Neth. J. Pl. Path. 94 (1988) 69-80

Effects of nitrogen fertilization and cultivar on the damage relation of powdery mildew (Erysiphe graminis) in winter wheat

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Accepted 4 September 1987

Abstract

The damage relation of powdery mildew in winter wheat was studied in field experiments in 1981 and 1983, in the Netherlands. No firm conclusion was obtained on the effect of nitrogen supply (175 and 235 kg ha^{-1} N totally) on the damage relation. The relation was not affected by cultivars (four) and did not differ significantly between both years. The measured relation averaged 0.0125 kg are^{-1} damage per pustule-day mildew per leaf, at yields of 70-90 kg are^{-1}. The effect of the fungicide triadimefon on yield could be ascribed to its effect on diseases. The vertical distribution of mildew in the crop was described.

Additional keywords: Triticum aestivum, epidemiology, vertical distribution, AUDPC-value, tolerance, integrated control, *Mycosphaerella graminicola*, triadimefon.

Introduction

Powdery mildew epidemics in winter wheat reduce yield. The three yield components, tiller number, grain number and kernel weight may be affected by mildew (Royse et al., 1980). The damage (kg or percentage yield reduction) depends on the intensity of the epidemic (Large and Doling, 1963) and on the location of mildew in the crop (Rabbinge et al., 1985). Cultural practices such as the use of resistant cultivars (Wolfe, 1983), application of fungicides, split or lowered nitrogen applications (Last, 1954 and 1962) reduce the intensity of mildew epidemics and thus reduce damage caused by mildew. The question arose whether this reduction of damage can be ascribed totally to the reduction in intensity of the epidemic or whether the damage relation depends also directly on nitrogen application or cultivar. If the damage relation of powdery mildew is independent of these cultural practices, models which describe their effects on yield and on intensity of mildew may be easily connected by means of a simple damage function, for application in supervised or integrated control systems.

Two field experiments were done to determine whether the damage relation of powdery mildew in winter wheat depends on nitrogen supply or cultivar. Attention is given to the location of mildew in the crop.

Materials and methods

The experiments were carried out at the farm 'De Bouwing' near Wageningen, situated

Table 1. Experimental conditions of the nitrogen and cultivar field experiment with winter wheat.

	Nitrogen experiment	Cultivar experiment
Cultivar	Okapi	four different
Sowing date	16 Oct. 1980	25 Oct. 1982
Seed rate	300 grains m^{-2}	330 grains m^{-2}
Row distance	12.5 cm	15 cm
Nitrogen in January (0-1 m)	80 kg ha^{-1} N	45 kg ha^{-1} N
Nitrogen applications	24 Febr. 65 kg ha^{-1} N 21 May, two levels	17 Febr. 60 kg ha^{-1} N 6 May, 60 kg ha^{-1} N
Chlormequat	23 April and 8 May, CCC 1 l ha^{-1}	6 May, CCC 1 l ha^{-1}
Control of:		
mildew	two levels	two levels
foliar diseases	23 June, 3 kg ha^{-1} maneb and carbendazim (Bavistin-M 72)	10 June, 2 kg ha^{-1} captafol (Ortho-Difolatan-80) 23 June, 2 kg and 1 l ha^{-1} captafol and fenpropimorph (Corbel)
aphids	23 June, 0.25 kg ha^{-1} pirimicarb (Pirimor)	24 June, 0.25 kg ha^{-1} pirimicarb (Pirimor)
Design	completely randomized block	split-plot; cultivars on main plots and mildew treatment on plots
Replications	6	6
Plot size	7.5 × 6.2 m^2	8 × 7 m^2
Net plot size	5.7 × 4.2 m^2	6 × 4.5 m^2
Harvest date	12 August 1981	4 and 8 August 1983

on heavy clay soil (50-60% clay). Usually, moderate mildew epidemics occur on this farm. The experimental conditions of the nitrogen experiment in 1981 and the cultivar experiment in 1983 are given in Table 1. Nitrogen was applied as calcium ammonium nitrate. In both experiments, fungicides were sprayed in June (Table 1) to control foliar diseases and to preserve the effects of the mildew treatments before that moment.

Nitrogen experiment, 1981. In the nitrogen experiment the spontaneous infection of mildew was supplemented by planting three mildew infected plants per plot on 3 April, 1981. To create different mildew epidemics, treatments with the fungicide triadimefon (0.5 kg ha^{-1} Bayleton) and application of nitrogen in plots with a full (F) and without (O) mildew control and with a high (H) and low (L) nitrogen top-dressing were:

	13 May	21 May	3 June
F + L	triadimefon	30 kg ha^{-1} N	triadimefon
O + L	—	30 kg ha^{-1} N	—
F + H	triadimefon	90 kg ha^{-1} N	triadimefon
O + H	—	90 kg ha^{-1} N	—

