

United Kingdom Cereal Pathogen Virulence Survey 2020 Annual Report

Amelia Hubbard, Sarah Wilderspin and Lucy James

NIAB, 93 Lawrence Weaver Road, Cambridge CB3 0LE

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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

The UK *Pst* population continues to show high levels of diversity since the incursion of the Warrior population in 2011. The current population remains dominated by isolates from the Red group, and within that group there are a broad range of virulence profiles, which continue to change. Several new combinations of virulence were detected, with novel isolates displaying a reaction on *Yr8*, Kranich and Crusoe. Five isolates displaying novel pathotypes were investigated in the adult plant trials. All five isolates infected KWS Firefly in adult plant trials, in particular isolate 19/215, and may help explain an outbreak on KWS Firefly reported during the 2020 season.

Wheat Brown Rust

A new differential set was used for the fourth year to analyse the *P. triticina* population. As seen in previous years, virulence was detected for many of the *Lr* genes tested and seedling variety tests highlighted that almost all varieties tested were susceptible to at least one of the races under evaluation. Seedling virulence frequency changes to both *Lr20* and *Lr28* were found, otherwise no major changes in varietal performance from seedling virulence frequencies were identified. Low levels of disease pressure in the 2020 field season made detailed evaluation of varietal resistance at adult plant stage challenging, however KWS Firefly was identified as moderately susceptible, supporting data collected in 2019.

Wheat and Barley Powdery Mildew

Small changes in the *Bgh* population were detected, but this should be interpreted with caution due to the very limited number of isolates tested. As in previous years, no unusual outbreaks were reported, so it is unlikely that these changes have translated into detrimental effects on variety performance.

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 to 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 53rd 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 currently rare, 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 and 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 (designated *Yr, Lr, Pm, Ml* or similar for yellow rust, brown rust, wheat mildew and barley mildew respectively). 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 UKC.

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

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 the resistance gene *Yr7* and the variety Spaldings Prolific. It is important to note that virulence for the resistance gene *Yr7* had been seen before, but not in combination with virulence to the resistance genes *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, 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 they are 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 (since renamed Purple 3) and later that year the Blue 7 group of isolates were detected (Hubbard, Pritchard, and Holdgate 2016). An epidemic year followed the arrival of these two groups of isolates, although it was later found that another group, Red 24, first detected in 2016, was the most likely culprit for substantial changes to Recommended List (RL) ratings that year (Hubbard, Wilderspin, and Holdgate 2017). An unusual outbreak on KWS Zyatt and Dunston in some parts of the country was identified during 2019. After close examination of UKCPVS adult plant trials

carried out in 2019, a Red 27 isolate was identified as the likely cause of the outbreak and is currently under further investigation.

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 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. 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, starting 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 RL 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 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 1). 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 pathogen population has therefore mirrored this and the frequency of detection continues to decline. In 2014, a change to the population overcame the moderate resistance in the variety Crusoe, however it is still unclear what resistance gene has broken down. Over recent years pathogen populations have remained relatively stable, however, an unusual outbreak on KWS Firefly in some parts of the country was identified during 2019.

Year	Variety	Key Resistance Gene Combination
1973*	Sappo	<i>Lr20</i> (WBR3)
1973*	Maris Halberd	<i>Lr20</i> (WBR4)
1974*	Maris Fundin	Lr17b (WBR2)
1976	Maris Huntsman	WBR5 (APR)
1977	Clement	<i>Lr26</i> (WBR1)
1977	Sterna	Lr3a (WBR7)
1978	Maris Ranger	WBR8
1980	Avalon	WBR9
1982	Gamin	WBR6
1991	Slejpner	<i>Lr</i> 26 + APR
1993	Spark	Not specified
1994	Flame	Not specified
1995	Chablis	Lr3a + ?
1999	Rialto	<i>Lr17b, Lr26</i> + APR
2005	Glasgow	Lr1
2005	Claire	<i>Lr3a, Lr17b, Lr20, Lr26,</i> APR
2006	Robigus	Lr28
2006	Multiple Lr37	Lr1,Lr3a,Lr17b,Lr26,Lr37
	varieties	
2011	Stigg	Lr24
2014	Crusoe	Unknown

Table 1: Key wheat brown rust changes in the UK since the start of the survey

* 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 operators of RL trials. Spores from the infected samples were transferred on to plants of the universally susceptible variety Victo or Vuka (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 (Hubbard et al. 2015). The differentials used and the resistance genes they carry are listed in Table 2 and Table 9. 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. As an alternative to foliar fungicide applications to eliminate natural infection, plots were directly inoculated every 7-14 days from approx. GS 13 onwards, with the aim of increasing disease pressure of the target isolate and preventing natural influx which can confound experimental results in high disease pressure seasons. The wheat yellow rust trials were inoculated ten times and the wheat brown rust trials inoculated fifteen times. Assessments were made from inflorescence onwards 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.

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 15 and Table 16. Each differential was represented by 4 detached leaf sections, giving four replicates. This was to ensure the maximum amount of information was 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 2019 the UKCPVS received 243 samples of wheat yellow rust from 34 different counties across the UK (Figure 1).



2 sample locations unknown

Figure 1: Map of the UK with the number of samples of wheat yellow rust received in 2019 from the different counties.

Disease pressure was higher compared to that experienced in 2018. The UKCPVS did receive some reports of unexpected varietal performance especially for KWS Zyatt. In total, samples were received from 56 different varieties consisting of current and past RL varieties, spreader plots and other breeding lines. The variety most sampled was KWS Zyatt. 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-one 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 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 3). No new virulences to individual genes were detected in the isolates collected in 2019 using the differentials tested at the seedling stage. Changes in frequency of virulence to the individual resistance genes remained relatively minor for known resistance genes in comparison to previous years (Table 4), with the exception of Yr8, which showed an increase in the percentage of isolates identified for virulence to the gene. In addition, the variety Kranich also saw an increase in virulence compared to data collected in 2018. Virulence for Rendezvous and Evolution continued to decrease in frequency, as seen in 2018 and virulence for Cadenza also decreased, returning to levels seen previously in 2016. After seeing a significant drop in virulence for varieties Warrior and KWS Sterling in 2018, the percentage of isolates identified with virulence to these varieties was seen to increase in 2019. It is unclear at this stage whether these recent changes are significant, but it is possible that this could indicate further changes in the pathogen population.

4.1.2.2. Virulence frequencies for pathotype groups

Some of the isolates were assigned to different genetic groups using tools developed in the Field Pathogenomics project (Diane Saunders, *pers. comm.*, Table 3). In the cases where this information was unavailable at the time of writing, the isolates were classed according to the pathotype data only based on results from previous years. Considering the population by genetic group, the frequencies of isolates found in each group was similar to that found in 2018 (Table 5). The Red group almost entirely dominated the surveyed isolates, with only one Pink isolate being found. There were also a number of isolates which could not be classified into a genetic group due to the expression of seemingly novel pathotypes. These isolates are under further investigation and have been prioritised for detailed pathogenomic analysis in order to assign a genetic group. These isolates will remain in the 'Other' category until such a time that they can be assigned to a genetic group.

Table 2: Average infection type (A.I.T.) scores for the 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.

		1	٢	2	3a, 4a	3b,4b	4,Su	5	9	2,6	2,6,25	7	7,22,23	6,7	7,17	8	8,19	6	2,9,25	10	15	17	17	17	24	2,25	25,Sd	32	25,32	Sp	Sp	Ro	So	Wa	St		Am					
lsolate code	Host	Avocet Yr1	Chinese 166	Kalyansona	Vilmorin 23	Hybrid 46	Suwon Omar	Avocet Yr5	Avocet Yr6	Heines Kolben	Heines Peko	Avocet Yr7	Lee	Cadenza	Apache	Avocet Yr8	Compair	Avocet Yr9	Clement	Moro	Avocet Yr15	VPM 1	Rendezvous	Avocet Yr17	Avocet Yr24	Heines VII	Strubes Dickkopf	Avocet Yr32	Carstens V	Avocet Sp	Spaldings Prolific	Robigus	Solstice	Warrior	KWS Sterling	Claire	Ambition	Crusoe	Avocet S	Vuka	Kranich	Evolution
19/001	KWS Kinetic	4.0	4.0	4.0	4.0	3.0	3.0	0.0	4.0	3.0	3.0	4.0	4.0	2.7	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.5	3.0	3.2	0.0	4.0	4.0	4.0	3.0	3.1	3.2	3.5	4.0	2.8	2.3	4.0	1.6	0.0	3.0	<mark>3.1</mark>	1.7	1.3
19/002	Dunston	3.0	3.0	3.0	4.0	3.0	4.0	0.0	4.0	3.0	3.0	4.0	3.5	3.0	3.0	0.0	0.0	4.0	3.0	0.0	0.0	3.0	3.0	4.0	0.0	3.9	4.0	4.0	4.0	4.0	3.0	4.0	4.0	2.2	0.5	4.0	1.8	0.0	3.0	4.0	0.9	0.0
19/003	Elicit	3.0	3.2	3.3	3.1	1.1	3.0	0.0	3.0	3.0	3.0	3.0	2.8	2.3	1.2	0.0	0.0	3.0	3.0	0.2	0.0	3.0	1.9	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	1.7	0.1	3.0	1.0	0.0	3.0	3.0	0.0	0.1
19/006	Gleam	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	2.9	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	2.9	3.0	3.0	2.3	0.0	3.0	3.0	0.4	3.0
19/010	KWS Zyatt	0.0	1.1	3.0	3.0	1.7	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	0.5	3.0	2.7	0.0	0.0	0.0	0.0	2.1	0.1	3.0	0.1	3.0	3.0	3.0	3.0	1.8	2.1	3.0	3.0	0.2	1.6	1.3	1.1	0.0	3.0	0.3	1.2	0.2
19/017	KWS Siskin	3.0	3.0	3.0	3.0	1.0	4.0	0.0	3.0	3.0	3.0	3.0	3.0	2.9	2.1	0.0	0.0	3.5	3.0	0.3	0.0	3.0	0.3	3.5	0.0	3.0	3.0	3.0	3.0	3.5	3.0	3.0	3.0	2.1	0.8	4.0	0.3	0.0	3.0	3.0	0.3	0.0
19/017 A	Re-isolate A	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	2.1	1.4	0.0	0.0	3.0	3.0	0.0	0.0	3.0	0.6	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	1.5	3.0	2.0	0.0	3.0	3.0	2.3	2.0
19/017 B	Re-isolate B	3.0	3.0	3.0	3.0	2.6	3.0	0.0	3.0	3.0	3.0	3.0	3.0	1.2	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.3	3.0	2.0	0.0	3.0	3.0	1.2	1.9
19/022	RGT Gravity	3.1	3.0	3.0	2.8	3.0	3.0	0.0	3.0	3.0	2.9	3.0	3.0	2.3	2.0	0.0	0.0	4.0	3.0	0.2	0.0	3.0	1.0	3.0	0.0	3.0	2.9	3.0	3.0	3.5	2.8	4.0	3.0	1.7	0.2	4.0	1.4	0.0	3.0	3.1	0.0	0.0
19/025	Unknown	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	2.7	1.7	0.0	0.0	3.0	3.0	0.0	0.0	3.0	0.2	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.3	3.3	0.0	0.0	3.0	3.5	0.0	0.7
19/038	Shabras	3.0	3.0	3.0	2.0	2.0	3.0	0.0	3.0	2.0	3.0	3.0	3.0	1.2	2.2	3.0	0.0	3.0	3.0	0.0	0.0	3.0	1.6	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	3.0	3.0	2.5	3.0	3.0	3.0	2.3
19/041	KWS Firefly	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	0.0	3.0	3.0	0.0	0.0	3.0	1.8	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.5	1.6	3.0	2.1	0.0	3.0	3.0	1.7	2.2
19/044	KWS Zyatt	3.0	3.0	3.0	3.0	2.2	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	2.5	3.0	0.0	3.0	3.0	3.0	3.0	3.0	2.5	3.0	3.0	3.0	3.0	3.0	2.9	0.3	3.0	3.0	2.9	0.0
19/045	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	0.0	3.0	3.0	0.0	0.0	3.0	2.9	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.2	3.2	2.2	1.7	3.2	2.5	0.3	3.0	3.0	2.1	2.3
19/057	KWS Zyatt	3.0	3.0	3.0	3.0	2.0	2.3	0.0	3.0	2.0	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	3.0	3.0	2.2	2.0	4.0	3.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0
19/061	Graham	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	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	3.5	3.3	3.0	3.0	3.2	2.0	0.1	3.0	3.0	0.4	3.0
19/069	Reflection	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	0.0	3.0	3.0	0.0	0.0	3.0	2.9	3.0	0.0	3.0	3.0	3.0	3.0	3.0	2.5	3.0	3.0	3.0	2.8	3.0	1.2	0.1	3.0	3.0	0.0	3.0
19/073	KWS Firefly	3.0	3.0	3.0	3.0	2.2	3.0	0.0	3.0	3.0	3.0	3.0	3.0	1.6	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	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.8	3.0	2.7	0.0	3.0	3.0	1.8	3.0
19/085	Gleam	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	2.5	3.0	3.0	2.8	2.8	2.7	0.2	0.0	3.0	3.0	0.0	0.0	3.0	1.4	3.0	0.0	2.8	3.0	3.0	3.0	3.0	2.9	3.0	3.0	2.9	0.0	3.0	2.6	0.1	3.0	3.0	1.0	0.1
19/094	KWS Zyatt	3.0	3.0	3.0	2.9	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	1.9	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	3.0	2.0	0.0	3.0	3.0	2.7	1.9

