table 6: Pathotype group frequencies from 2012 to 2016

Pathotype Group	Frequency of Isolates Found (%)				
	2012	2013	2014	2015	2016
Pink	61	28	19	3	4
Blue	0	20	8	28	29
Red	18	52	69	66	64
Purple	0	0	4	3	2
Mix	0	0	0	0	0
<b>Number of isolates</b>	<b>28</b>	<b>25</b>	<b>26</b>	<b>29</b>	<b>45</b>

#### 4.1.2.3. Commonly detected races

In 2016, again considering the data from 45 isolates, there were 21 different pathotypes detected, 16 of which were unique to this year. Three of these were novel due to the addition of Evolution to the differential set, however the remaining 13 pathotypes were novel using the existing differentials. As in previous years, this was not unexpected due to the very diverse nature of the current *Pst* population. Generally, new variants identified have had relatively low impact, with no major changes in the reaction of UK varieties at the adult plant stage. However with changes in the resistance status of multiple varieties during the course of 2016, it was possible that some of these novel combinations may be important. Out of the 21 pathotypes detected this year, there were two pathotypes that dominated.

The most common race, represented by eight isolates, was the race Red 5. This race carried virulence for *Yr1,2,3,4,6,7,9,17,25,32,Re,Sp,Ro,So,Ca,Ap* and has been seen before in 2013 and 2014 at very low levels (2 and 1 isolate respectively). The isolates of this race were collected from the varieties Reflection, Invicta, Scout, KWS Croft and JB Diego and were found mainly in East Anglia with the exception of one isolate that was found in Gloucestershire. This race is similar to the most commonly found race in 2016, Red 3, with the difference being that Red 5 carries additional virulence for *Rendezvous*. This could explain the increased frequency of detection of virulence for this variety discussed in 4.1.2.1.

The second most common race was Blue 7, also previously named the Invicta race. This race carried virulence for *Yr1,2,3,4,6,9,17,25,32,Re,Ro,So,Ev* and was identified in six samples. The isolates from this group were collected from the varieties Zulu, Spyder (two isolates), RGT Marlborough, RGT Conversion and KWS Silverstone and came from East Yorkshire, Northumberland, Cambridgeshire and Hampshire (three samples). We believe that this race is the same as the race Blue 1 that was detected at a high frequency last year. The difference between the two races is virulence for the variety Evolution, a variety only added to the differential set part way through the 2016 testing season.

There were three other races identified in 2016 that were particularly interesting to the UKCPVS. Races Red 23 and Red 24 both carried virulence for *Yr1,2,3,4,6,7,9,17,25,32,Re,Sp,Ro,So,Wa,Ca,Ap*, and Red 24 also carried virulence for KWS Sterling. Between them, six samples contained these two races and were identified on the varieties KWS Target (two samples), Reflection, an anonymous breeding line, Amplify and Invicta. They were found across the country in Bedfordshire, Gloucestershire, Oxfordshire and Lincolnshire (three samples). This was a novel pathotype for this year and is the first race that is in the Red genetic group but carries virulence for *Warrior*. Historically, isolates in the red group have been in the so-called “Warrior” group – so this new additional virulence is very interesting. Finally, one sample was obtained of the race Pink 14. This had a novel and very complex pathotype with virulence for *Yr1,2,3,4,6,9,17,25,32,Re,Sp,Ro,So,Wa,Ca,St,Kr,Cr*. Virulence for *Crusoe* in the seedling differential tests is rare and this isolate could therefore be very interesting under field conditions.

An isolate from the purple group (Kranich) was detected only once in 2016, which followed the pattern of previous years that this group was only present at a low frequency. Given the

high levels of disease in the adult plant trials in 2015 with this race (A. Hubbard et al. 2015), it is surprising that this race is not found more often.

#### **4.1.3. Variety testing of isolates from 2016**

Five isolates were selected for further testing on the wider set of RL varieties and candidates (Table 7). The isolates were selected to best represent the results of the 37 tested isolates choosing isolates with the most complex virulence profiles where possible. The race Red 11 was selected to represent the most commonly found race last year, Red 5. The difference between these races is that Red 11 has additional virulence for KWS Sterling. Races Blue 7, Red 24, Pink 14 were all noted to be of interest (Section 4.1.2.3) and isolate 15/601, an isolate of the Kranich race (Purple 3) is a repeat test from 2015 where natural infection hindered the trial.

##### **4.1.3.1. Seedling Tests**

The five selected isolates were tested in seedling tests containing RL and candidate varieties in the controlled environment rooms at NIAB in the summer of 2017. Results are combined with the adult plant test results (Table 8) and are sorted by the reaction on the adult plant trials (see 4.1.3.2). In general, there was good agreement between the control differentials included in this test and the original differential test results. The only isolate of the Pink 14 race, 16/292, was unfortunately not available for testing in the wider variety tests. Another isolate was obtained from one of the UKCPVS collaborators and this isolate was immediately bulked for use in the trials and seedling test. In order to ensure trials were inoculated at the optimal stage, this isolate was not tested on a differential test. It was assumed to carry similar virulences to the isolate 16/292. For the majority of differential controls, the results were consistent with the Pink 14 race; however the isolate differed slightly as it appeared to carry virulence for *Yr7* and was avirulent on KWS Sterling. Therefore, isolate 16/342 was named the Pink 15 race. Only three of the RL varieties and candidates tested were resistant to all of the isolates tested: Costello, KWS Crispin and KWS Siskin. There were no varieties that were susceptible this year that had been resistant in previous years. Varieties that are only occasionally susceptible at the seedling stage include Cougar, Crusoe, Evolution, and Moulton. Virulence for Cougar was detected in a test using a mixed isolate in 2016, but no virulence was detected in any of the tests this year. Virulence for Crusoe was detected previously in tests where the isolates from the Purple group have been used.

Table 7: Virulence profile of the isolates chosen for further characterisation in seedling and adult plant tests. Re = Rendezvous, Sp = Spaldings Prolific, Ro = Robigus, So = Solstice, Wa = Warrior, Am = Ambition, Ca = Cadenza, St = KWS Sterling, Kr = Kranich, Ap = Apache, Cr = Crusoe, Ev = Evolution. Yellow shading = compatible reaction (virulence), blank = avirulence, \* = missing data.

Isolate code	Host	Group	Race number	Virulence Profile																										
				1	2	3	4	5	6	7	8	9	10	15	17	24	25	27	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ap	Cr	Ev
16/035	Reflection	Red	24	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So	Wa	Ca	St		Ap		*
16/135	Cordiale	Red (Path)	11	1	2	3	4		6	7		9			17		25		32	Re	Sp	Ro	So		Ca	St		Ap		*
16/189	Spyder	Blue	7	1	2	3	4		6			9			17		25		32	Re		Ro	So							Ev
16/342	LGW110 <sup>1</sup>	Pink	14	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
15/601	Monterey	Purple	3	1	*	3			6	7	8	9			17		25		32			Ro	So	Wa	Ca	St	Kr	Ap	Cr	*

<sup>1</sup> No differential test data available for the isolate 16/342. It was believed to have the same virulence profile as the isolate 16/292 (virulence for Yr1,2,3,4,6,9,17,25,32,Re,Sp,Ro,So,Wa,Ca,St,Kr,Cr.), however this had not been confirmed by the UKCPVS.

Table 8: Seedling and adult plant reactions to the five isolates selected for further characterisation. Seedling results are shown as average infection types on a scale of 0-4. Adult plant results are given as a percentage leaf area infected averaged over four assessments. Varieties are ordered in level of disease at adult plant stage. Control varieties are highlighted in green text.

Variety	RL Rating 2017/18	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		16/135	16/035	15/601	16/342	16/189	16/135	16/035	15/601	16/342	16/189
Revelation	9	0.3	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.2
KWS Crispin	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KWS Jackal	Candidate	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0
KWS Trinity	9	1.8	2.4	0.9	1.9	3.0	0.0	0.0	0.0	0.0	0.0
Hardwicke	8	0.2	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.5
RGT Illustrious	9	2.1	1.6	2.9	1.9	2.9	0.0	0.0	0.0	0.0	0.0
KWS Luther	Candidate	2.8	3.0	3.0	2.9	3.1	0.0	0.0	0.0	0.5	0.2
Dickens	9	3.0	3.0	3.0	2.9	3.0	0.0	0.0	0.2	0.0	0.0
LG Motown	9	3.0	3.1	3.0	2.7	3.0	0.0	0.1	0.0	0.0	0.0
RGT Universe	Candidate (7)	2.5	3.0	3.0	3.0	3.0	0.0	0.1	0.3	0.1	0.7
Crusoe	9	1.0	1.0	3.0	3.0	0.3	0.0	0.2	0.0	0.0	0.0
Elation	Candidate (8)	3.0	3.0	3.0	3.0	3.5	0.0	0.3	0.1	0.0	0.0
KWS Siskin	9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Costello	9	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
Elicit	Candidate (9)	3.0	3.0	3.0	3.0	3.2	0.0	0.8	0.0	0.0	0.0
KWS Bassett	8	3.0	3.5	3.0	3.0	3.1	0.0	0.8	0.0	0.0	1.5
LG Sundance	9	3.0	3.0	3.0	3.0	3.0	0.0	0.8	0.6	0.1	0.0
KWS Barrel	8	3.0	3.0	3.0	3.0	3.0	0.0	0.1	0.0	0.1	0.0
Napier		3.0	2.9	3.0	3.0	3.0	0.1	0.0	0.3	0.5	1.6
Shabras	8	3.0	3.0	3.0	2.7	3.0	0.1	1.3	0.1	0.0	1.0
Cougar		0.0	0.8	0.0	1.4	0.0	0.1	0.0	0.0	0.2	0.0
KWS Santiago	6	3.0	3.0	3.0	3.0	3.0	0.1	0.0	0.7	0.5	0.7
Graham	8	2.6	3.0	3.0	3.0	3.1	0.2	0.0	0.7	0.0	0.0
Mulika		3.0	3.0	3.0	3.0	0.0	0.4	0.0	0.1	0.3	0.0
RGT Gravity	Candidate (8)	2.2	3.0	1.8	1.5	3.0	0.0	2.0	0.1	0.0	0.1
KWS Gator		2.4	3.0	2.2	2.2	3.0	0.0	7.2	0.4	0.0	0.7
Evolution	8	0.0	2.8	2.1	1.3	3.0	0.0	0.1	0.1	4.5	0.0
Rendezvous		3.0	3.0	3.0	3.0	3.0	0.0	0.3	0.0	0.0	1.7
Delphi		3.0	3.1	3.0	3.0	3.0	0.0	1.4	0.0	0.0	2.1
Savello	8	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	2.8
Brock		3.0	2.8	3.0	3.0	0.1	2.6	2.4	0.3	1.0	0.0



Variety	RL Rating 2017/18	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		16/135	16/035	15/601	16/342	16/189	16/135	16/035	15/601	16/342	16/189
KWS Lili	7	3.0	3.0	2.9	2.9	3.0	4.2	2.2	0.1	0.3	0.3
Hustler		*	*	*	*	*	2.0	0.7	3.9	0.0	0.2
KWS Zyatt	7	3.0	3.0	3.0	3.0	0.0	1.8	0.2	0.3	5.8	0.1
KWS Kerrin	7	2.8	3.0	2.1	2.0	3.0	0.0	2.1	0.1	0.0	3.2
Dunston	7	2.9	3.0	3.0	3.0	3.1	0.1	2.3	0.1	0.0	7.7
Moulton	8	1.6	2.7	1.2	1.9	3.1	0.0	2.8	0.2	0.0	11.6
Viscount	6	3.5	3.5	3.0	3.5	3.5	1.5	5.2	0.2	0.1	4.4
KWS Silverstone	7	2.1	2.9	0.9	1.3	3.0	0.2	4.0	0.4	0.5	10.1
LG Generation	Candidate	3.0	3.0	3.0	3.0	3.0	1.1	11.0	1.4	0.1	2.5
Bennington	7	3.0	3.0	1.4	2.0	3.0	0.2	7.2	0.3	0.0	12.4
Verso	Candidate (7)	2.9	3.0	2.0	2.3	3.1	0.2	7.5	0.1	0.3	18.8
Freiston	9	3.0	3.0	3.0	1.5	3.1	0.6	1.4	3.5	3.7	0.1
Kranich		1.8	1.5	3.0	3.0	0.0	0.1	0.8	6.8	13.6	0.0
Brigadier		3.0	2.4	3.0	3.0	3.0	0.2	0.1	10.0	0.0	13.0
Spyder	6	3.0	3.0	3.0	3.0	3.1	0.2	1.0	1.1	7.7	3.1
Grafton	6	3.0	3.0	2.4	3.0	0.0	6.9	4.6	3.6	0.6	0.0
Hobbit		*	*	*	*	*	4.4	7.0	1.1	1.7	0.9
Zulu	5	2.7	3.0	2.8	2.9	3.0	2.6	11.8	0.4	0.2	7.2
KWS Sterling		2.8	2.1	2.2	1.3	0.0	2.8	0.2	4.4	15.2	0.0
Cadenza		3.0	2.3	2.2	2.8	0.1	6.6	0.2	3.0	7.2	0.2
Gleam	Candidate (7)	2.8	3.0	2.9	2.5	3.0	0.2	4.5	6.6	0.2	5.5
Belgrade	6	1.8	3.0	3.0	2.1	3.1	0.4	1.9	8.7	0.5	3.5
Compair		0.0	0.2	3.0	0.0	0.0	1.0	5.4	1.3	2.6	4.8
Leeds	6	3.0	3.0	2.2	2.9	3.0	0.2	1.4	2.3	3.5	5.2
JB Diego	5	3.0	2.6	2.0	3.0	3.0	3.1	17.7	6.2	0.4	5.9
Myriad	4	2.6	3.0	2.4	2.8	3.0	4.7	15.3	3.6	0.1	8.5
Claire	5	3.0	3.0	2.3	3.0	3.0	2.8	7.3	8.5	4.1	0.9
Warrior		2.3	2.3	3.0	3.0	1.3	5.8	3.6	10.3	2.8	0.6
Apache		3.1	3.0	3.0	3.0	0.0	4.8	2.2	9.9	10.0	0.1
Talon		3.0	3.0	3.0	3.0	3.0	8.9	3.0	21.0	12.4	0.1
Ambition		2.8	3.0	3.0	3.0	0.0	9.0	5.1	12.7	22.6	0.4
Cordiale	4	3.0	3.0	2.3	3.0	0.1	12.5	8.7	5.7	11.5	0.0
Skyfall	6	3.0	3.0	1.4	2.2	0.0	13.6	9.0	7.5	9.3	0.3
Britannia	4	3.1	3.0	3.0	3.0	3.0	1.8	13.0	5.0	2.9	7.4
Reflection	3	3.0	3.0	3.0	3.0	3.0	1.8	16.2	8.6	4.1	4.2

