The EUCARPIA multisite rust evaluation – results 2001

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Abstract

Upon an initiative taken at the 2000 EUCARPIA Fodder Crops Meeting on the Azores, a multisite row trial was established in 2001 with the aim to evaluate spatial and temporal variation of susceptibility to rust (*Puccinia spp.*) of a set of ryegrass cultivars. 18 cultivars of *Lolium multiflorum* and 33 cultivars of *Lolium perenne*, having different levels of rust susceptibility and originating from a wide range of breeding programmes, were sown at 30 sites across Europe in spring of 2001.

Puccinia coronata was recorded most frequently in both species: at 23 sites for *L. multiflorum* and at 19 sites for *L. perenne*. In *L. multiflorum*, no other rust species appeared to be of importance. In contrast, significant differences for susceptibility to *Puccinia graminis* were found at 13 sites for *L. perenne.*

A small but significant cultivar × site interaction was observed for both *Lolium* species and, in the case of *L. perenne*, for both *P. coronata* and *P. graminis*. The interaction was more prominent for *L. perenne* than for *L. multiflorum.* Multivariate statistics identified sites with particularly deviating rankings and partly allowed to meaningfully group the sites on the basis of the pattern of cultivar response. However, the most striking result of this first trial year was the overall consistent ranking of the cultivars across the different sites.

Introduction

Rust caused by *Puccinia spp.* is considered the most important leaf disease in forage ryegrasses (*Lolium spp.*) in Europe. Consequently, rust resistance is a major target of selection in many breeding programmes. Although inoculation techniques are available to screen for resistance under greenhouse conditions, most breeders prefer to select the healthiest plants in their nurseries, relying on natural infection (Reheul *et al.* 2000). Therefore, they are concerned about the stability of the resistance obtained in this way, both in space and in time. The local occurrence of different rust species, or of races within species, as well as differences in climatic conditions, may affect the performance of cultivars. Moreover, extensive cultivation of a cultivar in a particular region may favour natural selection within the rust fungi, eventually leading to cultivar-specific races and a “break-down” of resistance.

No systematic information about this type of response of ryegrasses to *Puccinia* rust diseases is available. Participants of the EUCARPIA Fodder Crops Section Meeting held on the Azores in 2000 therefore decided to initiate a multisite evaluation trial to determine spatial and temporal diversity in rust susceptibility of a set of ryegrass cultivars. Here, we report on the first results of this trial which were obtained in 2001.

Materials and Methods

Experimental sites. Potential participants were asked in autumn 2000 if they were willing to plant and assess one or more row trials for at least two planting periods. This inquiry resulted in a total of 30 participating sites well distributed accross the important grass growing regions of Europe (Fig. 1).

Choice of cultivars. Each participant was allowed to nominate 2 cultivars for each trial planted, either *L. multiflorum* or *L. perenne*. Participants were encouraged to nominate both highly resistant and moderately susceptible cultivars. Not all participants used their allowance completely, but some preferred to nominate two *L. perenne* cultivars. Breeders obviously nominated their own cultivars, while officials either renounced of their right or nominated cultivars with expectedly great differences in susceptibility. For some of these latter cultivars, seed was no longer available. The final list of cultivars comprised 15 Italian (*L. multiflorum*), 3 hybrid (*L.* × *boucheanum*) and 33 perennial (*L. perenne*) ryegrasses. The hybrid ryegrasses were described as more similar to Italian ryegrass and were therefore included in the Italian ryegrass trial.

Experimental design. Two separate row trials, one with the Italian and one with the perennial ryegrass cultivars, were established at each site as completely randomized blocks with 4 replications. As a rule, 3 m rows 0.5 m apart were sown in spring of 2001. Each participant received an experimental plan with an individual randomization. The trials were fertilized and cut according to local practice.

Fig. 1. Geographical location of 30 experimental sites where trials were established in 2001.

Rust disease scoring. Disease severity was recorded on a 1 to 9 scale. A detailed description of each score was given to the participants, ranging from 1=no disease to 9=entire foliage completely covered with rust and frequent necrosis. Scores were taken when participants judged differentiation among cultivars to be maximal. For the evaluation of the 2001 results, only scoring dates with an average score of at least 2.0 and a standard deviation of cultivar means of at least 0.6 were included.
Identification of rust species. Participants were asked to indicate the rust species that was most prevalent at each scoring, and if possible to send leaf samples with typical disease symptoms. Rust species was determined on these samples by microscopic inspection of teliospores, if present, or on the basis of the shape and germ pore position of urediospores. In most cases, rust species indicated and determined were the same. However, if indication and determination were equivocal, or if no leaf samples were sent, the scoring was assigned to that rust species for which the ranking of the cultivars represented best the ranking observed on average over all sites.
Statistical analysis. The results were analyzed using SAS software. For principal component analysis, average cultivar scores (x) of each site were standardized by transforming them to $(x-\mu)/\sigma_x$.

Results

Table 1. *Puccinia coronata* disease scores of 18 *Lolium multiflorum* cultivars at 23 sites (means of 1 to 2 scorings per site). Cultivars are ranked according to the mean over sites.