		1	1	2	3a, 4a	3b,4b	4,Su	5	9	2,6	2,6,25	7	7,22,23	6,7	7,17	8	8,19	6	2,9,25	10	15	17	17	17	24	2,25	25,Sd	32	25,32	Sp	Sp	Ro	So	Wa	St		Am					
Isolate code	Host	Avocet Yr1	Chinese 166	Kalyansona	Vilmorin 23	Hybrid 46	Suwon Omar	Avocet Yr5	Avocet Yr6	Heines Kolben	Heines Peko	Avocet Yr7	Lee	Cadenza	Apache	Avocet Yr8	Compair	Avocet Yr9	Clement	Moro	Avocet Yr15	VPM 1	Rendezvous	Avocet Yr17	Avocet Yr24	Heines VII	Strubes Dickkopf	Avocet Yr32	Carstens V	Avocet Sp	Spaldings Prolific	Robigus	Solstice	Warrior	KWS Sterling	Claire	Ambition	Crusoe	Avocet S	Vuka	Kranich	Evolution
19/119	KWS Firefly	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	2.6	3.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0	2.2	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.1	3.1	3.0	3.0	4.0	1.7	0.6	3.0	3.0	1.6	2.8
19/136	KWS Zyatt	3.0	3.0	3.0	3.0	2.4	3.0	0.0	3.0	2.5	3.0	3.0	3.0	3.0	3.0	2.6	0.1	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	2.9	3.0	3.0	2.9	2.5	3.0	3.0	3.0	0.0
19/145	KWS Zyatt	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	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	3.5	3.5	2.5	3.0	3.0	2.1	0.7	3.0	3.0	2.6	3.0
19/165	KWS Zyatt	0.3	1.4	3.5	3.0	3.0	3.5	0.0	3.5	2.5	3.0	3.0	3.0	3.0	1.6	3.0	3.0	0.9	0.2	0.0	0.0	2.6	0.4	3.0	0.2	3.0	3.0	3.0	3.0	2.0	2.8	3.0	3.0	1.6	2.8	2.7	1.8	0.1	3.0	3.0	2.5	0.6
19/173	KWS Zyatt	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	2.5	3.0	3.0	3.0	3.0	0.1	3.0	2.7	3.0	3.0	0.0	0.0	2.9	0.3	3.0	0.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	1.8	2.0	2.1	1.7	0.0	3.0	3.0	2.5	0.2
19/195	Mulika	3.0	3.1	3.1	3.0	2.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.6	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	3.0	3.0	3.0	3.0	3.0	3.0	1.9
19/198	KWS Zyatt	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	1.2	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	2.5	3.5	3.1	2.2	3.0	2.7	0.8	0.5	3.0	3.0	2.0	1.2
19/215	KWS Extase	3.0	3.0	3.0	1.6	3.0	3.0	0.0	3.0	2.0	2.0	3.0	3.0	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	3.0	3.0	3.0	3.0	3.0	3.0	2.0
19/216	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	0.0	3.0	3.0	0.0	0.0	3.0	2.3	3.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	3.0	3.0	2.6	0.0	3.0	3.0	2.0	2.0
19/219	KWS Zyatt	3.0	3.0	3.0	3.0	2.3	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	2.5	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	1.7	0.1	3.0	3.0	3.0	0.3
19/227	KWS Zyatt	3.0	3.0	3.0	3.0	3.0	3.0	0.0	3.0	2.5	3.0	3.0	3.0	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	3.0	2.2	0.6	3.0	3.0	3.0	0.3

Table 3: Pathotypes of the 2019 wheat yellow rust isolates based on the differential test results in Table 2. Yellow shading indicates virulence of an isolate for a particular resistance gene or variety; orange shading with parentheses indicates a borderline reaction.

Isolate	Heat	Race														Virul	ence l	Profile ²										
code	позі		1	2	3	4	5	6	7	8	9	10	15	17	24	25	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ар	Cr	Ev
19/001	KWS Kinetic	Red 23	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Ca			Ар		
19/002	Dunston	Red 5	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So		Ca			Ар		
19/003	Elicit	Red 9	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So							
19/006	Gleam	Red 24	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Ca	St		Ар		Ev
19/010	KWS Zyatt			2	3	4		6	7	8				17		25	32			Ro	So		Ca					
19/017	KWS Siskin	Red 8	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So		Ca					
19/017 A			1	2	3	4		6	7		9			17		25	32		Sp	Ro	So	Wa						
19/017 B		Pink 11	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So	Wa				Ар		
19/022	RGT Gravity	Red 9	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So							
19/025	Unknown	Red 8	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So		Ca					
19/038	Shabras		1	2		4		6	7	8	9			17		25	32		Sp	Ro	So	Wa		St	Kr		(Cr)	
19/041	KWS Firefly	Red 3	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So	(Wa)	Ca			Ар		
19/044	KWS Zyatt	Red 39	1	2	3	4		6	7		9			17		25	32	(Re)	(Sp)	Ro	So	Wa	Ca	St	Kr	Ар		
19/045	Stigg	Red 5	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So		Ca			Ар		
19/057	KWS Zyatt		1	2	3			6	7		9			17		25	32	Re		Ro	So	Wa	Ca	St	Kr	Ар	Cr	
19/061	Graham	Red 24	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Ca	St		Ар		Ev
19/069	Reflection	Red 24	1	2	3	4		6	7		9			17		25	32	Re	(Sp)	Ro	So	Wa	Ca	St		Ар		Ev
19/073	KWS Firefly		1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa				Ар		Ev
19/085	Gleam	Red 43	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So	Wa	Ca			Ар		
19/094	KWS Zyatt	Red 38	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Ca	St	Kr			
19/119	KWS Firefly		1	2	3	4		6	7		9			17		25	32		Sp	Ro	So	Wa	(Ca)	St		Ар		Ev
19/136	KWS Zyatt	Red 36	1	2	3	4		6	7	(8)	9			17		25	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ар	(Cr)	
19/145	KWS Zyatt	Red 28	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	(Wa)	Ca	St	(Kr)	Ар		Ev
19/165	KWS Zyatt			2	3	4		6	7	8				17		25	32		Sp	Ro	So		Ca	St	(Kr)			
19/173	KWS Zyatt		1	2	3	4		6	7	8	9			17		25	32			Ro	So		Ca		(Kr)			

Isolate	Heat	Race														Virul	ence	Profile ²										
code	nosi	number 1	1	2	3	4	5	6	7	8	9	10	15	17	24	25	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ар	Cr	Ev
19/195	Mulika	Red 29	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Са	St	Kr	Ар	Cr	
19/198	KWS Zyatt		1	2	3	4		6	7	8	9			17		25	32	Re	(Sp)	Ro	So		Ca	St		Ар		
19/215	KWS Extase		1	2		4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ар	Cr	
19/216	Stigg	Red 41	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So	Wa	Ca	St		Ар		
19/219	KWS Zyatt	Red 39	1	2	3	4		6	7		9			17		25	32	(Re)	Sp	Ro	So	Wa	Ca	St	Kr	Ар		
19/227	KWS Zyatt	Red 36	1	2	3	4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Са	St	Kr	Ар		

¹ Race number assigned by the UKCPVS using pathotype data in Table 2.
² Numbers refer to previously designated Yr genes, Re = Rendezvous, Sp = Spaldings Prolific, Ro = Robigus, So = Solstice, Wa = Warrior, Ca = Cadenza, St = KWS Sterling, Kr = Kranich, Ap = Apache, Cr = Crusoe, Ev = Evolution. * = Missing data

Virulence For Resistance Gene or	Percent	age of Isol for (ates Identi Gene or Va	fied with V riety	ïrulence
variety	2015	2016	2017	2018	2019
Yr1	100	100	96	97	94
Yr2	97	100	100	100	100
Yr3	100	100	100	100	94
Yr4	97	100	100	100	97
Yr5	0	0	0	0	0
Yr6	100	100	100	100	100
Yr7	76	89	100	100	100
Yr8	3	3	4	0	16
Yr9	100	100	100	100	94
Yr10	0	0	0	0	0
Yr15	0	0	0	0	0
Yr17	97	100	100	100	100
Yr24	0	0	0	0	0
Yr25	100	97	100	100	100
Yr32	100	100	100	100	100
Rendezvous	38	87	96	67	48
Spaldings Prolific	72	82	96	100	94
Robigus	100	100	100	100	100
Solstice	90	100	100	100	100
Warrior	3	37	46	20	61
Cadenza	55	76	96	93	77
KWS Sterling	24	32	89	17	55
Kranich	7	8	7	0	29
Apache	52	55	96	83	68
Crusoe	0	5	7	0	10
Evolution	*	16	75	43	19
Total Number of Isolates	29	38	28	30	31

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

Table 5: Pathotype group frequencies from the past five years.

Pathotype Group*	Freq	uency o	f Isolate	es Foun	d (%)
Famotype Group	2015	2016	2017	2018	2019*
Pink	3	8	0	0	3
Blue	28	29	3	0	0
Red	66	63	93	93	65
Purple	3	0	0	3	0
Other	0	0	4	4	32
Number of					
isolates	29	46	28	30	31

* Genetic groups have been assigned using phenotyping data until all pathogenomics data is available. Novel isolates are currently classified as 'Other' until a genetic group can be assigned.

4.1.2.3. Commonly detected isolates

In 2019 there were 24 different pathotypes detected (Table 3), ten of which were unique to this year. This contrasts with the 2018 results where 14 pathotypes were identified and only three isolates were found to be unique. Similar to 2018, the isolates fell predominantly into the Red group, however, no particular Red pathotype dominated in 2019 (Table 3). This contrasts greatly from 2018 where two pathotypes – Red 27 and Red 23 - dominated the population.

