

Supplementary material

Table S1. List of locations tested in Europe from 2001 to 2013. Site numbers refer to the location code used during the analysis.

Site number	Sites	Country	Site number	Sites	Country
1	Aberystwyth	UK (Wales)	18	Malchow	Germany
2	Les Alleuds	France	19	Merelbeke	Belgium
3	Hof Steimke Asendorf	Germany	20	Montours	France
4	Aston le Walls	UK	21	Neuhof	Germany
5	Boelshoj	Denmark	22	Nort s. E.	France
6	Bornhof	Germany	23	Orchies	France
7	Druelle	France	24	Ottersum	Netherlands
8	Flaujaques	France	25	Perugia	Italy
9	Gumpenstein	Austria	26	Pulling	Germany
10	Hladke Zivotice	Czechia	27	Radzików	Poland
11	Hohenheim	Germany	28	Zurich (Reckenholz)	Switzerland
12	Jevicko	Czechia	29	Rennes	France
13	Lelystad Barenbrug	Netherlands	30	Rilland/Swifterband	Netherlands
14	Lelystad Cebeco	Netherlands	31	Les Rosiers	France
15	Lodi	Italy	32	Roznov Zubri	Czechia
16	Loughgall	UK (Northern Ireland)	33	Spitalhof	Germany
17	Gross Luesewitz	Germany	34	Steinach	Germany

Table S2. The adopted scoring scale reported by Schubiger et al. [4]. The rating values represent a relative estimate of the leaf area affected by rust.

SCORE	PHENOTYPE
1	no rust
2	trace of rust
3	5 % of the foliage covered with rust
4	10% of the foliage covered with rust

5	25 % of the foliage covered with rust; predominantly leaves with scattered pustules
6	40 % of the foliage covered with rust; leaves spotted with many pustules
7	60 % of the foliage covered with rust; leaves densely covered with areas of rust and few necroses
8	75 % of the foliage covered with rust; leaves densely covered with rust and many necrotic leaves
9	more than 75 % of the foliage covered with rust; predominantly leaves with necrosis

