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United Kingdom Cereal Pathogen Virulence Survey
2016 Annual Report
Part 1: Wheat Yellow Rust, Wheat Powdery Mildew and Barley Powdery Mildew

Amelia Hubbard, Laura Pritchard and Sarah Holdgate

NIAB, Huntingdon Road, Cambridge, CB3 0LE

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Foreword

The report for the UK Cereal Pathogen Virulence Survey is divided into two parts this year. We have experienced problems with the variety testing for the wheat brown rust and repeat testing is required. This should be completed within the next three months. We feel however that the results for the wheat yellow rust in particular should be made available as soon as possible and would therefore rather split the annual report this year.

Sarah Holdgate
Project Manager

1. Summary

The UKCPVS monitors the populations of the important cerealpathogens wheat yellow rust (*Puccinia striiformis* f.sp. *tritici*), wheat brown rust (*Puccinia triticina*), wheat powdery mildew (*Blumeria graminis* f.sp. *tritici*) and barley powdery mildew (*Blumeria graminis* f.sp. *hordei*). The results contained in this report relate to wheat yellow rust and wheat and barley powdery mildew, with the results of wheat brown rust to follow later this year.

Wheat yellow rust

Since the incursion of the Warrior population in 2011, the UK yellow rust population has been changing, with the old UK population now entirely replaced by the new Warrior group. In 2014, the Kranich race was also detected for the first time. Results from the tests on isolates collected in 2015 showed new pathotype combinations not seen before. Whilst not unusual in this very diverse population, the new pathotypes were associated with higher than expected levels of disease across the country. A subset of isolates tested on a wide range of varieties revealed that the Kranich race was very likely to have been present in 2015, with a potentially mixed isolate (15/088) showing signs of its presence. A pathotype resembling the Old European Solstice race was also frequently detected and was associated with high levels of disease in Lincolnshire. Results from this project and from the associated Field Pathogenomics project suggest that this group of isolates should be considered a new race, and these isolates have been assigned to the new Invicta race. The full impact of this race at the adult plant stage remains to be confirmed, with adult plant trials conducted in 2016 confounded by natural infection.

Wheat powdery mildew

Low levels of disease in 2015 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 Sicco, Wembley, Shamrock, Warrior and Stigg. For the most part, the virulence frequencies compare well with previous years, with the exception of the aforementioned varieties whose frequencies differ between years. Most notably, virulence for Amigo, which carries the gene *Pm17*, has been identified for the first time since 2010. There were however no reports of 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.

Barley powdery mildew

Similar to the wheat powdery mildew, there were very few samples received by the UKCPVS of barley powdery mildew. 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. This is most

likely an artefact due to the small number of starting samples. For the remaining genes there were some deviations from previous years, with a decrease in virulence frequency for the differentials Goldfoil, Zephyr, Porter, Lotta, Ricardo and Optic and an increase in the virulence frequency for the differentials Tyra, Roland and Propino. For the second year in a row virulence for KWS Meridian was detected and the frequency has increased from last year. As with the wheat powdery mildew, no adult plant tests are conducted with these isolates and the full impact of any change in the population will not become evident until the following season.

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 thrive. Warmer summers have also led to the presence of brown (leaf) rust at the end of the season which can be serious if left unchecked on susceptible cultivars. 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 rusts 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 49th 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 populations of wheat yellow and brown rust and wheat and barley powdery mildew. A close eye is also kept on 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 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

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 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	*Yr9, Yr17, Yr32*
2008	Solstice	*Yr6, Yr9, Yr17, Yr32*
2011	Warrior	*Yr6, Yr7, Yr9, Yr17, Yr32,* Spaldings Prolific

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; 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 et al., 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.

2.1.4. Further changes since the arrival of the Warrior group

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; 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 is 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).

In addition to highlighting changes in the pathogen population, the UKCPVS also performs trials to assess the reaction of current UK Recommended List (RL) varieties to the newest isolates, including those that are suspected to be of a new race. In the past varieties have been highly susceptible to new races, with catastrophic decreases in resistance ratings as so-called major resistance genes have been overcome. The Hornet race caused the RL yellow rust rating for Hornet drop from a 9 to a 2 in the space of a year, and a similar drop was seen for Brigadier (9 to 2). More recent race changes have seen more modest drops in ratings, for example Solstice changed from a 9 to a 4 in response to the Solstice race and Beluga from a 9 to a 5 and Claire from a 9 to a 6, both in response to the Warrior race. This suggests that some of the current varieties have other background resistance unaffected by the new races that reduce the effect of the breakdown. It is for this reason that it is difficult to predict the likely impact of a new race on different varieties and that a complete breakdown should never be assumed.

2.2. Aims and objectives

The principal aim of the project is to detect new races of economically important diseases 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 wheat yellow rust and

brown rust and wheat and barley powdery mildew. As detailed in 2.1.2.2, a subset of isolates will be characterised to identify any new races. The reactions of the current RL varieties and candidates will be assessed using the newest isolates at both the seedling and adult plant stages.

3. Materials and methods

3.1. Wheat yellow 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). 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 plants for each isolate under test. The differentials used and the resistance genes they carry are listed in Table 2. 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 sown in field trials 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. Each plot consisted of 2 x 1m rows, which was adjacent to two rows of spreader plants. The spreader rows were inoculated with the individual isolates in the spring using infected seedlings produced under controlled environment conditions. Prior to inoculation, natural infection was eliminated as far as possible by the use of a seed treatment and follow-up foliar fungicide applications. 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 10 and Table 12. 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 isolates 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 2015, the UKCVPS received 187 samples of wheat yellow rust from 20 different counties across the UK. As with previous years, the UKCPVS has been actively encouraging samples from wheat crops outside of the East of England to give a better understanding of the UK population of *Puccinia striiformis* f.sp. *tritici* (Figure 1).

Figure 1: Map of the UK with the number of samples of wheat yellow rust received in 2015 from the different counties.

The full sample register is provided in Appendix 1. There were several reports of unusual levels of yellow rust on different varieties throughout the year which may have been exacerbated by the relatively mild autumn and winter in 2014/15. Four reports of interest that were followed up by the UKCPVS were as follows:

- Higher than expected levels of disease in RL trials when the dataset was evaluated for the calculation of disease ratings. Two sites in particular were noted: one in

Essex and one in North Yorkshire. Direct samples were not available for either of these trials, however by chance there were some samples available from nearby sites. Although this is not ideal and a direct link cannot be made between test results and field results, the samples could give an early indication of what might be behind these field results.

- Verbal reports of high levels of disease in Scotland. Several samples were received from Scotland and a few were selected for further testing.
- Higher than expected levels of disease on the variety Invicta. The UKCPVS went to a site in Lincolnshire where late season disease had taken hold on a range of varieties previously noted as being resistant. Samples were taken directly from the trial in question providing the best opportunity to explain this outbreak.

Outside of these reports samples were once again received from a wide range of varieties, ranging from RL ratings of 4 and the unclassified varieties such as Robigus and Oakley through to the more resistant varieties such as Evolution, KWS Trinity and Spyder. As in previous years the survey was particularly interested in samples from varieties with a high RL rating as rust on these varieties could indicate a change in the pathogen population. 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.

4.1.2. Pathotyping of isolates

4.1.2.1. Virulence for individual resistance genes and varieties

Twenty nine isolates were selected for further pathotyping (Table 2). 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. 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 is possible to combine the scores for reactions to different resistance genes to infer a pathotype for each of the isolates (Table 3). No new virulences to individual genes were detected in the isolates collected in 2015 using the differentials tested at the seedling stage and frequency of virulence to the individual resistance genes remained relatively