The most common group of isolates in 2019, represented by 3 isolates, was Red 24. This group carried virulence for *Yr 1,2,3,4,6,7,9,17,25,32*,Re,Sp,Ro,So,Wa,Ca,St,Ap,Ev and was detected for the first time in 2016. The isolates of this group were collected from the varieties Gleam, Graham and Reflection and were collected from Lincolnshire, Oxfordshire and Shropshire respectively. Of particular note was an increase in novel isolates displaying a reaction on *Yr8*, Kranich and Crusoe, with some isolates appearing to be avirulent to *Yr1* and *Yr9* when displaying virulence for *Yr8*. No correlation between pathotype and location was found when the data was examined.

No isolates from the purple or blue pathotype groups were found in 2019, but a single isolate from the pink group was identified, carrying virulence for *Yr 1,2,3,4,6,7,9,17,25,32*,Sp,Ro,So,Wa,Ap. This pathotype, Pink 11, is relatively rare and has previously been detected in 2013 and 2014 at low frequency levels.

4.1.3. Variety testing of isolates from 2019

Five isolates from the 41 isolates tested were selected for further testing on the wider set of RL varieties and candidates (Table 6). Each year's isolates are selected to best represent the results of the tested isolates, choosing isolates with the most complex or novel virulence profiles where possible. In 2019, the isolates 19/010, 19/038, 19/119, 19/165 and 19/215 were all selected due to their novel pathotypes.

Table 6: 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, Ca = Cadenza, St = KWS Sterling, Kr = Kranich, Ap = Apache, Cr = Crusoe, Ev = Evolution. Yellow shading = compatible reaction (virulence), blank = avirulence, * = missing data.

Isolate	Host													Vir	ulen	ce Pr	ofile										
code		1	2	3	4	5	6	7	8	9	10	15	17	24	25	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ар	Cr	Ev
19/010	KWS Zyatt		2	3	4		6	7	8				17		25	32			Ro	So		Ca					
19/038	Shabras	1	2		4		6	7	8	9			17		25	32		Sp	Ro	So	Wa		St	Kr		(Cr)	
19/119	KWS Firefly	1	2	3	4		6	7		9			17		25	32		Sp	Ro	So	Wa	(Ca)	St		Ар		Ev
19/165	KWS Zyatt		2	3	4		6	7	8				17		25	32		Sp	Ro	So		Са	St	(Kr)			
19/215	KWS Extase	1	2		4		6	7		9			17		25	32	Re	Sp	Ro	So	Wa	Ca	St	Kr	Ар	Cr	

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 spring of 2020. Results are combined with the adult plant test results (Table 7) 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 (Table 8). Some variation was seen in the "supplementary" differentials, these are differentials that are included as they carry currently uncharacterised resistance genes. The reasons for these discrepancies are unclear, although it is possible that despite our best efforts, some of the isolates are mixtures at the differential test stage. Following subsequent rounds of multiplication it's possible that one or more of the isolates are more heavily selected for, hence the differences. As in previous years, the three RL varieties Costello, KWS Crispin and KWS Siskin were resistant to all isolates tested, along with KWS Parkin, RGT Saki and Theodore. Interestingly, KWS Jackal which was previously resistant to all isolates was susceptible to the majority of the isolates tested. Full resistance was maintained in adult plants. In addition, although not considered susceptible, KWS Firefly saw an increase in seedling infection type for a number of isolates. There was also a significant increase in infection on KWS Firefly across all isolates during the adult plant tests in 2020. This ties in with reports during the 2020 season of higher than expected levels of yellow rust on KWS Firefly.

Varieties that are only occasionally susceptible at the seedling stage included Cougar, Crusoe, Evolution, KWS Extase and LG Detroit. Virulence for Crusoe was first detected in 2013 and continues to be detected in occasional isolates, such as 19/038 and 19/215 in 2019. Isolate 19/215 was also found to be virulent on Crusoe at the adult plant stage. Similarly, isolate 19/215 was found to be virulent on KWS Extase during both seedling tests and adult plant tests. However, increases of virulence at the seedling stage of LG Detroit did not translate into increased infection during the adult plant trials. A number of isolates were also found to have increased virulence on Cougar at both seedling and adult plant stages.

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 2020 which contained RL and candidate varieties. Plots were directly inoculated early in the season to help keep natural infection at bay and inoculated every 7-14 days until the flag leaf had fully emerged. The first inoculation was carried out on the 19th March 2020 and the first assessment was made on 2nd June when the

plants were at GS57. The percentage of plot area infected was assessed and the mean was calculated from four assessments (Table 7). Disease levels were moderate to high in the trials. As in 2019, hot and dry weather may have impacted on the disease levels this year but infection levels were much higher than in recent years. 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. As expected, the susceptible controls Reflection and Robigus produced the highest levels of disease with up to 52.1% as an average of the percentage plot area infected assessments. Out of the 41 RL varieties and candidates under evaluation, 15 were resistant to all isolates tested.

During the 2020 field season, the UKCPVS received reports of higher than expected levels of disease in some varieties. The most commonly reported varieties in the first half of the season were KWS Firefly and Gleam, in particular KWS Firefly, where widespread reports were received. In these adult plant trials, Gleam was noticeably more susceptible in the trial inoculated with 19/038 and in the case of KWS Firefly, was susceptible to all isolates, in particular isolate 19/215. Very late season samples included ones from KWS Extase, (rating of 9 on the Recommended list), which also saw heavy infection in the trial when inoculated with 19/215.

Table 7: 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.

	Curront		Seedling (A	verage Infe	ction Type)			Adult Plan	t (% plot are	a infected)	
Variety	RL Rating	19/010	19/038	19/119	19/165	19/215	19/010	19/038	19/119	19/165	19/215
SY CLIPPER	Candidate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LG TAPESTRY	Candidate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COSTELLO	9	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1
THEODORE	9	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
KWS PARKIN		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0
KWS JACKAL	9	2.9	2.1	2.9	3.0	3.0	0.0	0.3	0.0	0.1	0.3
ELICIT	9	0.4	3.0	3.0	0.7	3.0	0.0	0.1	0.8	0.0	0.0
LG DETROIT	9	0.8	2.7	2.1	1.9	3.0	0.0	0.1	0.1	0.1	0.7
LG SUNDANCE	9	3.0	3.0	3.0	2.9	3.0	0.1	0.3	0.0	0.0	0.6
KWS SISKIN	9	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.8	0.1	0.1
RENDEZVOUS		0.0	3.0	1.8	0.0	3.0	0.0	0.6	0.4	0.3	0.1
CRUSOE	9	0.0	1.5	0.0	0.0	3.0	0.0	0.0	0.3	0.0	2.4
LG ASTRONOMER	Candidate	0.0	0.0	0.0	0.0	0.0	0.2	0.3	1.2	0.1	1.1
ASTOUND	Candidate	0.2	1.0	2.3	0.0	1.4	0.3	1.2	1.4	0.9	0.1
RGT ILLUSTRIOUS	9	2.0	1.9	2.8	2.0	2.5	0.5	0.9	1.7	1.0	0.1
GRAHAM	8	0.1	3.0	2.5	0.0	3.0	0.0	0.8	0.1	0.1	4.1
KWS CRANIUM	Candidate	0.0	0.0	0.0	0.0	0.0	0.9	0.7	1.4	1.4	1.5
LG PRINCE	Candidate	0.0	0.2	0.0	0.0	0.0	0.2	0.5	0.1	1.2	5.6
RGT SAKI	9	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.9	0.9	5.2
RGT SILVERSURFER	Candidate	0.7	1.5	1.3	1.8	1.3	0.2	3.3	1.6	0.9	2.7
ELATION	9	2.9	3.0	3.0	2.9	3.0	1.3	2.8	1.7	0.4	5.6
KWS EXTASE	9	1.0	1.9	0.9	0.6	3.0	0.1	0.7	0.0	0.0	14.9
RGT QUICKSILVER	Candidate	0.0	0.1	0.2	0.0	0.1	1.2	3.8	1.7	2.3	7.2
STRATOSPHERE		3.0	3.0	3.0	3.0	3.0	0.1	15.1	0.0	3.4	0.8
LG SKYSCRAPER	8	2.8	3.0	3.0	3.0	3.0	0.6	11.0	0.1	0.9	7.5
MERIT	Candidate	0.0	0.0	0.1	0.0	0.0	1.9	3.4	5.6	7.5	5.7
WARRIOR		0.0	2.1	0.2	0.0	3.0	2.8	10.8	2.5	1.5	7.9
SHABRAS	7	2.6	3.0	3.0	2.8	3.0	4.4	9.0	7.2	3.0	4.2
COUGAR		1.9	1.6	1.6	2.1	2.1	2.8	5.6	8.9	9.5	7.7
KWS BARREL	9	3.0	3.0	3.0	3.0	3.0	3.2	4.9	10.7	6.8	9.3

Veriety	Current		Seedling (A	verage Infe	ction Type)			Adult Plan	t (% plot are	a infected)	
variety	RL Rating	19/010	19/038	19/119	19/165	19/215	19/010	19/038	19/119	19/165	19/215
RGT LANTERN		0.0	3.0	3.0	0.0	3.0	3.9	13.5	8.3	9.0	1.1
LG QUASAR	Candidate	0.0	0.0	0.0	0.0	0.0	4.8	11.4	8.1	8.3	7.3
ELYSIUM		0.6	3.0	2.9	0.8	3.0	6.6	10.1	7.7	9.1	6.5
LG IIIUMINATE	Candidate	0.0	0.0	0.1	0.0	0.1	0.7	7.7	12.2	8.9	10.9
RGT GRAVITY	8	2.1	2.9	3.0	2.3	2.0	1.5	8.6	13.4	11.6	7.5
BANQUO	Candidate	2.3	3.0	3.0	1.4	3.0	1.6	11.3	10.5	9.5	10.5
SY INSITOR	7	3.0	3.0	3.0	3.0	3.0	5.0	12.7	7.6	6.2	15.1
RGT GALACTUS	Candidate	0.0	0.1	0.0	0.0	0.0	6.6	13.4	10.2	9.3	8.1
KRANICH		2.9	2.8	1.9	3.0	3.1	2.2	11.0	5.7	10.6	26.4
SWALLOW	Candidate	0.0	0.0	0.0	0.0	0.0	10.1	17.7	11.9	10.1	11.4
KWS PLECTRUM	Candidate	0.0	3.0	3.0	0.0	3.0	7.4	13.1	14.0	13.2	14.3
LGW110		0.5	3.0	0.3	0.0	3.0	0.9	16.4	6.0	6.2	32.6
GLEAM	7	0.0	3.0	3.0	0.0	3.0	5.7	29.7	10.8	8.4	8.9
APACHE		0.0	3.0	3.0	0.5	3.0	7.3	11.5	8.9	11.3	26.2
KWS FIREFLY	9	1.3	1.1	0.3	1.7	2.1	10.8	14.1	12.6	12.0	18.1
DELPHI		3.0	3.0	3.0	2.8	3.0	12.9	21.1	12.3	12.3	11.9
KWS KERRIN	7	2.3	2.9	3.0	1.4	1.6	7.5	16.5	25.3	12.1	11.1
KWS GATOR		1.6	2.7	3.0	2.5	3.0	8.2	24.4	15.4	14.5	10.7
KWS STERLING		0.9	0.4	1.6	2.0	3.0	7.6	13.8	10.1	13.4	30.7
RGT WASABI		1.9	3.0	3.0	3.0	3.0	6.1	20.0	19.5	19.8	16.4
LG SPOTLIGHT	8	3.0	3.0	3.0	2.8	3.0	12.3	17.6	14.5	12.8	26.3
LG SEEKER	Candidate	2.4	3.0	3.0	1.7	2.7	6.9	16.0	27.1	16.1	20.2
TORCH		4.0	2.7	-	3.0	3.0	10.0	23.5	6.0	19.5	34.6
RGT WOLVERINE	Candidate	3.0	2.1	3.0	3.0	3.0	10.0	24.5	17.6	21.8	20.1
RGT BLOSSOM		3.0	3.0	3.0	3.0	3.0	10.7	24.7	24.4	19.0	23.1
CADENZA		3.0	1.9	2.5	3.5	3.0	26.8	15.9	11.8	30.4	26.2
AMBITION		2.2	3.0	1.4	2.1	3.0	7.4	43.9	2.0	7.3	50.7
CORDIALE		0.9	3.0	3.0	0.3	3.0	17.9	22.8	22.5	18.9	31.6
HOBBIT		2.9	3.0	3.0	2.9	3.0	17.4	25.8	27.5	25.8	19.8
KWS ZYATT	7	3.0	2.9	3.0	4.0	3.0	26.0	19.5	27.2	24.8	39.8
SOLSTICE		3.0	3.0	3.0	3.0	3.0	22.1	30.8	36.7	34.3	28.9
KWS KINETIC	6	3.0	3.0	3.0	3.0	3.0	20.0	35.7	32.8	34.6	33.0
CLAIRE		3.0	3.0	3.5	1.8	3.0	30.1	44.4	24.5	34.2	23.3
SKYFALL	5	2.8	3.0	3.0	2.8	3.0	18.4	37.5	26.3	39.3	36.3
BRITANNIA		3.0	3.0	3.0	3.0	3.0	30.0	43.1	34.8	37.5	26.2