Cultivar (H=hybrid ryegrass, *Lolium* × *boucheanum*)	mean over sites	Aberystwyth	Boelshoj	Bornhof	Druelle	Flaujaques	Gross Luesewitz	Hladke Zivotice	Hohenheim	Lelystad (BAR)	Les Alleuds	Lodi	Loughgall	Malchow	Merelbeke	Montours	Neuhof	Nort s. Erdre	Orchies	Ottersum	Perugia	Pulling	Reckenholz	Steinach
Tarandus	**2.36**	1.5	2.0	2.0	2.8	2.9	2.9	2.8	1.6	2.3	1.3	2.9	3.2	1.3	2.3	2.4	2.3	4.9	2.8	1.3	2.5	2.0	2.0	2.6
Domino	**2.54**	2.0	1.0	2.5	3.0	3.6	2.5	2.8	1.4	2.5	1.7	2.6	3.7	1.8	2.8	2.4	2.0	5.1	2.8	1.5	3.5	1.5	3.0	3.0
Caballo	**2.58**	1.8	1.5	2.8	3.4	3.2	2.5	3.0	1.8	2.0	2.0	2.5	3.6	1.5	2.8	2.4	1.8	5.3	2.8	1.1	3.9	2.5	2.5	3.1
Zorro	**2.59**	1.8	1.0	2.5	2.9	3.4	2.8	3.4	1.8	2.0	2.0	3.1	4.5	2.3	2.8	2.3	2.0	4.3	3.0	1.5	2.5	2.1	2.8	3.1
Tonyl	**2.70**	1.8	1.5	2.8	2.9	3.8	2.8	2.9	1.5	2.3	1.7	3.2	5.7	1.8	3.0	2.3	1.8	4.6	3.3	1.6	3.8	1.9	2.8	2.9
Bolero	**2.75**	1.8	1.8	2.3	3.6	4.0	3.0	3.3	1.6	2.3	1.7	2.9	4.5	1.5	3.0	2.5	2.0	4.6	4.2	1.5	3.4	1.4	3.8	2.9
Aberexcel (H)	**2.80**	1.0	2.5	2.8	3.0	3.4	3.4	2.8	2.1	2.5	1.7	2.7	3.9	1.5	3.3	2.3	2.0	5.3	3.5	1.8	4.4	2.3	3.0	3.6
Barprisma (H)	**3.16**	1.8	3.3	2.8	3.4	4.0	3.0	3.6	2.4	2.0	3.0	3.9	6.0	1.5	3.3	3.3	3.0	5.6	3.7	1.8	3.5	1.6	3.0	3.5
Ellire	**3.21**	2.0	2.5	2.8	3.5	4.7	2.5	3.6	1.8	2.8	2.0	4.7	6.0	2.0	3.8	3.1	2.0	5.3	3.8	1.9	4.3	2.0	3.5	3.6
Fastyl	**3.41**	1.5	2.8	2.8	3.1	4.5	3.0	4.2	2.3	2.5	3.0	3.8	6.3	1.8	3.5	3.4	3.0	6.1	3.8	2.1	5.4	2.3	4.0	3.5
Pirol	**4.17**	2.3	2.3	3.8	3.8	5.4	4.4	4.9	3.0	4.0	3.3	5.3	6.4	2.5	5.0	4.0	3.0	7.0	5.3	3.4	5.4	3.1	4.8	3.9
Meryl	**4.41**	3.5	2.8	3.8	4.4	5.8	3.8	6.3	3.8	3.8	4.3	4.7	5.3	3.0	5.0	5.1	2.8	6.9	6.0	3.4	3.6	3.0	5.8	4.8
Danergo	**4.82**	3.3	2.5	3.8	3.9	6.3	4.0	5.8	4.6	5.8	5.3	5.1	4.1	3.8	5.5	4.9	2.5	8.0	6.3	5.6	4.6	2.6	7.0	5.6
Lolita	**5.16**	3.5	4.0	5.0	4.9	6.8	5.0	6.5	4.5	5.0	5.0	5.2	4.9	4.0	6.3	4.5	2.8	7.8	4.8	6.1	5.9	3.3	7.0	6.3
Ligrande	**5.95**	3.8	3.3	6.0	5.6	7.0	4.9	7.5	5.8	6.8	6.7	5.3	6.6	4.0	7.5	7.1	3.5	8.4	7.1	5.5	6.0	4.6	8.0	6.0
Lema	**6.26**	5.8	4.3	4.3	5.3	7.3	5.3	8.0	5.9	6.5	7.0	6.0	5.8	4.5	8.3	7.4	4.5	8.5	7.3	7.0	5.5	4.9	8.5	6.5
Gordo	**6.34**	4.5	2.0	4.3	5.6	8.1	5.5	7.9	6.3	7.5	7.7	6.5	6.3	4.8	8.8	7.4	4.0	8.5	7.4	8.3	5.8	5.0	8.0	6.0
Gumpensteiner (H)	**6.40**	4.0	5.0	6.8	5.3	7.7	4.6	7.9	5.8	6.8	7.3	6.2	7.3	5.3	7.3	7.5	4.5	8.5	7.0	7.5	6.1	5.4	7.3	6.5
mean	3.98	2.6	2.5	3.5	3.9	5.1	3.6	4.8	3.2	3.8	3.7	4.2	5.2	2.7	4.7	4.1	2.7	6.4	4.7	3.5	4.4	2.9	4.8	4.3
std.dev.	1.49	1.3	1.1	1.3	1.0	1.7	1.0	2.0	1.8	2.0	2.2	1.3	1.2	1.3	2.1	2.0	0.9	1.6	1.7	2.5	1.2	1.3	2.2	1.4
corr. w. overall mean		.92	.73	.89	.96	.99	.94	.99	.99	.97	.99	.94	.63	.97	.99	.98	.89	.97	.96	.97	.83	.94	.97	.97

The *Lolium multiflorum* trial yielded significant results for *Puccinia coronata* from 23 sites which mostly reflected a highly consistent ranking of the 18 cultivars (Table 1). For 19 sites, local disease scores correlated over 0.90 with the overall mean of the 23 sites. The 3 sites showing the most distinct pattern of response were Boelshoj, Loughgall and Perugia. These

sites also mark the north, north-west and south corners of the geographical distribution of the experimental sites (Fig. 1). Principal component analysis did not identify additional clear groups of sites with similar responses (data not shown). There was no clear indication that rust species other than *P. coronata* were of importance for the disease symptoms recorded on *L. multiflorum.*

Table 2. *Puccinia coronata* disease scores of 33 *Lolium perenne* cultivars at 19 sites (means of 1 to 2 scorings per site). Cultivars are ranked according to the mean over sites.