Table 2: Average infection type (a.i.t.) scores for the 29 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 Variety	1	2	3a+	3a+	3b,4b	4,Su	5	6	2,6	2,6	7	7	6,7	7,17	8	9	9	10	15	9,17	17	17	17	24	2,25	25,Sd	32	32	32	Sp	Ro	So	Wa	St		Am						
		Chinese 166	Kalyansona	Vilmorin 23	Nord Desprez	Hybrid 46	Suwon Omar	Avocet Yr5	Avocet Yr6	Heines Kolben	Heines Peko	Lee	AV x Yr 7 NIL	Cadenza	Apache	Compair	Kavkaz x 4 fed	Clement	Moro	AVS x yr15	Brigadier	VPM 1	Rendezvous	AV x Yr17	Avocet Yr24	Heines VII	Strubes Dickkopf	Carstens V	Talon	Av x Yr32	Spaldings Prolific	Robigus	Solstice	Warrior	KWS Sterling	Claire	Ambition	Crusoe	Revelation	Delphi	Mosaic	Monterey	Kranich	Vuka
15/013	Evolution	3.0	3.0	3.0	3.0	3.0	3.0	0.0	4.0	3.0	4.0	3.0	3.5	3.0	2.8	0.0	3.5	3.0	0.0	0.0	2.2	3.0	2.2	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.6	1.8	3.0	1.7	0.0	2.3	2.8	2.8	2.0	2.1	3.1
15/018	KWS Santiago	3.0	3.0	3.0	3.0	2.5	3.0	0.0	3.0	2.0	3.0	3.0	3.0	2.8	2.9	0.0	3.0	3.0	0.0	*	2.9	2.0	2.1	3.0	0.0	3.0	3.0	2.6	3.0	3.0	3.0	3.0	3.0	1.0	1.1	2.4	0.2	0.0	2.2	2.1	2.1	0.3	0.0	2.5
15/020	KWS Kielder	3.1	3.0	3.0	3.4	3.0	3.0	0.0	3.5	3.0	3.5	3.0	3.3	3.5	3.0	0.0	3.5	3.0	0.0	0.0	3.0	3.0	2.0	3.0	0.0	3.5	3.0	2.8	2.9	3.5	3.5	3.5	3.5	0.9	3.0	3.5	0.3	0.0	1.9	3.0	2.9	0.8	0.5	3.0
15/037	Britannia	3.0	3.0	3.0	2.8	3.0	3.0	0.0	4.0	2.7	3.0	3.0	3.0	2.6	3.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	1.9	3.0	0.0	3.0	3.0	3.0	3.0	3.1	3.1	3.0	2.9	0.0	1.6	2.2	0.0	0.0	1.3	2.7	2.1	0.4	0.0	3.0
15/044	Stigg	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	0.0	*	3.0	3.0	1.6	3.0	0.0	3.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.1	1.7	2.8	0.0	0.0	0.5	1.7	2.0	0.0	0.0	3.0
15/048	Canadian Spring Wheat	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.1	3.0	3.0	3.0	3.1	3.0	2.0	0.0	3.0	3.0	0.0	*	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.1	3.1	3.0	3.1	2.0	3.0	3.0	2.1	0.1	0.4	2.0	2.2	0.2	0.7	3.0
15/049	KWS Santiago	3.0	3.0	3.0	3.0	2.0	3.0	0.0	3.5	3.0	3.0	3.0	3.1	3.0	0.3	0.0	3.0	3.0	0.0	*	2.5	3.0	2.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.6	2.1	0.8	1.7	0.0	1.2	1.0	2.0	0.2	0.7	3.0
15/057	Kranich	3.0	3.0	3.0	2.0	2.0	2.3	0.0	3.0	3.0	3.0	3.0	3.0	2.6	2.2	0.0	3.0	2.5	0.0	*	1.5	2.0	0.4	3.0	0.0	3.0	3.0	3.0	2.2	3.0	3.0	3.0	2.2	2.1	0.8	3.1	3.0	0.0	1.6	1.9	1.8	1.6	2.3	3.0
15/058	Warrior	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	2.0	3.0	3.0	3.0	2.6	2.0	0.3	3.0	3.0	0.0	*	2.0	2.0	0.0	2.5	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.8	3.0	1.2	2.1	3.0	0.1	2.0	2.1	2.0	2.0	2.8	3.0
15/076	KWS Lili	3.0	3.0	3.2	2.5	2.2	3.0	0.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	4.0	2.8	0.0	*	1.5	3.0	2.1	3.0	0.0	3.0	3.0	3.0	3.0	3.5	3.1	3.0	3.0	0.2	2.0	3.0	0.0	0.0	1.0	3.0	3.0	0.2	0.0	3.0
15/079	KWS Kielder	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	2.5	4.0	3.0	3.0	0.0	3.0	3.0	0.0	*	3.0	3.0	2.5	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.6	3.0	2.5	0.0	0.0	2.4	3.0	3.0	0.0	0.5	3.0
15/088	Horatio	3.5	3.0	3.0	3.0	3.0	3.0	0.0	4.0	3.0	3.0	3.0	3.0	2.7	3.0	0.0	3.5	3.0	0.0	0.0	3.0	3.0	2.0	3.0	0.2	3.0	3.0	3.0	3.0	3.1	3.0	3.1	3.0	0.7	1.4	3.0	0.5	0.0	2.0	3.0	2.8	0.3	0.8	3.5
15/100	KWS Croft	3.2	3.0	3.0	3.0	3.0	3.0	0.0	4.0	3.0	3.0	3.0	4.0	3.1	3.0	0.0	3.0	3.0	0.0	*	3.0	3.0	3.0	3.0	0.0	3.5	3.5	3.2	3.0	3.0	3.0	3.0	1.5	2.1	3.0	4.0	0.0	0.0	2.8	3.0	2.9	0.5	0.0	3.0
15/113	Delphi	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.1	3.0	3.0	1.7	0.5	0.0	0.0	0.0	3.0	3.0	0.0	*	3.1	3.0	3.0	3.0	0.1	3.2	3.0	1.8	3.0	2.9	0.0	2.8	2.9	0.1	0.0	3.0	0.0	0.0	3.2	4.0	3.1	3.0	0.0	3.1
15/115	Icon	3.0	3.0	3.0	3.0	3.0	2.5	0.0	3.0	3.0	3.0	0.4	0.4	0.0	0.0	0.2	3.0	2.5	0.0	*	3.0	3.0	3.0	3.0	0.2	3.0	3.0	3.0	3.0	3.0	0.0	3.0	2.8	0.0	0.0	3.0	0.0	0.0	3.0	3.0	3.0	3.0	0.0	3.0
15/132	Skyfall	3.0	3.0	3.0	3.0	3.0	3.0	0.0	4.0	2.5	3.2	2.8	4.0	3.0	3.0	0.0	3.0	2.9	0.0	*	3.0	3.2	0.6	3.0	2.5	3.2	3.1	3.1	3.0	3.1	3.1	3.1	3.1	2.0	2.4	2.8	0.6	0.0	2.8	2.4	2.6	2.0	1.9	3.1
15/139	Invicta	3.0	3.0	3.0	2.5	2.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	1.8	0.2	3.0	3.0	0.0	*	2.0	2.0	0.2	3.0	0.0	2.5	3.0	3.0	2.3	3.0	3.0	3.0	2.5	2.5	1.1	3.0	3.0	0.1	0.0	1.9	1.8	1.5	2.8	3.0
15/141	Zulu	3.0	3.0	3.0	3.0	3.0	3.0	0.0	4.0	3.0	3.0	0.0	2.0	0.0	0.0	0.2	3.0	3.0	0.0	0.3	3.5	3.0	2.6	3.0	0.0	3.0	4.0	3.0	3.0	2.8	0.0	3.0	3.0	0.5	0.0	3.0	0.5	0.0	4.0	3.1	3.0	3.0	0.6	3.0

Isolate Code	Host Variety	1	2	3a+	3a+	3b,4b	4,Su	5	6	2,6	2,6	7	7	6,7	7,17	8	9	9	10	15	9,17	17	17	17	24	2,25	25,Sd	32	32	32	Sp	Ro	So	Wa	St		Am					
		Chinese 166	Kalyansona	Vilmorin 23	Nord Desprez	Hybrid 46	Suwon Omar	Avocet Yr5	Avocet Yr6	Heines Kolben	Heines Peko	Lee	AV x Yr 7 NIL	Cadenza	Apache	Compair	Kavkaz x 4 fed	Clement	Moro	AVS x yr15	Brigadier	VPM 1	Rendezvous	AV x Yr17	Avocet Yr24	Heines VII	Strubes Dickkopf	Carstens V	Talon	Av x Yr32	Spaldings Prolific	Robigus	Solstice	Warrior	KWS Sterling	Claire	Ambition	Crusoe	Revelation	Delphi	Mosaic	Monterey	Kranich	Vuka
15/142	KWS Croft	3.0	3.0	3.0	3.0	3.0	3.0	0.0	4.0	3.0	3.0	2.9	3.0	2.3	1.4	0.0	3.0	3.0	0.0	0.3	3.0	3.0	3.0	3.1	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.9	1.9	3.0	0.6	0.0	3.0	3.0	3.0	2.3	0.3	3.0
15/146	Cocoon	3.0	3.0	3.0	3.0	3.0	2.0	0.0	4.0	3.0	3.0	3.0	3.1	3.0	2.9	0.0	3.0	3.0	0.0	0.9	2.7	3.0	2.3	3.0	0.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.9	2.3	3.0	0.7	0.0	1.4	2.3	3.0	1.0	0.0	3.0
15/151	Invicta	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	1.0	1.1	0.0	0.0	0.0	3.0	4.0	0.0	*	3.0	3.0	3.1	3.0	0.0	3.0	3.5	3.0	3.0	3.0	0.3	3.0	3.0	0.7	0.0	3.5	0.0	0.0	3.2	3.2	3.0	3.0	0.0	3.0
15/161	KWS Santiago	3.5	3.0	3.0	3.0	3.0	3.0	0.0	4.0	3.0	3.5	3.0	3.0	1.8	3.0	0.0	3.5	3.0	0.0	0.0	3.0	3.0	3.0	3.0	0.0	3.0	3.5	3.0	3.0	3.5	3.0	3.0	3.0	0.3	3.0	2.3	0.0	0.0	2.7	3.0	2.0	2.0	1.2	3.0
15/170	Invicta	3.5	2.6	3.0	3.3	3.0	3.0	0.0	3.5	3.0	3.0	0.4	3.0	0.3	0.0	0.0	3.0	3.0	0.0	*	3.0	3.0	3.0	3.0	0.0	4.0	4.0	3.5	3.1	3.2	0.0	3.0	3.0	0.8	0.0	4.0	0.0	0.0	4.0	4.0	3.8	4.0	0.0	3.0
15/176	Zulu	3.0	3.0	3.0	4.0	3.5	3.0	0.0	4.0	3.0	3.0	2.3	2.5	0.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.5	3.0	0.0	4.0	3.0	3.1	3.1	3.5	0.2	3.0	3.2	0.0	0.0	3.0	0.0	0.0	3.5	3.2	3.1	3.0	0.0	3.0
15/180	Skyfall	3.5	3.0	3.0	3.0	2.0	3.0	0.0	3.5	2.0	4.0	3.0	3.5	3.0	2.9	0.0	3.0	3.0	0.0	0.0	3.0	3.0	1.7	3.0	0.0	3.1	3.0	3.0	3.0	3.5	3.0	3.5	3.0	0.2	2.8	3.0	0.0	0.0	1.7	3.0	3.0	0.7	0.0	3.0
15/185	KWS Kielder	3.0	3.0	3.0	3.0	2.1	3.0	0.0	3.5	3.0	3.0	2.9	3.2	4.0	3.0	0.0	3.0	2.5	0.0	0.0	3.5	2.9	2.5	3.0	0.0	4.0	3.0	4.0	3.0	3.0	2.8	3.0	3.0	0.3	2.7	3.5	0.0	0.0	0.6	3.2	3.0	0.0	0.0	3.0
15/186	Invicta	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.2	3.0	3.0	2.0	2.3	0.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	2.9	3.0	0.0	3.0	3.0	3.0	3.0	3.0	0.5	3.0	3.0	0.0	0.0	3.0	0.0	0.0	3.0	3.0	3.0	3.0	0.0	3.0
15/187	JB Diego	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	1.7	2.3	0.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	3.0	3.0	2.8	0.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	0.0	0.0	3.0	0.2	0.0	3.0	3.0	3.0	3.0	0.0	3.0

Table 3: Pathotypes of the 2015 wheat yellow rust isolates based on the differential test results in Table 2. Re = Rendedezvous, Sp = Spaldings Prolific, Ro = Robigus, So = Solstice, Wa = Warrior, Am = Ambition, Ca = Cadenza, St = KWS Sterling, Kr = Kranich, Ap = Apache. * Pathotype groups explained further in Table 5.

Isolate Code	Host Variety	Pathotype Group	Virulence Profile																							
			1	2	3	4	5	6	7	8	9	10	15	17	24	25	32	Re	Sp	Ro	So	Wa	Am	Ca	St	Kr	Ap
15/013	Evolution	Warrior 4	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So			Ca			Ap
15/018	KWS Santiago	Warrior 4	1	2	3	4		6	7		9		*	17		25	32		Sp	Ro	So			Ca			Ap
15/020	KWS Kielder	Warrior 4	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So			Ca	St		Ap
15/037	Britannia	Warrior 4	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So			(Ca)			Ap
15/044	Stigg	Warrior 4	1	2	3	4		6	7		9		*	17		25	32		Sp	Ro	So			Ca			Ap
15/048	Canadian Spring Wheat	Warrior 4	1	2	3	4		6	7		9		*	17		25	32	Re	Sp	Ro	So			Ca	St		
15/049	KWS Santiago	Warrior 4	1	2	3	4		6	7		9		*	17		25	32		Sp	Ro	So			Ca			
15/057	Kranich	Warrior 4	1	2	3			6	7		9		*	17		25	32		Sp	Ro			Am	(Ca)			
15/058	Warrior	Warrior 1	1	2	3	4		6	7		9		*	(17)		25	32		Sp	Ro	So	Wa	Am	(Ca)		Kr	
15/076	KWS Lili	Warrior 4	1	2	3	4		6	7		9		*	17		25	32		Sp	Ro	So			Ca			Ap
15/079	KWS Kielder	Warrior 4	1	2	3	4		6	7		9		*	17		25	32	(Re)	Sp	Ro	So			Ca	St		Ap
15/088	Horatio	Warrior 4	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So			Ca			Ap
15/100	KWS Croft	Warrior 4	1	2	3	4		6	7		9		*	17		25	32	Re	Sp	Ro				Ca	St		Ap
15/113	Delphi	Warrior 3/Old European	1	2	3	4		6			9		*	17		25	32	Re		Ro	So						
15/115	Icon	Warrior 3/Old European	1	2	3	4		6			9		*	17		25	32	Re		Ro	So						
15/132	Skyfall	Warrior 4	1	2	3	4		6	7		9		*	17	(24)	25	32		Sp	Ro	So			Ca	(St)		Ap
15/139	Invicta	Warrior 4	1	2	3	4		6	7		9		*	17		25	32		Sp	Ro	(So)	(Wa)	Am	Ca		Kr	
15/141	Zulu	Other	1	2	3	4		6			9			17		25	32	(Re)		Ro	So						
15/142	KWS Croft	Warrior 4	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So						
15/146	Cocoon	Warrior 4	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So			Ca			Ap
15/151	Invicta	Warrior 3/Old European	1	2	3	4		6			9		*	17		25	32	Re		Ro	So						
15/161	KWS Santiago	Warrior 4	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So				St		Ap
15/170	Invicta	Warrior 3/Old European	1	(2)	3	4		6	7		9		*	17		25	32	Re		Ro	So						
15/176	Zulu	Warrior 3/Old European	1	2	3	4		6	(7)		9			17		25	32	Re		Ro	So						
15/177	KWS Kielder	Warrior 4	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So			Ca			Ap
15/180	Skyfall	Warrior 4	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So			Ca	St		Ap
15/185	KWS Kielder	Warrior 4	1	2	3	4		6	7		9			17		25	32	(Re)	Sp	Ro	So			Ca	St		Ap
15/186	Invicta	Warrior 3/Old European	1	2	3	4		6			9			17		25	32	Re		Ro	So						
15/187	JB Diego	Warrior 3/Old European	1	2	3	4		6			9			17		25	32	Re		Ro	So						