Variaty	Current		Seedling (A	verage Infe	ction Type)			Adult Plan	t (% plot are	a infected)	
variety	RL Rating	19/010	19/038	19/119	19/165	19/215	19/010	19/038	19/119	19/165	19/215
REFLECTION		3.0	4.0	3.0	3.3	3.0	28.6	52.1	38.3	46.2	36.6
ROBIGUS		3.0	3.0	3.0	3.0	3.0	29.1	47.2	45.7	42.3	46.4
Avocet Yr1		0.0	3.0	3.0	0.0	3.0	*	*	*	*	*
Chinese 166		1.0	3.0	3.0	0.3	3.0	*	*	*	*	*
Kalyansona		3.0	3.0	3.0	3.2	3.0	*	*	*	*	*
Vilmorin 23		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Hybrid 46		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Suwon Omar		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Avocet Yr6		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Heines Kolben		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	3.0	3.0	3.0	*	*	*	*	*
Lee		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Avocet Yr8		3.0	3.0	0.0	3.5	0.3	*	*	*	*	*
Compair		2.1	0.3	0.0	3.1	0.0	*	*	*	*	*
Avocet Yr9		0.0	3.0	1.6	0.0	3.0	*	*	*	*	*
Clement		0.0	3.0	1.8	0.0	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	*	*	*	*	*
VPM1		2.1	3.0	2.0	0.9	3.0	*	*	*	*	*
Avocet Yr17		3.0	4.0	3.0	3.0	3.0	*	*	*	*	*
Heines VII		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Strubes Dickkopf		3.0	3.0	1.9	1.1	3.0	*	*	*	*	*
Avocet Yr27		0.2	3.0	3.0	0.0	3.0	*	*	*	*	*
Avocet Yr32		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Carstens V		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Avocet Sp		0.0	3.0	2.8	0.0	3.0	*	*	*	*	*
Spaldings Prolific		1.2	3.0	3.0	1.0	3.0	*	*	*	*	*
Avocet S		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Vuka		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Evolution		0.0	2.1	3.0	1.2	2.1	*	*	*	*	*
Mean		*	*	*	*	*	6.9	13.4	10.4	10.8	13.5

Table 8: 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 2020 variety tests and trials. ¹ Diff = Differential test result, ² Seed = Variety seedling test result, ³ Re-Isol = Re-isolation results from adult plant trials, * = missing data

		19/010			19/038			19/119	Ð		19/165	5		19/215	5
Differential	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³
Avocet Yr1	0.0	0.0	2.4	3.0	3.0	3.0	3.0	3.0	3.0	0.3	0.0	0.0	3.0	3.0	3.0
Chinese 166	1.1	1.0	2.2	3.0	3.0	3.0	3.0	3.0	3.0	1.4	0.3	0.7	3.0	3.0	3.0
Kalyansona	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.2	3.0	3.0	3.0	3.0
Vilmorin 23	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.6	3.0	3.0
Hybrid 46	1.7	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.9	3.0	3.0	3.0
Suwon Omar	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0	3.0	3.0	3.0	3.0
Avocet Yr5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avocet Yr6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0	3.0	3.0	3.0	3.0
Heines Kolben	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	2.6	2.5	3.0	3.0	2.0	3.0	3.0
Heines Peko	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0
Avocet Yr7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Lee	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Avocet Yr8	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	3.0	3.5	3.0	0.0	0.3	0.0
Compair	2.7	2.1	3.0	0.0	0.3	0.0	0.0	0.0	0.0	3.0	3.1	3.0	0.0	0.0	0.0
Avocet Yr9	0.0	0.0	2.4	3.0	3.0	3.0	3.0	1.6	3.0	0.9	0.0	0.0	3.0	3.0	3.0
Clement	0.0	0.0	0.5	3.0	3.0	3.0	3.0	1.8	3.2	0.2	0.0	0.0	3.0	3.0	3.0
Moro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avocet Yr15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VPM 1	2.1	2.1	2.5	3.0	3.0	3.0	3.0	2.0	3.0	2.6	0.9	2.8	3.0	3.0	3.0
Avocet Yr17	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5
Avocet Yr24	0.1	*	0.0	0.0	*	0.0	0.0	*	0.0	0.2	*	0.0	0.0	*	0.0
Heines VII	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.8	3.0	3.0	3.0
Strubes Dickkopf	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.9	3.0	3.0	1.1	3.0	3.0	3.0	3.0
Avocet Yr32	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.8	3.0	3.0	3.0
Carstens V	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Rendezvous	0.1	0.0	0.3	1.6	3.0	2.0	2.2	1.8	3.0	0.4	0.0	0.0	3.0	3.0	2.9

		19/010			19/038	}		19/119)		19/16	5		19/21	5
Differential	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³
Avocet Sp	1.8	0.0	2.5	3.0	3.0	3.0	3.0	2.8	3.0	2.0	0.0	0.0	3.0	3.0	3.0
Spaldings Prolific	2.1	1.2	2.0	3.0	3.0	3.0	3.0	3.0	3.0	2.8	1.0	0.0	3.0	3.0	3.0
Robigus	3.0	3.0	4.0	3.0	3.0	3.0	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0
Solstice	3.0	3.0	3.0	3.0	3.0	3.0	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Warrior	0.2	0.0	1.5	3.0	2.1	2.0	3.0	0.2	2.0	1.6	0.0	0.0	3.0	3.0	3.0
Cadenza	3.0	3.0	3.0	1.2	1.9	3.0	2.6	2.5	3.0	3.0	3.5	3.0	3.0	3.0	3.0
KWS Sterling	1.6	0.9	2.5	2.9	0.4	1.8	3.0	1.6	3.0	2.8	2.0	2.9	3.0	3.0	3.0
Kranich	1.2	2.9	2.8	3.0	2.8	1.8	1.6	1.9	2.0	2.5	3.0	2.0	3.0	3.1	3.0
Apache	0.5	0.0	0.1	2.2	3.0	3.0	3.0	3.0	3.0	1.6	0.5	0.4	3.0	3.0	3.0
Crusoe	0.0	0.0	1.0	2.5	1.5	0.0	0.6	0.0	0.3	0.1	0.0	0.0	3.0	3.0	2.2
Evolution	0.2	0.0	0.2	2.3	2.1	0.9	2.8	3.0	3.0	0.6	1.2	0.0	2.0	2.1	2.0

4.2. Wheat Brown Rust

4.2.1. Samples received

In 2019, the UKCPVS received 55 samples of wheat brown rust from 9 different counties across the UK (Figure 2).



Figure 2: Map of the UK with the number of samples of wheat brown rust received in 2019 from the different counties.

The full sample register is provided in Appendix 1. Samples were received from 28 different varieties, with the most frequent variety being KWS Firefly. There were no unexpected outbreaks of brown rust on established varieties. 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

4.2.2.1. Virulence for individual resistance genes and varieties

Twenty-eight isolates were selected for further pathotyping (Table 9). 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 10). This was the fourth year that the UKCPVS adopted a new differential set in order to bring the UKCPVS into line with other virulence surveys across the world (for example Kolmer et al. 2013). No new virulences were detected. The frequency of detection of virulence for the Lrgenes monitored remained stable and were at similar levels to 2018 (Table 11). Interestingly, seedling virulence frequency changes to both Lr20 and Lr28 were identified, with virulence for Lr20 decreasing and Lr28 slightly increasing. Following reports of unusual outbreaks on KWS Firefly, we included KWS Firefly in our differential tests and found KWS Firefly appears to carry the same resistance as Lr28. Otherwise there were no major changes in varietal performance from seedling virulence frequencies.

4.2.2.2. Commonly detected races

In 2019 there were 16 different pathotypes detected in the 28 isolates tested, most of which were unique to this year. As discussed previously, this may well reflect the additional resolution afforded to us using the new differential set. In addition to this, it is likely that there will be more than one race present in some of the samples based on the experience of colleagues in France (H. Goyeau, *pers. comm.*).

4.2.3. Variety testing of isolates from 2019

Five isolates from the 28 tested isolates were selected for further testing on the wider set of RL varieties and candidates (Table 12) and were selected to best represent the diversity of the isolates tested.

Table 9: Average infection type (A.I.T.) scores for the 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	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)
19-002	Elicit	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	1.2	3.0	0.3	3.0	3.0	3.0	3.0	0.0
19-003	KWS Firefly	2.0	0.2	0.7	1.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	0.9	3.0	0.0	3.0	3.0	3.0	3.0	0.0
19-004	Breeding Line	3.0	0.4	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.5	3.0	2.0	3.0	3.0	3.0	3.0	2.0
19-005	KWS Firefly	3.0	1.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	2.0	1.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19-006	KWS Firefly	3.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	1.0	2.6	3.0	3.0	3.0	3.0	3.0	2.0
19-007	KWS Firefly	3.0	1.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.9	2.7	3.0	3.0	3.0	3.0	3.0	3.0
19-009	Crusoe	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.6	3.0	2.0	3.0	3.0	3.0	3.0	2.0
19-010	KWS Extase	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	0.6	3.0	0.1	3.0	3.0	3.0	3.0	0.0
19-012	KWS Firefly	3.0	1.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	2.0	0.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19-013	Elicit	3.0	0.0	0.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	3.0	0.3	3.0	1.2	3.0	3.0	3.0	3.0	2.0
19-014	KWS Basset	3.0	0.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.6	2.0	0.5	3.0	3.0	3.0	3.0	0.6
19-016	LG Motown	3.0	0.5	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.5	3.0	0.4	3.0	3.0	3.0	3.0	0.0
19-017	Revelation	3.0	0.0	0.2	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.3	2.0	1.0	3.0	3.0	3.0	3.0	0.5
19-025	KWS Firefly	3.0	0.0	1.0	2.0	1.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19-027	Crusoe	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	1.8	3.0	3.0	3.0	3.0	3.0	3.0	2.0
19-030	Crusoe	3.0	0.0	0.0	1.0	1.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	0.6	3.0	2.0	3.0	3.0	3.0	3.0	2.1
19-032	KWS Firefly	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.9	2.6	2.0	3.0	3.0	3.0	3.0	2.0
19-033	Graham	3.0	0.0	1.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	0.9	3.0	0.1	3.0	3.0	3.0	3.0	0.0
19-037	KWS Firefly	3.0	0.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	0.7	2.0	2.0	3.0	3.0	3.0	3.0	2.0

