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Effect of partial resistance to barley leaf rust, *Puccinia hordei*, on the yield of three barley cultivars

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Abstract Three barley cultivars, Shyri, Clipper and Terán, with different levels of partial resistance to barley leaf rust, caused by *Puccinia hordei*, were exposed to six levels of the pathogen. These levels were obtained by 5, 4, 3, 2, 1 and 0 fungicide (Propiconazol) applications respectively and occurred every 15 days starting at 66 days after sowing. No application served as the control treatment. There were three replicates. The six-row plots were surrounded by a row of a highly susceptible barley cultivar in which the barley leaf rust arrived naturally in a fairly early plant stage. The disease severity was assessed five times with 15 days intervals starting at 66 days after sowing. The yields were determined by harvesting the inner four rows of the plots.

An analysis of variance was carried out on the area under the disease progress curve (AUDPC) data and on the yield data. 'Shyri' was the least susceptible cultivar, 'Terán' the most. The percentage yield losses varied with the six levels of pathogen from 0 to 31.5% ('Shyri'), from 0 to 46% ('Clipper') and from 0 to 63.5% ('Terán'). The yield losses correlated strongly with the AUDPC, the linear correlation coefficient being 0.97. The yield losses indicate the importance of the pathogen in Ecuador. It also means that high levels of partial resistance are needed to prevent significant yield damage.

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Introduction

Barley leaf rust, caused by *Puccinia hordei,* is a major pathogen of barley, *Hordeum vulgare*, in Ecuador. Although many major resistance (Rph) genes are known (>16) they are of little use in protecting commercial cultivars. Virulence to most of these resistance genes occurs world wide in the barley leaf rust (Parlevliet, 1983). Partial resistance, defined as a resistance characterized by a susceptible infection type and a reduced disease severity (Parlevliet, 1975) however, is a good alternative. This resistance is readily available in barley cultivars (Parlevliet et al., 1980). It is inherited polygenically (Parlevliet, 1978), considered to be a durable form of resistance (Parlevliet, 1981a) and high levels can be selected for quite easily (Parlevliet and van Ommeren, 1988). Also in the barley cultivars present in Ecuador it was not difficult to find substantial levels of partial resistance (Vivar, 1994).

The aim of the experiment described here was to study the yield reduction caused by barley leaf rust and the effect of partial resistance on this yield reduction. To this end three barley cultivars differing in their levels of partial resistance were exposed to various levels of barley leaf rust.

Materials and methods

Three cultivars, Shyri, Clipper and Terán, were exposed to six levels of the pathogen in an experiment carried out at the Santa Catalina Experimental Station (INIAP) at an altitude of 3050 m near Quito-Ecuador. The 18 treatments were replicated three times in a split plot design with cultivars on main plots and fungicide treatments on sub-plots. Each plot consisted of six rows of 3.0 m by 1.8 m. The plots were surrounded by a row of a highly susceptible barley cultivar in which the barley leaf rust arrived naturally in a fairly early plant stage. The yields were determined by harvesting the four inner rows and threshing the ears per plot.

The six levels of barley leaf rust were obtained by applying the fungicide propiconazol (Tilt) 5, 4, 3, 2, 1 and 0 times respectively (treatments F5, F4, F3, F2, F1 and F0). These applications occurred every 15 days starting at 66, at 81, at 96, at 111 or at 126 days after sowing. F0 served as the control treatment. The fungicide was diluted in tap water to a concentration of 1 cc per liter and applied uniformly on the foliar area until runoff. Propiconazol also controls scald, caused by *Rhynchosporium secalis*, which occurred only in the cultivar Clipper. Disease assessment was carried out five times, 66, 81, 96, 111 and 126 days after sowing using the modified Cobb scale (Melchers & Parker, 1922; James, 1971). The area under the disease progress curve (AUDPC) was calculated as described by Shaner and Finney (1977).

An analysis of variance was carried out on the AUDPC data and on the yield data.

Results and discussion

The differences in partial resistance between the cultivars can be seen when the disease severities (DS), expressed by the AUDPCs of the unprotected treatments (F0), are compared. 'Shyri' was the least affected and 'Terán' the most (Table 1). The yield losses of the three cultivars were associated with the levels of barley leaf rust, the yield loss being larger the more susceptible the cultivar (Table 1). The linear correlation coefficient, r, between the AUDPC and the percentage yield loss taken over the three cultivars was 0.97, very significant. In fact 94% of the variation in yield loss can be explained by the variation in barley leaf rust levels. 'Clipper' also developed a significant level of scald, up to 40% at the last assessment date. Despite this, its AUDPC/percentage yield loss relationship was not different from those of the other two cultivars. This could mean that scald did not affect the yield to any significant extent or that 'Clipper' is more tolerant to barley leaf rust than the other cultivars.

The leaf rust reduced the yield of the cultivars Shyri, Clipper and Terán with 0.81%, 0.96% and 0.81% respectively per 1% increase in DS at a similar development stage, early dough, when the leaf rust had reached its maximum. This estimate of yield loss, of about 0.9% for each increment of 1% leaf rust severity, is within the wide range of observations reported by others; 0.4% (King & Polley, 1976), 0.42% (Griffey et al.,1994), 0.77% (Melville et al., 1976) and 0.6 to 1.5% (Udeogalanya & Clifford, 1982). In the latter study the lower yield loss occurred at low N-regimes, the higher loss at high N-regimes. In all cases a critical point model was used. This is considered to be acceptable when the epidemic develops fairly late, after the flag leaves have emerged as is usually the case with leaf rust in barley (Melville et al., 1976; Gaunt, 1995). For other cereal rusts similar yield losses per 1% rust severity increment were observed. For wheat leaf rust, *P. triticina*, yield losses ranged from 0.25 to 1% (Milus, 1994; Khan et al., 1997), for common rust, *Puccinia sorghi*, of corn Pataky (1987) reported a loss of 0.6%. In oats Jones, (1977) measured an average yield loss over the cultivars tested of 1.0% per 1% increase in powdery mildew.