stable for known resistance genes in comparison to previous years (Table 4). The exception to this was the frequency of virulence for *Yr7*, which reduced to being present in 76% of isolates, down from 93% in 2014. A similar trend was also seen for some of the varieties in the test, with virulence frequencies for Warrior Spaldings Prolific Ambition, Apache and Cadenza all being lower this year. Conversely, virulence frequencies for Rendezvous, Claire and KWS Sterling all increased this year. These changes can be explained when the broader pathotype group frequencies are considered.

4.1.2.2. Virulence frequencies for pathotype groups

As in previous years, the isolates generally belonged to the Warrior group, as indicated by virulence for Spaldings Prolific (21 isolates). In order to further analyse these isolates, particularly in light of the fact that only one of these isolates was virulent on Warrior, the isolates are subdivided into groups based on the reaction to other key differentials (Table 5). This has been done by the UKCPVS for the past two years and has highlighted some important changes in the population that could have been missed by considering virulence to individual resistance genes alone. Since the initial grouping of the isolates there have also been advances in Field Pathogenomics at The Earlham Institute (EI) and John Innes Centre (JIC), which the UKCPVS has been heavily involved in, and this year the groups identified by both the UKCPVS and EI/JIC were brought together for the first time. This has led to a slight re-structure of the group divisions; however this reflects the constantly changing nature of the population (Table 5). Within the new groupings there are two entries for isolates with a pathotype for the Solstice race. The Solstice race in the UK was first detected in 2008 and was classified according to the new combination of virulence for *Yr6,9,17,32* and Solstice. Since the incursion of the Warrior population isolates have been identified that have a virulence profile similar to this race but using new sequencing approaches they have been shown to be members of the new population (D. Saunders, *pers. comm.*.). In these cases the isolates in question have shown a near-identical pathotype in differential tests to isolates of the original Solstice race, however they are completely unrelated. For this reason, isolates with the Solstice pathotype are grouped as either Warrior 3 or old European until further genotypic analysis is carried out to confirm the groupings.

In 2015 there were 14 different pathotypes detected in the 29 isolates tested, nine of which were unique to this year. This is a similar number to the previous four years. Since the incursion of the Warrior population of yellow rust, the UK yellow rust population has become very diverse and it is not uncommon to identify subtle changes in the combinations of virulences. In previous years these new variants have had relatively low impact, with no

Table 4: Frequency of detection of isolates carrying virulence to the different yellow rust resistance genes over the past five years. * = missing data.

Virulence For Resistance Gene or Variety	**Percentage of Isolates Identified with Virulence for Gene or Variety**				
	2011	**2012**	**2013**	**2014**	**2015**
Yr1	100	100	100	100	100
Yr2	100	100	100	100	97
Yr3	100	100	100	96	100
Yr4	100	100	100	96	97
Yr5	0	0	0	0	0
Yr6	93	97	100	100	100
Yr7	70	97	92	93	76
Yr8	0	0	0	4	0
Yr9	100	100	100	96	100
Yr10	*	*	0	0	0
Yr15	0	0	0	0	0
Yr17	96	100	100	100	97
Yr24	*	*	0	0	0
Yr25	*	*	92	100	100
Yr32	96	90	100	100	100
Robigus	0	97	100	100	100
Solstice	96	97	100	85	90
Warrior	56	59	28	26	3
Spaldings Prolific	*	76	80	89	72
Rendezvous	63	28	48	11	38
Ambition	*	79	28	22	10
Apache	*	*	76	67	52
KWS Sterling	11	28	44	7	24
Cadenza	*	76	80	70	55
Claire	*	45	92	56	79
Crusoe	*	0	4	0	0
Kranich	*	*	*	4	7
Total Number of Isolates	**27**	**29**	**25**	**27**	**29**

Table 5: Pathotype groups of the current UK yellow rust population. Key differentials used in grouping isolates are given with their effect being either virulent (V) or avirulent (A).

Old Group Name	European Name	Field Pathogenomics Group	New Combined Group Name	Effect on			
				Spaldings Prolific	Rendezvous	Warrior	Kranich
Warrior 1	Warrior	Pink	Warrior 1	V	A	V	A/V
Warrior 2	Warrior	Green	Warrior 2	V	V	V	A/V
Warrior 3	Warrior -	Red	Warrior 4	V	A	A	A/V
Warrior 4	Warrior -	Red	Warrior 4	V	V	A	A/V
Solstice	Solstice	Blue	Warrior 3	A	V	A	A
Solstice	Solstice	Old UK	Old European	A	V	A	A
Kranich	Kranich	Purple	Kranich	A	A	A	V

no major changes in the reaction of UK varieties at the adult plant stage. Out of the 14 pathotypes detected this year, there were three pathotypes that dominated. Firstly, the most common pathotype, represented by seven isolates, was a Warrior 4 pathotype that was a novel combination. This pathotype carried virulence for *Yr1,2,3,4,6,7,9,17,25,32,Sp,Ro,So,Ca,Ap* and is classified as Warrior 4 based on virulence for Spaldings Prolific and avirulence on Warrior. The isolates carrying this virulence profile were from varieties with a range of resistance ratings from KWS Kielder through to Evolution and were found across the country from East Lothian down to Dorset and Kent across many time points in the year. Two of these samples were from Scotland and Essex and could perhaps represent isolates behind the higher than expected levels of disease at these locations.

The second most common pathotype was the virulence combination *Yr1,2,3,4,6,9,17, 25,32,Re,Ro,So*, which was identified in six isolates. This is the pathotype for the Solstice race, which as discussed earlier could represent a resurgence of the Old European strains or a novel combination from the Warrior group. Subsequent genomic analysis of the isolates 15/151 and 15/176 show that these isolates are in fact part of the wider Warrior group and are therefore classified as Warrior group 3 isolates (D. Saunders, *pers. comm.,* https://wheatis.tgac.ac.uk/yellowrust-map/). The isolates from this group were isolated only from varieties with high resistance ratings, and they were also found very late in the season, with the first isolate from this group being detected in June 2015. Amongst these isolates are two that were directly from an unexpected outbreak in Lincolnshire giving a high degree of confidence that this new variant is behind the outbreak. Although the virulence profile suggests that these isolates should behave in the same way as the Old European isolates, there are likely to be additional uncharacterised virulences in the background that are causing the damage.

Finally, the third most common pathotype carried the virulence combination, identified in four isolates was similar to the most common pathotype but with additional virulence for Apache. This pathotype has been seen before in 2013. This pathotype was again a Warrior 4 type and found across the country, but three out of the four isolates this time were found on KWS Kielder. Amongst these isolates, one of the isolates was from North Yorkshire which may explain unusual sightings in this area during 2015.

No pathotypes were detected that were similar to the Kranich race, as confirmed by the lack of virulence for *Yr8*. There were however a few isolates with virulence for the variety

Kranich, and although this does not necessarily indicate the presence of the Kranich race, the UKCPVS were interested in following up some of these isolates in further tests.

Comparing the frequencies of the different pathotype groups across the past four years (Table 6), it is clear that the Warrior 4 group continues to dominate the population and that the original Warrior 1 group continues to decline in frequency. Following on from the identification of the Warrior 3 isolates this year there is a noticeable increase in frequency for this group and will be important to monitor through 2016.

4.1.3. Variety testing of isolates from 2015

Five isolates from the 29 tested 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 29 tested isolates and included one isolate from each of the three most common pathotype groups detailed in 4.1.2.2., an isolate of the Kranich race (15/601, an isolate taken from the adult plant trial inoculated with the 2014 Kranich race isolate) and an isolate that contained virulence for Kranich that was not thought to be the Kranich race.

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 2016. 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). Only four of the RL varieties and candidates tested were resistant to all of the isolates tested: Costello, KWS Crispin, KWS Siskin and Marston. Virulence was detected for the first time for the varieties Cougar (isolate 15/088), Crusoe (isolate 15/601), KWS Silverstone (isolates 15/151, 15/185 and 15/088), and RGT Illustrious (isolates 15/151 and 15/185).

An additional differential variety was added as a control: the Avocet *Yr8* NIL. We have previously been concerned that the reaction on Compair, our differential for *Yr8*, was not as strong as we might expect, even when challenged with a pure Kranich isolate which carries virulence for *Yr8*. When the Avocet NIL is used, the isolates 15/601 and 15/088 both very clearly show virulence for *Yr8*. The reaction on Compair for both of these isolates was avirulence for 15/088 and virulence for 15/601. This result was partly expected, the isolate 15/601 was an isolate of the Kranich race. The results for 15/088 were unexpected however.

Table 6: Pathotype group frequencies from 2012 to 2015

Pathotype Group	Frequency of Isolates Found (%)			
	2012	2013	2014	2015
Warrior 1	59	20	22	3
Warrior 3/Old European	24	20	7	24
Warrior 4	17	52	67	69
Other	0	8	0	3
Kranich	0	0	4	0
Number of isolates	**29**	**25**	**27**	**29**

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. Yellow shading = compatible reaction (virulence), orange shading and parentheses = borderline reaction, blank = avirulence, * = missing data.