Variety	RL Rating 2017/18	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		16/135	16/035	15/601	16/342	16/189	16/135	16/035	15/601	16/342	16/189
Invicta		3.0	3.0	3.0	3.0	3.0	2.0	18.0	15.1	1.8	15.6
KWS Target		*	*	*	*	*	4.6	16.0	10.6	5.3	21.4
Torch		3.0	3.0	3.0	3.0	3.0	14.7	11.0	35.8	31.3	14.1
Robigus		3.0	3.0	3.0	3.0	3.0	19.7	10.3	22.1	17.0	25.0
Hornet		3.0	3.0	3.0	3.5	3.1	20.1	6.7	10.7	10.7	12.9
Chinese 166		2.9	3.0	3.0	3.0	3.0					
Kalyansona		3.0	3.0	3.0	3.0	3.0					
Nord Desprez		3.0	3.1	3.0	3.0	3.0					
Hybrid 46		3.0	3.0	1.3	3.0	3.0					
Avocet Yr5		0.0	0.0	0.0	0.0	0.0					
Avocet Yr6		3.0	3.0	3.0	3.0	3.0					
Heines Peko		3.0	3.0	3.0	3.0	3.0					
Avocet Yr7		3.0	3.0	2.3	3.0	3.0					
Lee		2.7	3.0	3.0	3.0	2.3					
Avocet Yr8		1.0	2.0	2.4	0.1	0.0					
Clement		3.0	3.1	3.0	3.0	3.0					
Kavkaz x 4 Fed		3.0	3.0	3.0	3.0	3.0					
Moro		0.0	0.0	0.0	0.0	0.0					
Avocet Yr15		0.0	0.0	0.0	0.0	0.0					
VPM 1		3.0	3.1	3.0	3.0	3.0					
Avocet Yr17		3.0	3.0	3.0	3.0	3.0					
Carstens V		3.0	3.0	3.0	2.9	3.0					
Avocet Yr32		3.0	2.0	3.0	3.0	3.0					
Spaldings Prolific		3.0	2.8	0.0	3.0	0.0					
Solstice		3.0	3.0	3.1	3.0	2.8					
Average L.S.D. (Mean)							4.51	8.91	6.86	5.72	6.56

As expected, virulence for Crusoe was repeated this year using an isolate of the Purple 3 race, and in addition Crusoe was susceptible to the rare Pink 15 race. Virulence for Evolution was detected for the first time last year in response to the Blue 7 race. Similar results were seen this year and it was also susceptible to the new Red 24 race. The Red 24 race caused disease on the highest number of varieties tested (63 out of 77 varieties tested) and this highlights the difference between this race and others detected from the Red group in previous years. This is the second year that the UKCPVS had worked with the Blue 7 race and results from the two years showed good agreement. Results from tests with the isolates from the Purple group are a little more variable in their agreement between years.

#### **4.1.3.2. Adult plant tests**

Alongside the seedling tests, the five isolates were also evaluated in the UKCPVS adult plant trials at NIAB in the summer of 2017 which contained RL and candidate varieties. A new method of inoculation was trialled for the first time, where plots were treated with fungicides up to and including the T1 application. Leaf two and the flag leaf were then inoculated directly to ensure that only the isolates under investigation were present. The first inoculation was carried out on the 11<sup>th</sup> May and the first assessment was made on 7<sup>th</sup> June when the plants were at GS61. The percentage of leaf area infected was assessed and the mean was calculated from four assessments. Samples were taken from the trials and analysed using a subset of differentials to confirm that the trials were infected with the races used for inoculation (Table 9). In combination with results from the control varieties included in the trials, the results suggested that the trials were generally infected with the correct races. The exception to this was the trial inoculated with the Purple 3 race. This trial was not as well established as the others and suffered from pest damage early in the season which may have impacted on the efficacy of the fungicide treatments and/or the timings of inoculation. The trials produced lower levels of disease in comparison to previous years due to the delayed epidemic as a result of the new method used. As expected, the susceptible controls Torch and Robigus produced the highest levels of disease with up to 35% as an average of the percentage leaf area infected assessments. Out of the 48 RL varieties and candidates under evaluation, 21 were resistant to all isolates tested. One of these was the previously susceptible variety KWS Santiago and this agreed with data from previous years. Only three varieties were susceptible to all isolates tested: Robigus, Torch and Hornet. The remaining varieties showed different levels of disease depending on the isolate used, with evidence of clear variety x race interactions.

Table 9: Pathotypes of isolates taken from the inoculated trials. The pathotypes of the isolates used for inoculation are included for comparison.

Isolate code	Host	Group	Race number	Lee	Avocet Yr7	Compair	Avocet Yr8	Avocet Yr17	Rendezvous	Spaldings Prolific	Warrior	KWS Sterling	Crusoe	Evolution <sup>1</sup>
16/035	Reflection	Red	24	3.0	3.0	0.0	0.0	3.5	3.0	3.0	2.7	2.7	0.0	2.8
17/503	JB Diego			3.0	3.0	0.0	0.0	3.0	3.5	3.0	2.7	3.0	0.0	3.0
16/135	Cordiale	Red (Path)	11	3.0	3.0	0.0	0.0	3.0	2.9	3.0	2.2	3.0	0.0	0.0
17/502	Robigus			3.0	3.1	0.0	0.0	3.0	3.0	3.0	2.3	3.1	0.2	2.2
16/189	Spyder	Blue	7	0.1	2.0	0.0	1.0	3.0	3.0	0.0	1.9	0.0	2.0	3.0
17/512	Gleam			2.0	3.0	0.0	0.0	3.0	3.0	0.0	2.0	0.3	0.1	3.5
16/342 <sup>2</sup>	LGW110	Pink	15	3.0	3.0	0.0	0.1	3.0	3.0	3.0	3.0	1.3	3.0	1.3
17/510	Robigus			3.0	3.0	0.0	0.0	3.0	3.0	3.0	3.0	2.6	3.0	2.3
15/601	Monterey	Purple	3	3.0	3.0	2.6	3.0	2.4	2.2	0.0	3.0	2.7	2.9	2.1
17/506	Invicta			3.0	3.0	0.0	0.0	3.0	3.5	3.0	1.9	1.9	0.3	3.0

<sup>1</sup> Evolution not included in the original differential test for these isolates, data is therefore presented from the variety test results shown in Table 8.

<sup>2</sup> No differential test data available for isolate 16/342, therefore data from the variety seedling test presented as a comparison.

The trial inoculated with isolate 16/189, the Blue 7 race showed good levels of disease, with the most susceptible variety (Robigus), showing an average percentage leaf infected score of 25%. There were low levels of specific variety x race interactions for three varieties in trial: Rendezvous, Delphi and Savello. Disease levels were low in these varieties (1.7-2.8%) and not significantly different from 0% (L.S.D. = 6.56%), however, for the other trials these varieties generally showed no or trace amounts of disease. From the remaining varieties, 24 were susceptible to this race to varying degrees.

The Red 24 race was of interest to the UKCPVS due to the interesting pathotype recorded. New for 2016, this was the first isolate from the red group that had virulence for the variety Warrior. Two varieties showed a specific reaction to this race: RGT Gravity (2.0%) and KWS Gator (7.2%). Neither of these scores are significantly different from 0% (L.S.D. = 8.91%), however, as in the Blue 7 trial, the varieties were generally clean or had trace levels of disease in the other trials. This is the first report of susceptibility of KWS Gator in the UKCPVS trials and could explain some of the higher than expected disease reports received during 2016. Finally, a specific reaction to the Pink 15 race was seen in two varieties: Evolution (4.5%) and KWS Zyatt (5.8%). With a trial L.S.D. of 5.72%, the score for Evolution is not significantly different from 0%; however it stands out due to the absence of disease on this variety in all of the other trials.

The individual race x variety interactions failed to explain some of the changes seen in varietal performance in the 2016 season. When considering all of the data from all of the trials it is clear that the varieties most notably affected last year were in fact susceptible to two of the new races to varying degrees. The varieties KWS Kerrin, Dunston, Moulton, Viscount, KWS Silverstone, LG Generation, Bennington, Verso, Britannia, JB Diego, Myriad, Reflection and Zulu were all notably more susceptible to both the Blue 7 and Red 24 races compared to other races under investigation. Britannia for example was very susceptible to the Red 24 race (13.0%) but was also susceptible to the Blue 7 race (7.4%). The difference in disease levels between these trials could explain why the variety may have looked worse in some trials and demonstrations than others and highlight the importance of considering data from as wide a geographic area as possible to judge varietal performance. The variety Spyder also saw a change in disease rating last year. This variety was most susceptible to the Pink 15 race (7.7%) but also showed some susceptibility to the Blue 7 race (3.1%). Given that the Pink 15 race is currently very rare, it is most likely that the changes seen in this variety last year were as a result of the Blue 7 race.

## 4.2. Wheat Brown Rust

#### 4.2.1. Samples Received

In 2016, the UKCVPS received 33 samples of wheat brown rust from 12 different counties across the UK (Figure 2).

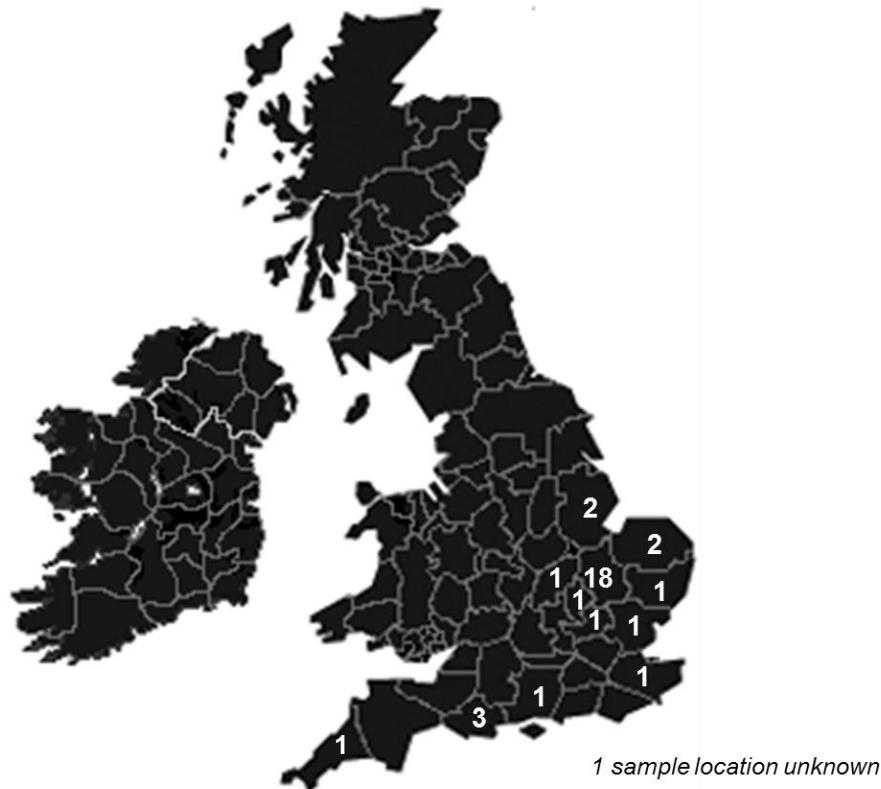


Figure 2: Map of the UK with the number of samples of wheat brown rust received in 2016 from the different counties.

The full sample register is provided in Appendix 1. As in 2014 and 2015, high levels of disease were seen in the variety Crusoe; however no further reports of unusual levels of disease were received by the UKCPVS. Samples were received from 21 different varieties, with the most frequent variety being Crusoe. The host varieties in the sample register have not all been confirmed and it is entirely possible that a sample listed as coming from a resistant variety may turn out to be another more susceptible variety. For this reason the sample register is included as an indicator of what was received but should not be used to infer any breakdowns in resistance or changes in rating at this stage.