Variety	**mean over sites**	Aberystwyth	Bornhof	Flaujaques	Gross Luesewitz	Hladke Zivotice	Hof Steimke	Hohenheim	Lelystad (BAR)	Lelystad (CBC)	Les Alleuds	Malchow	Merelbeke	Montours	Nort s. Erdre	Orchies	Ottersum	Pulling	Reckenholz	Steinach
Gwendal	**2.11**	1.0	2.5	2.1	3.8	2.0	2.0	1.0	2.2	2.0	2.3	2.0	3.0	1.5	5.5	2.1	1.5	1.8	1.8	3.5
Bocage	**2.34**	1.3	3.3	3.6	4.3	2.0	2.3	1.5	2.2	2.5	2.0	2.5	3.3	2.3	5.0	2.5	1.4	1.3	2.0	4.0
Lacerta	**2.53**	2.0	3.3	3.3	3.3	2.0	2.5	1.3	2.3	2.5	2.7	2.5	2.8	2.3	5.0	2.9	2.1	1.5	2.3	4.3
Carrera	**2.75**	1.5	2.5	3.3	5.4	2.0	3.8	1.5	2.8	2.8	4.0	1.8	3.8	3.3	6.5	3.0	2.0	2.0	1.8	3.3
Orval	**2.77**	1.8	3.3	4.4	6.0	5.0	3.0	1.0	2.0	2.0	2.3	2.5	3.3	3.5	7.0	4.9	1.8	1.3	2.0	2.0
Pastoral	**2.80**	1.8	4.8	3.1	4.9	2.3	2.5	1.3	3.3	2.8	2.7	2.8	3.8	2.5	5.5	3.8	1.3	1.5	2.3	4.8
Vincent	**3.09**	1.5	3.0	3.5	5.8	2.0	2.8	2.3	2.8	3.5	4.3	2.0	5.0	3.8	6.5	4.8	2.8	1.3	2.5	4.5
Aubisque	**3.11**	2.3	4.5	3.6	4.9	2.0	2.8	1.3	3.4	4.3	2.0	3.8	5.8	3.0	5.5	3.5	2.3	1.3	4.0	4.5
Option	**3.17**	1.0	3.7	4.3	5.3	2.5	3.5	2.0	2.4	2.8	3.7	2.5	4.5	4.3	6.0	4.0	2.6	1.8	2.8	4.5
Heraut	**3.28**	1.8	3.5	3.4	5.8	2.3	3.0	2.3	3.5	4.0	3.3	2.0	5.3	3.5	7.5	5.0	3.1	2.3	2.3	4.3
Elgon	**3.43**	2.0	3.5	3.6	4.3	2.5	3.3	1.3	3.8	4.5	3.3	3.3	4.8	4.3	9.0	4.4	2.1	1.5	3.8	6.3
Roy	**3.49**	2.0	3.3	4.5	5.0	5.8	3.5	1.3	3.2	3.5	4.0	3.5	5.0	4.5	7.5	4.0	1.6	1.0	4.3	5.5
Barnhem	**3.61**	1.5	4.0	4.1	5.9	2.3	4.0	2.5	4.8	2.8	4.0	3.3	6.0	3.5	6.5	5.0	3.1	1.5	2.3	5.3
Kells	**3.61**	1.8	5.5	3.3	6.9	2.0	4.0	1.5	3.6	3.5	4.0	3.8	6.0	3.8	7.5	5.4	3.4	1.0	2.5	3.5
Kentaur	**3.79**	2.0	5.8	4.5	5.4	2.3	3.3	1.5	4.8	3.8	4.0	3.5	6.0	3.8	8.0	4.5	2.9	1.5	4.0	4.8
Aberdart	**3.91**	2.5	3.0	5.4	7.0	6.3	3.3	1.8	3.7	3.0	3.3	4.0	4.3	5.3	9.0	6.6	2.5	1.8	4.0	5.0
Fennema	**3.94**	1.8	5.3	4.9	6.5	6.3	4.0	1.3	3.2	5.0	3.7	3.0	7.3	4.3	7.0	6.1	3.6	1.3	2.3	4.8