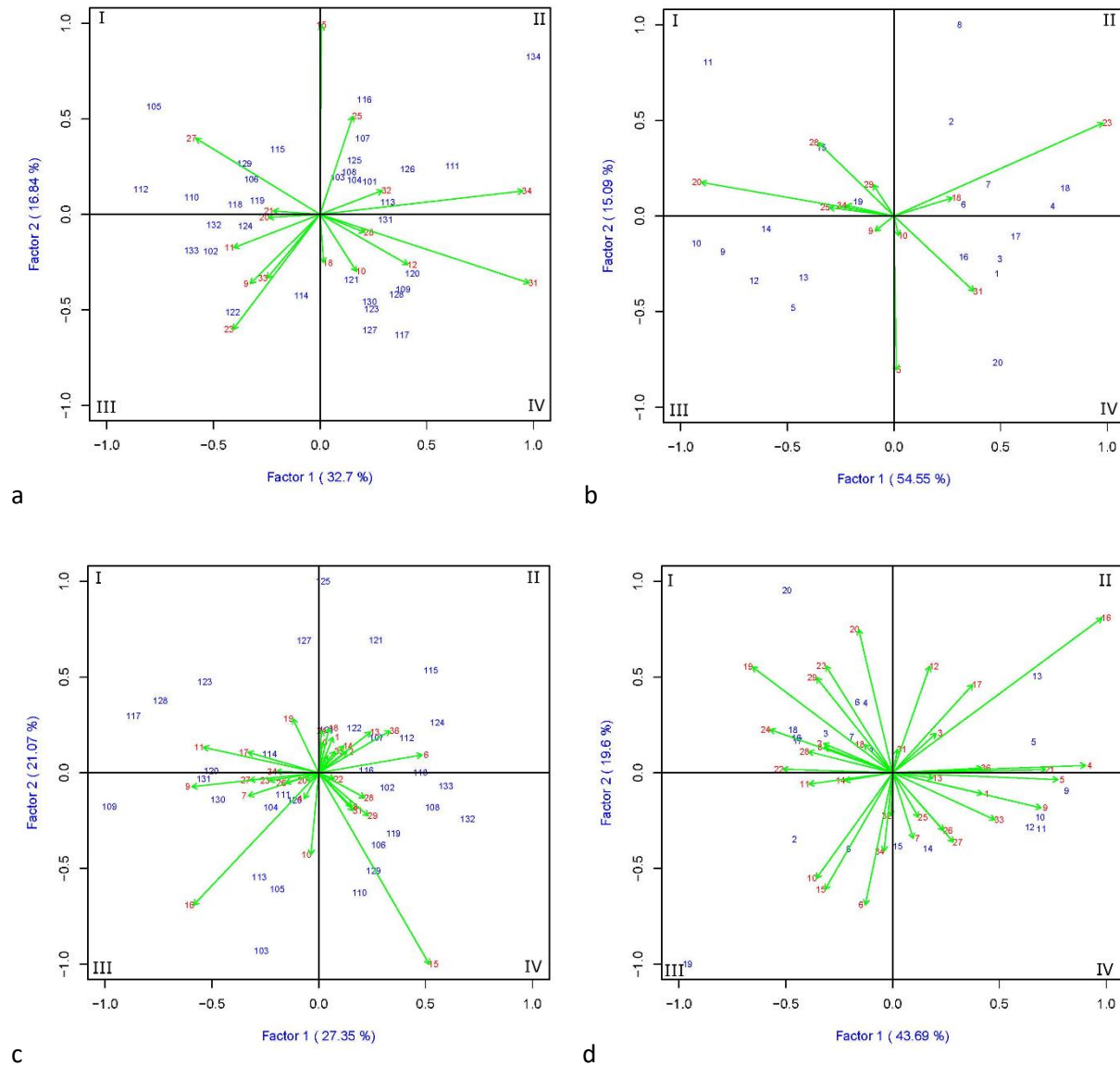


Figure S1. AMMI 2 biplot for PGR in a) LP and b) in LM and for PCO c) LP and d) LM. Green arrows refer to environmental vectors, the red numbers represent the locations and the blue numbers represent the varieties. The arrows' length indicates variability in the variation response for that particular environment: the longer the arrow, the higher is the response variability. Only the endpoints of the genotype vectors are represented in the plots. The angle between their vectors assesses the interaction between varieties and environments. Acute angles indicate positive interaction; obtuse angle indicates a negative correlation, and right angle represents no interaction.

Table S3. Summary of perennial ryegrass varieties information. Mean of the rust resistance scores across all tested environments; coefficient of variation % (CVar); slope of regression (b_i), deviation from regression (S^2_{di}) of the perennial ryegrass varieties