#### **4.2.2. Pathotyping of isolates**

Twenty five isolates were selected for further pathotyping (Table 10). The isolates were selected based on their county of origin and the resistance rating of the host. Isolates from known susceptible varieties were also selected to investigate whether the same or similar isolates are found on different varieties across the resistance spectrum. Isolates were assessed for their reactions on a differential set and their reactions, expressed as an average infection type (a.i.t.), were recorded. As before isolates were classified as virulent if the a.i.t. score was 2.7 or above. Scores between 2.4 and 2.7 were considered borderline. Using these scores it was possible to combine the scores for reactions to different resistance genes to infer a pathotype for each of the isolates (Table 11). A new differential set was used this year in order to bring the UKCPVS into line with other virulence surveys across the world (for example Kolmer et al. 2013). Virulence for some of the *Lr* genes was reported for the first time, however this does not necessarily indicate a change in the population, rather this was the first year that virulence for these genes had been assessed. Virulence for *Lr1*, *Lr3a*, *Lr20*, *Lr26*, *Lr28* and *Lr37* were detected at lower frequencies compared to previous years (Table 12). Virulence for *Lr26* was not detected at all this year which was unusual given the high frequency of detection in previous years. It is possible that the new differentials in use may not have reacted in the same way as previous differentials and so the frequencies observed should be interpreted with caution. Further work is currently under way to compare the new differentials with the old set and also investigate the impact of temperature on the expression of resistance at the seedling stage.

#### **4.2.3. Variety testing of isolates from 2016**

Five isolates from the 25 tested isolates were selected for further testing on the wider set of RL varieties and candidates (Table 13) and were selected to best represent the diversity of the isolates tested.

##### **4.2.3.1. Seedling Tests**

The five selected isolates were tested in seedling tests containing RL and RL candidate varieties in the controlled environment rooms at NIAB in the summer of 2017. Results are combined with the adult plant test results (Table 14) and are sorted by the reaction on the adult plant trials (see 4.2.3.1). Only four of the RL varieties and candidates tested were resistant to all of the isolates tested, down from thirteen last year. Out of these, only Leeds had been noted as susceptible to another race in the past in the UKCPVS seedling tests. No new virulences were detected to previously resistant varieties in this extended test.

Table 10: Average infection type (a.i.t.) scores for the 25 selected isolates against the UKCPVS differential set. Yellow shading indicates a compatible reaction; orange shading indicates a borderline reaction. Compatible interactions classify the isolate as virulent against a particular resistance gene or variety.

Isolate Code	Host Variety	Thatcher Lr1	Thatcher Lr2a	Thatcher Lr2b	Thatcher Lr2c	Thatcher Lr3a	Thatcher Lr3bg	Thatcher Lr3ka	Thatcher Lr10	Thatcher Lr13	Thatcher Lr14a	Thatcher Lr15	Thatcher Lr16	Thatcher Lr17	Thatcher Lr20	Thatcher Lr23	Thatcher Lr24	Thatcher Lr26	Thatcher Lr28	Thatcher Lr37	Armada	Crusoe	Maris Fundin (Lr17b)	Robigus (Lr28)
16/001	KWS Trinity	0.3	2.0	1.4	2.0	2.3	2.0	2.7	2.3	2.2	2.5	2.2	2.0	2.0	2.0	2.0	0.4	2.0	0.0	2.7	3.0	3.0	3.0	0.0
16/003	Revelation	1.0	1.0	1.0	2.0	2.4	2.5	2.3	2.1	2.0	2.5	2.1	2.0	2.5	2.5	2.1	2.0	1.0	0.0	2.4	2.8	3.0	2.7	0.0
16/004	Revelation	1.0	1.4	1.0	1.0	2.5	2.0	2.0	2.2	3.0	2.3	2.0	2.1	2.6	3.0	2.7	2.3	1.9	0.0	2.2	3.0	3.0	3.0	0.0
16/005	Stigg	2.0	2.0	2.0	2.0	3.0	2.8	2.9	3.0	2.8	2.7	2.8	2.6	3.0	2.2	2.3	2.9	2.0	0.1	3.0	3.0	3.0	3.0	0.0
16/006	Marston	2.5	2.0	2.0	2.0	2.5	2.1	2.5	2.0	2.5	2.5	2.5	2.0	2.4	2.0	2.0	2.0	1.0	0.0	2.2	3.0	3.0	3.0	0.0
16/007	Crusoe	2.4	1.0	1.0	2.0	2.4	2.1	2.5	2.5	2.5	2.2	2.4	2.0	2.5	2.0	2.0	2.2	2.5	0.0	3.0	3.0	3.0	3.0	0.0
16/008	Costello	2.5	1.0	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.4	2.0	2.0	2.0	2.0	2.0	2.1	2.0	0.0	2.3	2.7	3.0	3.0	0.0
16/009	Dickens	2.8	2.0	2.0	2.0	2.0	2.0	2.0	2.8	2.1	2.1	2.0	2.0	2.0	1.2	2.0	0.4	2.0	0.0	2.8	3.0	3.0	3.0	0.0
16/010	LG Sundance	2.0	1.6	2.0	2.0	2.8	2.7	3.0	2.7	2.7	3.0	3.0	3.0	2.2	2.0	2.0	0.0	2.0	0.0	3.0	3.0	2.8	3.0	0.4
16/011	RGT Illustrious	2.1	2.0	2.0	2.0	2.2	2.4	2.3	2.1	2.5	2.5	2.3	2.2	2.5	1.8	1.9	2.2	2.0	0.3	2.5	3.0	2.5	3.0	0.8
16/012	Savello	2.0	2.0	2.0	2.0	2.0	2.0	2.4	2.4	2.1	2.1	2.0	2.2	2.1	2.0	2.0	2.0	1.0	0.2	3.0	3.0	2.9	3.0	0.0
16/013	Bassett	2.0	1.8	2.0	2.0	3.0	3.0	3.0	2.0	3.0	3.0	2.9	2.3	3.0	2.2	2.0	0.0	2.0	0.0	3.0	3.0	3.0	3.0	0.0
16/014	LG Cassidy	2.8	1.0	1.0	2.0	2.0	2.0	2.1	2.5	2.2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	0.0	2.4	3.0	2.5	3.0	1.0
16/015	KWS Siskin	3.0	1.0	2.0	2.7	3.0	3.0	2.9	2.8	2.8	3.0	2.2	2.0	2.9	2.2	2.2	1.0	2.0	0.3	3.0	3.0	2.2	3.0	1.0
16/016	Crusoe	2.0	2.0	2.0	2.0	2.5	2.1	2.1	2.1	2.2	2.2	2.0	2.1	2.0	2.0	2.0	2.0	2.0	0.0	2.1	3.0	3.0	3.0	0.2
16/017	KWS Trinity	2.9	2.1	2.0	2.0	2.0	2.2	2.2	2.0	2.3	2.6	2.1	2.0	2.2	2.6	2.0	0.4	2.0	0.0	2.8	2.8	3.0	3.0	0.1
16/019	Crusoe	2.4	0.2	0.3	1.0	2.0	2.2	2.0	2.1	2.4	2.8	2.0	2.0	2.0	2.1	2.0	0.0	0.3	0.1	2.1	2.8	3.0	3.0	0.0
16/020	KWS Siskin	3.0	1.0	2.0	2.0	2.5	2.2	2.2	3.0	2.0	2.5	2.5	2.5	2.0	2.0	2.0	2.3	2.0	0.0	2.5	3.0	3.0	3.0	0.0
16/021	KWS Santiago	3.0	2.0	2.0	2.0	3.0	2.5	2.8	3.0	2.2	2.1	2.0	2.7	2.2	2.0	2.0	2.0	2.0	0.2	2.0	3.0	3.0	3.0	0.0
16/022	Crusoe	2.0	2.0	1.0	2.0	2.0	2.5	2.5	2.4	2.2	2.5	2.0	2.2	2.1	2.0	2.1	2.0	2.0	0.0	2.1	3.0	3.0	3.0	0.0
16/026	KWS Silverstone	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.6	2.7	2.9	2.5	2.0	3.0	3.0	3.0	0.2	1.0	0.0	2.3	3.0	3.0	3.0	0.0
16/027	RGT Westminster	3.0	2.0	2.0	2.0	3.0	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	1.9	2.0	0.0	3.0	3.0	3.0	3.0	0.0
16/031	KWS Lili	2.9	2.0	2.0	2.8	3.0	3.0	3.0	3.0	2.8	3.0	2.2	2.0	3.0	2.0	2.6	1.4	2.0	0.0	4.0	4.0	4.0	4.0	0.0
16/032	KWS Lili	2.4	0.0	0.5	0.8	2.0	2.0	1.8	2.0	2.8	2.4	2.0	2.3	2.2	2.0	2.1	0.2	0.2	1.0	2.3	2.9	3.0	3.0	1.0
16/033	Cougar	2.0	2.0	2.0	2.0	3.0	2.4	3.0	3.0	3.0	3.0	3.0	2.8	2.9	2.7	2.3	2.0	2.0	2.0	3.0	3.0	3.0	3.0	2.0



Table 11: Pathotypes of the 2016 *Puccinia triticina* isolates based on the differential test results in Table 10. Numbers refer to specific *Lr* resistance genes, Cr = Crusoe, Ro = Robigus

Isolate Number	Host variety	Virulence Profile																					
		1	2a	2b	2c	3a	3bg	3ka	10	13	14a	15	16	17	20	23	24	26	28	37	17b	Ro	Cr
16/001	KWS Trinity							3ka			(14a)									37	17b		Cr
16/003	Revelation						(3bg)				(14a)			(17)	(20)					(37)	17b		Cr
16/004	Revelation					(3a)				13			(17)	20	23						17b		Cr
16/005	Stigg					3a	3bg	3ka	10	13	14a	15	(16)	17			24			37	17b		Cr
16/006	Marston	(1)				(3a)		(3ka)		(13)	(14a)	(15)		(17)							17b		Cr
16/007	Crusoe					(3a)		(3ka)	(10)	(13)			(17)				(26)		37	17b		Cr	
16/008	Costello	(1)							(10)	(13)											17b		Cr
16/009	Dickens	1							10											37	17b		Cr
16/010	LG Sundance					3a	3bg	3ka	10	13	14a	15	16							37	17b		Cr
16/011	RGT Illustrious						(3bg)			(13)	(14a)			(17)						(37)	17b		(Cr)
16/012	Savello								(10)											37	17b		Cr
16/013	Bassett					3a	3bg	3ka		13	14a	15		17						37	17b		Cr
16/014	LG Cassidy	1							(10)											(37)	17b		(Cr)
16/015	KWS Siskin	1			2c	3a	3bg	3ka	10	13	14a			17						37	17b		
16/016	Crusoe					(3a)															17b		Cr
16/017	KWS Trinity	1									(14a)				(20)					37	17b		Cr
16/019	Crusoe	(1)								(13)	14a										17b		Cr
16/020	KWS Siskin	1				(3a)			10		(14a)	(15)	(16)							(37)	17b		Cr
16/021	KWS Santiago	1				3a	(3bg)	3ka	10				16								17b		Cr
16/022	Crusoe						(3bg)	(3ka)	(10)		(14a)										17b		Cr
16/026	KWS Silverstone	1							(10)	13	14a	(15)		17	20	23					17b		Cr
16/027	RGT Westminster	1				3a	3bg	3ka	10	13	14a	15	16	17						37	17b		Cr
16/031	KWS Lili	1			2c	3a	3bg	3ka	10	13	14a			17		(23)				37	17b		Cr
16/032	KWS Lili	(1)								13	(14a)										17b		Cr
16/033	Cougar					3a	(3bg)	3ka	10	13	14a	15	16	17	20					37	17b		Cr

Table 12: Frequency of detection of isolates carrying virulence to the different brown rust resistance genes and varieties over the past five years. \* = missing data.

Virulence For Resistance Gene or Variety	Percentage of Isolates Identified with Virulence for Gene or Variety				
	2012	2013	2014	2015	2016
<i>Lr1</i>	15	33	76	46	36
<i>Lr2a</i>	*	*	*	*	0
<i>Lr2b</i>	*	*	*	*	0
<i>Lr2c</i>	*	*	*	*	8
<i>Lr3a</i>	15	17	76	62	32
<i>Lr3bg</i>	*	*	*	*	24
<i>Lr3ka</i>	*	*	*	*	36
<i>Lr10</i>	*	*	*	*	36
<i>Lr13</i>	*	*	*	*	40
<i>Lr14a</i>	*	*	*	*	36
<i>Lr15</i>	*	*	*	*	20
<i>Lr16</i>	*	*	*	*	16
<i>Lr17</i>	*	*	*	*	28
<i>Lr17b</i>	82	83	84	65	100
<i>Lr20</i>	21	22	96	77	12
<i>Lr23</i>	*	*	*	*	8
<i>Lr24</i>	53	17	20	4	4
<i>Lr26</i>	21	50	96	69	0
<i>Lr28</i>	44	28	12	8	0
<i>Lr37</i>	53	67	80	54	48
Robigus	56	50	12	8	0
Crusoe	59	56	92	50	88
<b>Total Number of Isolates</b>	<b>34</b>	<b>18</b>	<b>25</b>	<b>26</b>	<b>25</b>

Table 13: Virulence profile of the isolates chosen for further characterisation in seedling and adult plant tests. Numbers refer to specific *Lr* resistance genes, Ro = Robigus, Cr = Crusoe. Yellow shading = compatible reaction (virulence), orange shading and parentheses = borderline reaction, blank = avirulence.

Isolate Number	Host variety	Virulence Profile																					
		1	2a	2b	2c	3a	3bg	3ka	10	13	14a	15	16	17	20	23	24	26	28	37	17b	Ro	Cr
16/005	Stigg					3a	3bg	3ka	10	13	14a	15	(16)	17			24			37	17b		Cr
16/026	KWS Silverstone	1							(10)	13	14a	(15)		17	20	23					17b		Cr
16/027	RGT Westminster	1				3a	3bg	3ka	10	13	14a	15	16	17						37	17b		Cr
16/031	KWS Lili	1			2c	3a	3bg	3ka	10	13	14a			17		(23)				37	17b		Cr
16/033	Cougar					3a	(3bg)	3ka	10	13	14a	15	16	17	20					37	17b		Cr

Table 14: Seedling and adult plant reactions to the five isolates selected for further characterisation. Seedling results are shown as average infection types on a scale of 0-4. Adult plant results are given as a percentage leaf area infected averaged over four assessments. Varieties are ordered in level of disease at adult plant stage. Control varieties are highlighted in green text.