Isolate	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)
19-038	Skyfall	2.0	0.0	0.6	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.9	3.0	2.0	3.0	3.0	3.0	3.0	1.0
19-039	Revelation	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.9	3.0	1.0	3.0	3.0	3.0	3.0	1.0
19-040	Skyfall	3.0	0.0	1.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.6	3.0	2.0	3.0	3.0	3.0	3.0	2.0
19-044	KWS Firefly	3.0	0.0	0.1	1.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	1.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19-045	KWS Extase	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	0.6	3.0	2.0	3.0	3.0	3.0	3.0	1.4
19-048	Skyfall	3.0	0.0	0.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	2.0	1.2	3.0	0.4	3.0	3.0	3.0	3.0	0.3
19-052	KWS Firefly	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.6	3.0	2.0	3.0	3.0	3.0	3.0	2.0
19-053	RGT Blossom	3.0	0.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	1.8	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19-054	KWS Firefly	3.0	0.0	1.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	0.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0

Table 10: Pathotypes of the 2019 *Puccinia triticina* isolates based on the differential test results in Table 9. Numbers refer to specific *Lr* resistance genes, Cr = Crusoe, Ro = Robigus

Isolate	Host variaty										Vir	ulen	ice P	rofil	e								
Number	nost variety	1	2a	2b	2c	3a	3bg	3ka	10	13	14a	15	16	17	20	23	24	26	28	37	17b	Ro	Cr
19-002	Elicit	1				3a	3bg	3ka	10	13	14a	15	16	17		23		26		37	17b		Cr
19-003	KWS Firefly							<u>3ka</u>	10	13	14a	15	16	17	20			26		37	17b		Cr
19-004	Breeding Line DH (Gleam x Theodore)	(1)				3a	3bg	3ka	10	13	14a	15	16	17	20	23		26		37	17b		Cr
19-005	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17				26	28	37	17b	Ro	Cr
19-006	KWS Firefly	1			<mark>2</mark> c	3a	3bg	3ka	10	13	14a	15	16	17				(26)	(28)	37	17b		Cr
19-007	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17				26	28	37	17b	Ro	Cr
19-009	Crusoe	1				3a	3bg	3ka	10	13	14a	15	16	17	20	23		26		37	17b		Cr
19-010	KWS Extase	1				3a	3bg	<u>3ka</u>	10	13	14a	15	16	17		23		26		37	17b		Cr
19-012	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17				26	28	37	17b	Ro	Cr
19-013	Elicit	1				3a	3bg	<u>3ka</u>	10	13	14a	15	16	17		23		26		37	17b		Cr
19-014	KWS Basset	1			2c	3a	3bg	3ka	10	13	14a	15	16	17	20	23		(26)		37	17b		Cr
19-016	LG Motown	1				3a	3bg	3ka	10	13	14a	15	16	17	20	23		26		37	17b		Cr
19-017	Revelation	1							10	13	14a	15	16	17				(26)		37	17b		Cr
19-025	KWS Firefly	1						3ka	10	13	14a	15	16	17				26	28	37	17b	Ro	Cr
19-027	Crusoe	1				3a	3bg	3ka	10	13	14a	15	16	17		23		26	(28)	37	17b		Cr
19-030	Crusoe	1				(3a)			10	13	14a	15	16	17	20			26		37	17b		Cr
19-032	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17			(24)	(26)		37	17b		Cr
19-033	Graham	1						3ka	10	13	14a	15	16	17	20			26		37	17b		Cr
19-037	KWS Firefly	1			<mark>2</mark> c	3a	3bg	<u>3ka</u>	10	13	14a	15	16	17		23		(26)		37	17b		Cr
19-038	Skyfall					3a	3bg	3ka	10	13	14a	15	16	17				26		37	17b		Cr
19-039	Revelation	1				3a	3bg	3ka	10	13	14a	15	16	17				26		37	17b		Cr
19-040	Skyfall	1				3a	3bg	3ka	10	13	14a	15	16	17				26		37	17b		Cr
19-044	KWS Firefly	1						<u>3ka</u>	10	13	14a	15	16	17				26	28	37	17b		Cr
19-045	KWS Extase	1				3a	3bg	3ka	10	13	14a	15	16	17		23		26		37	17b		Cr
19-048	Skyfall	1			<mark>2c</mark>	3a	3bg	3ka	10	13	14a	15	16	17				26		37	17b		Cr
19-052	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17				26		37	17b		Cr
19-053	RGT Blossom	1				3a	3bg	3ka	10	13	14a	15	16	17	20			26	28	37	17b		Cr
19-054	KWS Firefly	1						3ka	10	13	14a	15	16	17				26	28	37	17b		Cr

Table 11: 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	Percentage	of Isolates Ide	entified with Vi	rulence for Ge	ne or Variety
Variety	2015	2016	2017	2018	2019
Lr1	39	29	68	81	89
Lr2a	*	0	0	0	0
Lr2b	*	0	16	0	0
Lr2c	*	6	48	26	11
Lr3a	52	26	87	48	75
Lr3bg	*	19	81	71	75
Lr3ka	*	29	77	74	93
Lr10	*	29	87	100	100
Lr13	*	32	84	100	100
Lr14a	*	29	87	100	100
Lr15	*	16	84	100	100
Lr16	*	13	58	52	96
Lr17	*	23	87	100	93
Lr17b	55	81	55	100	89
Lr20	65	10	87	77	21
Lr23	*	6	45	39	29
Lr24	3	3	3	0	0
Lr26	52	0	58	100	61
Lr28	6	0	0	6	18
Lr37	45	39	74	100	68
Robigus	6	0	0	6	4
Crusoe	42	71	77	100	61
Total Number of Isolates	26	25	27	31	28

Table 12: 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), blank = avirulence.

Isolate	Host variety										Vi	rulenc	e Prof	ile									
Number	nostvanety	1	2a	2b	2c	3a	3bg	3ka	10	13	14a	15	16	17	20	23	24	26	28	37	17b	Ro	Cr
19/005	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17				26	28	37	17b		Cr
19/012	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17				26	28	37	17b		Cr
19/032	KWS Firefly	1				3a	3bg	3ka	10	13	14a	15	16	17			(24)	(26)		37	17b		Cr
19/053	RGT Blossom	1				3a	3bg	3ka	10	13	14a	15	16	17	20			26	28	37	17b		Cr
19/054	KWS Firefly	1						<mark>3ka</mark>	10	13	14a	15	16	17				26	28	37	17b		Cr

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 spring of 2020. Results are combined with the adult plant test results (Table 13) and are sorted by the reaction on the adult plant trials (see 4.2.3.2). Only two of the RL varieties and candidates tested were resistant to all of the isolates tested, a lower number than seen previously (five in 2018), with isolate 19/032 showing virulence to all varieties with the exception of the differentials Maris Halberd and Sappo. Virulence for Theodore, Stigg, Warrior, RGT Saki and Viscount was detected for the first time this year. A general agreement was seen when these results were compared with those of the initial differential test, however some discrepancies were seen (Table 14). Further purification methods have now been used by the UKCPVS to solve the problem of multiple isolates in a sample. Discrepancies seen now are most likely due to environmental issues.

4.2.3.2. 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 2020 which contained RL and candidate varieties. As with the yellow rust trials, the plots were directly inoculated early in the season to help keep natural infection at bay and inoculated every 7-14 days until the flag leaf had fully emerged. The first inoculation was carried out on the 18th March 2020 and the first assessment was made on 9th June when the plants were at GS69. The percentage plot infected was assessed and the mean was calculated from three assessments (Table 7). Disease levels were low in the trials this year compared to last year making evaluation of resistance challenging. Similar to last year, dry conditions during the inoculation and assessment period may have impacted on the amount of disease established in the trials. Susceptible control Buster showed variable amounts of disease across the five trials, with the highest score being 11.7% and had the highest levels of symptoms overall. Samples were taken from the trials to confirm that isolates used to inoculate the trial were present (Table 14). Tests on these isolates generally agreed with the differential seeding tests, suggesting that the new inoculation techniques are significantly lowering levels of natural infection.

Out of the 42 RL varieties and candidates under evaluation, 19 were resistant to all isolates tested. During the 2020 field season, the UKCPVS did not receive any reports of higher than expected levels of disease in any particular variety. The most commonly reported variety was Crusoe, which is to be expected due to its low RL rating for brown rust and was

mirrored in 2020's adult plant trials. A number of samples collected from KWS Extase, KWS Parkin and KWS Firefly were also received during the 2019 season. Although disease levels were generally low in this year's trials, KWS Firefly was categorised as susceptible based on this year's adult plant trials. Both KWS Extase and KWS Parkin appeared resistant in these trials, suggesting that minor outbreaks during the season were localised.

Table 13: 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.

	Current RL		Seedling (A	Average Infe	ction Type)			Adult Plan	t (% plot are	a infected)	
Variety	Rating	19-005	19-012	19-032	19-053	19-054	19-005	19-012	19-032	19-053	19-054
STIGG		0.8	0.6	3.0	0.6	1.5	0.0	0.0	0.0	0.1	0.0
MARIS HALBERD		2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.1
MARIS RANGER		*	*	*	*	*	0.0	0.0	0.0	0.0	0.1
WARRIOR		0.4	0.0	3.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
STERNA		3.0	3.0	3.0	3.0	2.0	0.0	0.0	0.0	0.2	0.0
SY CLIPPER	Candidate	0.4	0.1	3.0	0.0	0.5	0.2	0.0	0.0	0.0	0.0
SKYFALL	8	3.0	3.0	3.0	3.0	2.9	0.2	0.0	0.0	0.0	0.0
KWS EXTASE	7	3.0	3.0	3.0	3.0	3.0	0.2	0.0	0.0	0.0	0.1
THEODORE	7	0.2	0.0	3.0	0.1	0.2	0.2	0.0	0.2	0.0	0.0
LG SEEKER	Candidate	3.0	3.0	3.0	3.0	2.0	0.0	0.2	0.1	0.0	0.1
RGT WOLVERINE	Candidate	3.0	3.0	3.0	3.0	3.0	0.2	0.0	0.0	0.1	0.0
ELYSIUM		3.0	3.0	3.0	3.0	3.0	0.2	0.0	0.2	0.2	0.0
GAMIN		3.0	3.0	3.0	3.0	3.0	0.6	0.0	0.0	0.0	0.1
SAPPO		2.0	2.0	2.0	2.0	2.0	0.2	0.0	0.2	0.4	0.0
KWS TARGET		3.0	3.0	3.0	3.0	3.0	0.2	0.8	0.0	0.0	0.0
KWS BARREL	5	3.0	3.0	3.0	3.0	3.0	0.1	0.5	0.2	0.0	0.4
ARMADA		3.0	3.0	3.0	3.0	3.0	0.5	0.2	0.1	0.3	0.3
RGT WASABI		3.0	3.0	3.0	3.0	3.0	0.8	0.2	0.2	0.2	0.2
LG ILLUMINATE	Candidate	3.0	3.0	3.0	3.0	3.0	0.2	0.9	0.2	0.1	0.2
RGT LANTERN		3.0	3.0	3.0	3.0	3.0	0.4	0.0	0.2	0.3	0.7
ASTOUND	Candidate	3.0	3.0	3.0	3.0	3.0	0.5	0.7	0.2	0.1	0.2
MARIS HUNTSMAN		3.0	3.0	3.0	3.0	3.0	0.4	0.6	0.0	0.3	0.5
KWS KERRIN	7	3.0	3.0	3.0	3.0	3.0	0.4	1.0	0.2	0.0	0.3
MERIT	Candidate	3.0	3.0	3.0	3.0	3.0	0.9	0.2	0.2	0.1	0.8
LG SPOTLIGHT	7	3.0	3.0	3.0	3.0	3.0	1.4	0.4	0.0	0.1	0.4
GRAHAM	6	3.0	3.0	3.0	3.0	3.0	0.2	0.9	0.2	0.8	0.0
ELICIT	7	3.0	3.0	3.0	3.0	3.0	0.6	0.9	0.5	0.1	0.4
RGT ILLUSTRIOUS	6	3.0	3.0	3.0	3.0	3.0	1.0	0.5	0.0	0.1	0.8
KWS PLECTRUM	Candidate	3.0	3.0	3.0	3.0	3.0	0.3	1.0	0.0	0.6	0.6