VARIETIES			PCO-LP					PGR-LP				
Name	Code	Ploidy	Mean	CVar	b_i	S^2_{di}	ASV	Mean	CVar	b_i	S^2_{di}	ASV
Aberdart	101	2x	5.6	27.45	1.22	-0.07	0,25	6.6	14.79	1.04	-0.11	0,53
Arabella	102	2x	5.7	22.24	1.02	-0.17	0,56	5.5	18.04	1.04	-0.09	1,07
Aristo	103	2x	5.1	32.88	1.21	0.44	1,32	6.4	13.28	0.96	-0.25	0,28
Aubisque	104	4x	6.5	17.83	0.89	-0.11	0,45	7.2	10.50	0.85	-0.27	0,38
Aurora	105	2x	3.1	43.47	0.75	0.72	0,87	4.3	34.24	1.31	0.70	1,61
Barnhem	106	2x	6.1	21.78	1.03	-0.01	0,69	5.8	16.44	1.01	-0.12	0,68
Bocage	107	4x	7.1	14.20	0.78	-0.17	0,52	7.4	11.15	0.92	-0.23	0,60
Carrera	108	2x	6.8	20.00	1.06	-0.02	0,94	7.0	10.73	0.78	-0.20	0,37
Condesa	109	4x	4.4	35.23	1.10	0.47	1,69	6.6	18.48	1.36	-0.10	0,95
Corbet	110	2x	5.8	24.72	1.12	0.04	0,88	5.2	19.33	0.95	0.08	1,24
Elgon	111	4x	6.1	24.19	1.18	-0.05	0,34	7.1	11.92	0.81	-0.06	1,29
Fennema	112	2x	5.8	22.62	1.01	-0.03	0,75	5.3	22.21	1.18	0.15	1,68
Foxtrot	113	2x	5.2	28.80	1.18	-0.04	0,85	6.4	16.55	1.18	-0.16	0,67
Gladio	114	2x	5.3	26.90	1.17	-0.20	0,42	6.2	16.85	1.15	-0.14	0,49
Guru	115	2x	5.4	30.06	1.04	0.83	1,09	6.0	15.04	0.85	0.00	0,56
Gwendal	116	4x	7.2	16.78	0.91	-0.02	0,36	7.6	10.06	0.79	-0.18	0,77
Helmer	117	4x	4.9	28.70	0.98	0.35	1,54	6.8	14.71	1.01	0.00	0,99
Heraut	118	2x	6.3	20.35	0.99	-0.06	0,82	5.6	17.66	1.06	-0.10	0,83
Kells	119	2x	6.1	22.27	1.08	-0.06	0,73	5.7	16.69	1.05	-0.20	0,59
Kentaur	120	4x	5.8	22.48	1.02	-0.09	0,86	7.1	12.27	0.95	-0.19	0,92
Lacerta	121	4x	6.9	14.31	0.60	0.15	1,02	7.1	11.34	0.84	-0.16	0,43
Lipresso	122	2x	4.7	26.95	0.94	0.04	0,42	5.0	21.68	1.07	0.06	1,01
Litempo	123	4x	5.4	24.40	1.00	0.04	1,11	6.7	15.01	1.13	-0.18	0,70
Option	124	2x	6.4	19.07	0.93	-0.02	1,02	6.0	15.72	1.01	-0.11	0,75
Orval	125	2x	6.4	25.64	1.10	0.72	1,28	7.0	12.10	0.85	-0.09	0,45
Pastoral	126	4x	6.8	17.00	0.92	-0.16	0,26	7.5	12.35	1.02	-0.18	0,89
Roy	127	4x	6.0	22.20	0.97	0.12	0,90	7.2	12.29	0.91	-0.11	0,79
Sirocco	128	4x	5.0	27.25	0.95	0.27	1,37	6.5	17.51	1.28	-0.16	0,87
Sponsor	129	2x	5.8	23.07	1.04	-0.08	0,80	5.7	13.58	0.80	-0.16	0,80
Terry	130	4x	5.6	21.96	0.97	-0.10	0,82	7.1	13.14	1.02	-0.18	0,64
Tivoli	131	4x	5.2	25.52	1.01	0.04	0,92	7.1	12.17	0.98	-0.24	0,63
Vincent	132	2x	6.5	19.52	0.94	0.06	1,24	5.7	14.59	0.83	-0.10	1,05
Weigra	133	2x	5.8	21.09	0.89	0.05	1,03	5.6	18.88	1.14	-0.08	1,24

Maja	134	4x	-	-	-	-	7.4	16.27	0.88	0.66	2,22
AVERAGE			5.8				6.4				

Table S4. Summary of Italian and hybrid ryegrass varieties information. Mean of the rust resistance scores across all tested environments; coefficient of variation % (CVar); slope of regression (b_i), deviation from regression (S^2_{di}) of Italian and boucheanum (Lb) varieties.