Isolate Code	Host Variety	Pathotype Group	Virulence Profile																							
			1	2	3	4	5	6	7	8	9	10	15	17	24	25	27	32	Re	Sp	Ro	So	Wa	Am	Ca	St	Kr	Ap
15/088	Horatio	Warrior 4	1	2	3	4		6	7		9			17		25	*	32		Sp	Ro	So			Ca			Ap
15/139	Invicta	Warrior 4	1	2	3	4		6	7		9		*	17		25	*	32		Sp	Ro	(So)	(Wa)	Am	Ca		Kr	
15/151	Invicta	Warrior 3	1	2	3	4		6			9		*	17		25	*	32	Re		Ro	So						
15/185	KWS Kielder	Warrior 4	1	2	3	4		6	7		9			17		25	*	32	(Re)	Sp	Ro	So			Ca	St		Ap
15/601	Monterey	Kranich	1	-	3			6	7	(8)	9			(17)		25		32			Ro	So	Wa	Am	Ca	St	Kr	Ap

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 five assessments. Varieties are ordered in level of disease at adult plant stage. Control varieties are highlighted in green text. Shading of adult plant results classifies varieties as resistant (green), moderately resistant (yellow), moderately susceptible (orange) and susceptible (red).

Variety	RL Rating 2016/17	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		15/151	15/088	15/185	15/139	15/601	15/151	15/088	15/185	15/139	15/601
Crusoe	8.7	0.0	0.8	2.0	0.3	3.0	0.0	0.0	0.0	0.0	0.0
Costello	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LG Cassidy		0.0	2.1	2.7	2.8	3.0	0.0	0.0	0.0	0.0	0.2
Compair		0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
LG Sundance		3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.2
KWS Trinity	8.6	3.2	3.0	1.5	0.0	3.0	0.0	0.1	0.0	0.0	0.0
Marston		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Rendezvous		3.0	3.0	3.0	2.0	2.8	0.0	0.1	0.0	0.0	0.0
Evolution	8.6	3.2	1.2	0.0	0.0	0.3	0.0	0.2	0.1	0.0	1.3
KWS Barrel	8.0	3.0	3.0	3.0	0.0	2.9	0.0	0.2	0.2	0.0	0.0
Napier		3.0	3.0	3.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0
KWS Basset	8.6	4.0	3.0	3.2	3.0	3.0	0.0	0.0	0.0	0.0	0.0
KWS Crispin	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3
LG Motown		3.0	0.6	3.0	0.0	3.0	0.0	0.0	0.6	0.0	0.0
Savello		4.0	3.0	3.0	3.0	3.0	0.0	0.0	0.3	0.0	0.1
Dunston		4.0	3.0	3.0	2.0	3.0	0.0	0.0	0.0	0.0	0.0
Moulton		3.0	2.0	2.6	0.0	1.3	0.0	0.0	0.6	0.2	0.5
RGT Westminster		3.5	3.0	3.0	2.0	3.0	0.0	0.0	0.7	0.0	0.1
KWS Sterling		0.0	3.0	2.9	3.0	3.0	0.0	0.5	0.6	0.7	2.4
Mulika		0.0	3.0	3.0	3.0	3.0	0.0	1.5	0.0	0.0	0.1
Hardwicke		3.0	2.8	3.0	0.0	3.0	0.1	0.0	0.1	0.0	0.0
RGT Illustrious	9.0	3.0	2.2	3.0	0.0	2.4	0.1	0.0	0.0	0.0	0.0
RGT Marlborough		3.1	3.0	3.0	0.5	3.0	0.1	0.0	0.0	0.3	0.0
Shabras		3.5	3.0	3.0	3.0	3.0	0.1	0.0	0.0	0.0	1.1
Bennington		3.0	3.0	3.0	0.2	3.0	0.1	0.0	0.0	1.0	0.1

Variety	RL Rating 2016/17	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		15/151	15/088	15/185	15/139	15/601	15/151	15/088	15/185	15/139	15/601
Graham	8.0	3.0	3.0	3.0	3.0	3.0	0.1	0.3	1.2	0.6	2.4
Revelation	8.7	3.5	3.0	3.0	0.2	3.0	0.1	0.0	0.7	0.0	0.0
Dickens	8.6	3.0	3.0	3.0	2.9	3.0	0.2	0.0	0.0	0.0	0.0
Relay	8.7	3.5	3.0	3.0	1.4	3.0	0.3	0.2	0.0	0.0	0.0
KWS Siskin	8.9	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.1
Cougar		1.3	3.0	0.5	0.0	0.2	1.1	0.2	0.0	0.0	0.0
KWS Silverstone	8.0	3.0	3.0	3.1	1.0	2.0	1.2	0.1	0.0	0.7	0.5
KWS Kerrin		3.0	3.0	3.0	0.0	2.1	1.4	1.1	0.2	0.0	0.2
Freiston		3.5	3.0	3.0	0.0	3.0	0.0	0.0	0.0	0.0	2.7
KWS Zyatt		0.0	3.0	3.0	(3.0)	3.0	0.0	0.1	0.5	1.0	2.9
RGT Paddington		3.0	3.0	3.0	3.0	3.0	0.2	0.1	1.2	0.0	3.2
LG Bletchley		3.0	3.0	3.0	0.8	2.8	0.0	0.0	0.1	0.1	3.6
Spyder	8.0	3.0	3.0	3.0	2.0	3.0	0.1	0.2	0.4	0.4	3.9
Brigadier		3.5	3.0	3.0	3.0	3.0	0.1	0.1	0.8	0.2	6.7
Marlowe		3.0	3.0	3.0	3.0	3.0	0.0	1.8	1.1	0.2	6.9
Warrior		1.6	2.1	3.0	3.0	3.0	1.0	1.6	0.1	1.6	9.6
Stratosphere		3.0	3.0	3.0	3.0	3.0	0.4	1.8	0.3	0.1	9.8
Kranich		0.0	2.0	0.4	3.0	3.0	1.1	1.6	0.1	1.0	11.3
Talon		3.0	3.0	3.0	3.0	3.0	1.8	9.8	3.8	6.3	23.0
Belgrade	7.0	3.0	2.1	3.0	0.0	3.0	3.0	3.8	2.7	3.8	11.2
Leeds	7.4	3.2	3.0	3.0	0.9	3.0	4.2	3.5	9.2	3.4	10.6
Ambition		0.0	3.0	2.8	3.0	3.0	6.2	10.2	3.3	9.1	22.5
Scout	8.7	3.0	3.0	3.0	0.0	3.0	1.9	3.9	0.1	1.3	0.1
RGT Knightsbridge		3.0	3.0	3.0	0.1	3.0	0.2	1.2	5.7	4.0	1.1
Gallant	4.2	3.0	3.1	3.5	3.1	3.0	5.3	9.7	15.6	17.3	3.8
Icon		3.2	3.0	3.0	0.4	3.0	8.0	8.5	12.0	11.1	8.3
Brock		0.4	3.0	3.0	3.0	3.0	8.7	6.7	10.9	11.4	7.1
KWS Santiago	6.1	3.0	3.0	3.1	1.9	3.0	0.2	0.9	0.5	4.1	6.9
Apache		0.0	3.0	3.0	3.0	3.0	2.4	2.3	4.5	1.8	5.1
RGT Conversion	8.0	3.0	3.0	3.0	2.0	2.5	2.2	4.6	3.4	7.4	0.5

Variety	RL Rating 2016/17	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		15/151	15/088	15/185	15/139	15/601	15/151	15/088	15/185	15/139	15/601
Hustler		3.0	3.0	3.0	3.0	3.0	3.7	5.2	4.5	2.1	8.9
Zulu	8.5	3.0	3.0	3.0	0.0	3.0	5.5	3.4	2.6	4.8	2.9
RGT Pembroke		3.0	3.0	4.0	2.0	3.0	3.0	7.9	6.5	5.4	5.6
Viscount	4.6	3.0	3.1	3.1	1.3	3.0	4.9	7.5	4.6	6.0	6.4
KWS Lili	7.0	3.0	3.0	3.0	2.7	3.0	4.4	8.5	10.8	5.9	5.0
Claire	6.1	3.0	3.0	3.5	2.7	3.0	6.9	7.3	10.9	9.6	8.3
Britannia	7.7	3.2	3.0	3.0	3.0	3.0	8.0	11.8	12.3	10.2	7.8
Grafton	6.3	0.0	3.0	3.0	2.8	0.0	7.4	10.4	17.2	17.5	11.8
Reflection	6.0	3.2	3.0	3.1	3.0	3.0	9.6	12.0	23.9	13.6	11.9
Amplify		3.1	3.0	3.5	3.0	3.0	9.7	34.3	12.4	20.7	14.9
Hobbit		3.0	3.0	3.0	2.0	2.2	10.4	12.0	12.1	14.0	6.5
Mosaic		3.0	3.0	3.0	0.1	3.0	10.7	11.8	12.1	14.0	9.1
Myriad	7.9	3.0	3.0	3.0	0.0	2.9	11.0	9.8	11.3	12.9	13.2
Skyfall	6.2	0.0	3.0	3.0	3.0	3.0	11.4	8.2	11.2	14.7	11.8
Cadenza		0.0	3.0	3.0	3.0	3.0	12.3	7.1	10.7	15.8	19.7
JB Diego	7.3	3.0	3.0	3.0	2.2	3.0	12.4	15.6	14.6	13.9	12.0
Cordiale	5.3	0.0	3.0	3.5	3.2	2.8	20.1	28.2	20.2	23.4	21.7
Torch		1.2	3.0	3.0	3.0	3.0	25.7	21.3	18.7	39.3	49.3
Hornet		3.0	3.0	3.0	3.0	3.0	27.5	40.8	36.7	40.5	40.8
Robigus		3.0	3.0	3.0	3.0	3.0	30.4	42.8	44.2	41.0	42.9
Chinese 166		3.0	3.0	3.0	3.0	3.0					
Kalyansona		3.0	3.0	3.0	3.0	3.0					
Nord Desprez		3.0	3.0	3.0	3.0	3.0					
Hybrid 46		3.0	3.0	3.0	2.2	0.0					
Avocet Yr6		3.0	3.0	3.0	3.0	3.0					
Heines Peko		3.2	3.0	3.0	4.0	3.0					
Lee		2.0	2.8	3.0	3.0	3.0					
Av x Yr7 NIL		3.0	3.0	3.0	3.0	3.0					
Av x Yr8 NIL		1.9	3.0	0.0	0.0	3.0					
Kavkaz x 4 Fed		3.2	3.0	3.0	3.0	3.0					

Variety	RL Rating 2016/17	Seedling (Average Infection Type)					Adult Plant (% leaf area infected)				
		15/151	15/088	15/185	15/139	15/601	15/151	15/088	15/185	15/139	15/601
Clement		3.2	3.0	3.0	3.0	3.0					
AVS x Yr 15		0.0	0.0	0.0	0.0	0.0					
VPM 1		3.3	3.0	3.0	3.0	3.0					
Av x Yr17 Nil		3.2	3.1	3.5	3.0	3.0					
Carstens V		3.5	3.1	3.0	3.0	3.0					
Av x Yr32		3.1	3.0	3.0	3.0	3.0					
Spaldings Prolific		0.0	3.0	3.0	3.0	0.0					
Solstice		3.0	3.1	3.0	3.0	3.0					
Heines VII		3.0	3.0	3.0	3.0	3.0					
Suwon Omar		0.6	3.0	-	3.0	0.0					
Delphi		3.0	3.0	3.0	0.1	3.0					
Monterey		3.0	3.0	3.0	2.8	3.0					
Vuka		4.0	3.5	3.0	3.0	3.2					
Invicta		4.0	4.0	3.0	3.0	3.0					
Target		4.0	3.2	3.5	-	3.4					
Moro		0.0	0.0	0.0	0.0	0.0					
Yr5		0.0	0.0	0.0	0.0	0.0					
Tulsa		3.0	3.0	0.9	-	3.0					

In the original differential test, this isolate was avirulent on our standard *Yr8* differential (Compair) and so this isolate was classified as another Warrior isolate. The same result arose in 2014 when the isolate 14/106 was initially characterised as a Warrior isolate, but later field and seedling tests highlighted that it was something else. The reason for the discrepancy between the results could be because Compair also contains the gene *Yr19* (Chen et al., 1995). The results from this test on isolate 15/088 also continue to show virulence for *Yr4* and Spaldings Prolific, suggesting that this isolate could be a mixture of two isolates, probably Warrior 4 and Kranich. At the 2016 annual Stakeholders meeting we reported that no isolates of the Kranich race had been collected during 2015. However, with this latest evidence available through improvements to the differential set, it appears that it was found at least once. The remaining 24 tested isolates from 2015 have not been tested with the new differential and given the volume of samples received in 2016 it is unlikely that they will be in the near future.