Variety	RL Rating 2017/18	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		16/005	16/026	16/027	16/031	16/033	16/005	16/026	16/027	16/031	16/033
STIGG ( <i>Lr24</i> )		0.7	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.2	3.8
WARRIOR ( <i>Lr24</i> )		1.0	0.1	0.0	0.0	0.2	2.4	6.1	0.6	3.2	0.2
ROBIGUS ( <i>Lr28</i> )		0.0	0.8	0.0	3.0	3.0	4.0	0.4	1.2	5.2	0.0
STERNA ( <i>Lr3a</i> )		3.0	3.0	3.0	3.0	3.0	1.4	1.1	0.6	6.4	2.5
LEEDS	5.3	0.0	0.0	0.1	0.0	0.0	0.1	1.9	0.1	17.5	0.0
VISCOUNT	8.4	0.0	0.0	0.0	0.2	0.0	2.6	6.5	0.0	9.0	0.1
MARIS RANGER (WBR8 APR)		3.0	3.0	3.0	3.0	3.0	1.0	4.3	2.5	1.0	7.4
MYRIAD	4.9	3.0	3.0	3.0	3.0	3.0	2.9	6.3	3.4	3.0	5.1
REFLECTION	8.9	0.0	0.0	0.0	0.0	0.0	2.0	1.4	5.0	7.1	1.0
KWS TARGET		*	*	*	*	*	1.6	0.2	0.0	15.5	7.2
MOULTON	6.8	3.0	3.0	3.0	3.0	3.0	3.3	5.5	2.0	9.2	4.7
MARIS FUNDIN ( <i>Lr17b</i> )		3.0	3.0	3.0	3.0	3.0	2.6	4.9	7.8	3.6	9.5
KWS LUTHER		2.2	3.0	3.0	2.8	3.0	2.1	6.3	5.2	9.3	1.7
SOISSONS ( <i>Lr14a</i> )		3.0	3.0	3.0	3.0	3.0	7.1	3.3	4.2	2.2	4.1
REVELATION	8.2	3.0	3.0	3.0	3.0	3.0	2.9	3.6	6.0	12.7	8.6
EVOLUTION	7.7	3.0	2.9	3.0	3.0	3.0	6.1	4.0	5.5	3.4	5.7
MARIS HALBERD ( <i>Lr20</i> )		2.0	2.0	2.0	2.3	2.0	2.2	5.6	7.9	12.9	7.4
RGT WESTMINSTER		2.7	2.9	3.0	3.0	3.0	5.5	3.0	5.1	11.8	5.3
ARMADA		3.0	3.0	3.0	3.0	3.0	12.5	0.7	5.7	6.4	8.2
MASCOT ( <i>Lr37</i> )		*	*	*	*	*	5.9	8.7	1.2	8.5	7.1
ZULU	4.4	3.0	3.0	3.0	3.0	3.0	6.6	11.3	3.2	11.0	6.4
DICKENS	6.3	3.0	3.0	3.0	3.0	3.0	7.9	9.6	4.2	13.4	9.9
RGT GRAVITY		2.0	2.7	3.0	3.0	3.0	12.0	11.4	2.7	12.5	7.4
KWS KERRIN	6.9	3.0	3.0	3.0	3.0	3.0	5.6	6.1	6.0	2.0	7.8

Variety	RL Rating 2017/18	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		16/005	16/026	16/027	16/031	16/033	16/005	16/026	16/027	16/031	16/033
KWS TRINITY	7.7	3.0	3.0	3.0	3.0	3.0	5.2	6.6	4.3	7.8	2.7
ELICIT		3.0	3.0	3.0	3.0	3.0	8.6	5.7	5.1	7.4	2.2
GRAHAM	5.4	3.0	3.0	3.0	3.0	3.0	8.8	11.7	8.8	9.5	2.2
SPYDER	6.8	3.0	3.0	3.0	3.0	3.0	8.9	6.3	10.0	6.8	1.5
LG MOTOWN	7.1	0.6	1.0	0.5	2.0	0.0	5.9	8.3	10.6	4.4	6.9
BELGRADE	5.0	3.0	3.0	3.0	3.0	3.0	5.7	11.7	6.6	8.2	12.3
SHABRAS	3.5	3.0	3.0	3.0	3.0	3.0	5.2	9.6	9.6	8.5	7.9
KWS SISKIN	5.3	3.0	3.0	3.0	3.0	3.0	6.3	6.1	5.7	6.3	8.6
LG SUNDANCE	5.8	3.0	3.0	3.0	3.0	3.0	7.7	5.0	7.0	6.6	6.5
GAMIN (WBR6)		2.9	3.0	3.0	3.0	3.0	7.6	8.4	5.6	6.1	5.2
HARDWICKE	6.4	3.0	3.0	3.0	3.0	3.0	8.6	7.7	7.1	7.4	5.1
KWS BARREL	6.3	3.0	3.0	3.0	3.0	3.0	7.3	9.0	5.8	10.2	8.1
SKYFALL	8.6	3.0	3.0	3.0	3.0	3.0	10.6	8.1	4.8	8.7	5.0
RGT ILLUSTRIOUS	6.6	2.9	3.0	2.0	3.0	3.0	8.6	8.4	7.3	11.2	6.0
KWS SILVERSTONE	7.6	3.0	3.0	3.0	3.0	3.0	9.6	12.2	5.5	5.7	5.8
KWS CRISPIN	5.3	3.0	3.0	3.0	2.7	2.7	8.0	8.7	6.0	13.0	12.6
LG GENERATION		3.0	3.0	3.0	3.0	3.0	8.9	4.8	10.1	13.8	6.6
KWS BASSET	6.3	3.0	3.0	3.0	3.0	3.0	8.9	10.3	6.9	4.8	10.6
COSTELLO	5.4	3.0	3.0	3.0	3.0	3.0	13.5	13.1	7.8	6.3	8.6
BENNINGTON	6.8	3.0	3.0	3.0	3.0	3.0	11.0	10.3	8.0	7.6	13.5
TUXEDO		3.0	3.0	2.6	3.0	3.0	10.4	13.9	7.7	14.2	7.0
MARIS HUNTSMAN (Lr13)		2.3	3.0	2.8	3.0	3.0	10.5	15.1	8.9	7.9	5.9
DUNSTON	6.4	3.0	3.0	3.0	3.0	3.0	12.9	14.7	6.8	8.4	12.6
KWS SANTIAGO	5.1	3.0	3.0	3.0	3.0	3.0	13.7	12.0	4.5	13.8	15.6
RGT KNIGHTSBRIDGE		3.0	3.0	3.0	3.0	3.0	15.7	16.2	4.4	11.7	11.9
GLASGOW (Lr1)		0.8	1.0	0.6	2.0	0.2	16.1	12.4	7.4	12.2	15.6
KWS ZYATT	6.1	3.0	3.0	3.0	3.0	3.0	10.2	11.8	7.4	10.0	10.0
ELATION		3.0	3.0	3.0	3.0	3.0	8.6	10.4	7.9	11.1	16.4
GRAFTON	4.6	3.0	3.0	3.0	3.0	3.0	12.9	14.8	10.7	6.5	12.7

Variety	RL Rating 2017/18	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		16/005	16/026	16/027	16/031	16/033	16/005	16/026	16/027	16/031	16/033
CORDIALE	4.3	3.0	3.0	3.0	3.0	3.0	14.6	11.8	9.8	16.2	9.1
GLEAM		3.0	3.0	3.0	3.0	3.0	6.7	16.9	3.4	16.8	13.4
KWS STERLING		3.0	3.0	3.0	3.0	3.0	7.4	18.7	7.0	7.4	5.8
VERSO		3.0	3.0	3.0	3.0	3.0	9.5	17.1	5.6	10.8	8.1
KWS JACKAL		3.0	3.0	3.0	3.0	3.0	9.7	17.0	8.1	13.4	12.5
REAPER (Lr37)		3.0	3.0	3.0	3.0	3.0	13.1	18.2	13.0	8.4	14.8
FREISTON	7.0	2.3	2.8	3.0	2.8	3.0	9.4	8.1	5.0	17.2	1.2
JB DIEGO	5.8	3.0	3.0	3.0	3.0	3.0	15.1	11.9	6.9	19.8	15.2
SAPPO (Lr20)		2.0	2.0	2.0	2.0	2.0	6.6	8.9	10.8	14.0	18.0
CONSORT (Lr10, Lr13, Lr26)		3.0	3.0	3.0	3.0	3.0	17.9	18.8	9.6	9.3	15.8
RGT UNIVERSE		3.0	3.0	3.0	3.0	3.0	18.1	16.9	7.0	16.5	16.0
AVALON (WBR9 APR)		2.2	3.0	3.0	3.0	3.0	12.1	18.6	11.1	12.7	17.5
CRUSOE	2.8	3.0	3.0	3.0	3.0	3.0	14.7	18.2	13.5	17.6	20.7
SAVELLO	3.8	3.0	3.0	3.0	3.0	3.0	10.4	24.6	10.2	16.8	23.7
KWS LILI	4.7	3.0	3.0	3.0	3.0	3.0	26.3	9.7	4.7	17.0	19.6
BUSTER		*	*	*	*	*	24.4	25.7	21.0	17.6	25.5
Clement (Lr26)		3.0	3.0	3.0	3.0	3.0					
Thatcher Lr1		1.0	2.0	0.1	2.0	0.2					
Thatcher Lr2a		2.0	2.0	1.0	1.0	2.0					
Thatcher Lr2b		2.5	2.6	2.0	2.0	2.0					
Thatcher Lr2c		2.0	2.8	3.0	2.0	2.0					
Thatcher Lr3a		3.0	3.0	3.0	3.0	3.0					
Thatcher Lr3bg		3.0	3.0	2.9	3.0	3.0					
Thatcher Lr3ka		3.0	3.0	3.0	3.0	3.0					
Thatcher Lr10		3.0	3.0	3.0	2.8	3.0					
Thatcher Lr13		3.0	3.0	3.0	3.0	3.0					
Thatcher Lr14a		3.0	2.8	3.0	3.0	3.0					
Thatcher Lr15		3.0	3.0	2.8	2.8	3.0					
Thatcher Lr16		3.0	3.0	3.0	2.9	2.0					

Variety	RL Rating 2017/18	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		16/005	16/026	16/027	16/031	16/033	16/005	16/026	16/027	16/031	16/033
Thatcher <i>Lr17</i>		3.0	3.0	3.0	3.0	3.0					
Thatcher <i>Lr20</i>		2.8	2.6	2.2	2.6	3.0					
Thatcher <i>Lr23</i>		3.0	3.0	3.0	2.8	2.0					
Thatcher <i>Lr24</i>		*	*	*	*	*					
Thatcher <i>Lr26</i>		3.0	3.0	2.7	3.0	2.6					
Thatcher <i>Lr28</i>		0.0	0.0	0.0	0.0	0.0					
Thatcher <i>Lr37</i>		3.0	3.0	3.0	3.0	3.0					

A general agreement was seen when these results were compared with those of the initial differential test, however some discrepancies were seen (Table 15). For example, in the initial differential tests, the isolate 16/005 carried virulence for *Lr24*; however in this test this was not evident. These discrepancies may be due to a number of factors including the potential for the presence of multiple isolates in the same sample and the UKCPVS is now investigating this further.

#### **4.2.3.1. Adult plant tests**

Alongside the seedling tests, the five isolates were also evaluated in the UKCPVS adult plant trials at NIAB in the summer of 2017 which contained RL and candidate varieties. As with the yellow rust trials, the adult plant trials were treated with fungicides up to and including the T1 application to keep the natural infection levels in the trial as low as possible. Assessments were made starting at growth stage 75 in the middle of June through to growth stage 87 in early July. Samples were taken from the trials to confirm that isolates used to inoculate the trial were present (



Table 15). As with the comparison between the initial differential test results and the variety seedling tests, there were some discrepancies between the re-isolation results and that expected from the other differential and variety seedling tests. Assuming that natural infection was no longer a factor in these trials, the data suggest that other isolates were present at the time of inoculation. As before, possible mixtures of isolates may be confounding these trials and this is under investigation. Due to the poor agreement between tests leading to uncertainty on causal races in the trials, further analysis of these results is not presented.