VARIETIES			PCO-LM					PGR-LM				
Name	code	Ploidy	Mean	CVar	b_i	S^2_{di}	ASV	Mean	CVar	b_i	S^2_{di}	ASV
Aberexcel (Lb)	1	4x	6.8	13.92	0.83	-	0.73	7.2	18.13	0.81	0.33	2,03
Barprisma	2	2x	6.6	16.94	1.00	-	1.50	6.8	18.35	0.81	0.14	1,26
Bolero	3	4x	7.0	11.94	0.80	-	0.97	7.7	13.06	0.67	-	2,08
Caballo	4	4x	7.2	12.66	0.82	-	1.13	7.9	10.29	0.48	0.04	3,08
Danergo	5	4x	5.0	28.62	1.33	0.03	2.61	7.3	26.59	1.36	0.06	2,04
Domino	6	4x	7.3	11.53	0.77	-	0.82	7.8	13.14	0.71	-	1,37
Ellire	7	4x	6.5	16.79	0.98	-	0.52	7.4	15.18	0.73	0.10	1,83
Fastyl	8	2x	6.4	17.76	1.04	-	1.35	6.9	16.98	0.65	0.42	1,74
Gordo	9	2x	3.9	40.15	1.39	0.25	3.10	6.2	34.96	1.54	0.12	3,31
Gumpens. (Lb)	10	2x	3.8	38.24	1.32	0.06	2.06	6.3	37.54	1.66	0.20	3,82
Lema	11	2x	3.9	34.44	1.21	0.11	2.18	6.0	38.02	1.48	0.89	3,73
Ligrande	12	2x	4.2	34.31	1.36	-	2.22	6.1	33.65	1.43	0.23	2,73
Lolita	13	4x	4.8	29.11	1.20	0.21	2.19	7.2	26.56	1.35	-	1,80
Meryl	14	2x	5.5	21.84	1.13	-	0.78	6.5	30.72	1.40	0.15	2,51
Pirol (Lb)	15	2x	5.7	22.73	1.26	-	0.66	6.3	28.93	1.28	0.07	1,48
Tarandus	16	4x	7.3	11.27	0.74	-	1.38	7.5	17.30	0.87	0.08	1,38
Tonyl	17	4x	7.0	13.72	0.87	-	1.37	7.7	13.94	0.68	0.10	2,37
Zorro	18	4x	7.2	12.79	0.82	-	1.34	7.9	9.71	0.44	0.04	3,34
Crema	19	2x	5.1	24.26	0.66	0.82	3.31	5.2	31.58	0.90	1.12	0,74
Gosia (Lb)	20	4x	7.2	12.63	0.47	0.29	2.20	7.0	19.85	0.76	0.77	2,21
AVERAGE			5.9					6.9				

Table S5. Summary of the phenotypic variation per location across years. Average of disease score (Average), standard deviation (Sd), min and max, and coefficient of variation (CVar) of each location per each of the tested years compared to the Brier score (BR) and standard deviation (Sd).

Location	Year	Min	Max	PCO-LP			BR (Sd)
				Average	Sd	CVar	
3	2001	3	8	6,42	1,03	0,16	0,48 (0.002)
3	2004	2	9	6,90	1,22	0,18	0,48 (0.002)
3	2007	3	8	5,29	1,25	0,24	0,48 (0.002)
3	2010	3	8	5,29	1,34	0,25	0,48 (0.002)
3	2013	2	8	5,50	1,35	0,25	0,48 (0.002)
4	2004	3	8	6,12	1,02	0,17	0,30 (0.005)
4	2010	5	9	6,96	0,78	0,11	0,30 (0.005)
4	2013	5	9	7,15	0,68	0,10	0,30 (0.005)
6	2001	1	8	5,33	1,81	0,34	0,47 (0.004)
6	2004	2	8	5,58	1,70	0,30	0,47 (0.004)
6	2007	3	9	6,46	1,53	0,24	0,47 (0.004)
6	2010	1	8	3,77	2,00	0,53	0,47 (0.004)
6	2013	1	8	3,46	1,55	0,45	0,47 (0.004)
7	2007	4	9	7,10	0,77	0,11	0,42 (0.004)
7	2010	4	9	6,32	1,02	0,16	0,42 (0.004)
7	2013	4	9	6,88	0,97	0,14	0,42 (0.004)
13	2001	2	8	5,92	1,52	0,26	0,45 (0.003)
13	2004	4	8	6,52	0,90	0,14	0,45 (0.003)
13	2010	3	8	5,01	1,26	0,25	0,45 (0.003)
13	2013	1	8	5,35	1,65	0,31	0,45 (0.003)
14	2001	1	8	5,78	1,63	0,28	0,45 (0.007)
14	2004	3	8	6,48	1,00	0,15	0,45 (0.007)
14	2007	2	9	6,24	1,27	0,20	0,45 (0.007)
15	2004	1	9	5,30	2,70	0,51	0,45 (0.092)
15	2007	1	9	7,79	2,25	0,29	0,45 (0.092)
15	2010	2	9	6,98	1,82	0,26	0,45 (0.092)
17	2001	1	7	4,09	1,23	0,30	0,43 (0.004)
17	2004	1	7	2,92	1,02	0,35	0,43 (0.004)
17	2007	1	5	2,78	0,99	0,36	0,43 (0.004)
18	2001	2	9	6,24	1,57	0,25	0,47 (0.001)
18	2004	3	8	6,42	1,20	0,19	0,47 (0.001)
18	2007	2	9	6,53	1,34	0,21	0,47 (0.001)
18	2010	3	9	6,66	1,34	0,20	0,47 (0.001)
18	2013	3	9	5,71	1,63	0,28	0,47 (0.001)

