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The development of the leaf rust, Puccinia hordei, population during winter, spring and early summer in 11 winter barley cultivars

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Abstract

The overwintering and the epidemic development in spring of leaf rust was studied in 11 winter barley cultivars at two different sites near Wageningen in 1976/1977. The amount of leaf rust decreased through the winter at both sites. Cultivars differed considerably in the amount of leaf rust in late winter. Both the moment and the rate of increase of leaf rust after the winter varied with cultivars. The ultimate amount of leaf rust in a cultivar was therefore determined by three factors: The amount of overwintering leaf rust, the onset of leaf rust increase and the rate of increase.

The latter was determined by the partial resistance of the cultivar. Why the epidemics did not start at the same moment is yet unknown. The differential overwintering could be explained from the amounts of leaf rust and powdery mildew at the start of the winter, the effect of powdery mildew being a negative one. The correlation coefficient between the values observed in March and those predicted from the December leaf rust and powdery mildew readings was 0.93.

In a second experiment carried out in 1979/1980 with six winter barley cultivars chosen from the first experiment the powdery mildew was succesfully excluded by treatment with fungicides. There was no decrease in the leaf rust over the winter nor a differential cultivar effect on overwintering.

Additional keywords: Erysiphe graminis f.sp. *hordei,* overwintering, partial resistance, powdery mildew.

Introductions

It is assumed that leaf rust, caused by *Puccinia hordei,* overwinters in Western Europe as a sporulating and/or a dormant uredo-mycelium in winter barley (Gassner and Pieschel, 1934; D'Oliveira, 1939; Simkin and Wheeler, 1974; Tan, 1976). Parlevliet and Van Ommeren (1976) observed that sporulating urediosori were present throughout the winter, the numbers decreasing steadily. The lowest levels were reached in March. Dormant mycelium did not play a role of significance in overwintering as the leaves formed before the winter were largely replaced by new ones at the end of the winter. The cultivars Dominator and Hudson allowed considerably more leaf rust to overwinter than did Herfordia, Hauters and Pella.

To study the cultivar effect on overwintering and epidemic development in spring two experiments were carried out.

Material and methods

Experiment 1. Eleven winter barley cultivars were sown at two sites at Wageningen: One site consisting of clay soil and exposed to wind, and one sheltered site with sandy soil. The sowing was done on 23 (clay site) and 24 (sandy site) September 1976, respectively. The seed rate used was 125 kg/ha. At each site 33 plots measuring 2.0 × 2.0 m were prepared. The row distance in each plot was 0.25 m. The plots were separated from one another by 1.0 m wide strips of winter rye sown at the same time. Interwoven in this experiment was a winter wheat experiment with 11 cultivars. Barley and wheat plots alternated with one another. Thus, the barley plots were well isolated from each other minimizing interplot interference in the epidemic development of leaf rust. There were three replicates in a randomized block design. Approximately three weeks after emergence spreader plants were planted in the barley plots. Seedlings of a highly susceptible cultivar had been infected with leaf rust in the greenhouse and brought outside just before eruption of the urediosori. Per plot four spreader plants were planted 0.5 m from the corners. After three weeks the spreader plants were removed.

The numbers of urediosori or clusters of urediosori were counted on six dates, 8 december, 26 January, 10 March, 20 April, 25 May and 24 June (clay site) and 28 January, 11 March, 21 April, 28 May and 27 June (sandy site). At the first four dates four clusters of seedlings were dug out randomly from each plot, planted in plastic pots and placed in a greenhouse at 15-20 °C. The number of urediosori per tiller (shoot) was determined immediately after planting. Many urediosori apparently were individual lesions. Sometimes, however, several to many urediosori were very closely clustered, and presumably originating from a single lesion either as secondary sori or from the germination of spores around the primary sorus in a drop of stagnating water. Such clusters were scored as single lesions. At the May and June sampling dates 20 tillers were taken randomly from each plot and the number of urediosori was determined on the upper three leaves using the scale of Parlevliet and Van Ommeren (1975).