Weigra	**3.98**	2.5	3.8	4.6	6.4	2.5	3.5	2.3	3.2	5.0	5.0	3.5	6.0	4.8	6.5	5.9	3.3	2.0	3.8	6.3
Arabella	**4.00**	1.8	3.8	4.4	6.5	2.5	3.8	2.0	4.2	4.8	4.7	4.0	6.8	5.0	7.0	5.6	3.8	1.8	3.5	4.5
Corbet	**4.11**	2.3	6.8	4.1	6.5	2.0	4.0	2.3	4.3	4.8	4.0	4.3	7.0	3.5	7.0	5.9	4.5	1.3	3.0	5.5
Sponsor	**4.16**	2.3	5.0	4.4	7.1	2.0	3.8	2.0	5.4	4.8	4.3	4.0	6.8	4.8	7.0	5.5	3.5	1.8	3.8	5.5
Litempo	**4.19**	2.3	5.3	5.6	6.0	4.8	4.0	1.8	4.4	4.5	5.0	4.5	6.0	4.0	7.5	4.9	2.9	2.5	6.3	4.5
Terry	**4.22**	3.3	5.8	4.6	5.5	3.0	4.3	1.8	5.0	5.8	4.3	4.3	6.3	4.5	7.0	5.1	2.5	2.0	4.8	6.0
Guru	**4.31**	1.8	3.8	6.3	5.9	5.5	3.0	2.3	2.7	2.8	5.7	2.0	6.3	8.0	8.5	6.3	3.8	2.5	6.3	5.3
Gladio	**4.38**	2.5	5.8	5.8	7.0	2.3	3.3	1.8	5.1	5.0	5.3	5.3	5.8	5.3	8.0	6.4	3.1	1.5	4.5	5.3
Tivoli	**4.55**	3.3	6.3	5.3	6.1	5.5	4.3	1.5	4.9	6.0	3.7	4.8	7.0	5.3	8.0	6.3	2.8	1.0	5.3	7.0
Helmer	**4.73**	2.5	5.5	5.6	5.3	4.0	4.5	1.5	5.6	6.0	5.7	5.0	6.8	5.0	8.5	6.3	3.4	1.8	6.5	5.8
Sirocco	**4.78**	3.0	6.5	6.5	6.1	4.5	4.5	3.0	5.5	5.5	5.3	4.0	6.5	5.0	8.0	6.8	3.9	1.8	4.8	6.0
Foxtrot	**4.79**	2.5	5.7	4.8	7.1	4.0	4.3	2.3	6.0	5.3	5.0	6.5	6.8	4.8	8.5	6.5	4.6	2.3	3.8	6.5
Aristo	**4.88**	4.0	4.0	6.1	7.1	2.5	4.8	2.3	5.9	6.5	4.0	6.5	7.0	6.3	9.0	7.4	5.3	2.0	3.5	5.8
Lipresso	**5.45**	3.3	5.5	6.6	6.5	6.5	3.5	2.5	5.1	3.3	7.3	4.8	8.0	7.3	8.5	6.3	4.8	4.5	6.5	6.0
Condesa	**5.64**	4.0	6.5	7.3	7.0	5.5	4.5	2.0	6.4	6.5	7.3	4.8	8.3	6.5	9.0	7.3	5.5	2.5	6.3	5.8
Aurora	**7.49**	8.0	8.8	8.1	8.3	8.0	5.0	4.3	7.7	8.0	8.3	7.5	9.0	7.5	9.0	8.9	8.9	6.0	8.8	7.3
mean	**3.92**	2.4	4.6	4.7	5.9	3.5	3.6	1.9	4.1	4.2	4.3	3.8	5.7	4.4	7.3	5.3	3.2	1.9	3.9	5.1
std.dev.	**1.07**	1.3	1.5	1.3	1.1	1.8	0.7	0.6	1.4	1.5	1.5	1.4	1.6	1.5	1.2	1.5	1.5	1.0	1.7	1.1
corr. with overall mean		.87	.79	.90	.76	.64	.79	.74	.88	.81	.89	.83	.89	.85	.76	.91	.91	.72	.85	.75