The mixed nature of the isolate 15/088 was confirmed in these tests with only moderate agreement seen between the results for this isolate and the results for 15/601 (a Kranich isolate). Some varieties were susceptible to 15/601 but not 15/088, such as Belgrade, Crusoe, Kranich and Warrior, which agree with the presence of a Warrior 4 isolate being present in the mixture. Conversely there were varieties that were resistant to the Kranich isolate (15/601) and susceptible to the mixture (15/088), such as Cougar, Grafton, KWS Kerrin, KWS Silverstone, LG Cassidy and LG Motown, suggesting that these varieties are resistant to the Kranich race but susceptible to the Warrior 4 component at the seedling stage. Comparing these results with those of the tests with the original Kranich isolate (14/106, data not shown) there were no varieties that were susceptible to both of the Kranich isolates (14/106 and 15/601) and 15/088. Results of 14/106 and 15/601 generally agreed, but this is to be expected as the isolate 15/601 was a re-isolate from the adult plant trial that used 14/106 in 2015. There were exceptions however, for example Britannia, Cadenza, Crusoe, Dickens, Icon, Invicta, JB Diego, KWS Lili, KWS Trinity, Leeds, Myriad, Relay, RGT Marlborough, Scout, Skyfall and Zulu were all resistant to the original isolate 14/106 at the seedling stage but are susceptible to 15/601 suggesting that perhaps there were minor differences in the isolate collected from the trial that are only now apparent on a wider variety set.

From the initial differential test results on these isolates, it was expected that varieties with Rendezvous in their pedigree would be susceptible to the isolate 15/151 (Warrior 3) at the seedling stage. This was confirmed, with the varieties Napier, Brigadier, KWS Santiago and Rendezvous all showing a compatible reaction with this isolate. Most of the other varieties were also susceptible to this isolate, with the exceptions including Cordiale, Crusoe, Grafton

and Skyfall. The variety Evolution was susceptible to this isolate, and bar a borderline reaction in 2013 this is the first time seedling susceptibility has been reported in this variety. Comparing the pathotype of this isolate to others with a similar pathotype in previous years (data not shown), it is clear that this isolate contains additional virulence factors with novel virulence seen on Britannia, Delphi, Icon, KWS Silverstone, Leeds, Myriad, Reflection, Relay, Revelation, RGT Conversion, RGT Illustrious, as well as Evolution compared to similar isolates from 2008, 2009, 2010 and 2014. Warrior 3 isolates were also found in 2012 and 2013; however they were not included in this comparison due to the additional virulence for *Yr7* carried by these isolates.

The isolate 15/185 (Warrior 4) was selected based on the association with high disease levels in North Yorkshire. In these tests it is evident that this isolate is virulent on a high number of varieties, although none that immediately explain the reason for the high levels of disease seen. Similarly the isolate 15/139, selected after showing virulence for the variety Kranich, has shown no obvious reason for being behind any of the outbreaks in 2015. This isolate in particular shows virulence for fewer varieties in the test compared to the others and the avirulent reaction on the Avocet *Yr8* NIL suggests that this is simply a Warrior 4 isolate that has virulence for the variety Kranich. This has been reported by others previously (M. Hovmøller*, pers. comm.*).

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 2016 which contained RL and candidate varieties. For the first time, the trials were given extra fungicide protection to prevent natural infection confounding the trials. This included a seed treatment and foliar sprays up until the inoculation of the trial. Assessments were made starting at growth stage 30 at the end of April through to growth stage 69 in the middle of June. The percentage of leaf area infected was assessed and the mean was taken of five assessments. The trials produced moderately high levels of disease, reflecting the relatively late starting time of the epidemic compared to other trials where natural infection had taken hold. As expected, the susceptible controls Hornet and Robigus produced the highest levels of disease. Out of the 55 RL varieties and candidates under evaluation, 28 were resistant to all isolates tested and 10 were either moderately susceptible or susceptible to all of the isolates tested. The remaining varieties showed different levels of disease depending on the isolate used. In the trial inoculated with the isolate 15/151, the Warrior 3 isolate, there were higher levels of disease on a number of varieties compared to trials with similar isolates in previous years. This included higher levels on Belgrade, Britannia, Cadenza, Claire, Icon, JB Diego, Leeds,

Myriad, Reflection and Zulu. There were also very high levels of disease on Cordiale, which should have been relatively clean due to the presence of *Yr7* in this variety and the avirulence of the isolate for *Yr7*. Natural infection was suspected and all of the trials were subsequently re-sampled to establish whether the isolate(s) present in the trial were the same as those inoculated (Table 9). Five of the six isolates taken from the trials showed different virulence profiles to those expected from the initial tests based on the results from a truncated differential set, indicating the presence of more than one pathotype in each of the adult plant trials. The exception to this was the trial inoculated with 15/139, where the pathotype appears to be the same as the inoculated isolate.

Although the trials were confounded by natural infection, making specific variety-isolate interactions difficult to untangle, the trials do continue to highlight good levels of resistance in some varieties to multiple isolates. It is also possible to draw some tentative conclusions from some of the results. For example, Scout, KWS Lili and Claire are all more susceptible than expected in the trial inoculated with 15/185 (Warrior 4). Re-isolation from this trial suggests additional isolates present, for example with the presence of virulence for Warrior. With such a pronounced difference, it was possible that these differences could have been due to the Kranich race. Results from adult plant trials carried out in 2015 showed that this race is particularly damaging to a wider range of varieties than other isolates from the Warrior population. In addition, the presence of the Kranich race was confirmed at least once in 2015 (see 4.1.3.1.). In the re-isolation tests for this particular trial however, no virulence for *Yr8* was detected, and this was using data from the Avocet NIL rather than Compair. This suggested that the susceptibility seen in Scout, KWS Lili and Claire was probably not due to the Kranich race, but could have been due to the inoculated isolate (15/185) and/or another additional damaging isolate that needs to be characterised. The adult plant trials using this set of isolates will not be repeated in their entirety in 2017 as there is only capacity within this project to trial five isolates per year. However it is likely that at least one of the adult plant trials will be inoculated with an isolate of the Invicta race and another will be inoculated with the Kranich race using isolates from either 2015 or any new isolates from these races collected in 2016.

Table 9: Pathotypes of isolates taken from the inoculated trials. The pathotypes of the inoculated isolates are included for comparison. * = missing data.

Isolate Code	Pathotype Group(s)	Virulence Profile								
		4	7	8	Re	Sp	Wa	St	Kr	Ap
15/088	Warrior 4 + Kranich?	4	7	8		Sp				Ap
16/504	Warrior 4 + Kranich + Other	4	7	8	Re	Sp	Wa		Kr	
15/139	Warrior 4	4	7			Sp	(Wa)		Kr	
16/509	Warrior 4	4	7			Sp	Wa		Kr	
15/151	Warrior 3	4			Re					
16/501	Warrior 3 + Other	4	7		Re	Sp	Wa	St	Kr	Ap
15/185	Warrior 4	4	7		(Re)	Sp		St		Ap
16/509	Warrior 4 + Warrior 1	*	7		Re	Sp	Wa	St		Ap
15/601	Kranich		7	8			Wa	St	Kr	Ap
16/510	Kranich + Other	4	7	8	Re		Wa	St		Ap
16/511	Kranich + Other	4	7	8	Re	Sp	Wa	St	*	Ap

4.1.4. Renaming the 2015 Warrior 3 isolates

The isolates collected from Lincolnshire and elsewhere that showed the same pathotype as the Old European Solstice race were of interest to the UKCPVS this year following the high levels of disease seen in trials late in 2015. These isolates were subsequently found to be genetically related to other isolates from the Warrior population and it was hoped that additional data from the seedling and adult plant tests conducted using the RL varieties and candidates would reveal additional virulences in the isolates that would help the UKCPVS to differentiate them from the Old European race. The seedling tests confirmed that the isolates were virulent on additional varieties compared to similar isolates in our collection, however the adult plant trials were inconclusive due to contamination with other isolates by natural infection. Due to the genetic differences, and the differences seen in the variety seedling test, we propose to rename the isolates collected this year as a new race, the Invicta race, after the variety first sampled. At this stage the naming is yet to be fully confirmed, with adult plant trials due to be repeated again next year. However, with a genotype obviously different from the Old European Solstice isolates, and a seedling pathotype using an extended variety set obviously different from both Old European Solstice Isolates and other Warrior 3 isolates from previous years, it is logical to classify this group separately. In the next 2-3 years these isolates will mainly be characterised by seedling tests, but in the long term we envisage incorporating field pathogenomics data to aid race identification. This particular case highlights however that both methods of detection must be used together; neither alone gives enough information to make informed decisions about race prevalence.

4.1.5. Conclusions

The yellow rust 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 and novel combinations of virulence are reported here. The link between the new pathotypes identified in 2015 and the disease reports in the 2014/15 season are not complete, with natural infection confounding adult plant trials. Data from the seedling tests using a wider set of varieties, including the RL varieties and candidates did however highlight the presence of the Kranich race in 2015. In addition, isolates that initially looked like isolates of the Solstice race have been confirmed as genetically different to the Old European strains and with the extended variety set virulence was detected for varieties that are not normally affected by the Old European Solstice race. For this reason we are tentatively assigning these isolates to the new Invicta race.

4.2. Wheat powdery mildew

4.2.1. Samples received

Levels of wheat powdery mildew were low to moderate in 2015 and the UKCPVS received 14 samples including samples from mobile trap nurseries (appendix 1). The samples came from 10 different varieties and four different counties.

4.2.2. Pathotyping of isolates

From the 14 samples, multiple isolates were obtained, and 14 samples were pathotyped using a differential set. Results from the tests (Table 10) were compared to virulence frequencies from the past five years of testing (Table 11).