19	2001	1	8	4,26	1,66	0,39	0,46 (0.002)
19	2004	1	9	6,23	1,68	0,27	0,46 (0.002)
19	2007	1	9	4,99	1,74	0,35	0,46 (0.002)
19	2010	1	9	5,43	1,53	0,28	0,46 (0.002)
19	2013	2	8	5,51	1,34	0,24	0,46 (0.002)
20	2001	1	9	5,57	1,59	0,29	0,47 (0.004)
20	2004	2	9	5,82	1,50	0,26	0,47 (0.004)
20	2007	1	8	5,50	1,77	0,32	0,47 (0.004)
20	2010	3	9	6,52	1,12	0,17	0,47 (0.004)
20	2013	2	9	5,85	1,59	0,27	0,47 (0.004)
23	2001	1	8	4,76	1,59	0,33	0,44 (0.003)
23	2004	4	8	5,31	0,92	0,17	0,44 (0.003)
23	2007	5	9	6,88	0,91	0,13	0,44 (0.003)
24	2001	1	9	6,86	1,64	0,24	0,46 (0.003)
24	2004	1	9	5,23	1,64	0,31	0,46 (0.003)
24	2007	2	8	6,31	1,46	0,23	0,46 (0.003)
24	2010	2	9	7,52	1,60	0,21	0,46 (0.003)
24	2013	2	8	4,57	1,22	0,27	0,46 (0.003)
26	2001	1	9	8,11	1,35	0,17	0,44 (0.011)
26	2007	4	8	7,27	0,87	0,12	0,44 (0.011)
26	2010	4	9	7,96	1,08	0,14	0,44 (0.011)
26	2013	4	8	6,30	0,93	0,15	0,44 (0.011)
28	2001	1	9	6,14	1,88	0,31	0,46 (0.002)
28	2004	3	9	7,75	1,28	0,17	0,46 (0.002)
28	2007	1	9	6,48	1,65	0,25	0,46 (0.002)
28	2010	1	9	7,02	1,79	0,25	0,46 (0.002)
28	2013	1	9	6,06	1,65	0,27	0,46 (0.002)
34	2001	2	9	4,93	1,43	0,29	0,48 (0.005)
34	2004	3	9	7,02	1,18	0,17	0,48 (0.005)
34	2007	2	9	6,21	1,61	0,26	0,48 (0.005)
34	2013	4	8	5,93	0,92	0,16	0,48 (0.005)

PCO_LM

Locatio n	Year	Min	Max	Average	Sd	CVar	BR (Sd)
3	2004	2	9	7,658	1,381	0,180	0,45 (0.005)
3	2007	2	8	5,588	1,940	0,347	0,45 (0.005)
3	2010	3	9	6,713	1,460	0,217	0,45 (0.005)
3	2013	4	9	6,900	1,374	0,199	0,45 (0.005)
4	2004	3	9	6,395	1,479	0,231	0,42 (0.013)