	Current RL		Seedling (A	Average Infe	ction Type)			Adult Plan	t (% plot are	a infected)	
Variety	Rating	19-005	19-012	19-032	19-053	19-054	19-005	19-012	19-032	19-053	19-054
LG SKYSCRAPER	6	3.0	3.0	3.0	3.0	3.0	0.4	0.7	0.2	0.6	0.7
LG TAPESTRY	Candidate	3.0	3.0	3.0	3.0	3.0	0.2	1.9	0.0	0.2	0.3
LG ASTRONOMER	Candidate	3.0	3.0	3.0	3.0	3.0	1.5	0.0	0.2	0.5	0.5
KWS KINETIC	6	3.0	3.0	3.0	3.0	3.0	0.9	0.7	0.0	1.2	0.2
KWS STERLING		3.0	3.0	3.0	3.0	3.0	1.1	1.1	0.0	0.1	1.0
RGT GALACTUS	Candidate	3.0	3.0	3.0	3.0	3.0	1.4	0.7	0.2	0.1	1.1
LG PRINCE	Candidate	3.0	3.0	3.0	3.0	3.0	0.9	0.7	0.1	1.2	0.6
KWS SISKIN	5	3.0	3.0	3.0	3.0	3.0	0.9	0.7	0.1	1.5	0.8
LG QUASAR	Candidate	3.0	3.0	3.0	3.0	3.0	1.0	0.5	0.1	0.3	1.9
KWS CRANIUM	Candidate	3.0	3.0	3.0	3.0	3.0	0.3	0.3	0.5	1.9	0.9
RGT GRAVITY	7	3.0	3.0	3.0	3.0	3.0	0.7	0.5	0.2	1.9	1.1
KWS PARKIN		3.0	3.0	3.0	3.0	3.0	1.8	1.6	0.0	0.0	1.4
BANQUO	Candidate	3.0	3.0	3.0	3.0	3.0	2.8	1.0	0.0	0.0	0.9
RGT BLOSSOM		3.0	3.0	3.0	3.0	3.0	1.4	1.3	0.0	0.7	1.3
KWS ZYATT	6	3.0	3.0	3.0	3.0	3.0	2.0	1.5	0.6	0.0	0.7
ROBIGUS		3.0	3.0	3.0	3.0	3.0	1.4	1.2	0.1	0.5	1.9
GLEAM	6	3.0	3.0	3.0	3.0	3.0	0.2	1.9	0.2	1.5	1.4
RGT SILVERSURFER	Candidate	3.0	3.0	3.0	3.0	3.0	1.0	1.9	0.5	1.0	0.7
KWS JACKAL	5	3.0	3.0	3.0	3.0	3.0	1.7	1.7	0.4	0.9	0.7
COSTELLO	5	3.0	3.0	3.0	3.0	3.0	2.9	0.6	0.2	0.7	1.2
SWALLOW	Candidate	3.0	3.0	3.0	3.0	3.0	2.2	2.4	0.0	0.3	1.0
GLASGOW		3.0	3.0	3.0	3.0	3.0	1.2	0.9	0.5	2.8	1.2
TUXEDO		3.0	3.0	3.0	3.0	3.0	1.9	2.6	0.2	0.7	0.7
RGT QUICKSILVER	Candidate	3.0	3.0	3.0	3.0	3.0	1.4	1.7	0.6	0.9	1.5
SHABRAS	5	3.0	3.0	3.0	3.0	3.0	1.4	0.2	0.2	2.7	2.0
SY INSITOR	4	3.0	3.0	3.0	3.0	3.0	2.7	0.7	0.2	0.9	2.4
RGT SAKI	8	3.0	3.0	3.0	3.0	3.0	0.5	0.5	0.0	1.8	4.0
AVALON		3.0	3.0	3.0	3.0	3.0	3.2	0.0	0.0	3.2	1.2
MASCOT		3.0	3.0	3.0	3.0	3.0	3.7	1.6	0.0	0.6	1.6
LG SUNDANCE	6	3.0	3.0	3.0	3.0	3.0	3.0	1.4	0.5	0.9	2.0
REAPER		3.0	3.0	3.0	3.0	3.0	1.9	1.4	1.4	1.0	2.3
ELATION	6	3.0	3.0	3.0	3.0	3.0	2.5	0.9	0.2	3.2	1.5

	Current RL		Seedling (A	Average Infe	ction Type)			Adult Plan	t (% plot are	a infected)	
Variety	Rating	19-005	19-012	19-032	19-053	19-054	19-005	19-012	19-032	19-053	19-054
LG DETROIT	5	3.0	3.0	3.0	3.0	3.0	3.0	0.9	0.7	2.7	3.5
CONSORT		3.0	3.0	3.0	3.0	3.0	3.4	1.0	1.5	1.2	4.7
CRUSOE	3	3.0	3.0	3.0	3.0	3.0	4.1	4.3	2.5	3.9	2.9
KWS FIREFLY	6	3.0	3.0	3.0	3.0	3.0	11.5	4.2	0.2	0.7	2.4
BUSTER		3.0	3.0	3.0	3.0	3.0	9.9	3.0	1.9	5.5	11.7
MARIS FUNDIN		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
SOISSONS		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr1		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr2a		1.0	1.0	1.0	0.0	1.0	*	*	*	*	*
Thatcher Lr2b		1.0	2.0	1.0	1.0	1.0	*	*	*	*	*
Thatcher Lr2c		2.0	2.0	2.0	2.0	2.0	*	*	*	*	*
Thatcher Lr3a		3.0	3.0	3.0	3.0	2.0	*	*	*	*	*
Thatcher Lr3bg		2.0	2.0	3.0	3.0	2.0	*	*	*	*	*
Thatcher Lr3ka		3.0	2.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr10		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr13		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr14a		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr15		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr16		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr17		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr20		2.0	2.0	2.0	2.0	2.0	*	*	*	*	*
Thatcher Lr23		2.0	2.0	3.0	2.0	2.0	*	*	*	*	*
Thatcher Lr24		0.8	0.9	3.0	1.2	1.6	*	*	*	*	*
Thatcher Lr26		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr28		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Thatcher Lr37		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Clement		3.0	3.0	3.0	3.0	3.0	*	*	*	*	*
Mean		*	*	*	*	*	1.4	0.8	0.3	0.8	1.1

Table 14: 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 2019 variety tests and trials. ¹ Diff = Differential test result, ² Seed = Variety seedling test result, ³Re-Isol = Re-isolation results from adult plant trials, * = missing data

Differential		19/00	5		19/01	2		19/03	2		19/05	3		19/054	4
Differentia	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³
Armada	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Clement	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0
Crusoe	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Glasgow	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Maris Fundin	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Maris Halberd	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0
Robigus	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Sappo	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0
Sterna	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	2.0	2.0	3.0
Stigg	1.6	0.8	0.6	1.5	0.6	0.3	3.0	3.0	0.3	1.5	0.6	0.3	0.9	1.5	0.9
Warrior	0.2	0.4	0.0	0.0	0.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
KWS Firefly	3.0	3.0	3.0	3.0	3.0	3.0	1.8	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr2a	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0
Thatcher Lr2b	1.0	1.0	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
Thatcher Lr2c	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Thatcher Lr3a	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.1	3.0	3.0	3.0	2.0	2.0	3.0
Thatcher Lr3bg	3.0	2.0	3.0	3.0	2.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	2.0	2.0	3.0
Thatcher Lr3ka	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr10	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr13	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr14a	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr15	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr16	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr17	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr20	1.0	2.0	2.0	1.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.1

Differential	19/005		19/012		19/032			19/053			19/054				
Differential	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³	Diff ¹	Seed ²	Re-Isol ³
Thatcher Lr23	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
Thatcher Lr24	1.7	0.8	1.5	0.9	0.9	0.6	2.9	3.0	1.5	1.8	1.2	0.6	0.9	1.6	0.9
Thatcher Lr26	3.0	3.0	3.0	3.0	3.0	3.0	2.6	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr28	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Thatcher Lr37	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

4.3. Wheat Powdery Mildew

4.3.1. Samples received

Levels of wheat powdery mildew were low in 2019 and the UKCPVS received 6 samples (appendix 1). The samples came from 4 different varieties and 4 different counties (Figure 3).



Figure 3: Map of the UK with the number of samples of wheat powdery mildew received in 2019 from the different counties.

4.3.2. Pathotyping of isolates

Unfortunately, none of the samples received survived incubation and no isolates were successfully cultured. No seedling tests were carried out in 2019. Virulence frequencies are listed for 2014 – 2018 in Table 15 for reference only.

Differential	Known Conce		Virulence	Frequence	cy by Yea	r
Differential	Known Genes	2014	2015	2016	2017	2018
Galahad	Pm2	72	71	88	100	100
Chul	Pm3b	20	14	8	20	15
Armada	Pm4b	84	64	84	100	96
Flanders	Pm5	76	71	76	84	81
Brimstone	Pm6	80	64	88	96	93
Clement	Pm8	44	50	88	84	93
Maris dove	Mld	60	64	64	68	100
Brock	Pm2,MITa2	88	71	84	96	100
Mercia	Pm5, MITa2	80	79	80	100	93
Tonic	MITo	24	14	28	64	85
Broom	Pm3d	20	14	28	60	85
Sicco	Pm5, MISi2	8	0	8	40	11
Wembley	MISo	8	0	4	44	11
Axona	MIAx	12	14	32	60	78
Amigo	Pm17	0	7	0	8	0
Shamrock	MISh	4	0	0	0	0
Robigus	MIRo	64	64	56	72	85
Warrior		8	0	8	16	74
Stigg		8	0	4	16	74
Crusoe		36	36	72	68	93
Total Number	of Isolates Tested	43	25	14	25	27

Table 15: Virulence frequencies of key wheat powdery mildew resistance genes and varieties over five years of testing.

The wheat powdery mildew isolates are 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.

4.4. Barley Powdery Mildew

4.4.1. Samples received

Like the wheat powdery mildew, low levels of barley powdery mildew were observed in 2019. The UKCPVS received 5 samples from 5 varieties from one county (Figure 4).



Figure 4: Map of the UK with the number of samples of barley powdery mildew received in 2019 from the different counties.

4.4.2. Pathotyping of isolates

From the samples received, 4 single pustule isolates were obtained from one sample and these were characterised using a differential set (Table 16). Virulence for most of the differentials were detected and were broadly in line with frequencies observed in previous years (Table 17). Exceptions were seen for differentials such as Lofa, and Porter, where increases in virulence frequency were observed, but these results must be interpreted with caution due to the low sample numbers received and tested. The UKCPVS received no reports of unexpected outbreaks of barley powdery mildew during 2019 so it is possible that this variation in the population will not translate into meaningful differences at the adult plant stage. 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.