Table 3. *Puccinia graminis* disease scores of 33 *Lolium perenne* cultivars at 13 sites (means of 1 to 2 scorings per site). Cultivars are ranked according to the mean over sites.

Variety	**mean over sites**	Boelshoj	Druelle	Hladke Zivotice	Hohenheim	Lodi	Loughgall	Malchow	Montours	Neuhof	Orchies	Perugia	Rilland	Spitalhof
Gwendal	**1.65**	2.8	2.4	2.3	2.3	2.1	4.1	1.3	1.3	2.0	1.3	2.8	2.0	1.0
Pastoral	**1.85**	3.0	2.5	2.3	2.3	2.4	2.9	1.8	1.0	1.5	1.3	3.5	2.3	1.5
Bocage	**2.15**	3.3	2.4	2.0	2.0	2.8	5.1	1.8	1.5	2.3	1.3	4.0	2.1	1.3
Elgon	**2.20**	3.3	2.9	2.8	2.0	3.0	4.5	2.3	2.0	2.0	1.5	3.5	2.4	1.3
Terry	**2.20**	4.3	2.8	2.0	2.0	3.1	5.0	1.8	1.3	2.0	1.5	4.5	2.4	1.5
Tivoli	**2.20**	4.3	2.6	2.3	2.3	3.5	5.4	1.8	2.0	2.3	1.3	3.8	2.6	1.3
Roy	**2.23**	4.5	2.5	2.3	2.3	3.4	7.1	1.8	2.3	2.0	1.5	4.1	2.1	1.0
Kentaur	**2.25**	4.5	2.5	2.0	2.0	3.0	4.9	2.0	1.0	2.3	1.3	4.5	2.4	1.5
Lacerta	**2.25**	5.3	2.4	2.3	2.3	3.8	5.7	2.0	1.8	2.8	1.5	3.8	2.3	1.0
Aberdart	**2.28**	4.0	3.3	3.0	2.0	3.8	5.6	1.8	1.3	2.8	3.0	3.9	3.3	1.8
Aubisque	**2.43**	3.3	2.5	2.0	2.0	2.6	3.9	2.3	1.5	2.5	1.5	4.6	2.4	1.3
Carrera	**2.43**	3.5	3.0	3.3	2.8	4.3	4.3	2.8	1.3	3.3	1.8	3.4	2.5	1.5
Orval	**2.58**	4.5	3.3	3.3	2.0	3.3	4.8	2.5	1.3	2.8	2.3	4.9	2.0	1.5
Condesa	**2.68**	5.8	3.5	2.8	2.8	4.1	4.3	2.5	1.5	3.3	2.8	4.9	3.5	1.3
Litempo	**2.85**	4.0	2.6	2.3	2.5	3.6	5.3	2.0	2.8	3.3	1.8	4.8	2.4	1.5
Sirocco	**2.90**	4.5	2.8	2.8	2.0	4.8	5.9	1.8	2.3	3.3	2.3	5.5	3.0	1.8
Helmer	**3.00**	3.5	3.0	2.8	2.3	3.2	5.7	2.0	3.5	2.8	1.3	5.8	2.3	1.0
Foxtrot	**3.05**	4.5	3.1	4.0	3.0	4.4	5.4	1.8	3.3	3.3	2.5	5.3	3.1	1.8
Aristo	**3.33**	4.0	3.0	3.5	2.3	4.0	4.4	2.3	4.0	3.0	3.0	5.6	2.9	1.8
Gladio	**3.35**	5.3	3.0	3.5	2.5	4.9	6.3	2.5	3.0	4.0	3.8	5.8	2.6	1.5
Guru	**3.38**	5.8	4.6	5.8	2.5	4.8	7.0	3.8	3.8	2.8	3.0	4.6	2.5	2.0
Barnhem	**3.40**	4.0	3.3	5.0	2.3	4.8	4.3	3.0	3.5	3.5	3.5	4.8	2.9	2.3
Option	**3.63**	4.0	3.0	4.0	2.5	4.0	6.2	3.3	3.3	3.3	3.3	6.9	2.3	1.5
Kells	**3.75**	4.3	3.1	4.3	3.0	5.9	5.3	3.5	3.5	3.5	3.5	6.3	3.5	2.0
Weigra	**3.75**	5.5	3.5	4.3	3.3	6.2	6.8	3.5	3.0	3.3	4.0	6.8	3.8	2.3
Vincent	**3.83**	4.0	3.0	3.8	3.3	5.0	5.2	3.8	3.5	3.3	3.0	6.4	3.8	2.3
Arabella	**3.85**	5.5	3.3	4.5	3.0	6.4	6.8	3.8	4.0	3.5	4.0	6.5	4.3	1.5
Sponsor	**3.90**	4.5	3.4	3.8	3.0	4.9	4.6	3.0	3.5	3.8	4.3	6.8	3.5	2.5
Heraut	**4.10**	4.3	3.4	5.0	3.0	4.6	5.9	4.3	4.3	3.3	3.5	6.5	2.5	2.3
Corbet	**4.23**	4.3	3.6	5.0	3.5	6.7	5.2	3.8	5.0	2.5	3.8	6.9	3.3	3.0
Lipresso	**4.23**	7.3	4.6	5.3	3.8	6.4	6.8	5.0	3.0	3.5	5.0	6.9	3.1	2.8
Fennema	**4.25**	5.3	3.5	4.8	3.3	5.8	6.7	4.0	4.0	3.5	3.5	7.0	3.5	2.8
Aurora	**4.58**	8.0	5.8	7.8	4.3	6.6	7.6	7.3	2.5	2.8	5.5	6.4	4.4	4.0
mean	**3.05**	4.5	3.1	3.5	2.6	4.3	5.4	2.8	2.6	2.9	2.7	5.2	2.8	1.8
std.dev.	**0.82**	1.1	0.7	1.3	0.6	1.3	1.1	1.2	1.1	0.6	1.2	1.3	0.7	0.7
corr. w. overall mean		.60	.71	.86	.83	.89	.55	.84	.83	.69	.90	.93	.70	.82

In contrast to *L. multiflorum*, the scorings of the *Lolium perenne* trial were influenced by the rust species present and showed clearly distinct results whether *Puccinia coronata* or *Puccinia graminis* was the more prevalent species. There was only a loose correlation between average disease scores for these two pathogens of the 33 cultivars (Fig. 2). For

example, the cultivars HERAUT, VINCENT, OPTION and FENNEMA ranked more than 12 places poorer for resistance against *P. graminis* than for resistance against *P. coronata*, whereas the opposite was true for TERRY, TIVOLI and CONDESA which proved to be quite resistant against *P. graminis* but much more susceptible for *P. coronata* (cf. Tables 2 and 3).