Table 15: Comparison between initial differential test results, variety seedling test results and re-isolations from samples taken from variety adult plant trials for the isolates used in the 2017 variety tests and trials. <sup>1</sup> Diff = Differential test result, <sup>2</sup> Seed = Variety seedling test result, <sup>3</sup>Re-Is = Re-isolation results from adult plant trials

Differential	16/005			16/026			16/027			16/031			16/033		
	Diff <sup>1</sup>	Seed <sup>2</sup>	Re-Is <sup>3</sup>	Diff <sup>1</sup>	Seed <sup>2</sup>	Re-Is <sup>3</sup>	Diff <sup>1</sup>	Seed <sup>2</sup>	Re-Is <sup>3</sup>	Diff <sup>1</sup>	Seed <sup>2</sup>	Re-Is <sup>3</sup>	Diff <sup>1</sup>	Seed <sup>2</sup>	Re-Is <sup>3</sup>
Armada	3.0	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5	4.0	3.0	2.5	3.0	3.0	2.5
Crusoe	3.0	3.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
Maris Fundin	3.0	3.0	2.5	3.0	3.0	2.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
Robigus	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	3.0	2.0	2.0	3.0	0.0
Stigg	*	0.7	*	*	0.0	*	*	0.0	*	*	0.0	*	*	0.0	*
Thatcher Lr1	2.0	1.0	2.5	3.0	2.0	2.5	3.0	0.1	0.4	2.9	2.0	2.0	2.0	0.2	2.0
Thatcher Lr2a	2.0	2.0	2.5	2.0	2.0	2.5	2.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0	2.0
Thatcher Lr2b	2.0	2.5	2.5	2.0	2.6	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Thatcher Lr2c	2.0	2.0	2.5	2.0	2.8	2.5	2.0	3.0	2.0	2.8	2.0	2.0	2.0	2.0	2.0
Thatcher Lr3a	3.0	3.0	2.5	2.0	3.0	2.5	3.0	3.0	2.5	3.0	5.0	2.5	3.0	3.0	2.5
Thatcher Lr3bg	2.8	3.0	2.5	2.0	3.0	2.5	2.9	2.9	2.5	3.0	3.0	2.5	2.4	3.0	2.5
Thatcher Lr3ka	2.9	3.0	2.5	2.0	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5
Thatcher Lr10	3.0	3.0	2.5	2.6	3.0	2.5	3.0	3.0	2.5	3.0	2.8	2.5	3.0	3.0	2.5
Thatcher Lr13	2.8	3.0	2.5	2.7	3.0	2.5	3.0	3.0	2.5	2.8	3.0	2.5	3.0	3.0	2.5
Thatcher Lr14a	2.7	3.0	2.5	2.9	2.8	2.5	3.0	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5
Thatcher Lr15	2.8	3.0	2.5	2.5	3.0	2.5	3.0	2.8	2.5	2.2	2.8	2.5	3.0	3.0	2.5
Thatcher Lr16	2.6	3.0	2.5	2.0	3.0	2.5	3.0	3.0	2.5	2.0	2.9	2.5	2.8	2.0	2.5
Thatcher Lr17	3.0	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5	3.0	3.0	2.5	2.9	3.0	2.5
Thatcher Lr20	2.2	2.8	2.5	3.0	2.6	2.5	2.0	2.2	2.5	2.0	2.6	2.0	2.7	3.0	2.5
Thatcher Lr23	2.3	3.0	2.5	3.0	3.0	2.5	2.0	3.0	2.0	2.6	2.8	2.0	2.3	2.0	2.5
Thatcher Lr24	2.9	*	0.3	0.2	*	2.5	1.9	*	0.8	1.4	*	0.0	2.0	*	0.1
Thatcher Lr26	2.0	3.0	2.5	1.0	3.0	2.5	2.0	2.7	2.0	2.0	3.0	2.0	2.0	2.6	2.0
Thatcher Lr28	0.1	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0	0.4
Thatcher Lr37	3.0	3.0	2.5	2.3	3.0	2.5	3.0	3.0	2.5	4.0	3.0	2.5	3.0	3.0	2.5

### **4.3. Wheat Powdery Mildew**

#### **4.3.1. Samples received**

Levels of wheat powdery mildew were low to moderate in 2016 and the UKCPVS received 46 samples including samples from mobile trap nurseries (appendix 1). The samples came from 31 different varieties and 13 different counties.

#### **4.3.2. Pathotyping of isolates**

From the 46 samples, multiple isolates were obtained, and 25 were pathotyped using a differential set (Table 16). Virulence was seen for most of the differentials tested, with avirulence seen on Amigo and Shamrock. For the most part, the virulence frequencies compared well with previous years (Table 17), with the exception of the aforementioned varieties whose frequencies differed between years. Although there were some minor differences between years, there were once again no reports of unusual mildew outbreaks during the year and based on this information we suspect that this population change is therefore unlikely to have much impact at the adult plant stage. The wheat powdery mildew isolates were not tested on varieties at the adult plant stage, and so the impact of these population changes can only be assessed through reports from growers, agronomists and trial managers.

Table 16: Pathotype results for the wheat powdery mildew detached seedling tests. Average infection types of 2.7 and above (yellow shading) indicate a compatible reaction, values between 2.5 and 2.7 (shaded orange) indicate a borderline reaction and values below 2.5 indicate an incompatible reaction. Differential varieties are listed along with the known resistance genes carried by these lines.

Isolate Number	Host variety		<i>Pm2</i>	<i>Pm3b</i>	<i>Pm4b</i>	<i>Pm5</i>	<i>Pm6</i>	<i>Mld</i>	<i>Pm8</i>	<i>Pm2, MITa2</i>	<i>Pm5, MITa2</i>			<i>Pm5, MISi2</i>			<i>Pm17</i>					
		Cerco	Galahad	Chul	Armada	Flanders	Brimstone	Clement	Maris dove	Brock	Mercia	Tonic	Broom	Sicco	Wembley	Axona	Amigo	Shamrock	Robigus	Warrior	Stigg	Crusoe
16-05-01	Revelation	3.3	3.3	0.0	3.0	3.3	3.3	3.5	2.8	3.5	3.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	3.5
16-07-01	JB Diego	2.8	2.8	1.0	2.5	2.5	3.0	2.5	2.0	2.3	2.8	3.0	2.8	0.0	0.0	3.0	0.0	1.0	0.0	0.0	0.0	3.0
16-09-02	Dickens	4.0	4.0	0.0	4.0	4.0	4.0	3.5	3.8	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.8	0.0	0.0	3.8
16-10-03	Santiago	3.0	3.0	2.0	3.3	3.0	3.0	3.0	3.0	3.0	3.0	0.8	0.0	0.0	0.0	0.5	0.5	0.5	3.3	0.3	0.0	3.0
16-11-01	Cougar	2.8	2.8	1.0	3.3	3.0	3.0	3.3	3.0	3.3	3.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	0.0	0.0	2.8
16-12-02	Zulu	2.8	3.3	0.0	3.0	2.3	3.0	3.0	3.0	3.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	0.0	0.0	3.0
16-13-01	Gallant	3.0	2.3	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	3.0
16-13-02	Gallant	3.3	3.0	0.0	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	1.0	3.0	0.0	0.8	0.5	0.0	0.0	3.5
16-14-02	Denman	3.0	3.0	0.8	3.0	3.0	3.0	3.0	0.8	3.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.8	0.0	0.0	2.8
16-15-02	Consort	2.0	2.5	0.0	2.0	2.5	2.0	2.0	1.3	2.0	2.5	1.5	1.8	0.0	0.0	2.0	0.0	1.0	0.5	0.3	0.0	1.3
16-16-02	Revelation	4.0	4.0	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.0	0.0	0.0	4.0
16-20-02	Reflection	3.0	3.5	0.0	3.3	3.3	3.0	3.0	3.0	3.3	3.0	0.0	0.0	0.0	0.0	0.0	1.5	1.0	3.3	0.0	0.0	3.0
16-21-01	RGT Illustrious	3.0	3.0	0.0	3.0	3.0	2.8	3.0	2.8	2.3	3.0	3.0	3.0	0.0	0.0	3.0	1.5	0.5	1.3	0.0	0.0	3.0
16-21-02	RGT Illustrious	1.8	1.8	0.0	2.5	2.0	2.5	2.3	1.3	0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.3	0.0	0.0	1.3
16-22-01	KWS Kielder	3.0	3.0	0.0	3.8	1.0	3.3	3.3	3.0	3.3	1.0	3.3	3.5	0.0	0.0	3.0	0.0	1.5	0.0	0.0	0.0	3.3
16-22-03	KWS Kielder	3.3	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	3.0	0.0	0.0	2.0	0.0	0.0	3.0
16-24	KWS Kielder	3.0	3.0	0.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	0.5	0.0	2.5	2.5	0.0	0.0	0.0	3.0	0.0	0.0	0.0

Isolate Number	Host variety		<i>Pm2</i>	<i>Pm3b</i>	<i>Pm4b</i>	<i>Pm5</i>	<i>Pm6</i>	<i>Mld</i>	<i>Pm8</i>	<i>Pm2, MITa2</i>	<i>Pm5, MITa2</i>	<i>MITo</i>	<i>Pm3d</i>	<i>Pm5, MISi2</i>	<i>MISo</i>	<i>MIAX</i>	<i>Pm17</i>	<i>MISh</i>	<i>MIRo</i>			
		Cerco	Galahad	Chul	Armada	Flanders	Brimstone	Clement	Maris dove	Brock	Mercia	Tonic	Broom	Sicco	Wembley	Axona	Amigo	Shamrock	Robigus	Warrior	Stigg	Crusoe
16-24-01	KWS Kielder	3.0	3.0	0.0	3.0	3.0	3.0	3.3	0.0	3.5	3.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
16-28	Spaldings Prolific	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	3.5	0.0	1.0	1.5	3.5	1.3	0.8
16-29	Spaldings Prolific	2.8	3.0	0.0	3.0	2.8	3.0	2.8	3.0	2.8	3.0	2.3	2.5	0.0	0.0	2.8	0.8	1.5	2.8	0.0	0.0	3.0
16-31-01	Leeds	3.0	3.0	0.0	3.0	3.5	3.0	3.3	0.0	3.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0
16-39-03	Cadenza	2.3	3.0	3.0	3.0	3.3	3.0	3.5	3.3	3.0	3.0	2.3	2.3	2.3	0.3	0.0	0.0	0.0	0.0	0.3	0.0	3.0
16-40-05	Unknown	3.0	3.0	0.0	2.5	2.0	3.0	3.0	2.5	3.0	3.0	0.0	0.0	2.8	2.8	0.0	0.0	1.0	3.0	3.0	3.0	3.0
16-41	Alfredo	3.0	3.5	0.0	3.3	3.3	3.0	3.0	3.0	3.3	3.0	0.0	0.0	0.0	0.0	0.0	1.5	1.0	3.3	0.0	0.0	3.0
16-42-01	Unknown	3.0	3.0	2.3	3.0	3.3	3.3	3.0	0.0	3.0	3.3	0.0	0.0	2.8	1.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0

Table 17: Virulence frequencies of key wheat powdery mildew resistance genes and varieties over the past five years of testing.

Differential	Known Genes	Virulence Frequency by Year				
		2012	2013	2014	2015	2016
Cerco		72	80	68	64	88
Galahad	<i>Pm2</i>	74	77	72	71	88
Chul	<i>Pm3b</i>	2	11	20	14	8
Armada	<i>Pm4b</i>	77	74	84	64	84
Flanders	<i>Pm5</i>	67	43	76	71	76
Brimstone	<i>Pm6</i>	74	80	80	64	88
Clement	<i>Pm8</i>	44	46	60	50	64
Maris dove	<i>Mld</i>	72	94	44	64	88
Brock	<i>Pm2, MITa2</i>	86	89	88	71	84
Mercia	<i>Pm5, MITa2</i>	67	77	80	79	80
Tonic	<i>MITo</i>	33	26	24	14	28
Broom	<i>Pm3d</i>	42	26	20	14	28
Sicco	<i>Pm5, MISi2</i>	2	3	8	0	8
Wembley	<i>MISo</i>	2	9	8	0	4
Axona	<i>MIAx</i>	30	17	12	14	32
Amigo	<i>Pm17</i>	0	0	0	7	0
Shamrock	<i>MISh</i>	0	0	4	0	0
Robigus	<i>MIRo</i>	28	51	64	64	56
Warrior		5	6	8	0	8
Stigg		5	6	8	0	4
Crusoe		47	40	36	36	72
<b>Total Number of Isolates Tested</b>		<b>43</b>	<b>35</b>	<b>25</b>	<b>14</b>	<b>25</b>

## **4.4. Barley Powdery Mildew**

### **4.4.1. Samples received**

Like the wheat powdery mildew, low levels of barley powdery mildew were observed in 2016 and as a result only 20 samples were received from growers, trial managers and agronomists. The samples came from 17 varieties across seven counties.

### **4.4.2. Pathotyping of Isolates**

From the samples received and collected, 26 isolates were obtained and characterised using a differential set (Table 18). Virulence for all of the differentials was detected with the exception of Riviera. Although virulence for Riviera has not been detected both this year and in 2015 (Table 19), it has been detected in the past and has equally been undetected in other years. For the remaining resistance genes and varieties there were some deviations from previous years, with an increase in virulence frequency for the resistance genes *MILa*, *Mlg*, *MI(CP)*, *MIAb*, *Mla1*, *mlo 11*, *Mla13*, *Mla3* and the variety NFC Tipple and a decrease in virulence frequency for the resistance genes *MLk1* and *Mla7*. Virulence for KWS Meridian was detected and the frequency was comparable to last year. As with the wheat powdery mildew, no adult plant tests were conducted with these isolates and the full impact of any change in the population will not become evident until the next season. The UKCPVS received no reports of unexpected outbreaks of barley powdery mildew during 2016 so it is possible that this variation in the population will not translate into meaningful differences at the adult plant stage.

Table 18: Pathotype results for the barley powdery mildew detached seedling tests. Average infection types of 2.7 and above (yellow shading) indicate a compatible reaction, values between 2.5 and 2.7 (shaded orange) indicate a borderline reaction and values below 2.5 indicate an incompatible reaction. Differential varieties are listed along with the known resistance genes carried by these lines.