Table 16: 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.

lsolate	Hoot Variaty	0	ЧIМ	MIra	MIg	MIg,MI(CP)	Mla6	MILa	Mla12	MIK1	Mla7	MIAb	MIa7,MIAb	Mla1	Mla9	mlo 11	Mlo Riv	Mla13	Mla3	Vanessa	Optic	Propino
Number	nost variety	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	Propino
19-5-1	AC11/325/32	3.8	3.8	3.0	3.0	3.0	3.0	2.3	3.8	3.0	3.5	2.3	2.0	0.0	0.0	2.5	0.0	0.0	0.5	3.5	1.3	0.0
19-5-2	AC11/325/32	3.3	3.3	3.3	3.0	3.0	3.3	2.8	3.0	0.5	2.8	3.8	3.3	0.0	0.0	2.3	1.8	3.0	0.8	3.8	2.5	0.0
19-5-3	AC11/325/32	4.0	3.8	3.0	3.0	3.3	3.0	2.8	3.5	2.0	3.0	3.0	1.5	3.0	0.5	1.8	0.5	3.0	1.0	3.8	1.8	0.0
19-5-4	AC11/325/32	3.5	3.5	3.3	3.0	3.0	3.0	2.8	3.5	1.0	3.0	4.0	1.8	0.0	0.0	2.0	1.3	3.0	1.5	3.8	3.5	0.0

Table 17: Virulence frequencies of key barley powdery mildew resistance genes over the past five years of testing. * = Not tested.

Differential	Known	V	/irulence	Frequend	cy by Yea	r
Differential	Genes	2015	2016	2017	2018	2019
Golden Promise	0	98	88	100	100	100
W.37/136	Mlh	100	100	100	100	100
W.41/145	Mlra	100	100	100	100	100
Goldfoil	Mlg	88	100	97	79	100
Zephyr	Mlg,Ml(CP)	88	100	97	79	100
Midas	Mla6	98	100	100	100	100
Lofa	MILa	90	96	84	38	100
Hassan	Mla12	93	96	84	83	100
H.1063	Mlk1	43	31	13	41	25
Porter	Mla7	35	27	53	31	100
Lotta	MIAb	38	35	78	59	75
Triumph	Mla7,MlAb	5	12	22	3	25
Tyra	Mla1	58	73	56	69	25
Roland	Mla9	15	15	16	14	0
Apex	mlo 11	8	15	38	14	0
Riviera	mlo 11	0	0	6	0	0
Digger	Mla13	5	23	25	14	75
Ricardo	Mla3	53	62	75	59	0
Vanessa	Van	98	100	97	100	100
Optic		18	19	25	7	25
NFC Tipple		58	77	88	*	*
Propino		65	65	88	59	0
Total Number of	Isolates	40	26	32	29	4

5. Conclusions

The UK *Pst* population continues to show high levels of diversity since the incursion of the Warrior population in 2011. The current population continues to be dominated by isolates from the Red group, and within that group there are a broad range of virulence profiles which continues to change. Several new combinations of virulence were detected, with novel isolates displaying a reaction on *Yr8*, Kranich and Crusoe. Five isolates displaying novel pathotypes were investigated in the adult plant trials. All five isolates infected KWS Firefly in adult plant trials, in particular isolate 19/215, and may help explain an outbreak on KWS Firefly reported during the 2020 season.

A new differential set was used for the fourth year to analyse the *P. triticina* population. As seen in previous years, virulence was detected for many of the *Lr* genes tested and seedling variety tests highlighted that almost all varieties tested were susceptible to at least one of the races under evaluation. Seedling virulence frequency changes to both *Lr20* and *Lr28* were found, otherwise there were no major changes in varietal performance from seedling virulence frequencies. Low levels of disease pressure in the 2020 field season made detailed evaluation of varietal resistance at adult plant stage challenging, however KWS Firefly was identified as moderately susceptible supporting data collected in 2019.

Small changes in the *Bgh* population were detected, but this should be interpreted with caution due to the very limited number of isolates tested. 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

2019 Wheat Yellow Rust Isolate Register

lsolate Number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-084	Belipi	May 2019	-	Warwickshire
19-031	Bennington	April 2019	6	Lincolnshire
19-117	Bennington	June 2019	6	Lincolnshire
19-153	Bennington	June 2019*	6	North Yorkshire
19-175	Bennington	June 2019	6	Bridgend County Borough
19-232	Bennington	July 2019	6	East Lothian
19-050	Claire	May 2019	-	Cambridgeshire
19-062	Claire	May 2019	-	Oxfordshire
19-093	Claire	May 2019	-	Essex
19-206	Claire	June 2019	-	Lincolnshire
19-213	Claire	June 2019	-	Edinburgh
19-068	Cordiale	May 2019	-	Shropshire
19-092	Cordiale	May 2019	-	Essex
19-177	Cordiale	June 2019	-	Bridgend County Borough
19-205	Cordiale	June 2019	-	Lincolnshire
19-032	Costello	April 2019	9	Hertfordshire
19-241	Costello	May 2019	9	Ireland
19-242	Costello	May 2019	9	Ireland
19-243	Costello	May 2019	9	Ireland
19-002	Dunston	January 2019	7	Cambridgeshire
19-026	Dunston	April 2019	7	Cambridgeshire
19-106	Dunston	June 2019	7	Warwickshire
19-132	Dunston	June 2019	7	Lincolnshire
19-150	Dunston	June 2019*	7	North Yorkshire
19-166	Dunston	June 2019	7	Lincolnshire
19-174	Dunston	June 2019	7	Bridgend County Borough
19-181	Dunston	June 2019	7	Somerset
19-233	Dunston	July 2019	7	East Lothian
19-239	Dunston	July 2019	7	Angus
19-098	Dunston	June 2019	7	Norfolk
19-003	Elicit	February 2019	9	Greater Manchester
19-016	Elicit	March 2019	9	West Berkshire
19-100	Elysium	June 2019	8	Norfolk
19-108	Elysium	June 2019	8	Herefordshire
19-135	Elysium	June 2019	8	Lincolnshire
19-146	Elysium	June 2019*	8	North Yorkshire
19-234	Elysium	July 2019	8	East Lothian
19-006	Gleam	March 2019	7	Lincolnshire

lsolate Number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-011	Gleam	March 2019	7	Essex
19-020	Gleam	April 2019	7	Lincolnshire
19-030	Gleam	April 2019	7	Lincolnshire
19-063	Gleam	May 2019	7	Lincolnshire
19-085	Gleam	May 2019	7	Warwickshire
19-130	Gleam	June 2019	7	Lincolnshire
19-140	Gleam	June 2019	7	Cambridgeshire
19-167	Gleam	June 2019	7	Lincolnshire
19-061	Graham	May 2019	8	Oxfordshire
19-065	Graham	May 2019	8	Lincolnshire
19-095	Graham	May 2019	8	Warwickshire
19-111	Graham	June 2019	8	Lincolnshire
19-189	Invicta	June 2019	-	Cambridgeshire
19-086	JB Diego	May 2019	4	Suffolk
19-110	JB Diego	June 2019	4	Herefordshire
19-033	KWS Barrel	April 2019	9	Lincolnshire
19-075	KWS Barrel	May 2019	9	Cambridgeshire
19-096	KWS Barrel	May 2019	9	Suffolk
19-102	KWS Barrel	June 2019	9	Norfolk
19-105	KWS Barrel	May 2019	9	Oxfordshire
19-121	KWS Barrel	June 2019	9	Lincolnshire
19-217	KWS Barrel	June 2019	9	Scottish Borders
19-225	KWS Barrel	July 2019	9	East Lothian
19-123	KWS Basset	June 2019	8	Lincolnshire
19-158	KWS Basset	June 2019*	8	North Yorkshire
19-222	KWS Basset	July 2019	8	East Lothian
19-014	KWS Cochise	March 2019	5	Lincolnshire
19-028	KWS Cochise	April 2019	5	Cambridgeshire
19-127	KWS Extase	June 2019	9	Lincolnshire
19-185	KWS Extase	June 2019	9	Cambridgeshire
19-215	KWS Extase	June 2019	9	Devon
19-041	KWS Firefly	May 2019	9	Cambridgeshire
19-073	KWS Firefly	May 2019	9	Cambridgeshire
19-119	KWS Firefly	June 2019	9	Lincolnshire
19-186	KWS Firefly	June 2019	9	Cambridgeshire
19-004	KWS Kerrin	March 2019	7	Cambridgeshire
19-019	KWS Kerrin	April 2019	7	Lincolnshire
19-036	KWS Kerrin	April 2019	7	Northumberland
19-074	KWS Kerrin	May 2019	7	Cambridgeshire
19-103	KWS Kerrin	June 2019	7	Norfolk
19-114	KWS Kerrin	June 2019	7	Lincolnshire
19-147	KWS Kerrin	June 2019*	7	North Yorkshire

lsolate Number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-168	KWS Kerrin	June 2019	7	Lincolnshire
19-184	KWS Kerrin	June 2019*	7	North Yorkshire
19-192	KWS Kerrin	June 2019	7	Norfolk
19-220	KWS Kerrin	July 2019	7	Norfolk
19-235	KWS Kerrin	July 2019	7	East Lothian
19-034	KWS Kielder	April 2019	_	Lincolnshire
19-042	KWS Kilburn	May 2019	5	Lincolnshire
19-001	KWS Kinetic	January 2019	6	Cambridgeshire
19-043	KWS Kinetic	May 2019	6	Suffolk
19-046	KWS Kinetic	May 2019	6	Cambridgeshire
19-116	KWS Kinetic	June 2019	6	Lincolnshire
19-143	KWS Kinetic	June 2019*	6	North Yorkshire
19-190	KWS Kinetic	June 2019	6	Norfolk
19-240	KWS Kinetic	July 19	6	Hampshire
19-024	KWS Lili	April 2019	7	Oxfordshire
19-113	KWS Lili	June 2019	7	Lincolnshire
19-211	KWS Lili	June 2019	7	Edinburgh
19-236	KWS Lili	July 2019	7	East Lothian
19-005	KWS Santiago	March 2019	-	Cambridgeshire
19-007	KWS Santiago	March 2019	-	Lincolnshire
19-027	KWS Santiago	April 2019*	-	Essex
19-035	KWS Santiago	April 2019	-	Lincolnshire
19-079	KWS Santiago	May 2019	-	Oxfordshire
19-107	KWS Santiago	June 2019	-	Herefordshire
19-148	KWS Santiago	June 2019*	-	North Yorkshire
19-017	KWS Siskin	April 2019	9	Northants
19-182	KWS Siskin	June 2019	9	Nottinghamshire
19-162	KWS W358	June 2019	-	Cheshire
19-059	KWS Willow	May 2019	6	Lincolnshire
19-160	KWS Zyatt	June 2019	8	Somerset
19-010	KWS Zyatt	March 2019	8	Essex
19-044	KWS Zyatt	May 2019	8	Kent
19-057	KWS Zyatt	May 2019	8	Leicestershire
19-058	KWS Zyatt	May 2019*	8	Hampshire
19-066	KWS Zyatt	May 2019	8	Lincolnshire
19-067	KWS Zyatt	May 2019*	8	Hampshire
19-081	KWS Zyatt	May 2019	8	Warwickshire
19-094	KWS Zyatt	May 2019	8	Kent
19-099	KWS Zyatt	June 2019	8	Norfolk
19-128	KWS Zyatt	June 2019	8	Lincolnshire
19-136	KWS Zyatt	June 2019	8	Surrey
19-145	KWS Zyatt	June 2019*	8	North Yorkshire