Virulence was seen for most of the differentials tested, with avirulence seen on Sicco, Wembley, Shamrock, Warrior and Stigg. This is slightly different to last year, where virulence was seen to all varieties except for Amigo. For the most part, the virulence frequencies compare well with previous years, with the exception of the aforementioned varieties whose frequencies differ between years. Most notably, virulence for Amigo, which carries the gene *Pm17*, has been identified for the first time since 2010. There were however no reports of 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 are not tested 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 10: 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		*Pm2*	*Pm3b*	*Pm4b*	*Pm5*	*Pm6*	*Mld*	*Pm8*	*Pm2,MlTa2*	*Pm5, MlTa2*	*MlTo*	*Pm3d*	*Pm5, MlSi2*	*MlSo*	*MlAx*	*Pm17*	*MlSh*	*MlRo*			
		Cerco	Galahad	Chul	Armada	Flanders	Brimstone	Clement	Maris dove	Brock	Mercia	Tonic	Broom	Sicco	Wembley	Axona	Amigo	Shamrock	Robigus	Warrior	Stigg	Crusoe
15/05/01	Cerco	3.0	3.0	2.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.5	0.3	0.0	0.0	0.0	0.5	0.8	3.3	0.5	0.5	3.0
15/06/01	JB Diego	4.0	4.0	2.5	4.0	4.0	4.0	4.0	4.0	3.8	3.8	3.5	3.5	0.0	0.0	3.8	0.5	0.8	4.0	0.0	0.0	4.0
15/10/01		2.0	1.5	2.3	2.5	2.5	2.5	3.0	3.0	2.8	3.0	1.8	2.3	0.0	0.0	3.0	1.0	0.0	2.8	0.5	0.3	2.5
15/04/02	Cerco	3.8	3.8	3.5	4.0	3.3	4.0	1.8	4.0	4.0	4.0	1.3	1.5	1.0	0.8	0.8	1.0	1.0	4.0	0.8	1.0	1.8
15/05/02	Cerco	4.0	4.0	0.8	3.8	4.0	3.5	2.0	3.8	3.8	2.8	0.3	0.3	0.0	0.0	0.0	0.3	0.5	3.5	0.0	0.0	3.3
15/06/02	JB Diego	2.0	2.3	0.3	2.5	2.5	2.5	2.3	2.5	2.3	2.8	2.3	2.3	2.0	1.8	2.3	0.5	0.3	2.0	0.0	0.0	2.0
15/08/02	Spaldings Prolific	3.0	3.3	1.8	3.3	2.8	3.3	3.0	3.3	3.0	3.0	1.5	1.5	0.0	0.0	0.0	0.8	0.8	3.5	0.0	0.0	2.0
15/09/02	Leeds	2.5	2.3	0.3	2.3	1.8	2.0	0.3	2.3	2.0	2.3	0.3	0.3	1.0	1.3	0.0	0.0	0.0	1.8	0.0	0.0	0.3
15/10/02		2.0	2.5	0.0	3.5	2.5	2.3	2.3	2.3	1.5	1.8	0.0	0.0	0.0	1.0	1.0	0.0	1.0	2.3	0.0	0.0	2.8
15/04/03	Cerco	4.0	4.0	0.8	4.0	3.0	4.0	3.8	4.0	4.0	4.0	0.8	0.8	0.0	0.0	0.0	1.3	0.5	4.0	0.5	0.0	1.5
15/05/03	Cerco	4.0	4.0	3.0	4.0	3.3	4.0	3.0	4.0	4.0	4.0	1.3	1.8	0.3	0.0	1.3	2.0	0.8	4.0	0.5	0.5	2.3
15/09/03	Leeds	3.0	3.0	1.8	4.0	3.3	3.3	3.0	3.8	3.5	3.3	3.0	3.0	0.5	0.8	0.8	3.0	1.8	3.5	0.0	0.0	3.0
15/13/01		2.8	3.3	0.0	2.3	2.8	3.0	2.3	2.3	3.3	3.0	0.0	0.0	0.0	0.0	0.0	0.3	1.5	1.0	0.0	1.3	2.0
15/14/02	Cerco	2.5	2.8	1.3	2.0	3.0	2.0	2.0	1.0	1.3	0.0	0.0	0.0	0.5	0.5	0.5	0.8	1.5	1.3	0.3	0.5	1.0

Table 11: Virulence frequencies of key wheat powdery mildew resistance genes over the past five years of testing. * = Not tested.

Differential	Known Genes	Virulence Frequency by Year				
		2011	2012	2013	2014	2015
Cerco		*	72	80	68	64
Galahad	*Pm2*	*	74	77	72	71
Chul	*Pm3b*	*	2	11	20	14
Armada	*Pm4b*	*	77	74	84	64
Flanders	*Pm5*	*	67	43	76	71
Brimstone	*Pm6*	*	74	80	80	64
Clement	*Pm8*	*	44	46	60	50
Maris dove	*Mld*	*	72	94	44	64
Brock	*Pm2,MlTa2*	*	86	89	88	71
Mercia	*Pm5, MlTa2*	*	67	77	80	79
Tonic	*MlTo*	*	33	26	24	14
Broom	*Pm3d*	*	42	26	20	14
Sicco	*Pm5, MlSi2*	*	2	3	8	0
Wembley	*MlSo*	*	2	9	8	0
Axona	*MlAx*	*	30	17	12	14
Amigo	*Pm17*	*	0	0	0	7
Shamrock	*MlSh*	*	0	0	4	0
Robigus	MlRo	*	28	51	64	64
Warrior		*	5	6	8	0
Stigg		*	5	6	8	0
Crusoe		*	47	40	36	36
Total Number of Isolates Tested		**0**	**43**	**35**	**25**	**14**

4.3. Barley powdery mildew

4.3.1. Samples received

Like the wheat powdery mildew, low levels of barley powdery mildew were observed in 2015 and as a result only 22 samples were received from growers, trial managers and agronomists. To provide further samples, trap pots of the susceptible variety Golden Promise were stationed around the Cambridge area to collect further isolates.

4.3.2. Pathotyping of isolates

From the samples received and collected, 40 isolates were obtained and characterised using a differential set. Results from the tests (Table 12) were compared with virulence frequencies from the past five years of testing (Table 13). 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. This is most likely an artefact due to the small number of starting samples. For the remaining genes there were some deviations from previous years, with a decrease in virulence frequency for the differentials Goldfoil, Zephyr, Porter, Lotta, Ricardo and Optic and an increase in the virulence frequency for the differentials Tyra, Roland and Propino. For the second year in a row virulence for KWS Meridian was detected and the frequency has increased from last year. As with the wheat powdery mildew, no adult plant tests are conducted with these isolates and the full impact of any change in the population will not become evident until the following season. Although the virulence for KWS Meridian was detected last year, the UKCPVS received no reports of unexpected outbreaks of barley powdery mildew during 2015 so it is possible that this variation in the population does not translate into meaningful differences at the adult plant stage.

Table 12: 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	Mlra	Mlg	Mlg,MI(CP)	Mla6	MILa	Mla12	Mlk1	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
15.5.1	Talisman	4.0	3.5	3.5	3.3	3.8	3.3	3.5	3.5	3.5	3.8	3.0	2.8	3.3	0.0	2.5	2.0	2.3	2.0	3.5	2.8	3.0	3.0	1.5
15.4.3	Discard mix	3.3	3.3	3.5	3.3	4.0	3.5	3.5	3.5	1.8	2.5	0.5	1.3	3.5	2.0	2.0	2.0	2.0	2.5	3.0	1.0	3.0	2.8	1.3
15.11.1	KWS Cassia	3.5	3.3	3.5	3.3	3.0	3.5	3.0	3.3	1.3	2.0	1.0	1.5	0.3	0.0	2.0	1.3	0.0	2.0	3.5	1.3	4.0	3.3	2.3
15.9.4	SC16666OH	3.3	3.3	3.3	3.0	3.0	3.3	2.5	3.3	3.3	2.0	1.0	0.5	2.8	0.0	1.8	0.5	0.0	2.8	3.5	0.8	3.0	3.0	0.0
15.13.1	Discard mix	3.8	3.5	4.0	3.8	3.5	3.8	3.5	3.8	1.3	2.3	0.8	0.5	3.3	0.0	2.0	1.8	2.8	1.8	3.5	1.3	2.0	2.3	1.3
15.10.8	LGB1355220	3.3	3.8	3.3	3.0	3.3	3.5	3.8	3.8	3.0	2.3	0.5	1.0	3.0	2.0	1.8	2.0	0.0	2.5	3.5	2.3	3.0	3.0	0.8
15.21.2	SB Spreader	4.0	3.5	4.0	4.0	3.8	3.3	4.0	3.0	3.0	3.8	1.5	2.0	3.5	0.0	2.5	1.5	0.0	3.5	3.5	1.5	3.5	3.0	2.8
15.AH.9	Golden Promise	2.8	3.0	3.3	3.8	3.3	3.5	3.3	4.0	4.0	2.0	2.0	0.3	2.8	0.0	1.3	1.8	0.0	2.5	3.5	0.0	0.0	0.0	0.8
15.14.1	Cassata	4.0	4.0	3.5	3.3	3.3	3.8	2.8	4.0	1.0	1.8	2.8	1.3	3.8	0.3	2.0	0.8	0.0	1.0	4.0	2.0	0.0	0.0	1.0
15.3.3	Cassata	3.0	3.3	3.0	3.3	3.0	3.5	3.5	3.5	2.5	2.0	1.5	0.0	2.0	0.0	1.3	1.5	0.0	2.8	2.8	0.3	1.0	2.8	0.5
15.17.1	KWSB111	3.3	4.0	3.8	3.3	3.0	3.3	2.8	3.5	3.0	2.0	2.3	1.3	3.3	0.8	2.5	0.5	0.0	2.0	4.0	0.5	2.8	3.0	0.0
15.1.1	Sultan	4.0	4.0	4.0	3.8	3.8	3.5	3.8	4.0	4.0	1.8	2.8	0.0	2.5	0.0	1.8	1.5	0.0	1.5	2.0	2.3	0.0	0.0	0.0
15.7.1	KWSB111	3.8	3.5	3.5	3.5	3.5	3.8	3.5	3.8	1.3	3.5	2.3	1.3	0.0	0.0	2.5	0.3	0.0	1.5	3.3	1.5	0.5	0.0	0.5
15.8.4	LGBU136095	3.3	4.0	4.0	3.8	3.5	3.5	3.0	4.0	1.3	0.0	2.0	0.0	0.0	0.0	2.0	1.3	0.0	2.8	4.0	0.8	3.5	3.3	1.3
15.AH.6	Golden Promise	4.0	4.0	4.0	1.8	2.5	3.8	4.0	3.8	1.5	2.0	2.8	1.5	2.5	3.5	0.0	0.0	0.0	3.5	4.0	1.3	3.5	4.0	3.8
15.AH.4	Golden Promise	2.8	4.0	3.3	0.0	0.5	3.0	3.0	3.0	1.0	1.3	2.8	0.5	0.0	2.5	0.0	0.0	0.0	3.0	3.3	0.0	3.8	4.0	3.8
15.19.2		2.5	4.0	3.0	1.8	2.3	2.3	3.3	3.0	2.8	1.8	1.5	0.0	2.8	0.0	1.0	0.0	0.0	2.5	3.3	0.0	2.3	2.8	1.0