Isolate Number	Host Variety	0	Mlh	Mlr	Mlg	Mlg,MI(CP)	Mla6	Mla	Mla12	MIk1	Mla7	MIAb	Mla7,MIAb	Mla1	Mla9	mlo 11	mlo 11?	Mla13	Mla3					
		Golden Promise	W.37/136	W.41/145	Goldfoil	Zephyr	Midas	Lofa	Hassan	H.1063	Porter	Lotta	Triumph	Tyra	Roland	Apex	Riviera	Digger	Ricardo	Vanessa	Optic	NFC Tipple	Propino	KWS Meridian
16/01/02	KWS Cassia	2.3	4.0	3.5	3.0	3.0	2.8	2.5	3.5	1.3	1.0	1.8	0.8	3.8	0.0	2.3	0.5	0.0	2.8	4.0	1.8	2.5	2.8	3.0
16/01/05	KWS Cassia	3.3	4.0	4.0	3.0	3.0	3.5	3.5	4.0	1.0	1.3	2.5	0.0	4.0	0.0	2.0	2.5	3.5	3.5	3.8	0.0	3.5	3.3	2.0
16/01/06	KWS Cassia	3.0	3.5	3.3	3.5	3.8	3.5	3.3	3.5	2.3	2.8	0.5	0.5	2.8	2.5	1.5	0.8	0.3	3.0	3.3	0.0	2.5	2.0	1.3
16/02/03	Bazooka	3.3	3.5	3.3	3.5	3.3	3.0	3.0	3.0	3.0	2.5	1.0	0.3	3.0	0.0	1.8	1.5	1.5	2.0	4.0	0.5	2.0	2.0	2.0
16/02/04	Bazooka	3.0	3.5	3.0	3.3	3.3	3.3	3.0	3.8	2.8	0.0	0.8	0.5	3.0	0.0	1.5	0.3	0.5	2.5	3.3	0.3	1.8	0.3	2.3
16/03/02	BR tunnel	3.5	4.0	4.0	3.8	3.8	3.8	4.0	3.8	1.0	2.3	2.0	1.0	0.0	0.0	2.0	1.8	0.0	3.5	4.0	0.5	4.0	4.0	1.0
16/04/08	KWS Orwell	3.0	4.0	3.8	3.5	3.5	3.8	3.5	3.5	1.3	0.5	2.5	0.3	3.8	0.0	2.5	1.3	0.0	3.8	4.0	0.3	3.3	4.0	1.8
16/05/01	WB line	3.0	3.5	3.0	3.0	3.3	3.0	3.8	3.8	0.5	3.3	3.0	2.8	3.3	0.0	1.8	1.5	0.0	2.0	3.3	3.0	3.8	3.8	0.0
16/05/02R	WB line	3.8	3.8	3.3	3.3	3.5	4.0	3.3	3.5	2.8	2.0	2.5	1.5	1.5	0.3	2.8	0.3	0.0	2.0	4.0	2.8	3.5	2.3	1.8
16/06/01	Bazooka	3.8	4.0	4.0	3.3	3.8	3.8	3.3	3.8	4.0	1.5	2.3	0.5	4.0	0.0	2.5	2.3	0.0	3.8	4.0	0.3	3.8	3.8	0.8
16/07/01	Funky	3.0	3.3	4.0	3.8	3.8	3.0	3.8	3.0	1.0	0.8	2.3	0.0	3.8	0.0	1.0	1.5	0.0	2.3	3.8	0.0	0.0	0.0	1.0
16/08/01	Surge	3.3	4.0	4.0	3.8	3.8	4.0	3.3	3.8	2.8	1.3	4.0	0.0	3.3	0.0	2.8	0.8	3.3	3.8	4.0	2.8	3.8	4.0	2.5
16/08/02	Surge	3.8	4.0	3.8	3.8	3.3	3.3	3.3	4.0	1.5	0.5	3.0	0.8	4.0	0.0	2.5	1.0	0.0	3.8	4.0	0.5	3.0	3.3	2.0
16/09	SY Venture	3.5	4.0	4.0	3.3	3.8	4.0	4.0	4.0	1.5	3.3	3.3	1.5	0.3	0.8	3.0	2.5	0.0	3.3	4.0	2.3	4.0	4.0	0.8
16/10/RR	KWS Tower	3.3	4.0	3.5	3.3	4.0	4.0	4.0	4.0	1.0	2.8	3.3	2.8	4.0	0.5	2.5	2.0	3.8	2.3	4.0	2.8	3.0	2.5	1.3
16/11/01	Volume	2.5	3.8	3.5	3.5	3.0	3.0	2.8	3.5	1.5	2.0	2.0	1.0	3.8	0.3	1.3	0.5	0.0	3.0	3.8	2.0	3.0	2.8	2.0
16/11/02	Volume	3.5	4.0	4.0	3.3	3.0	4.0	3.8	4.0	1.8	3.3	3.0	3.0	0.0	0.0	0.8	0.0	1.0	4.0	4.0	2.5	4.0	4.0	1.5



Isolate Number	Host Variety	0	MIh	Mira	MIg	MIg,MI(CP)	MIa6	MIa	MIa12	MIK1	MIa7	MIAb	MIa7,MIAb	MIa1	MIa9	mlo 11	mlo 11?	MIa13	MIa3					
		Golden Promise	W.37/136	W.41/145	Goldfoil	Zephyr	Midas	Lofa	Hassan	H.1063	Porter	Lotta	Triumph	Tyra	Roland	Apex	Riviera	Digger	Ricardo	Vanessa	Optic	NFC Tipple	Propino	KWS Meridian
16/12/01	Craft	3.3	4.0	3.8	4.0	3.5	4.0	3.3	4.0	3.3	2.3	2.5	1.5	3.0	1.0	1.5	1.0	3.0	3.8	4.0	0.8	3.5	4.0	2.8
16/14/01	California	2.8	4.0	3.5	3.8	3.5	3.3	2.8	4.0	1.5	2.5	2.8	1.5	0.0	0.3	3.0	0.3	0.0	3.0	4.0	2.8	4.0	4.0	1.3
16/14/02	California	3.3	3.3	3.8	3.5	3.5	3.3	3.0	3.5	2.3	3.0	3.3	1.8	3.8	3.0	2.3	1.0	1.0	2.5	4.0	1.3	4.0	4.0	2.3
16/15+	Belfry	3.8	4.0	4.0	4.0	4.0	3.8	4.0	4.0	1.8	3.0	2.0	0.8	3.8	0.0	1.5	1.5	0.0	2.8	4.0	2.3	4.0	4.0	3.0
16/17/02	KWS Orwell	3.0	3.5	3.0	3.5	2.8	3.5	3.5	3.5	1.3	0.3	1.5	0.0	2.3	2.8	2.0	0.3	0.0	2.5	2.8	0.0	2.8	2.5	2.3
16/17/03	KWS Orwell	2.3	3.8	3.0	2.8	3.3	3.0	3.3	3.5	1.8	1.8	1.3	1.3	2.8	2.5	2.0	1.5	1.3	2.3	3.8	2.0	2.8	2.5	2.3
16/18	KWS Orwell	3.3	3.8	3.8	3.8	3.8	4.0	3.8	2.3	3.5	1.5	2.3	0.8	1.3	0.0	2.5	0.5	0.0	1.5	4.0	0.5	1.0	1.8	0.3
16/19/01	Propino	3.0	4.0	3.3	3.0	2.8	3.5	3.3	3.8	2.5	0.0	0.0	1.0	3.3	3.3	2.3	0.8	2.8	3.3	4.0	0.0	2.8	3.0	2.0
16/20/02	breeding line	3.8	3.8	3.0	3.0	3.0	3.3	3.3	4.0	3.0	2.0	2.8	2.3	3.5	3.5	2.3	2.0	2.8	3.0	4.0	1.5	3.8	3.8	3.0

Table 19: Virulence frequencies of key barley powdery mildew resistance genes over the past five years of testing. \* = Not tested.

Differential	Known Genes	Virulence Frequency by Year				
		2012	2013	2014	2015	2016
Golden Promise	<i>O</i>	100	93	96	98	88
W.37/136	<i>MIh</i>	100	100	100	100	100
W.41/145	<i>MIra</i>	89	100	100	100	100
Goldfoil	<i>MIg</i>	96	93	100	88	100
Zephyr	<i>MIg,MI(CP)</i>	100	83	96	88	100
Midas	<i>Mla6</i>	100	90	93	98	100
Lofa	<i>MILa</i>	93	55	93	90	96
Hassan	<i>Mla12</i>	96	90	89	93	96
H.1063	<i>MIk1</i>	7	45	41	43	31
Porter	<i>Mla7</i>	67	48	74	35	27
Lotta	<i>MIAb</i>	44	17	78	38	35
Triumph	<i>Mla7,MIAb</i>	26	7	11	5	12
Tyra	<i>Mla1</i>	56	34	37	58	73
Roland	<i>Mla9</i>	7	0	0	15	15
Apex	<i>mlo 11</i>	4	3	15	8	15
Riviera	<i>mlo 11</i>	7	0	4	0	0
Digger	<i>Mla13</i>	7	7	11	5	23
Ricardo	<i>Mla3</i>	37	34	63	53	62
Vanessa	<i>Van</i>	89	86	81	98	100
Optic		48	10	26	18	19
NFC Tipple		37	14	56	58	77
Propino		33	21	52	65	65
KWS Meridian		0	0	4	15	15
<b>Total Number of Isolates</b>		<b>27</b>	<b>29</b>	<b>27</b>	<b>40</b>	<b>26</b>

## 5. Conclusions

The UK *Pst* population continues to show high levels of diversity since the incursion of the Warrior population in 2011. New reports of higher than expected levels of disease were received by the UKCPVS in 2016 and novel combinations of virulence are reported here. The link between the new pathotypes identified in 2016 and the disease reports in the 2015/16 season are now complete with the underlying cause most likely to be a combination of two races: Blue 7 and Red 24. A further new race, Pink 15, was also investigated by the UKCPVS, but only shows limited potential for damage compared to the Blue 7 and Red 24 races.

A new differential set was used to analyse the *P. tritici* population. Differences in reactions of differentials between years make cross-year comparisons difficult. Virulence was detected for many of the *Lr* genes tested and further work is underway to investigate discrepancies between the differential sets. Seedling and adult plant variety tests highlighted that most varieties were susceptible to at least one of the races under evaluation; however the possible presence of multiple isolates has made more detailed isolate x variety interactions impossible. Further work into isolating from single pustules is underway.

Small changes in the *Bgt* and *Bgh* populations were detected, but as in previous years no unusual outbreaks were reported so it is unlikely that these changes have translated into detrimental effects on variety performance.

## 6. Appendix 1: Sample Register

2016 Wheat Yellow Rust Isolate Register

Isolate Number	Host Variety	Date Received	RL Rating 2016/17	Location
16/001	Reflection	11/01/2016	6.0	Cambridgeshire
16/002	Zulu	15/01/2016	8.5	Essex
16/003	KWS Croft	15/01/2016	(8.4)	Essex
16/004	Cordiale	27/01/2016	5.3	Herefordshire
16/005	KWS Lili	27/01/2016	7.0	Herefordshire
16/006	Revelation	28/01/2016	8.7	Lincolnshire
16/007	KWS Kielder	28/01/2016	3.3	Lincolnshire
16/008	Reflection	29/01/2016	6.0	Hertfordshire
16/009	Reflection	02/02/2016	6.0	Cambridgeshire
16/010	YR spreader	11/02/2016		Cambridgeshire
16/011	YR spreader	11/02/2016		Cambridgeshire
16/012	JB Diego	15/02/2016	7.3	Norfolk
16/013	Revelation	15/02/2016	8.7	Norfolk
16/014	Reflection	15/02/2016	6.0	Lincolnshire
16/015	Reflection	15/02/2016	6.0	Cambridgeshire
16/016	KWS Lili	15/02/2016	7.0	Lincolnshire
16/017	KWS Lili	15/02/2016	7.0	Cambridgeshire
16/018	KWS Lili	15/02/2016	7.0	Cambridgeshire
16/019	KWS Target	17/02/2016		Bedfordshire
16/020	Reflection	17/02/2016	6.0	Hampshire
16/021	Grafton	19/02/2016	6.3	Lincolnshire
16/022	Graham	22/02/2016	8.0	Lincolnshire
16/023	Skyfall	22/02/2016	6.2	Cambridgeshire
16/024	Solstice	22/02/2016	3.3	Cambridgeshire
16/025	Belepi	22/02/2016		Cambridgeshire
16/026	Cordiale	22/02/2016	5.3	Cambridgeshire
16/027	KWS Kielder	22/02/2016	3.3	Cambridgeshire
16/028	Reflection	22/02/2016	6.0	Cambridgeshire
16/029	Reflection	25/02/2016	6.0	Oxfordshire
16/030	Revelation	29/02/2016	8.7	Lincolnshire
16/031	Evolution	29/02/2016	8.6	Lincolnshire
16/032	Reflection	02/03/2016	6.0	Buckinghamshire
16/033	Viscount	02/03/2016	4.6	Bedfordshire
16/034	Reflection	02/03/2016	6.0	Gloucestershire
16/035	Reflection	02/03/2016	6.0	Gloucestershire
16/036	KWS Lili	07/03/2016	7.0	Lincolnshire
16/037	Reflection	10/03/2016	6.0	Hertfordshire
16/038	Conqueror	10/03/2016		Cambridgeshire
16/039	Belepi	10/03/2016		Cambridgeshire
16/040	Reflection	10/03/2016	6.0	Cambridgeshire
16/041	RGT Illustrious	22/02/2016	9.0	Norfolk