Isolate			RL Rating	
Number	Host Variety	Date Sampled	2019/20	Location
19-165	KWS Zyatt	June 2019	8	North Yorkshire
19-173	KWS Zyatt	June 2019	8	Bridgend County Borough
19-183	KWS Zyatt	June 2019	8	Nottinghamshire
19-191	KWS Zyatt	June 2019	8	Norfolk
19-193	KWS Zyatt	June 2019	8	Herefordshire
19-196	KWS Zyatt	June 2019	8	Oxfordshire
19-198	KWS Zyatt	June 2019	8	Gloucestershire
19-219	KWS Zyatt	June 2019	8	Wiltshire
19-227	KWS Zyatt	July 2019	8	East Lothian
19-018	Leeds	April 2019	6	Lincolnshire
19-039	Leeds	April 2019	6	Stirling
19-171	Leeds	June 2019	6	Bridgend County Borough
19-212	Leeds	June 2019	6	Edinburgh
19-008	LG Graduate	March 2019	6	Cambridgeshire
19-055	LG Graduate	May 2019	6	Northern Ireland
19-115	LG Graduate	June 2019	6	Lincolnshire
19-155	LG Graduate	June 2019*	6	North Yorkshire
19-164	LG Graduate	June 2019	6	Lincolnshire
19-170	LG Graduate	June 2019	6	Bridgend County Borough
19-200	LG Graduate	June 2019	6	Gloucestershire
19-230	LG Graduate	July 2019	6	East Lothian
19-053	LG Rhythm	May 2019	-	Northern Ireland
19-101	LG Rhythm	June 2019	-	Norfolk
19-131	LG Rhythm	June 2019	-	Lincolnshire
19-194	LG Rhythm	June 2019	-	Oxfordshire
19-238	LG Rhythm	July 2019	-	East Lothian
19-071	LG Skyscraper	May 2019	8	Cambridgeshire
19-133	LG Skyscraper	June 2019	8	Lincolnshire
19-139	LG Skyscraper	June 2019	8	Cambridgeshire
19-223	LG Skyscraper	July 2019	8	East Lothian
19-023	LG Spotlight	April 2019	8	Cambridgeshire
19-029	LG Spotlight	April 2019	8	Lincolnshire
19-040	LG Spotlight	April 2019	8	Lincolnshire
19-072	LG Spotlight	May 2019	8	Cambridgeshire
19-129	LG Spotlight	June 2019	8	Lincolnshire
19-157	LG Spotlight	June 2019*	8	North Yorkshire
19-199	LG Spotlight	June 2019	8	Gloucestershire
19-226	LG Spotlight	July 2019	8	East Lothian
19-051	Malunas	May 2019	-	Cambridgeshire
19-195	Mulika	June 2019	7	Devon
19-169	Olympus	June 2019		Lincolnshire
19-009	Reflection	March 2019*	-	Unknown
19-012	Reflection	March 2019	-	Essex

Isolate			RL Rating	
Number	Host Variety	Date Sampled	2019/20	Location
19-013	Reflection	March 2019	-	Lincolnshire
19-047	Reflection	May 2019	-	Cambridgeshire
19-048	Reflection	May 2019	-	Cambridgeshire
19-049	Reflection	May 2019	-	Cambridgeshire
19-069	Reflection	May 2019	-	Shropshire
19-080	Reflection	May 2019	-	Warwickshire
19-178	Reflection	June 2019	-	Bridgend County Borough
19-091	Relay	May 2019	-	Essex
19-188	Relay	June 2019	-	Cambridgeshire
19-204	Relay	June 2019	-	Lincolnshire
19-122	Revelation	June 2019	9	Lincolnshire
19-144	Revelation	June 2019*	9	North Yorkshire
19-109	RGT Blossom	June 2019	-	Herefordshire
19-120	RGT Blossom	June 2019	-	Lincolnshire
19-231	RGT Blossom	July 2019	-	East Lothian
19-022	RGT Gravity	April 2019	8	Cambridgeshire
19-064	RGT Gravity	May 2019	8	Lincolnshire
19-077	RGT Gravity	May 2019	8	Cambridgeshire
19-083	RGT Gravity	May 2019	8	Warwickshire
19-118	RGT Gravity	June 2019	8	Lincolnshire
19-154	RGT Gravity	June 2019*	8	North Yorkshire
19-197	RGT Gravity	June 2019	8	Oxfordshire
19-229	RGT Gravity	July 2019	8	East Lothian
19-124	RGT Illustrious	June 2019	9	Lincolnshire
19-078	RGT Lantern	May 2019	7	Cambridgeshire
19-142	RGT Lantern	June 2019*	7	North Yorkshire
19-224	RGT Lantern	July 2019	7	East Lothian
19-134	RGT Lantern	June 2019	7	Lincolnshire
19-126	RGT Saki	June 2019	-	Lincolnshire
19-054	RGT Wasabi	May 2019	-	Northern Ireland
19-070	RGT Wasabi	May 2019	-	Cambridgeshire
19-097	RGT Wasabi	June 2019	-	Norfolk
19-112	RGT Wasabi	June 2019	-	Lincolnshire
19-137	RGT Wasabi	June 2019	-	Norfolk
19-156	RGT Wasabi	June 2019*	-	North Yorkshire
19-090	Robigus	May 2019	-	Essex
19-179	Robigus	June 2019	-	Bridgend County Borough
19-209	Robigus	June 2019	-	Lincolnshire
19-210	Robigus	June 2019	-	Edinburgh
19-138	RW41648	June 2019	-	Norfolk
19-015	Shabras	March 2019	7	Lincolnshire
19-021	Shabras	April 2019	7	Lincolnshire

lsolate Number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-037	Shabras	April 2019	7	Northumberland
19-038	Shabras	April 2019	7	Bedfordshire
19-082	Shabras	May 2019	7	Warwickshire
19-149	Shabras	June 2019*	7	North Yorkshire
19-228	Shabras	July 2019	7	East Lothian
19-060	Skyfall	May 2019	5	Wiltshire
19-076	Skyfall	May 2019	5	Cambridgeshire
19-104	Skyfall	May 2019	5	Herefordshire
19-159	Skyfall	June 2019	5	Hampshire
19-202	Skyfall	June 2019	5	Gloucestershire
19-218	Skyfall	June 2019	5	Wiltshire
19-089	Solstice	May 2019	-	Essex
19-180	Solstice	June 2019	-	Bridgend County Borough
19-208	Solstice	June 2019	-	Lincolnshire
19-088	Spyder	May 2019	-	Essex
19-207	Spyder	June 2019	-	Lincolnshire
19-045	Stigg	May 2019*	-	Hampshire
19-187	Stigg	June 2019	-	Cambridgeshire
19-216	Stigg	June 2019	-	Cambridgeshire
19-056	SY Insitor	May 2019	-	Northern Ireland
19-125	SY Insitor	June 2019	-	Lincolnshire
19-152	SY Insitor	June 2019*	-	North Yorkshire
19-163	SY118301	June 2019	-	Cheshire
19-025	Unknown	April 2019*	-	Unknown
19-087	Victo	May 2019	-	Essex
19-203	Victo	June 2019	-	Lincolnshire
19-141	Viscount	June 2019*	7	North Yorkshire
19-172	Viscount	June 2019	7	Bridgend County Borough
19-214	Viscount	June 2019	7	Edinburgh
19-237	Viscount	July 2019	7	East Lothian
19-052	Zulu	May 2019	5	Northern Ireland
19-151	Zulu	June 2019*	5	North Yorkshire
19-176	Zulu	June 2019	5	Bridgend County Borough
19-201	Zulu	June 2019	5	Gloucestershire
19-221	Zulu	July 2019	5	East Lothian
19-161	Zulu	June 2019	5	Gloucestershire

2019 Wheat Brown Rust Isolate Register

Isolate Number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-015	Bennington	June 2019	7	Cambridgeshire
19-004	Breeding Line	May 2019	-	Oxfordshire
19-026	Cordiale	June 2019	-	Bridgend County Borough
19-009	Crusoe	June 2019	3	Cambridgeshire
19-027	Crusoe	June 2019	3	Bridgend County Borough
19-030	Crusoe	June 2019	3	Lincolnshire
19-034	Crusoe	June 2019	3	Lincolnshire
19-013	Elicit	June 2019	7	Cambridgeshire
19-043	Elicit	July 2019	7	Norfolk
19-002	Elicit	April 2019	7	Surrey
19-033	Graham	June 2019	6	Lincolnshire
19-035	Graham	June 2019	6	Lincolnshire
19-029	Kranich	June 2019	-	Bridgend County Borough
19-050	KWS Barrel	July 2019	5	Cambridgeshire
19-014	KWS Basset	June 2019	8	Cambridgeshire
19-010	KWS Extase	June 2019	7	Cambridgeshire
19-045	KWS Extase	July 2019	7	Norfolk
19-003	KWS Firefly	May 2019	8	Cambridgeshire
19-007	KWS Firefly	June 2019	8	Cambridgeshire
19-012	KWS Firefly	June 2019	8	Cambridgeshire
19-054	KWS Firefly	July 2019	8	Hampshire
19-006	KWS Firefly	June 2019	8	Kent
19-052	KWS Firefly	July 2019	8	Kent
19-032	KWS Firefly	June 2019	8	Lincolnshire
19-037	KWS Firefly	June 2019	8	Lincolnshire
19-025	KWS Firefly	June 2019	8	Norfolk
19-044	KWS Firefly	July 2019	8	Norfolk
19-005	KWS Firefly	May 2019	8	Suffolk
19-018	KWS Kerrin	June 2019	7	Cambridgeshire
19-055	KWS Kinetic	July 2019	6	Hampshire
19-011	KWS Lili	June 2019	4	Cambridgeshire
19-023	KWS Montana	June 2019	-	Cambridgeshire
19-021	KWS Parkin	June 2019	5	Cambridgeshire
19-042	KWS Parkin	July 2019	5	Norfolk
19-049	KWS Santiago	July 2019	-	Cambridgeshire
19-001	KWS Siskin	March 2019	5	Cambridgeshire
19-028	KWS Siskin	June 2019	5	Bridgend County Borough
19-031	KWS Siskin	June 2019	5	Lincolnshire
19-016	LG Motown	June 2019	7	Cambridgeshire
19-024	LG Skyscraper	June 2019	5	Lincolnshire

Isolate Number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-017	Revelation	June 2019	8	Cambridgeshire
19-036	Revelation	June 2019	8	Lincolnshire
19-039	Revelation	July 2019	8	Suffolk
19-053	RGT Blossom	July 2019	-	Kent
19-041	RGT Blossom	July 2019	-	Norfolk
19-047	RGT Gravity	July 2019	-	Cambridgeshire
19-051	RGT Illustrious	July 2019	6	Cambridgeshire
19-020	RGT Lantern	June 2019	7	Cambridgeshire
19-008	Skyfall	June 2019	8	Cambridgeshire
19-048	Skyfall	July 2019	8	Cambridgeshire
19-038	Skyfall	June 2019	8	Lincolnshire
19-040	Skyfall	July 2019	8	Suffolk
19-019	SY Insitor	June 2019	-	Cambridgeshire
19-046	SY Insitor	July 2019	_	Norfolk
19-022	Theodore	June 2019	7	Cambridgeshire

2019 Wheat Powdery Mildew Isolate Register

Isolate Number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-004	Claire	June 2019	-	Edinburgh
19-001	DSV316126	June 2019	-	Hampshire
19-005	Istabraq	June 2019	-	Edinburgh
19-002	Leeds	June 2019	3	Moray
19-003	Leeds	June 2019	3	Edinburgh
19-006	Leeds	July 2019	3	Angus

lsolate number	Host Variety	Date Sampled	RL Rating 2019/20	Location
19-005	AC11/325/32	May 2019	-	County Antrim
19-004	Electrum	May 2019	6	County Antrim
19-003	KWS Creswell	May 2019	4	County Antrim
19-001	KWS Orwell	May 2019	3	County Antrim
19-002	Surge	May 2019	6	County Antrim

2019 Barley Powdery Mildew Isolate Register

7. References

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