The powdery mildew, *Erysiphe graminis* f.sp. *hordei,* was evaluated several days after potting to enable the powdery mildew mycelium, present on the leaves but not easily visible, te develop into well discernable pustules.

Experiment 2. Six winter barley cultivars from experiment 1 were sown at the clay site at Wageningen on 24 September 1979. The seed rate was 120 kg/ha. Each plot measured 2.0 × 2.0 m, the row distance being 0.25 m. The plots were separated from one another by 6 m winter rye sown at the same day. There were six replicates. Tu suppress powdery mildew the seed was treated with Milstem (ethirimol). Just prior to the planting of the spreader plants, four per plot about three weeks after emergence, the plots were sprayed with Milgo E (ethirimol). Three weeks later the spreader plants were removed.

The evaluation of leaf rust was identical to that in experiment 1. The sampling dates of three replicates were 22 november, 17 March, 28 April and 9 June. The other three replicates were sampled on 29 April and 10 June only. These latter replicates were treated with Calixin (tridemorph) on 16 april to reduce the leaf rust population to zero. In this way it was hoped to study the epidemic development in het various cultivars independently of the varying amounts of leaf rust that overwintered. The sampling before April was done by digging out plants and potting them. The sampling from April onward consisted of collecting tillers. Powdery mildew was assessed at the same data as described in experiment 1.

The data in both experiments were transformed to ln values to allow a statistical analysis. A few observations gave values of 0.00 (sandy site, Table 2). To allow transformation the 0.00 values were replaced by 0.005, a value below 0.01, the lowest non-zero-observation.

Results

Experiment 1. The level of leaf rust decreased until a minimum was reached in late winter, after which there was a recovery, slow in early spring, faster in May. At the clay site there was always more leaf rust present that at the sandy site (Table 1).

Table 1. Number of urediosori of leaf rust per shoot or tiller on winter barley at two sites during the winter and spring of 1977.

Site	Sampling date					
	Dec.	Jan.	March	April	May	June
clay	2.4[a]	0.3	0.6	1.0	9.7	158
sand	–[b]	0.1	0.1	0.3	1.3	12.3

[a] Means over 11 cultivars.
[b] Not determined.

Tabel 1. Aantal dwergroestsporehoopjes per scheut of halm op wintergerst op twee plaatsen tijdens de winter en het voorjaar van 1977.

At each site te cultivar effects were highly significant on each sampling date ($P = 0.01$). There were some cultivar × sampling date interactions exemplified by Vögelsänger Gold and WN 5-52. The former cultivar had significantly more leaf rust in December and June, but not so in the period between (Table 2). This different survival over the winter seemed related to both the amount of powdery mildew and the amount of leaf rust present in December. A multiple regression analysis, predicting the March levels of leaf rust (y) from the December leaf rust (x_1) and powdery mildew (x_2) data, was carried out on the ln transformed observations of the clay site. The regression equation was $y = 1.20x_1 - 0.97x_2 - 1.64$. The multiple correlation coefficient between the predicted y values and the observed March data was 0.93.

Other cultivar × sampling date interactions arose from differences in recovery after the winter. In 'Dominator' leaf rust started to build up in late March, in 'Banteng' in early May for instance.

The course of the leaf rust population in the various cultivars was very similar at the two sites although they represented rather different ecological situations (Table 2).

Table 2. Number of urediosori of leaf rust per shoot or tiller on 11 winter barley cultivars at two sites during the winter and spring of 1977. The percentage leaf area affected by powdery mildew at the December sampling is indicated between brackets.