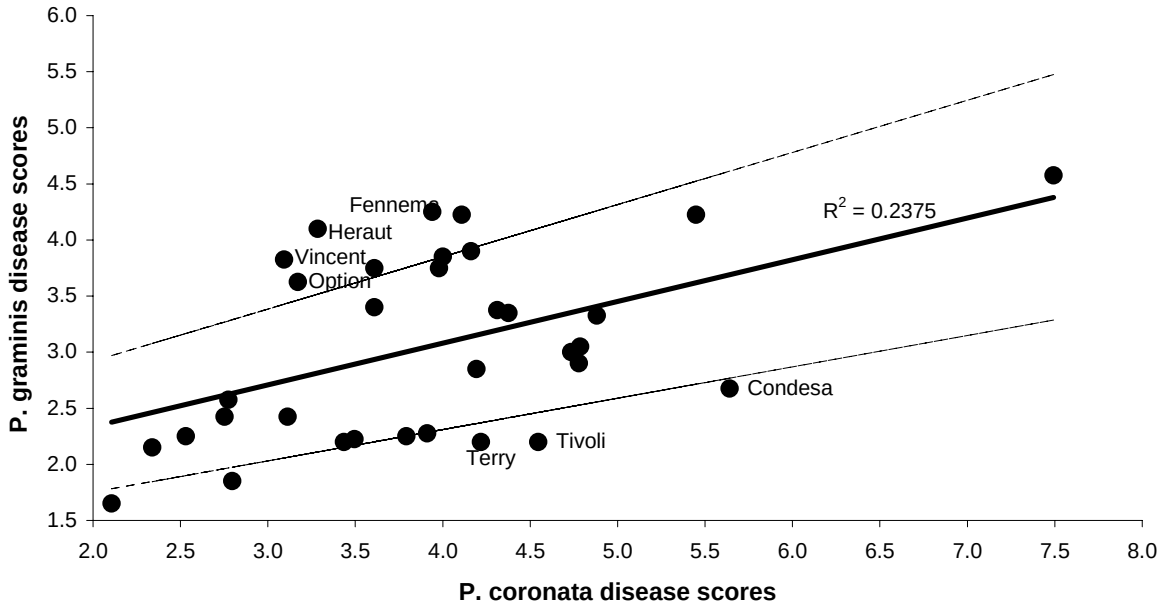

Figure 2. Relationship between average disease scores for either *Puccinia coronata* or *Puccinia graminis* for 33 cultivars of *Lolium perenne*. The solid line represents the linear regression, the dotted lines limit a zone of ± 25 % of the regression.

Significant differences among disease scores of *L. perenne* for *P. coronata* were obtained at 19 sites (Table 2). The ranking of the cultivars, taking into account their larger number, was as consistent as for *L. multiflorum*. For all sites, the correlation of the local disease scores with the overall mean was significantly different from 0 at the p=0.001 level.

A principal component analysis of standardized scores (with mean=0 and standard deviation=1 for each site) revealed a separation of experimental sites based on the differential response of the set of *L. perenne* cultivars to *P. coronata* (Fig. 3) which partly reflected the geographical arrangement of the sites. Principal component 1 separated all sites of the "North" and "North-West" regions except Ottersum from all other sites. Principal component 2 joined the regions "West" and "North-West" and separated these two regions from all other sites except Pulling. The plot of principal components 1 vs. 3 revealed a clear separation of the "West" region from the joined regions "North" and "North-West". The sites of the "Central" region did not form a coherent group in the principal component 1 vs. 2 plot but appeared loosely grouped in the principal component 1 vs. 3 plot. The site Hladke Zivotice, situated at the east border of the zone covered by the experimental sites, remained separated from all other sites in both plots.

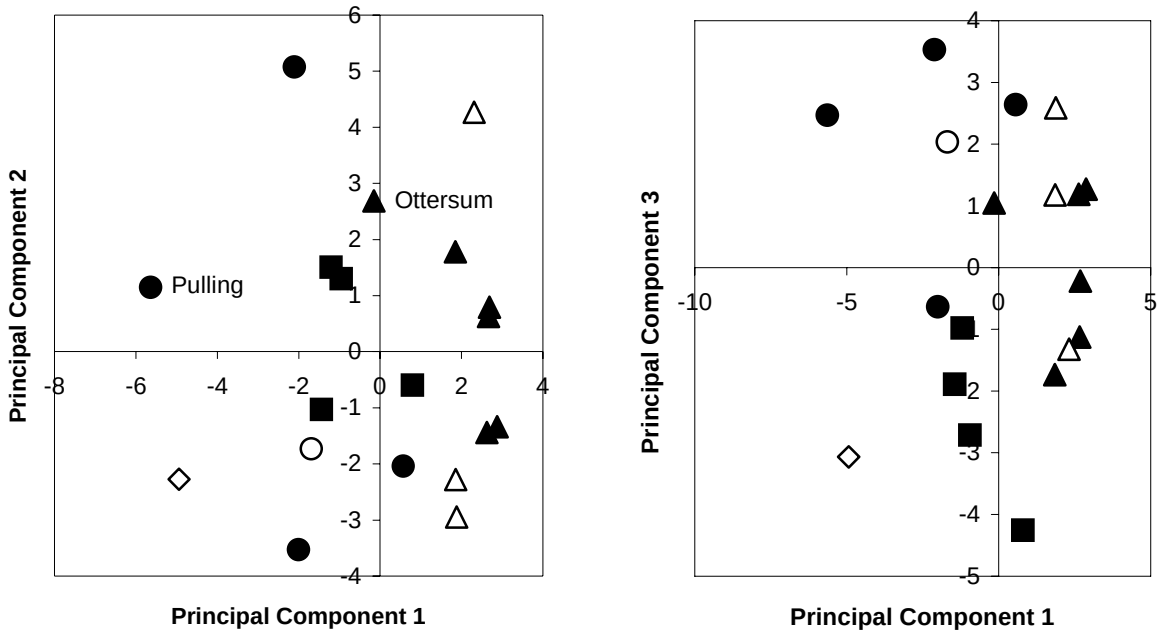

Figure 3. Pairwise plots of the first 3 principal components for standardized *P. coronata* disease scores of 33 *Lolium perenne* cultivars at 19 sites from regions Central (●), West (■), North-West (▲) and North (▵) as well as from Aberystwyth (○) and Hladke Zivotice (◇).