4	2010	5	9	7,675	1,028	0,134	0,42 (0.013)
4	2013	5	9	7,413	0,977	0,132	0,42 (0.013)
6	2001	2	8	6,486	1,547	0,239	0,47 (0.004)
6	2004	1	8	5,461	1,822	0,334	0,47 (0.004)
6	2007	3	9	6,863	1,613	0,235	0,47 (0.004)
6	2010	2	9	7,613	1,673	0,220	0,47 (0.004)
6	2013	1	8	5,838	1,912	0,328	0,47 (0.004)
7	2001	4	7	6,194	1,002	0,162	0,45 (0.007)
7	2007	3	8	6,213	1,177	0,189	0,45 (0.007)
7	2010	3	7	4,663	1,201	0,258	0,45 (0.007)
7	2013	3	8	5,575	1,385	0,248	0,45 (0.007)
9	2004	5	8	6,697	0,938	0,140	0,44 (0.006)
9	2007	4	9	7,725	1,031	0,133	0,44 (0.006)
9	2010	7	9	7,863	0,791	0,101	0,44 (0.006)
11	2001	3	9	6,819	2,078	0,305	0,43 (0.01)
11	2004	1	9	5,276	2,359	0,447	0,43 (0.01)
11	2007	3	7	5,363	1,334	0,249	0,43 (0.01)
13	2001	2	8	6,167	2,042	0,331	0,45 (0.01)
13	2004	4	9	7,487	1,291	0,172	0,45 (0.01)
13	2010	4	9	7,638	1,486	0,195	0,45 (0.01)
13	2013	4	9	6,650	1,148	0,173	0,45 (0.01)
15	2001	3	8	5,750	1,480	0,257	0,47 (0.005)
15	2004	1	9	5,737	2,211	0,385	0,47 (0.005)
15	2007	1	9	5,225	2,658	0,509	0,47 (0.005)
15	2010	1	8	4,688	1,718	0,367	0,47 (0.005)
17	2001	4	9	6,292	1,131	0,180	0,45 (0.009)
17	2004	1	7	3,974	1,505	0,379	0,45 (0.009)
17	2007	1	7	3,363	1,686	0,501	0,45 (0.009)
18	2001	4	9	7,306	1,460	0,200	0,44 (0.011)
18	2004	3	9	6,605	1,617	0,245	0,44 (0.011)
18	2007	2	9	5,900	1,978	0,335	0,44 (0.011)
19	2001	1	8	5,347	2,150	0,402	0,46 (0.002)
19	2004	1	8	5,724	1,964	0,343	0,46 (0.002)
19	2007	1	9	4,575	2,704	0,591	0,46 (0.002)
19	2010	1	9	5,913	2,486	0,421	0,46 (0.002)
19	2013	3	9	5,950	1,525	0,256	0,46 (0.002)
20	2001	2	9	5,875	1,846	0,314	0,47 (0.004)
20	2004	1	7	3,684	2,041	0,554	0,47 (0.004)
20	2007	2	9	6,400	2,259	0,353	0,47 (0.004)
20	2010	3	9	6,750	1,978	0,293	0,47 (0.004)

20	2013	2	9	5,738	1,734	0,302	0,47 (0.004)
23	2001	2	8	5,278	1,713	0,325	0,47 (0.009)
23	2004	1	8	4,461	2,375	0,532	0,47 (0.009)
23	2007	2	8	4,750	1,818	0,383	0,47 (0.009)
25	2001	3	9	5,625	1,505	0,268	0,46 (0.004)
25	2004	1	7	4,763	1,743	0,366	0,46 (0.004)
25	2007	4	8	6,075	0,965	0,159	0,46 (0.004)
25	2010	3	10	6,763	1,193	0,176	0,46 (0.004)
25	2013	4	9	6,700	1,216	0,181	0,46 (0.004)
26	2001	3	9	7,153	1,469	0,205	0,42 (0.006)
26	2007	6	9	7,500	0,871	0,116	0,42 (0.006)
26	2010	4	9	7,775	1,283	0,165	0,42 (0.006)
26	2013	4	8	5,950	1,211	0,203	0,42 (0.006)
27	2004	3	7	5,092	1,416	0,278	0,43 (0.006)
27	2007	3	8	5,950	1,349	0,227	0,43 (0.006)
27	2010	4	8	6,013	0,934	0,155	0,43 (0.006)
27	2013	3	7	5,550	1,030	0,186	0,43 (0.006)
28	2001	1	9	5,194	2,281	0,439	0,46 (0.002)
28	2004	1	9	6,224	1,887	0,303	0,46 (0.002)
28	2007	3	9	7	1,669	0,238	0,46 (0.002)
28	2010	3	9	7,575	1,629	0,215	0,46 (0.002)
28	2013	1	7	4,125	1,945	0,471	0,46 (0.002)
31	2004	3	8	5,434	1,247	0,230	0,48 (0.005)
31	2007	2	8	5,263	1,597	0,303	0,48 (0.005)
31	2010	3	9	6,513	1,509	0,232	0,48 (0.005)
31	2013	1	9	5,925	2,305	0,389	0,48 (0.005)

PGR-LP							
Location	Year	Min	Max	Average	Sd	CVar	BR (Sd)
10	2001	2	8	6,485	1,475	0,227	0,44 (0.004)
10	2004	1	8	5,326	1,220	0,229	0,44 (0.004)
10	2007	3	8	5,529	1,108	0,200	0,44 (0.004)
10	2013	3	7	4,353	1,072	0,246	0,44 (0.004)
15	2001	2	8	5,705	1,445	0,253	0,46 (0.003)
15	2004	1	9	6,500	1,967	0,303	0,46 (0.003)
15	2007	3	9	7,449	1,429	0,192	0,46 (0.003)
18	2001	2	9	7,212	1,508	0,209	0,44 (0.008)
18	2004	6	9	7,462	0,659	0,088	0,44 (0.008)
18	2007	4	9	6,941	1,052	0,152	0,44 (0.008)