Isolate Number	Host Variety	0	Mlh	Mlra	Mlg	Mlg,Ml(CP)	Mla6	MlLa	Mla12	Mlk1	Mla7	MlAb	Mla7,MlAb	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
15.AH.10	Golden Promise	3.0	4.0	3.0	3.3	3.0	3.3	3.5	4.0	4.0	1.3	2.8	1.0	0.0	0.0	1.8	0.5	0.0	3.3	4.0	0.5	3.3	3.3	1.0
15.AH.7	Golden Promise	3.0	4.0	4.0	3.8	3.3	3.3	2.8	3.3	1.0	2.0	2.0	2.0	3.5	0.0	3.0	0.8	0.0	3.3	3.5	1.5	2.8	3.5	0.0
15.12.4	KWSB121	3.0	4.0	4.0	3.5	3.5	3.3	2.8	2.5	4.0	2.5	2.3	0.0	3.8	0.0	1.8	0.5	0.0	3.5	4.0	0.0	2.0	2.0	0.0
15.2.-	Discard mix	3.0	4.0	4.0	3.8	3.5	4.0	3.0	4.0	2.8	3.0	2.5	2.3	3.8	0.3	2.3	1.5	2.8	2.8	4.0	1.8	2.8	2.8	0.0
15.20.2	RGT Planet	3.3	3.5	3.8	3.3	3.3	3.5	2.3	1.8	3.3	3.0	2.3	1.5	3.8	0.0	2.0	0.0	0.0	3.3	3.3	0.0	1.5	1.8	0.3
15.8.6	LGBU136095	3.8	3.8	3.8	3.3	3.5	3.8	3.5	4.0	3.0	1.3	1.8	0.0	0.0	0.0	2.0	1.5	0.0	1.0	3.0	2.0	0.0	0.0	0.0
15.12.2	KWSB121	4.0	4.0	4.0	4.0	3.5	4.0	3.5	4.0	2.0	3.0	3.3	1.3	3.5	2.8	1.8	0.8	0.0	2.0	3.8	2.3	2.0	3.0	2.3
15.AH.11	Golden Promise	3.8	4.0	3.3	3.3	3.5	3.8	3.5	4.0	1.0	0.8	3.0	1.0	3.8	2.8	1.0	1.8	0.0	2.0	3.3	2.8	3.0	3.0	1.3
15.3.4	Cassata	3.5	3.8	3.8	4.0	3.5	4.0	3.5	3.5	2.5	2.5	2.8	0.5	2.8	1.8	1.5	1.3	2.0	2.8	4.0	2.8	3.0	3.5	0.0
15.AH.12	Golden Promise	3.5	4.0	3.5	3.5	3.8	4.0	3.0	4.0	4.0	2.0	2.8	1.8	3.3	0.0	2.8	1.0	0.0	3.8	3.3	1.8	2.8	3.3	2.5
15.19.1		3.3	3.8	4.0	3.5	4.0	3.5	3.5	4.0	3.3	3.0	2.5	1.3	2.0	1.3	2.5	1.5	2.0	3.3	3.8	0.3	2.8	2.5	1.8
15.7.3	KWSB111	3.8	4.0	4.0	4.0	3.8	4.0	3.5	4.0	1.0	3.0	2.5	0.5	0.0	3.5	0.8	1.3	0.0	1.8	3.0	1.5	0.0	0.0	0.0
15.10.11	LGB1355220	3.3	4.0	3.8	4.0	3.8	4.0	2.8	4.0	2.5	2.5	2.3	1.3	3.5	0.5	2.0	2.0	0.0	3.0	3.8	1.3	2.3	3.0	2.0
15.20.1	RGT Planet	4.0	4.0	4.0	4.0	4.0	4.0	3.8	4.0	1.0	4.0	3.8	2.3	4.0	0.0	1.5	2.0	0.0	1.5	4.0	2.8	0.0	0.0	0.0
15.8.2	LGBU136095	4.0	4.0	4.0	3.8	4.0	4.0	3.5	4.0	1.3	3.5	2.5	1.8	3.3	0.5	1.8	1.5	0.0	2.0	3.8	2.3	0.0	0.3	0.0
15.AH.2	Golden Promise	4.0	4.0	3.5	0.0	0.0	4.0	3.8	3.8	1.3	3.0	3.3	2.8	1.0	4.0	0.0	0.0	0.0	2.8	4.0	3.3	3.5	4.0	3.0
15.AH.8	Golden Promise	3.8	3.5	3.0	3.0	3.3	3.5	2.5	3.5	2.5	1.3	2.5	0.5	0.3	0.0	2.0	0.8	0.0	2.8	4.0	2.0	3.8	4.0	0.3
15.AH.1	Golden Promise	3.5	3.0	3.0	0.0	0.0	3.0	3.3	3.3	1.0	2.3	2.8	1.5	0.0	3.0	0.0	0.0	0.0	2.3	3.0	2.8	3.3	3.8	2.8
15.21.1	SB Spreader	4.0	3.5	3.5	3.5	3.3	3.8	2.8	3.3	1.8	2.3	2.3	1.5	2.3	0.0	2.0	0.0	1.8	2.8	3.3	3.0	3.0	4.0	3.8
15.AH.3	Golden Promise	4.0	4.0	4.0	3.8	3.8	3.8	3.0	4.0	4.0	2.0	3.5	1.8	0.5	0.0	2.8	1.0	0.0	3.8	3.8	2.5	4.0	4.0	0.8
15.12	KWSB121	3.5	3.3	3.3	3.5	3.3	3.8	2.0	1.5	3.3	3.5	2.0	0.5	3.3	0.0	1.0	0.0	0.0	3.3	2.8	0.0	1.5	1.5	0.3

Isolate Number	Host Variety	0	Mlh	Mlra	Mlg	Mlg,MI(CP)	Mla6	MILa	Mla12	Mlk1	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
15.14.2	Cassata	3.5	3.5	3.3	3.0	3.3	3.5	3.0	4.0	2.0	3.0	3.0	1.8	4.0	0.0	2.3	1.3	0.0	3.3	3.8	2.5	3.5	3.8	0.0
15.1.3	Sultan	3.3	3.8	3.3	3.5	3.8	3.5	3.0	4.0	2.0	3.3	2.5	1.5	2.3	0.0	1.5	1.8	0.0	2.0	4.0	2.3	1.5	2.3	0.0

Table 13: 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				
		2011	2012	2013	2014	2015
Golden Promise	*0*	99	100	93	96	98
W.37/136	*Mlh*	91	100	100	100	100
W.41/145	*Mlra*	84	89	100	100	100
Goldfoil	*Mlg*	97	96	93	100	88
Zephyr	*Mlg,Ml(CP)*	88	100	83	96	88
Midas	*Mla6*	86	100	90	93	98
Lofa	*MlLa*	93	93	55	93	90
Hassan	*Mla12*	96	96	90	89	93
H.1063	*Mlk1*	32	7	45	41	43
Porter	*Mla7*	67	67	48	74	35
Lotta	*MlAb*	71	44	17	78	38
Triumph	*Mla7,MlAb*	43	26	7	11	5
Tyra	*Mla1*	52	56	34	37	58
Roland	*Mla9*	6	7	0	0	15
Apex	*mlo 11*	3	4	3	15	8
Riviera	*mlo 11*	0	7	0	4	0
Digger	*Mla13*	9	7	7	11	5
Ricardo	*Mla3*	51	37	34	63	53
Vanessa	*Van*	90	89	86	81	98
Optic		61	48	10	26	18
NFC Tipple		56	37	14	56	58
Propino		51	33	21	52	65
KWS Meridian		*	0	0	4	15
Total Number of Isolates		**112**	**27**	**29**	**27**	**40**

5. Appendix 1: Sample Register

2015 Wheat Yellow Rust Isolate Register

Isolate Number	Host Variety	Date Received	RL Rating 2015/16	Location
15/001	Solstice	Dec-14	3.9	Scottish Borders
15/002	Zulu	Dec-14	8.6	Scottish Borders
15/003	Evolution	Dec-14	8.7	Scottish Borders
15/004	KWS Kielder	Dec-14	3.8	Scottish Borders
15/005	KWS Trinity	Dec-14	8.7	Scottish Borders
15/006	Meridian	Dec-14		Scottish Borders
15/007	KWS Santiago	Dec-14	5.7	Scottish Borders
15/008	Nelson	Feb-15		Hertfordshire
15/009	Mulika	Feb-15	7.4	Bedfordshire
15/010	JB Diego	Feb-15	7.5	Bedfordshire
15/011	YR Spreader	Mar-15		Cambridgeshire
15/012	BR Spreader	Mar-15		Cambridgeshire
15/013	Evolution	Apr-15	8.7	Suffolk
15/014	Victo	Apr-15		Cambridgeshire
15/015	Breeding line (SYN03)	Apr-15		Cambridgeshire
15/016	Victo	Apr-15		Norfolk
15/017	Claire	Apr-15	5.8	Kent
15/018	KWS Santiago	Apr-15	5.7	Cambridgeshire
15/019	SY1130019B	Apr-15		Cambridgeshire
15/020	KWS Kielder	May-15	3.8	Herefordshire
15/021	Icon	May-15	8.4	Northamptonshire
15/022	KWS Santiago	May-15	5.7	Lincolnshire
15/023	Victo	May-15		Herefordshire
15/024	Solstice	May-15	3.9	Herefordshire
15/025	Cordiale	May-15	5.4	Herefordshire
15/026	Robigus	May-15		Herefordshire
15/027	Oakley	May-15		Cambridgeshire
15/028	KWS Kielder	May-15	3.8	Cambridgeshire
15/029	KWS Kielder	May-15	3.8	Lincolnshire
15/030	KWS Barrel	May-15	8.0	Lincolnshire
15/031	Leeds	May-15	6.9	Lincolnshire
15/032	Reflection	May-15	5.6	Lincolnshire
15/033	Solstice	May-15	3.9	Lincolnshire
15/034	Gallant	May-15	4.9	Lincolnshire
15/035	KWS Lili	May-15	6.7	Lincolnshire
15/036	Skyfall	May-15	5.9	Lincolnshire
15/037	Britannia	May-15	8.2	Lincolnshire
15/038	KWS Santiago	May-15	5.7	Lincolnshire
15/039	Cubanita	May-15	6.0	Lincolnshire
15/040	Amplify	May-15	5.5	Lincolnshire
15/041	JB Diego	May-15	7.5	Lincolnshire
15/042	Mosaic	May-15	8.0	Lincolnshire