Significant *P. graminis* disease scores were recorded on *L. perenne* at 13 sites (Table 3). At 5 of these sites (Hladke Zivotice, Hohenheim, Malchow, Montours and Orchies) *P. coronata* had also been recorded. *P. graminis* scores were generally lower than *P. coronata* scores. As for *P. coronata*, the ranking of the cultivars was quite consistent. The sites Boelshoj and Loughall correlated markedly poorer with the overall mean than the other sites. Principal component analysis clearly separated these two sites from the rest but did not reveal a consistent grouping which would have reflected the geographical distribution of the sites. (data not shown).

Table 4. Results of analysis of variance of rust disease scores taken at individual sites

Ryegrass species	*L. multiflorum*	*L. perenne*	
Rust species	*P. coronata*	*P. coronata*	*P. graminis*
No. of cultivars	18	33	33
No. of sites	23	20	13
No. of scorings (total)	40	26	17
F-value for cultivars	551.00	170.08	84.72
F-value for cultivar × site interaction	4.50	4.72	3.81
F-value for cultivar × scorings(site) interact.	2.81	2.85	1.98

All F-values are significant at the $p<0.001$ level

Analysis of variance revealed a small but highly significant cultivar × site interaction for each *Lolium* species and – within *L. perenne* – for both *P. coronata* and *P. graminis* (Table 4). Relative to the main effect of the cultivars, this interaction was more prominent for *L. perenne* than for *L. multiflorum*, particularly for disease scores of *P. graminis*.

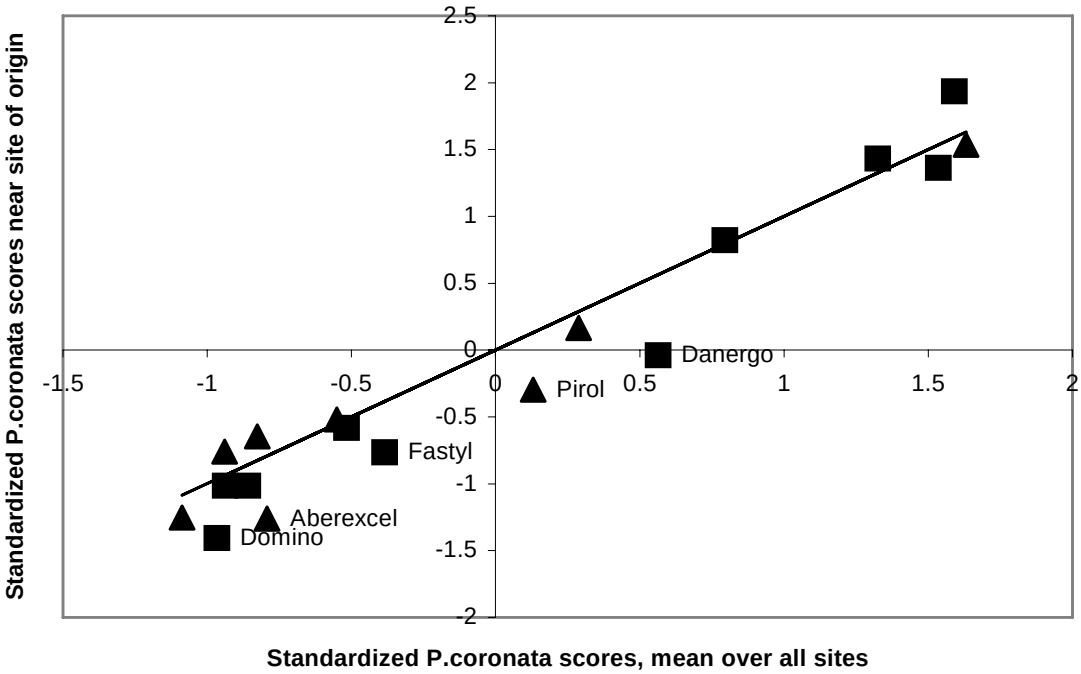

Figure 4. Relative performance of *L. multiflorum* cultivars (■ =cultivars older than 10 years; ▲ =more recent cultivars) with respect to resistance against *P.coronata*, at or near their site of origin as compared to the mean over all sites