<b>Isolate Number</b>	<b>Host Variety</b>	<b>Date Received</b>	<b>RL Rating 2016/17</b>	<b>Location</b>
16/042	Reflection		6.0	Northumberland
16/043	Revelation		8.7	Northumberland
16/044	YR spreader	17/03/2016		Cambridgeshire
16/045	Reflection	21/03/2016	6.0	East Yorkshire
16/046	Myriad	21/03/2016	7.9	East Lothian
16/047	Leeds	21/03/2016	7.4	Cambridgeshire
16/048	Myriad	23/03/2016	7.9	Cambridgeshire
16/049	KWS Lili	29/03/2016	7.0	East Lothian
16/050	Leeds	29/03/2016	7.4	East Lothian
16/051	SHW089	01/04/2016	8.6	Cambridgeshire
16/052	Breeding line	04/04/2016		Oxfordshire
16/053	Zulu	06/04/2016	8.5	Lincolnshire
16/054	KWS Kielder	14/04/2016	3.3	Shropshire
16/055	Reflection	14/04/2016	6.0	West Midlands
16/056	RGT Illustrious	15/04/2016	9.0	Cambridgeshire
16/057	KWS Kerrin	15/04/2016	8.6	West Yorkshire
16/058	Sherif	15/04/2016		West Yorkshire
16/059	Shabras	15/04/2016	8.6	West Yorkshire
16/060	Evolution	15/04/2016	8.6	West Yorkshire
16/061	SJ13572002	15/04/2016		West Yorkshire
16/062	Marlowe	15/04/2016	7.4	West Yorkshire
16/063	KWS Lili	15/04/2016	7.0	West Yorkshire
16/064	Moulton	15/04/2016	8.6	West Yorkshire
16/065	Dunston	15/04/2016	8.7	West Yorkshire
16/066	Evolution	19/04/2016	8.6	Norfolk
16/067	Unknown	21/04/2016		Cambridgeshire
16/068	AFP 9130	21/04/2016		Cambridgeshire
16/069	AFP 2698	21/04/2016		Cambridgeshire
16/070	Britannia	22/04/2016	7.7	Cambridgeshire
16/071	Reflection	27/04/2016	6.0	Scottish Borders
16/072	KWS Kerrin	28/04/2016	8.6	Cambridgeshire
16/073	Leeds	29/04/2016	7.4	Scottish Borders
16/074	Viscount	03/05/2016	4.6	Cambridgeshire
16/075	Zulu	03/05/2016	8.5	Cambridgeshire
16/076	Britannia	03/05/2016	7.7	Cambridgeshire
16/077	Icon	03/05/2016		Cambridgeshire
16/078	Evolution	03/05/2016	8.6	Cambridgeshire
16/079	Claire	03/05/2016	6.1	Buckinghamshire
16/080	Reflection	03/05/2016	6.0	Suffolk
16/081	KWS Croft	03/05/2016		Buckinghamshire
16/082	Reflection	05/05/2016	6.0	Cheshire
16/083	Reflection	06/05/2016	6.0	Dorset
16/084	Evolution	06/05/2016	8.6	Oxfordshire
16/085	Evolution	06/05/2016	8.6	Oxfordshire

<b>Isolate Number</b>	<b>Host Variety</b>	<b>Date Received</b>	<b>RL Rating 2016/17</b>	<b>Location</b>
16/086	Evolution	06/05/2016	8.6	Oxfordshire
16/087	Leeds	09/05/2016	7.4	Lincolnshire
16/088	Belgrade	09/05/2016	7.0	Lincolnshire
16/089	Reflection	09/05/2016	6.0	Lincolnshire
16/090	Britannia	09/05/2016	7.7	Lincolnshire
16/091	Myriad	09/05/2016	7.9	Lincolnshire
16/092	Spyder	09/05/2016	8.0	Lincolnshire
16/093	Zulu	09/05/2016	8.5	Lincolnshire
16/094	KWS Kerrin	10/05/2016	8.6	Lincolnshire
16/095	Reflection	10/05/2016	6.0	Lincolnshire
16/096	JB Diego	10/05/2016	7.3	Lincolnshire
16/097	Dunston	10/05/2016	8.7	Lincolnshire
16/098	KWS Zyatt	10/05/2016	6.3	Lincolnshire
16/099	Monroe	10/05/2016		Lincolnshire
16/100	Claire	11/05/2016	6.1	Hampshire
16/101	KWS Kielder	11/05/2016	3.3	Hampshire
16/102	Marlowe	11/05/2016	7.4	Shropshire
16/103	Solstice	11/05/2016	3.3	Shropshire
16/104	KWS Kielder	11/05/2016	3.3	Shropshire
16/105	Britannia	12/05/2016	7.7	Kent
16/106	Myriad	16/05/2016	7.9	Scottish Borders
16/107	Reflection	13/05/2016	6.0	Warwickshire
16/108	Invicta	18/05/2016		Essex
16/109	Monterey	18/05/2016		Essex
16/110	WPB09SW025-11	18/05/2016		Shropshire
16/111	KWSW326	18/05/2016		Shropshire
16/112	Faller	18/05/2016		Shropshire
16/113	Mulika	18/05/2016	7.2	Shropshire
16/114	KWS Kielder	19/05/2016	3.3	Suffolk
16/115	Gallant	19/05/2016	4.2	Suffolk
16/116	JB Diego	19/05/2016	7.3	Suffolk
16/117	KWS Santiago	19/05/2016	6.1	Suffolk
16/118	Skyfall	19/05/2016	6.2	Suffolk
16/119	Leeds	20/05/2016	7.4	Oxfordshire
16/120	Skyfall	20/05/2016	6.2	Oxfordshire
16/121	Britannia	20/05/2016	7.7	Oxfordshire
16/122	Belgrade	20/05/2016	7.0	Oxfordshire
16/123	Monterey	20/05/2016		Essex
16/124	Monterey	20/05/2016		Essex
16/125	Monterey	20/05/2016		Essex
16/126	Invicta	20/05/2016		Essex
16/127	Invicta	20/05/2016		Essex
16/128	Invicta	20/05/2016		Essex
16/129	Stratosphere	23/05/2016	7.5	Lincolnshire

<b>Isolate Number</b>	<b>Host Variety</b>	<b>Date Received</b>	<b>RL Rating 2016/17</b>	<b>Location</b>
16/130	KWS Kerrin	23/05/2016	8.6	Lincolnshire
16/131	Amplify	23/05/2016		Lincolnshire
16/132	Mosaic	23/05/2016		Lincolnshire
16/133	Reflection	23/05/2016	6.0	Northumberland
16/134	KWS Santiago	23/05/2016	6.1	West Yorkshire
16/135	Cordiale	23/05/2016	5.3	Northumberland
16/136	Solstice	23/05/2016	3.3	Northumberland
16/137	Leeds	23/05/2016	7.4	North Yorkshire
16/138	Unknown	23/05/2016		Cambridgeshire
16/139	Unknown	24/05/2016		unknown
16/140	Unknown	24/05/2016		unknown
16/141	Belepi	24/05/2016		Norfolk
16/142	Zulu	24/05/2016	8.5	Norfolk
16/143	Reflection	24/05/2016	6.0	Norfolk
16/144	KWS Gator	24/05/2016	8.4	Norfolk
16/145	KWS Kielder	24/05/2016	3.3	Northumberland
16/146	Reflection	24/05/2016	6.0	Northumberland
16/147	Myriad	24/05/2016	7.9	Northumberland
16/148	Evolution	24/05/2016	8.6	Northumberland
16/149	KWS Santiago	24/05/2016	6.1	Northumberland
16/150	Mosaic	24/05/2016		Northumberland
16/151	Dunston	25/05/2016	8.7	North Yorkshire
16/152	Gallant	25/05/2016	4.2	North Yorkshire
16/153	Mosaic	25/05/2016		North Yorkshire
16/154	Britannia	25/05/2016	7.7	North Yorkshire
16/155	Spyder	25/05/2016	8.0	North Yorkshire
16/156	Amplify	25/05/2016		North Yorkshire
16/157	KWS Santiago	25/05/2016	6.1	North Yorkshire
16/158	KWS Kerrin	25/05/2016	8.6	North Yorkshire
16/159	Marlowe	25/05/2016	7.4	North Yorkshire
16/160	Cordiale	25/05/2016	5.3	North Yorkshire
16/161	JB Diego	25/05/2016	7.3	North Yorkshire
16/162	Icon	25/05/2016		North Yorkshire
16/163	Evolution	25/05/2016	8.6	North Yorkshire
16/164	RGT Conversion	25/05/2016	8.0	North Yorkshire
16/165	Bennington	25/05/2016	8.4	North Yorkshire
16/166	Stratosphere	25/05/2016	7.5	North Yorkshire
16/167	Reflection	25/05/2016	6.0	North Yorkshire
16/168	Claire	25/05/2016	6.1	North Yorkshire
16/169	Armada	27/05/2016		Lincolnshire
16/170	Britannia	27/05/2016	7.7	Oxfordshire
16/171	JB Diego	27/05/2016	7.3	Nottinghamshire
16/172	KWS Santiago	27/05/2016	6.1	Nottinghamshire
16/173	Reflection	27/05/2016	6.0	Nottinghamshire

<b>Isolate Number</b>	<b>Host Variety</b>	<b>Date Received</b>	<b>RL Rating 2016/17</b>	<b>Location</b>
16/174	RGT Illustrious	27/05/2016	9.0	Hertfordshire
16/175	KWS Trinity	27/05/2016	8.6	Hertfordshire
16/176	Relay	27/05/2016	8.7	Hertfordshire
16/177	KWS Basset	27/05/2016	8.6	Hertfordshire
16/178	KWS Barrel	27/05/2016	8.0	Hertfordshire
16/179	JB Diego	27/05/2016	7.3	Hampshire
16/180	Cordiale	31/05/2016	5.3	Leicestershire
16/181	Britannia	31/05/2016	7.7	Suffolk
16/182	Leeds	31/05/2016	7.4	Northumberland
16/183	Gallant	31/05/2016	4.2	Northumberland
16/184	Zulu	31/05/2016	8.5	Northumberland
16/185	Britannia	31/05/2016	7.7	Northumberland
16/186	Viscount	31/05/2016	4.6	Northumberland
16/187	Cordiale	01/06/2016	5.3	Northamptonshire
16/188	Marlowe	03/06/2016	7.4	East Yorkshire
16/189	Spyder	03/06/2016	8.0	East Yorkshire
16/190	Myriad	03/06/2016	7.9	Cambridgeshire
16/191	JB Diego	03/06/2016	7.3	Cambridgeshire
16/192	KWS Basset	03/06/2016	8.6	Cambridgeshire
16/193	Zulu	03/06/2016	8.5	Cambridgeshire
16/194	Britannia	03/06/2016	7.7	Cambridgeshire
16/195	Cordiale	03/06/2016	5.3	Cambridgeshire
16/196	Leeds	03/06/2016	7.4	Cambridgeshire
16/197	Mosaic	06/06/2016		Cambridgeshire
16/198	Relay	06/06/2016	8.7	Cambridgeshire
16/199	Scout	06/06/2016	8.7	Cambridgeshire
16/200	RGT Westminster	06/06/2016	7.5	Cambridgeshire
16/201	Shabras	06/06/2016	8.6	Cambridgeshire
16/202	Reflection	06/06/2016	6.0	Cambridgeshire
16/203	RGT Conversion	06/06/2016	8.0	Cambridgeshire
16/204	Icon	06/06/2016		Cambridgeshire
16/205	KWS Croft	06/06/2016		Cambridgeshire
16/206	Spyder	06/06/2016	8.0	Cambridgeshire
16/207	Claire	06/06/2016	6.1	Cambridgeshire
16/208	RGT Marlborough	06/06/2016		Cambridgeshire
16/209	LG Bletchley	06/06/2016	8.5	Cambridgeshire
16/210	Skyfall	06/06/2016	6.2	Northumberland
16/211	KWS Lili	06/06/2016	7.0	Northumberland
16/212	Claire	06/06/2016	6.1	Northumberland
16/213	Solstice	07/06/2016	3.3	Warwickshire
16/214	Solstice	07/06/2016	3.3	Warwickshire
16/215	Torch	07/06/2016		Warwickshire
16/216	Torch	07/06/2016		Warwickshire
16/217	KWS Lili	07/06/2016	7.0	Warwickshire