Cultivar	Sampling date					
	Dec.	Jan.	March	April	May	June
Clay site						
Dominator	6.9 (4)	1.4	5.6	25	71	1530
Vogelsänger Gold	9.6 (21)	0.4	1.5	3.3	16	1310
Banteng	6.0 (7)	1.2	2.3	2.2	18	810
W.B. 5-52	1.8 (2)	0.5	1.6	5.7	17	720
Regia	2.2 (33)	0.1	0.6	0.6	12	185
Almersfelder	0.6 (4)	0.2	0.6	1.9	7	160
Hauters	0.7 (25)	0.03	0.03	0.2	3.5	150
Jumbo	3.2 (15)	0.4	0.2	0.6	7	150
Pella	3.2 (25)	0.2	0.5	0.5	10	140
Herfordia	1.5 (15)	0.1	0.1	0.1	4.5	100
Melior	0.3 (43)	0.01	0.01	0.1	2.5	60
Sandy site						
Dominator	– [a] (4)	1.4	1.7	7	13	400
Vogelsänger Gold	– (7)	0.1	0.1	0.6	3.2	215
Banteng	– (7)	0.7	0.9	0.5	3.4	110
W.B. 5-52	– (2)	0.2	0.4	0.5	4.0	46
Regia	– (33)	0.02	0.00	0.1	1.2	7
Almersfelder	– (3)	0.1	0.05	0.2	0.4	7
Hauters	– (21)	0.4	0.04	0.1	0.5	10
Jumbo	– (10)	0.1	0.3	0.5	2.0	14
Pella	– (33)	0.2	0.1	0.1	0.8	13
Herfordia	– (15)	0.1	0.02	0.1	0.6	6
Melior	– (43)	0.00	0.00	0.2	0.3	6

[a] Not determined.

Tabel 2. Aantal dwergroestsporehoopjes per scheut of halm op 11 wintergerstrassen op twee plaatsen tijdens de winter en het voorjaar van 1977. Het percentage door meeldauw aangetast blad in december is tussen haakjes aangegeven.

The amount of powdery mildew present in December varied considerably with cultivars (Table 2). The amount of powdery mildew decreased steadily from December onward, the amounts being insignificant in the spring. The mean leaf areas affected over the 11 cultivars in December, January, March and April were 17.4, 8.1, 6.4 and 0.8% for the clay site and 15.9, 4.8, 5.0 and 0.7% for the sandy site, respectively.

Experiment 2. The cultivars did not differ significantly (P = 0.01) for the number of leaf rust pustules with the exception of the June sampling. Here Vögelsänger Gold had significantly more leaf rust than the other cultivars, while Almersfelder

Table 3. Number of urediosori of leaf rust per shoot or tiller on six winter barley cultivars during the winter and spring of 1980.

	Sampling date					
	treatment A[a]				treatment B[a]	
	22-11	17-3	28-4	9-6	29-4	1-6
Dominator	17	34	16	47	2.8	22
Vogelsänger Gold	13	29	16	145	4.0	54
Banteng	10	13	18	44	1.1	23
Regia	15	33	28	78	7.2	17
Almersfelder	15	25	21	22	1.2	4
Herfordia	12	15	12	15	1.1	4

[a] Powdery mildew was kept at a low level by ethirimol in the autumn (treatments A and B). B was treated with Tridemorph on 16-4 to reduce the leaf rust population.

Tabel 3. Aantal dwergroestsporehoopjes per scheut of halm op zes wintergerstrassen tijdens de winter en het voorjaar van 1980.

and Herfordia carried significantly less leaf rust. The epidemic development in the spring, however, was very poor and rather irregular, resulting from prolonged dry weather (Table 3).

The measures to control powdery mildew were adequate. There was no powdery mildew of any significance in this experiment throughout the observation period. The calixin treatment (Table 3) did not succeed as hoped for. The leaf rust levels though reduced, kept varying with the cultivars as shown by the data of the sampling on 29-4.