18	2013	2	9	7,346	1,335	0,182	0,44 (0.008)
20	2001	5	9	7,386	1,282	0,174	0,47 (0.001)
20	2004	4	9	7,614	1,276	0,168	0,47 (0.001)
20	2007	5	9	7,956	1,010	0,127	0,47 (0.001)
20	2010	3	8	6,426	1,165	0,181	0,47 (0.001)
20	2013	4	9	6,647	1,244	0,187	0,47 (0.001)
25	2001	2	9	4,833	1,494	0,309	0,43 (0.003)
25	2004	2	7	5,182	1,104	0,213	0,43 (0.003)
25	2007	5	9	7,221	0,971	0,135	0,43 (0.003)
27	2004	1	8	4,621	1,269	0,275	0,45 (0.014)
27	2007	3	8	5,581	1,086	0,195	0,45 (0.014)
27	2013	3	7	5,721	1,031	0,180	0,45 (0.014)
28	2004	2	9	6,485	1,784	0,275	0,45 (0.009)
28	2007	4	9	7,676	1,135	0,148	0,45 (0.009)
28	2010	5	7	6,654	0,703	0,106	0,45 (0.009)
32	2004	5	9	7,038	0,936	0,133	0,44 (0.002)
32	2007	4	9	7,346	1,330	0,181	0,44 (0.002)
32	2010	4	9	7,787	1,319	0,169	0,44 (0.002)
32	2013	2	8	5,772	1,743	0,302	0,44 (0.002)

PGR-LM

Locatio n	Year	Min	Max	Average	Sd	CVar	BR (Sd)
10	2004	3	8	5,487	1,260	0,230	0.42 (0.006)
10	2007	5	8	6,275	0,693	0,110	0.42 (0.006)
10	2013	3	8	5,713	1,486	0,260	0.42 (0.006)

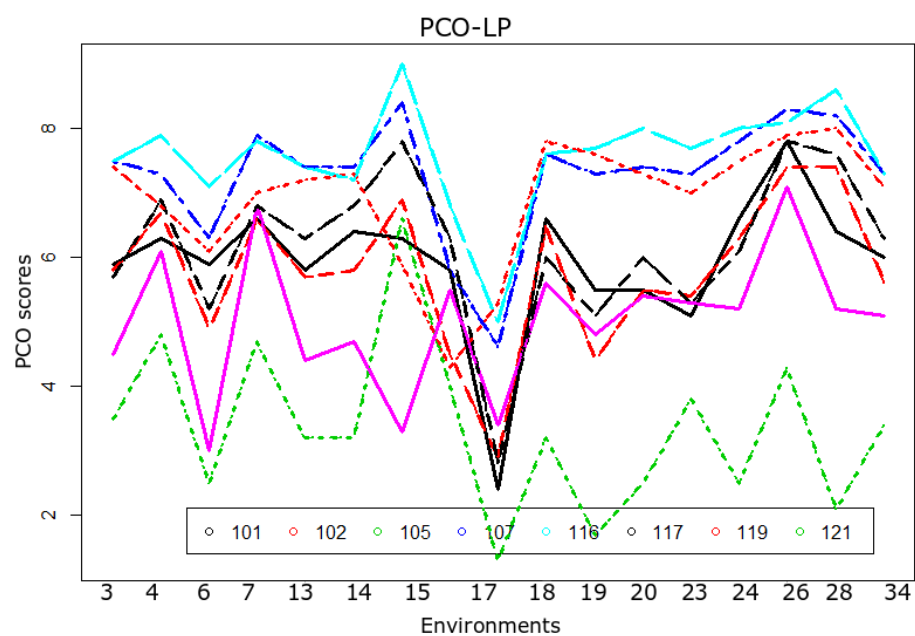


Figure S2. Response variability across environments. Scoring levels (y-axis) of eight perennial ryegrass varieties to crown rust in different environments (x-axis). Colors of the lines refer to the varieties.