Only pathosystems were compared in which a biotrophic pathogen was involved. Although Gaunt (1995) and Gooding et al. (2000) suggested that, for many foliar diseases, the effect on the hosts is through the green area duration, Lopes and Berger (2001) concluded, that the green area duration is not always suitable to estimate the effect of a pathogen on its host. The effects on common bean of the necrotrophic anthracnose extended far beyond the visual lesions, whereas the effect of the biotrophic bean rust on photosynthesis was essentially limited to the pustule and halo. The yield losses of the pathosystems referred to above differed greatly, from 0.25% to 1.5% per % increase in disease severity. These differences occurred both within and between pathosystems and are easily explained by

Table 1 Disease severity in percentage leaf area affected (DS) at five dates, area under the disease progress curve (AUDPC), yield, yield loss and percentage yield loss of three barley cultivars with different levels of partial resistance against *Puccinia hordei* and protected at six levels with a fungicide (F0-F5)

		DS**							Yield loss	
Cultivar	Treatment*	66	81	96	111	126	AUDPC	Yield kg/ha	kg/ha	%
Shyri	F5	***1***	***1***	***1***	***1***	***2***	68 g***	4001 a***	0	0
Shyri	F4	1	***3***	***1***	***10***	***15***	330 g	3774 ab	231	5.8
Shyri	F3	1	5	***27***	***30***	***33***	1185 ef	3387 abcd	618	15.4
Shyri	F2	1	5	27	***37***	***40***	1343 ef	3170 abcd	835	20.8
Shyri	F1	1	5	25	45	***40***	1433 cdef	2669 de	1336	33.4
Shyri	F0	1	5	27	40	40	1388 def	2745 de	1260	31.5
Clipper	F5	***4***	***2***	***1***	***1***	***2***	105 g	3311 abcd	0	0
Clipper	F4	5	***20***	***13***	***20***	***17***	1110 f	2887 cde	424	12.8
Clipper	F3	5	30	***30***	***33***	***27***	1635 bcde	2297 ef	1014	30.6
Clipper	F2	5	30	27	***43***	***40***	1838 bcd	2205 ef	1106	33.4
Clipper	F1	5	30	27	43	***43***	1860 bc	2051 efg	1260	38.1
Clipper	F0	5	30	30	43	50	1958 b	1789 fg	1522	46.0
Terán	F5	***3***	***1***	***1***	***3***	***5***	135 g	3643 abcd	0	0
Terán	F4	5	***30***	***8***	***20***	***23***	1080 f	3164 abcd	479	13.1
Terán	F3	5	37	***47***	***30***	***40***	2603 a	2131 efg	1512	41.5
Terán	F2	5	33	50	***63***	***80***	2828 a	1518 fg	2125	58.3
Terán	F1	5	30	50	77	***83***	3015 a	1523 fg	2120	58.8
Terán	F0	5	30	50	77	83	3015 a	1330 g	2313	63.5

*F5, F4, F3, F2, F1 and F0 represent 5, 4, 3, 2, 1 and 0 applications with fungicide.
**Fungicide application and disease assessment dates in days after sowing. The DS data in bold and italics were treatments protected by fungicide from that date onward
***Significantly different according to Duncan's New Multiple Range Test at $P = 0.01$ if letters are different

differences in the start and the progress of the epidemics in the different experiments. So within a similar type of pathogen the suggestion of Gaunt (1995) and Gooding et al. (2000) may hold, that yield losses would be similar between different pathosystems, provided the epidemic development is the same.

However, there is a factor affecting the yield loss per 1% increase in DS independent of the green area duration viz., the tolerance of the host genotype to the pathogen. Cultivars may differ considerably in this respect. Jones (1977) reported yield losses per 1% increase in powdery mildew DS of three oat cultivars with a similar level of susceptibility, Milford, Sun II and Mostyn, of 1.3%, 0.9% and 0.45% respectively. Little & Doodson (1972) compared yield losses and mildew severities from 36 barley trials and concluded that cultivar Proctor had a mean yield loss about 50% smaller than those of the similarly susceptible cultivars Zephyr and Sultan.

The yield losses due to barley leaf rust as reported here can be large in Ecuador. Major gene resistance is no solution, so partial resistance is a good alternative. Selection for tolerance would be another possibility, but its heritability is low (Parlevliet, 1981b). which makes selection for partial resistance, with its fairly high heritability (Parlevliet et al., 1980), much more effective. Table 1 shows that a moderate level of partial resistance ('Shyri') reduced the yield loss with some 50% compared with the highly susceptible 'Terán'. Due to the high leaf rust pressure in Ecuador high levels of partial resistance will be needed. This is quite possible. Parlevliet and van Ommeren (1988) and Parlevliet et al. (1985) showed that very high levels of partial resistance are not difficult to obtain.

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