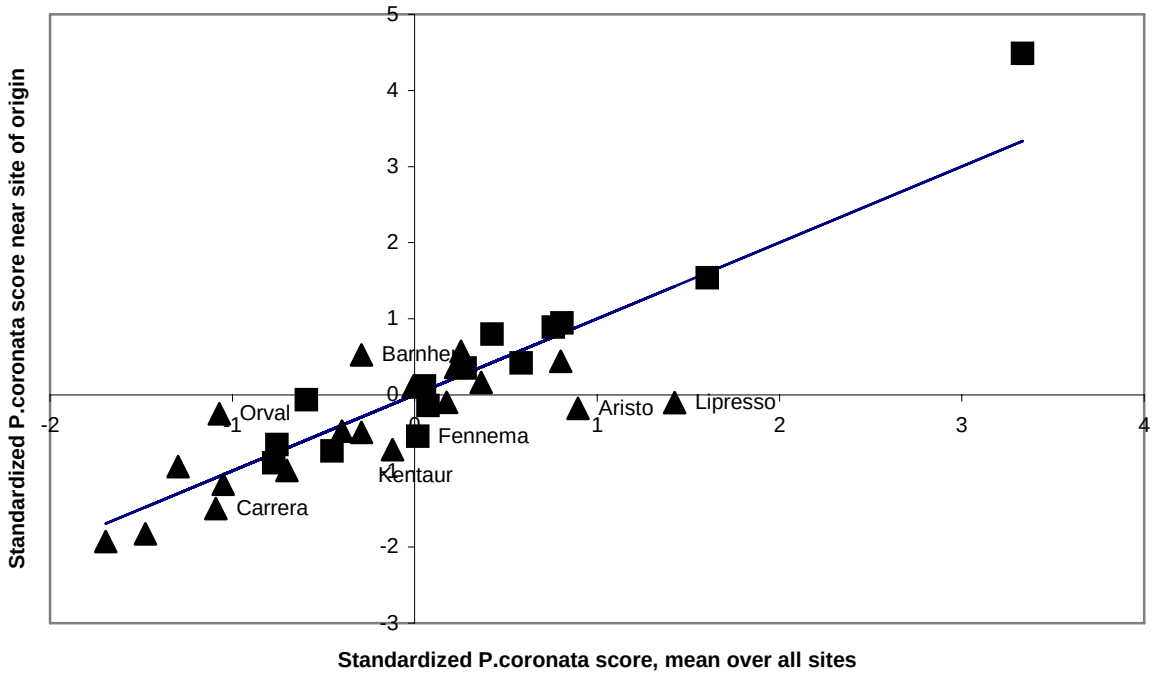

Figure 5. Relative performance of *L. perenne* cultivars (■ =cultivars older than 10 years; ▲ =more recent cultivars) with respect to resistance against *P.coronata*, at or near their site of origin as compared to the mean over all sites.

We further examined whether the origin of a cultivar was related to its site-specific response, i.e. to its performance with respect to rust resistance at or near the place where it had been selected. Within *L. multiflorum*, there was clear tendency for a better performance of cultivars at or near their site of origin (Fig. 4). A similar, although less consistent tendency was observed within *L. perenne* (Fig. 5). A better performance at or near their site of origin was observed mainly for more recent cultivars. Cultivars older than 10 years were distributed evenly between a better or poorer performance.

Discussion

This first evaluation year revealed a widespread occurrence of natural rust infection of *Lolium* all over Europe. At the great majority of experimental sites, significant differences in rust disease scores among the cultivars were observed (Tables 1, 2 and 3). The two species investigated, *L. multiflorum* and *L. perenne*, differed fundamentally in that *L. multiflorum* was exclusively attacked by *Puccinia coronata* whereas in *L. perenne*, often at the same sites, both *P. coronata* and *P. graminis* contributed significantly to the disease scores. Lellbach (2000) cited several observations of an increased occurrence of *P. graminis* in Europe. The simultaneous occurrence of the two rust species on *L. perenne* may be partly responsible for the less consistent ranking of the *L. perenne* cultivars than was observed in *L. multiflorum*. Indeed, the ranking of the *L. perenne* cultivars with respect to rust susceptibility was strongly influenced by the more prevalent rust species (Fig. 2). The relative importance of the two rust species appears to be a major factor leading to cultivar × environment interaction when "rust" is scored without clearly identifying the *Puccinia* species present.

Within one rust species, the response of the set of cultivars was largely similar among the experimental sites. The disease scores of each site correlated strongly ($p<0.001$) with the overall means. This finding is in contrast to what is known for cereal rusts. Cultivar-specific races of *Puccinia* fungi are known since nearly a century (Roelfs, 1984) and are a major concern of cereal breeders. The relative stability of the ranking observed here within *Lolium* may reflect a broader genetic basis of rust resistance in outbreeding species, or a lesser specialization within the pathogen populations based on the genetically variable character of the ryegrass cultivars.

Nevertheless, a certain cultivar × site interaction persisted. Multivariate statistics identified individual sites where the cultivars responded differently from the majority of the other sites. In many cases, these "outlyers" marked the geographical borders of the zone of Europe covered by the experimental sites. For *P. coronata* on *L. perenne*, principal component analysis suggested an additional grouping of the sites which reflected their geographical arrangement (Fig. 3). The "West" region, comprising 4 sites in the West of France, consistently formed a cluster which was separated from the "North-West" and "North" regions. These two regions, comprising the lowland zones near the North and the Baltic Sea, respectively, together formed a second, somewhat less compact group of sites. In contrast, this analysis did not clearly group the sites of the "Central" region.

Further evidence for a site-specific resistance of *Lolium* cultivars against *P. coronata* was obtained by comparing the relative performance of cultivars at their site of origin with the performance over all sites. A large number of cultivars performed better at or near their site of origin than on average (Fig. 4 and 5). This was particularly true of more recent cultivars.

While these findings strongly suggest that the rust resistance of *Lolium* cultivars is modified by site-specific factors, this is not yet a proof of the existence of local rust races with particular pathogenicity. The relative similarity of the response of the tested set of cultivars within regional groups of sites, as suggested by principal component analysis of the *L. perenne* results, may also reflect the similarity of climatic conditions within these groups. Roderick *et al.* (2000) reported on temperature-dependent differences in response of *Lolium perenne* cultivars to crown rust infection. Such an interpretation might explain why principal component analysis failed to group the sites of the climatically diverse "Central" region but clearly joined the sites of the climatically more uniform "West" and "North-West" regions. It is planned to investigate cultivar response to inoculation with rust isolates originating from the different sites under uniform conditions to better understand the observed differences.

Conclusions

The most prominent finding of this first year of our multisite rust evaluation was the quite consistent ranking of the *Lolium* cultivars with respect to rust resistance over a large number of sites. For *Lolium perenne*, it was necessary to determine the most prevalent rust species (either *Puccinia coronata* or *P. graminis*) to confirm this consistent ranking. However, even within one rust species, there remained a significant interaction between cultivars and sites. Multivariate statistics identified sites with particularly deviating rankings and partly allowed to meaningfully group the sites on the basis of the pattern of cultivar response to spontaneous rust infection.

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