Isolate Number	Host Variety	Date Received	RL Rating 2015/16	Location
15/043	Cougar	May-15	8.4	Dorset
15/044	Stigg	May-15		Dorset
15/045	JB Diego	May-15	7.5	Dorset
15/046	Icon	May-15	8.4	Oxfordshire
15/047	Panorama	May-15	7.4	Bedfordshire
15/048	Canadian Spring wheat	Jun-15		Lincolnshire
15/049	KWS Santiago	Jun-15	5.7	Shropshire
15/050	Cordiale	Jun-15	5.4	Shropshire
15/051	Tybalt	Jun-15	6.7	Oxfordshire
15/052	KWS Willow	Jun-15	7.4	Oxfordshire
15/053	Myriad	Jun-15	8.1	Scottish Borders
15/054	Britannia	Jun-15	8.2	Scottish Borders
15/055	JB Diego	Jun-15	7.5	Cambridgeshire
15/056	KWS Santiago	Jun-15	5.7	Cambridgeshire
15/057	Kranich	Jun-15		Cambridgeshire
15/058	Warrior	Jun-15		Cambridgeshire
15/059	Timber	Jun-15		Cambridgeshire
15/060	Alchemy	Jun-15	6.9	Cambridgeshire
15/061	Amplify	Jun-15	5.5	Cambridgeshire
15/062	Energise	Jun-15		Cambridgeshire
15/063	Icon	Jun-15	8.4	Cambridgeshire
15/064	Mosaic	Jun-15	8.0	Cambridgeshire
15/065	Belepi	Jun-15		Cambridgeshire
15/066	JB Diego	Jun-15	7.5	East Yorkshire
15/067	Britannia	Jun-15	8.2	Lincolnshire
15/068	Mosaic	Jun-15	8.0	Lincolnshire
15/069	Cougar	Jun-15	8.4	Lincolnshire
15/070	JB Diego	Jun-15	7.5	Lincolnshire
15/071	Solstice	Jun-15	3.9	Kent
15/072	Claire	Jun-15	5.8	Kent
15/073	Belepi	Jun-15		Kent
15/074	Mulika	Jun-15	7.4	Kent
15/075	Panorama	Jun-15	7.4	Kent
15/076	KWS Lili	Jun-15	6.7	Kent
15/077	Dauntless	Jun-15		Hampshire
15/078	Gallant	Jun-15	4.9	Hampshire
15/079	KWS Kielder	Jun-15	3.8	Hampshire
15/080	Claire	Jun-15	5.8	Herefordshire
15/081	Gallant	Jun-15	4.9	East Lothian
15/082	Twister	Jun-15	6.1	East Lothian
15/083	KWS Kielder	Jun-15	3.8	East Lothian
15/084	Sherlock	Jun-15	9.0	East Lothian
15/085	Butler	Jun-15	7.0	East Lothian
15/086	Spyder	Jun-15	9.0	East Lothian
15/087	Solstice	Jun-15	3.9	East Lothian
15/088	Horatio	Jun-15	5.6	East Lothian

Isolate Number	Host Variety	Date Received	RL Rating 2015/16	Location
15/089	Skyfall	Jun-15	5.9	East Lothian
15/090	JB Diego	Jun-15	7.5	East Lothian
15/091	Energise	Jun-15		East Lothian
15/092	RGT Conversion	Jun-15	8.0	East Lothian
15/093	Cordiale	Jun-15	5.4	East Lothian
15/094	Amplify	Jun-15	5.5	East Lothian
15/095	Gallant	Jun-15	4.9	East Lothian
15/096	Reflection	Jun-15	5.6	East Lothian
15/097	RGT Pembroke	Jun-15		East Lothian
15/098	Viscount	Jun-15	4.3	East Lothian
15/099	KWS Santiago	Jun-15	5.7	East Lothian
15/100	KWS Croft	Jun-15	8.4	Kent
15/101	Amplify	Jun-15	5.5	North Yorkshire
15/102	RGT Marlborough	Jun-15	8.0	North Yorkshire
15/103	KWS Kielder	Jun-15	3.8	North Yorkshire
15/104	Energise	Jun-15		North Yorkshire
15/105	Spyder	Jun-15	9.0	North Yorkshire
15/106	KWS Bassett	Jun-15		North Yorkshire
15/107	Sherlock	Jun-15	9.0	North Yorkshire
15/108	KWS Santiago	Jun-15	5.7	North Yorkshire
15/109	Solstice	Jun-15	3.9	North Yorkshire
15/110	Britannia	Jun-15	8.2	North Yorkshire
15/111	Reflection	Jun-15	5.6	North Yorkshire
15/112	Alchemy	Jun-15	6.9	North Yorkshire
15/113	Delphi	Jun-15	8.4	North Yorkshire
15/114	Myriad	Jun-15	8.1	North Yorkshire
15/115	Icon	Jun-15	8.4	Oxfordshire
15/116	Energise	Jun-15		North Yorkshire
15/117	Spyder	Jun-15	9.0	North Yorkshire
15/118	RGT Pembroke	Jun-15		North Yorkshire
15/119	Gallant	Jun-15	4.9	North Yorkshire
15/120	Butler	Jun-15	7.0	North Yorkshire
15/121	KWS Lili	Jun-15	6.7	North Yorkshire
15/122	Britannia	Jun-15	8.2	North Yorkshire
15/123	Solstice	Jun-15	3.9	North Yorkshire
15/124	KWS Santiago	Jun-15	5.7	North Yorkshire
15/125	Amplify	Jun-15	5.5	North Yorkshire
15/126	Cubanita	Jun-15	6.0	North Yorkshire
15/127	Horatio	Jun-15	5.6	North Yorkshire
15/128	KWS Kielder	Jun-15	3.8	North Yorkshire
15/129	Reflection	Jun-15	5.6	North Yorkshire
15/130	Cocoon	Jun-15		Essex
15/131	Xi19	Jun-15		Essex
15/132	Skyfall	Jun-15	5.9	Essex
15/133	Myriad	Jun-15	8.1	Northumberland
15/134	Myriad	Jun-15	8.1	Northamptonshire

Isolate Number	Host Variety	Date Received	RL Rating 2015/16	Location
15/135	Skyfall	Jun-15	5.9	Northamptonshire
15/136	JB Diego	Jun-15	7.5	Northamptonshire
15/137	Reflection	Jun-15	5.6	Northamptonshire
15/138	KWS Lili	Jun-15	6.7	Northamptonshire
15/139	Invicta	Jun-15	7.8	Northamptonshire
15/140	Amplify	Jun-15	5.5	Oxfordshire
15/141	Zulu	Jun-15	8.6	North Yorkshire
15/142	KWS Croft	Jun-15	8.4	North Yorkshire
15/143	Sherlock	Jun-15	9.0	East Lothian
15/144	Spyder	Jun-15	9.0	East Lothian
15/145	Xi19	Jun-15		East Yorkshire
15/146	Cocoon	Jun-15		East Yorkshire
15/147	Revelation	Jun-15	8.8	East Yorkshire
15/148	KWS Alderon	Jun-15	7.4	Oxfordshire
15/149	Gallant	Jun-15	4.9	Norfolk
15/150	Belepi	Jun-15		Norfolk
15/151	Invicta	Jul-15	7.8	Lincolnshire
15/152	Invicta	Jul-15	7.8	Lincolnshire
15/153	Apache	Jul-15		Lincolnshire
15/154	Tulsa	Jul-15		Lincolnshire
15/155	JB Diego	Jul-15	7.5	Lincolnshire
15/156	JB Diego	Jul-15	7.5	Lincolnshire
15/157	Soissons	Jul-15		Lincolnshire
15/158	Victo	Jul-15		Kent
15/159	Solstice	Jul-15	3.9	Kent
15/160	Robigus	Jul-15		Kent
15/161	KWS Santiago	Jul-15	5.7	Leicestershire
15/162	JB Diego	Jul-15	7.5	Leicestershire
15/163	KWS Lili	Jul-15	6.7	Leicestershire
15/164	KWS Santiago	Jul-15	5.7	Norfolk
15/165	KWS Cashel	Jul-15	8.4	Norfolk
15/166	Spyder	Jul-15	9.0	Norfolk
15/167	KWS Lili	Jul-15	6.7	Norfolk
15/168	Mosaic	Jul-15	8.0	Norfolk
15/169	Energise	Jul-15		Norfolk
15/170	Invicta	Jul-15	7.8	Norfolk
15/171	JB Diego	Jul-15	7.5	Norfolk
15/172	Britannia	Jul-15	8.2	Norfolk
15/173	KWS Croft	Jul-15	8.4	Norfolk
15/174	Gallant	Jul-15	4.9	Lincolnshire
15/175	Gallant	Jul-15	4.9	Suffolk
15/176	Zulu	Jul-15	8.6	Lincolnshire
15/177	KWS Kielder	Jul-15	3.8	Oxfordshire
15/178	Gallant	Jul-15	4.9	Oxfordshire
15/179	Belepi	Jul-15		Lincolnshire
15/180	Skyfall	Jul-15	5.9	Lincolnshire

Isolate Number	Host Variety	Date Received	RL Rating 2015/16	Location
15/181	KWS Kielder	Jul-15	3.8	Lincolnshire
15/182	Gallant	Jul-15	4.9	Lincolnshire
15/183	Gallant	Jul-15	4.9	North Yorkshire
15/184	Panacea	Jul-15		North Yorkshire
15/185	KWS Kielder	Jul-15	3.8	North Yorkshire
15/186	Invicta	Jul-15	7.8	Lincolnshire
15/187	JB Diego	Jul-15	7.5	Lincolnshire

2015 Wheat Powdery Mildew Sample Register

Isolate number	Host Variety	Date Received	RL Rating 2015/16	Location
WM15/04	Cerco	Feb-15		Cambridgeshire
WM15/05	Cerco	Feb-15		Cambridgeshire
WM15/14	Cerco	Aug-15		Cambridgeshire
WM15/12	Crusoe	Jul-16	7	Lincolnshire
WM15/02	Evolution	Dec-14	6	
WM15/06	JB Diego	Dec-14	6	Bedford
WM15/09	Leeds	May-15	3	Cambridgeshire
WM15/07	Maris butler/Armada spreader	Apr-15		Cambridgeshire
WM15/03	Meridian	Dec-14		
WM15/08	Spaldings Prolific	May-15		South Wales
WM15/11	Twister	May-15	4	Cambridgeshire
WM15/01	Zulu	Dec-14	7	
WM15/10		May-15		
WM15/13		Jul-15		

2015 Barley Powdery Mildew Sample Register

Isolate Number	Host Variety	Date Received	RL Rating 2015/16	Location
BM15/01	Sultan	Dec-14		Cambridgeshire
BM15/02	Discard mix	Feb-15		Cambridgeshire
BM15/03	Cassata	Apr-15	4	Cambridgeshire
BM15/04	Discard mix	Apr-15		Cambridgeshire
BM15/05	Talisman		6	Cambridgeshire
BM15/06	SJ091049			Cambridgeshire
BM15/07	KWSB111			Cambridgeshire
BM15/08	LGBU136095			Cambridgeshire
BM15/09	SC16666OH			Cambridgeshire
BM15/10	LGB1355220			Cambridgeshire
BM15/11	KWS Cassia		4	Cambridgeshire
BM15/12	KWSB121			Cambridgeshire
BM15/13	Discard mix	Jun-15		Cambridgeshire
BM15/14	Cassata	Jun-15	4	Cambridgeshire
BM15/15	KWS Cassia	Jun-15	4	Cambridgeshire
BM15/16	KWS Glacier	Jun-15	3	Cambridgeshire
BM15/17	KWSB111	Jun-15		Cambridgeshire
BM15/18	KWS Tower	Jun-15	5	Cambridgeshire
BM15/19		Jun-15		Cambridgeshire
BM15/20	RGT Planet	Jun-15	9	Cambridgeshire
BM15/21	SB Spreader	Jun-15		Cambridgeshire
BM15/22	Propino	Jun-15	6	Cambridgeshire

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