Discussion

The decline in leaf rust during the winter of 1972/1973 reported by Parlevliet and Van Ommeren (1976) was reproduced in 1976/1977. The cultivar and site effects in the two winters resembled each other strongly. The 1976/1977 experiment gave the impression that the differential overwintering of leaf rust on barley cultivars was negatively related to the powdery mildew and positively related to the leaf rust present at the start of the winter. The regression equation supports this view, the influence of powdery mildew and leaf rust (coefficients -0.97 and $+1.20$ respectively) being of a similar magnitude. The multiple correlation of 0.93 between the values predicted from the December observations and the March observations suggests that the overwintering of leaf rust is affected mainly by the initial leaf rust and powdery mildew populations. This is not difficult to explain. Leaves which are affected by both pathogens turn yellow and die faster than leaves affected by leaf rust alone. Leaves with sporulating urediosori of leaf rust are shed earlier when the plants are more heavily infected with powdery mildew. This results in a reduced spread of the rust.

The observations of experiment 2 are consistent with a strong effect of powdery mildew on the overwintering of leaf rust. In the absence of powdery mildew there was neither a decline in the leaf rust population nor was there a differential cultivar effect on overwintering as in the former experiments. However, it cannot be ruled out that the observations in this experiment differ from those of the other experiments because of interactions between leaf rust and the winters itself. The three experiments were done in three winters, which, although all being normal winters, had their own peculiar weather patterns.

From the two experiments reported here and the one reported by Parlevliet and Van Ommeren (1976) it is clear that winter barley cultivars differ widely in susceptibility (or its reverse, partial resistance) in the same way as spring barley cultivars (Parlevliet and Van Ommeren, 1975). Vogelsänger Gold is the most susceptible cultivar (Table 3), although in experiment 1 Dominator had more leaf rust than Vogelsänger Gold in June. This higher level was due to the earlier start of the epidemic in Dominator. The multiplication factor between the last two samplings (Tables 2) gives a better indication of the level of partial resistance. For Vogelsänger Gold this was 75 × (average over the two sites), for Dominator 26 ×. Even 'Banteng' might be slightly more susceptible than Dominator with a multiplication factor of 39 ×. 'WB 5-52' is probably of a similar level of susceptibility as Dominator. The other cultivars have a fair level of partial resistance.

The ultimate level of leaf rust in winter barley appears to be the result of several characteristics; the susceptibility to leaf rust and the susceptibility to powdery mildew determine the amount of leaf rust that overwinters. This is the initial inoculum from which the epidemic develops. The ultimate level then depends on this initial inoculum, the moment the epidemic starts (cultivars appeared to differ for this too) and the rate at which the epidemic develops (the partial resistance of the cultivar).

Samenvatting

De ontwikkeling van de dwergroestpopulatie (Puccinia hordei) tijdens winter, voorjaar en vroege zomer in 11 wintergerstrassen

De overwintering en de epidemiologische ontwikkeling in het voorjaar van dwergroest werd bestudeerd aan 11 wintergerstrassen op twee verschillende plaatsen nabij Wageningen in 1976/1977. De hoeveelheid dwergroest nam op beide plaatsen af gedurende de winter. De rassen verschilden aanzienlijk in de dwergroestniveaus direct na de winter (maart). Het moment waarop de dwergroestpopulatie begon toe te nemen en de snelheid waarmee dit gebeurde varieërde met het ras. Het uiteindelijke dwergroestniveau in een ras werd zodoende bepaald door drie factoren: de mate waarin de dwergroest overwinterde op dat ras, het moment waarop de dwergroestpopulatie ging toenemen en de snelheid waarmee de dwergroest toenam. Dit laatste werd bepaald door de partiële resistentie van het ras. De differentiële raseffecten op de overwintering zijn te verklaren uit de meeldauw- en dwergroestaantastingen bij het begin van de winter. De invloed van de meeldauw was een negatieve. De multipele correlatiecoëfficiënt tussen de dwergroestwaarden waargenomen in maart en de

waarden voorspeld uit de meeldauw- en dwergroestaantastingen in december was 0.93.

In een tweede experiment, uitgevoerd in 1979/1980 met zes wintergerstrassen uit proef 1, werd de meeldauw met succes buitengesloten. Er was geen afname in de dwergroestpopulatie tijdens de winter. Ook was er geen differentiëel raseffect op de dwergroestoverwintering.

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