Isolate Number	Host Variety	Date Received	RL Rating 2016/17	Location
16/218	Robigus	07/06/2016		Warwickshire
16/219	Britannia	07/06/2016	7.7	Warwickshire
16/220	RGT Conversion	07/06/2016	8.0	Warwickshire
16/221	Reflection	07/06/2016	6.0	Warwickshire
16/222	KWS Kielder	07/06/2016	3.3	Warwickshire
16/223	Cordiale	07/06/2016	5.3	Warwickshire
16/224	Reflection	07/06/2016	6.0	Norfolk
16/225	Relay	07/06/2016	8.7	Leicestershire
16/226	JB Diego	07/06/2016	7.3	Leicestershire
16/227	Evolution	07/06/2016	8.6	Leicestershire
16/228	Zulu	07/06/2016	8.5	Leicestershire
16/229	Cougar	07/06/2016		Leicestershire
16/230	KWS Gator	07/06/2016	8.4	Leicestershire
16/231	Britannia	07/06/2016	7.7	Leicestershire
16/232	Skyfall	07/06/2016	6.2	Leicestershire
16/233	Belepi	09/06/2016		Scottish Borders
16/234	KWS Zyatt	10/06/2016	6.3	Hampshire
16/235	Relay	10/06/2016	8.7	Hampshire
16/236	Shabras	10/06/2016	8.6	Hampshire
16/237	Evolution	10/06/2016	8.6	Hampshire
16/238	Stratosphere	10/06/2016	7.5	Hampshire
16/239	Cordiale	10/06/2016	5.3	Hampshire
16/240	KWS Basset	10/06/2016	8.6	Hampshire
16/241	Belgrade	10/06/2016	7.0	Hampshire
16/242	RGT Conversion	10/06/2016	8.0	Hampshire
16/243	Leeds	10/06/2016	7.4	Hampshire
16/244	Freiston	10/06/2016	8.7	Hampshire
16/245	KWS Barrel	10/06/2016	8.0	Hampshire
16/246	Moulton	10/06/2016	8.6	Hampshire
16/247	Skyfall	10/06/2016	6.2	Hampshire
16/248	Hardwicke	10/06/2016		Hampshire
16/249	RGT Paddington	10/06/2016	6.4	Hampshire
16/250	JB Diego	10/06/2016	7.3	Hampshire
16/251	KWS Santiago	10/06/2016	6.1	Hampshire
16/252	Marlowe	10/06/2016	7.4	Hampshire
16/253	Reflection	10/06/2016	6.0	Hampshire
16/254	Britannia	10/06/2016	7.7	Hampshire
16/255	Savello	10/06/2016	8.7	Hampshire
16/256	LG Bletchley	10/06/2016	8.5	Hampshire
16/257	Dunston	10/06/2016	8.7	Hampshire
16/258	RGT Westminster	10/06/2016	7.5	Hampshire
16/259	Bennington	10/06/2016	8.4	Hampshire
16/260	Spyder	10/06/2016	8.0	Hampshire
16/261	KWS Lili	10/06/2016	7.0	Hampshire

Isolate Number	Host Variety	Date Received	RL Rating 2016/17	Location
16/262	KWS Silverstone	10/06/2016	8.0	Hampshire
16/263	RGT Knightsbridge	10/06/2016	8.3	Hampshire
16/264	Zulu	10/06/2016	8.5	Hampshire
16/265	KWS Kerrin	10/06/2016	8.6	Hampshire
16/266	Alchemy	10/06/2016		Essex
16/267	Scout	10/06/2016	8.7	Essex
16/268	Claire	10/06/2016	6.1	Essex
16/269	RGT Conversion	10/06/2016	8.0	Essex
16/270	RGT Westminster	10/06/2016	7.5	Essex
16/271	JB Diego	10/06/2016	7.3	Gloucestershire
16/272	KWS Lili	13/06/2016	7.0	Oxfordshire
16/273	RGT Conversion	13/06/2016	8.0	Oxfordshire
16/274	Belgrade	13/06/2016	7.0	Oxfordshire
16/275	Britannia	13/06/2016	7.7	Lincolnshire
16/276	Reflection	13/06/2016	6.0	North Yorkshire
16/277	Hereford	10/06/2016		Lincolnshire
16/278	Hereford	17/06/2016		Lincolnshire
16/279	RGT Knightsbridge	17/06/2016	8.3	Lincolnshire
16/280	JB Diego	17/06/2016	7.3	Lincolnshire
16/281	Icon	17/06/2016		Lincolnshire
16/282	RGT Conversion	17/06/2016	8.0	Lincolnshire
16/283	Shabras	17/06/2016	8.6	Lincolnshire
16/284	KWS Croft	17/06/2016		Lincolnshire
16/285	RGT Paddington	17/06/2016	6.4	Lincolnshire
16/286	Invicta	21/06/2016		Lincolnshire
16/287	Warrior	21/06/2016		Lincolnshire
16/288	Deben	21/06/2016		Lincolnshire
16/289	Apache	21/06/2016		Lincolnshire
16/290	KWS Target	21/06/2016		Lincolnshire
16/291	Zulu	21/06/2016	8.5	Lincolnshire
16/292	LGW110	21/06/2016		Lincolnshire
16/293	KWS Cashel	23/06/2016		Essex
16/294	Zulu	23/06/2016	8.5	Kent
16/295	Zulu	23/06/2016	8.5	Norfolk
16/296	Bennington	23/06/2016	8.4	Norfolk
16/297	KWS Basset	23/06/2016	8.6	Norfolk
16/298	RGT Knightsbridge	23/06/2016	8.3	Norfolk
16/299	KWS Kerrin	23/06/2016	8.6	Norfolk
16/300	Shabras	23/06/2016	8.6	Norfolk
16/301	Relay	23/06/2016	8.7	Norfolk
16/302	Britannia	23/06/2016	7.7	Norfolk
16/303	LG Bletchley	23/06/2016	8.5	Norfolk
16/304	RGT Conversion	23/06/2016	8.0	Norfolk
16/305	Dunston	23/06/2016	8.7	Norfolk

<b>Isolate Number</b>	<b>Host Variety</b>	<b>Date Received</b>	<b>RL Rating 2016/17</b>	<b>Location</b>
16/306	JB Diego	23/06/2016	7.3	Norfolk
16/307	Savello	23/06/2016	8.7	Norfolk
16/308	Moulton	23/06/2016	8.6	Norfolk
16/309	KWS Santiago	23/06/2016	6.1	Norfolk
16/310	Tybalt	28/06/2016		Cambridgeshire
16/311	Dunston	11/07/2016	8.7	Scotland
16/312	Leeds	12/07/2016	7.4	Scotland
16/313	JB Diego	13/07/2016	7.3	Scotland
16/314	Bennington	14/07/2016	8.4	Scotland
16/315	Myriad	15/07/2016	7.9	Scotland
16/316	RGT Conversion	16/07/2016	8.0	Scotland
16/317	KWS Kerrin	17/07/2016	8.6	Scotland
16/318	RGT Knightsbridge	18/07/2016	8.3	Scotland
16/319	Hardwicke	19/07/2016		Scotland
16/320	KWS Barrel	20/07/2016	8.0	Scotland
16/321	RGT Marlborough	21/07/2016		Scotland
16/322	Britannia	22/07/2016	7.7	Scotland
16/323	KWS Santiago	23/07/2016	6.1	Scotland
16/324	Zulu	24/07/2016	8.5	Scotland
16/325	Freiston	25/07/2016	8.7	Scotland
16/326	LG Bletchley	26/07/2016	8.5	Scotland
16/327	Spyder	27/07/2016	8.0	Scotland
16/328	Belgrade	28/07/2016	7.0	Scotland
16/329	Moulton	29/07/2016	8.6	Scotland
16/330	Skyfall	30/07/2016	6.2	Scotland
16/331	Reflection	31/07/2016	6.0	Scotland
16/332	RGT Westminster	01/08/2016	7.5	Scotland
16/333	Evolution	02/08/2016	8.6	Scotland
16/334	KWS Silverstone	03/08/2016	8.0	Scotland
16/335	KWS Lili	04/08/2016	7.0	Scotland
16/336	Shabras	05/08/2016	8.6	Scotland
16/337	Graham	06/08/2016	8.0	Scotland
16/338	Cordiale	07/08/2016	5.3	Scotland
16/339	Marlowe	08/08/2016	7.4	Scotland
16/340	RGT Pembroke	09/08/2016		Scotland
16/341	Reflection	19/08/2016		Cornwall

# 2016 Wheat Brown Rust Isolate Register

Isolate Number	Host Variety	Date Received	RL Rating 2016/17	Location
16/001	KWS Trinity	14/12/2015	8	Lincolnshire
16/002	Crusoe	30/01/2016	3	Bedfordshire
16/003	Revelation	15/02/2016	8	Norfolk
16/004	Revelation	15/02/2016	8	Norfolk
16/005	Stigg	26/04/2016		Kent
16/006	Marston	06/06/2016		Cambridgeshire
16/007	Crusoe	06/06/2016	3	Cambridgeshire
16/008	Costello	08/06/2016	6	Cambridgeshire
16/009	Dickens	08/06/2016	7	Cambridgeshire
16/010	LG Sundance	08/06/2016		Cambridgeshire
16/011	RGT Illustrious	08/06/2016	8	Cambridgeshire
16/012	Savello	08/06/2016		Cambridgeshire
16/013	KWS Basset	08/06/2016	6	Cambridgeshire
16/014	LG Cassidy	08/06/2016		Cambridgeshire
16/015	KWS Siskin	08/06/2016	7	Cambridgeshire
16/016	Crusoe	08/06/2016	3	Cambridgeshire
16/017	KWS Trinity	08/06/2016	8	Cambridgeshire
16/018	Crusoe	10/06/2016	3	Hampshire
16/019	Crusoe	16/06/2016	3	Cambridgeshire
16/020	KWS Siskin	16/06/2016	7	Cambridgeshire
16/021	KWS Santiago	16/06/2016	6	Cambridgeshire
16/022	Crusoe	17/06/2016	3	Northamptonshire
16/023	Hereford	17/06/2016		Lincolnshire
16/024	Shabras	23/06/2016		Cambridgeshire
16/025	LG Cassidy	23/06/2016		Cambridgeshire
16/026	KWS Silverstone	23/06/2016	8	Cambridgeshire
16/027	RGT Westminster	10/06/2016		Essex
16/028	Crusoe	30/06/2016	3	Dorset
16/029	KWS Lili	30/06/2016	6	Dorset
16/030	Graham	30/06/2016	7	Dorset
16/031	KWS Lili	15/07/2016	6	Suffolk
16/032	KWS Lili	21/07/2016	6	Herefordshire
16/033	Cougar	26/08/2016		Cornwall

**2016 Wheat Powdery Mildew Isolate Register**

<b>Isolate number</b>	<b>Host Variety</b>	<b>Date sampled/received</b>	<b>RL Rating 2016/17</b>	<b>Location</b>
16/001	unknown	14/10/2015		Unknown
16/002	unknown	14/10/2015		Unknown
16/003	unknown	14/10/2015		Lincolnshire
16/004	Cougar	28/01/2016		Herefordshire
16/005	Revelation	28/01/2016	6	Unknown
16/006	Cordiale	28/01/2016	6	Herefordshire
16/007	JB Diego	28/01/2016	6	Herefordshire
16/008	Evolution	28/01/2016	6	Herefordshire
16/009	Dickens	28/01/2016	8	Herefordshire
16/010	KWS Santiago	28/01/2016	4	Unknown
16/011	Cougar	28/01/2016		Herefordshire
16/012	Zulu	28/01/2016	7	Unknown
16/013	Gallant	28/01/2016	6	Herefordshire
16/014	Denman	28/01/2016		Herefordshire
16/015	Consort	28/01/2016		Unknown
16/016	Revelation	28/01/2016	6	Kent
16/017	Reflection	02/02/2016	7	Gloucestershire
16/018	Crusoe	30/01/2016	7	Herefordshire
16/019	Revelation	13/02/2016	6	Lincolnshire
16/020	Reflection	02/03/2016	7	Yorkshire
16/021	RGT Illustrious	11/03/2016	7	Scottish borders
16/022	KWS Kielder	15/03/2016	5	Herefordshire
16/023	KWS Kielder	06/04/2016	5	Herefordshire
16/024	KWS Kielder	06/04/2016	5	Lincolnshire
16/025	Solstice	06/04/2016	4	Unknown
16/026	unknown	24/05/2016		Lincolnshire
16/027	unknown	24/05/2016		Warwickshire
16/028	Spaldings prolific	24/05/2016		Unknown
16/029	Spaldings prolific	26/05/2016		Unknown
16/030	Leeds	07/06/2016	3	Cambridgeshire
16/031	Leeds		3	Bedfordshire
16/032	LG Cassidy			Buckinghamshire
16/033	Rahma	17/06/2016		Suffolk
16/034	Najia	17/06/2016		Hampshire
16/035	Remax	17/06/2016		Unknown
16/036	Zola	17/06/2016		Unknown
16/037	Sensas	17/06/2016		Unknown
16/038	Faiza	17/06/2016		Herefordshire
16/039	Cadenza	17/06/2016		Unknown
16/040	unknown	21/06/2016		Unknown
16/041	Alfredo	21/06/2016		Unknown
16/042	unknown	21/06/2016		Unknown

<b>Isolate number</b>	<b>Host Variety</b>	<b>Date sampled/received</b>	<b>RL Rating 2016/17</b>	<b>Location</b>
16/043	Specifik	17/06/2016		Unknown
16/044	Lennox	17/06/2016		Norfolk
16/045	Matthus	17/06/2016		Norfolk
16/046	Triso	17/06/2016		Unknown

# 2016 Barley Powdery Mildew Isolate Register

Isolate number	Host Variety	Date sampled/received	RL Rating 2016/17	Location
16/001	KWS Cassia	Jan-16	4	Herefordshire
16/002	Bazooka	Feb-16	5	Surrey
16/003	BR tunnel Discard	Apr-16		
16/004	KWS Orwell	Apr-16	3	
16/005	WB line	May-16		Wiltshire
16/006	Bazooka	May-16	5	Cambridgeshire
16/007	Funky	May-16		Cambridgeshire
16/008	Surge	May-16	6	Hampshire
16/009	SY Venture	May-16	6	Hampshire
16/010	KWS Tower	May-16	5	Hampshire
16/011	Volume	May-16	5	Hampshire
16/012	Craft	May-16	6	Hampshire
16/013	Talisman	May-16	6	Hampshire
16/014	California	May-16	6	Hampshire
16/015	Belfry	May-16	6	Hampshire
16/016	KWS Cresswell	May-16		East Yorkshire
16/017	KWS Orwell	Jun-16	3	Cambridgeshire
16/018	KWS Orwell	Jun-16	3	Lincolnshire
16/019	Propino	Jul-16	6	Cambridgeshire
16/020	spring breeding line	Jul-16		Lincolnshire

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