Cultivar experiment, 1983. On 15 April 1983 eight mildew infected plants per subplot of cultivar Okapi were planted to supplement the spontaneous mildew infection. Three commercial cultivars were used of different origin and susceptibilities to mildew and one line (SVP7348/5/4) was used because of its low susceptibility. The latter was kindly provided by the Foundation for Agricultural Plant Breeding (SVP). The origin of the cultivars and the line is:

Nautica	Mildress × Manella, crossed in 1962
Arminda	Carsten 854 × Ibis, crossed in 1963
SVP7348/5/4	(Record × Vogel 219) × (Record × Vogel 219), crossed in 1973
Durin	<(Vilmorin 29 × Vg 8058) × Cappelle Desprez> × [<(Cl 12633 × Cappelle Desprez^{4}) × (Heine 110 × Cappelle Desprez)> × Nord Desprez], crossed in 1966

To create different mildew epidemics, treatments with triadimefon in plots with (F) and without (O) mildew control were carried out on 6 May and 10 June.

Disease assessment. Diseases were assessed on samples of 15 tillers per plot, taken from the area to be combine-harvested. The nitrogen experiment was sampled on 13 May (DC 32, Zadoks et al., 1974), 2 June (DC 47), 23 June (DC 69) and 7 July (DC 75). During the last three dates, 10 tillers per plot were sampled. On 23 July (DC 83) lodging was assessed. The cultivar experiment was sampled on 10 May (DC 31), 26 May (DC 33), 8 June (DC 47), 22 June (DC 69) and 4 July (DC 73).

For each green and fully unfolded leaf, the number of mildew pustules at the upper surface was counted and averaged for eacht leaf position (Daamen, 1986). The percentage leaf area, without clorosis, with speckled leaf blotch (*Mycosphaerella graminicola* (*Septoria tritici*)) was estimated. These were main diseases in both experiments. Mildew intensity on ears was below one pustule per ear and other ear diseases were virtually absent in both experiments. In the nitrogen experiment, leaf rust (*Puccinia recondita*) severity was low, 0.02% on the second leaf on 4 July. This late attack did not show any significant effect of the triadimefon applications. In the cultivar experiment, 8% of the tillers were infected by eyespot (*Pseudocercosporella herpotrichoides*) and 3% by *Fusarium* brown footrot on 1 May. The damage caused by these diseases is neglected as disease intensities were low. Moreover, these foot diseases are insensitive to triadimefon thus their intensities will be independent of the treatments against mildew. Thus it is assumed that yield reduction in the experiments is only due to mildew and speckled leaf blotch; the damage caused by other diseases is neglected.

Computations. To summarize the disease intensities during the growth period, disease intensity was averaged over leaf positions and the area under the disease progress curve (AUDPC-value in disease-days per leaf) was calculated. In the nitrogen experiment, there was hardly any mildew in the plots on 5 May. That date was taken as starting date of the epidemic. It is assumed that kernel filling stops and all leaves are dead at early dough (DC 83), so 21 July was taken as the end of the epidemic. In the cultivar experiment, 1 May was taken as the start and 26 July as the end of the epidemic, for the same reasons. Yields were standardized at 16% moisture content.

Analyses of variance and covariance designs were done with Genstat V. Analysis of variances were followed by a least significant range test; Tukey's w-procedure. Residuals were inspected on heteroscedasticity and when necessary, variables were transformed to stabilize variances. One plot of the nitrogen experiment (F +H) was ecluded from the analyses. The yield of this plot (65.6 kg are^{-1}) was very low because of heavy lodging (60%).

Results

Mildew epidemics. The course of the mildew epidemics in the nitrogen experiment is shown in Fig. 1. An effect of the nitrogen treatment was absent ($p > 0.05$). Mildew control by triadimefon on 13 May and 3 June was nearly complete. Mildew intensity in the untreated plots was rather stable from 13 may to 23 June. The decrease in intensity at the end of the season is mainly caused by the dying of the diseased third leaf.

The course of the epidemics in the cultivar experiment is shown in Fig. 2. The mildew intensities in cv. Arminda and the SVP-line did not differ ($p > 0.05$). Mildew control by triadimefon on 6 May and 10 June, though not complete, decreased mildew intensities during the whole period ($p < 0.01$), except at the first observation on 10 May. Average disease intensity increased in May and was rather stable from 26 May to 8 June, when the healthy flag leaf appeared and the diseased fifth leaf died. Mid June, mildew intensity increased despite the dying of the diseased fourth leaf. From 23 June to 4 July, mildew intensity decreased due to the partial dying of the diseased third leaf and the overall treatment with fenpropimorph on 23 June.

Differences in partial resistance to the local mildew population caused three different types of mildew epidemics. Nautica had less mildew on 10 May than the other cultivars

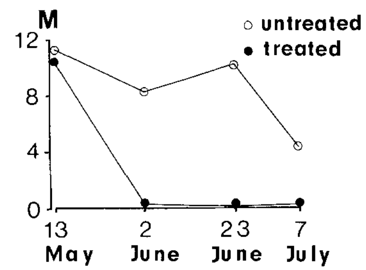


Fig. 1. Course of mildew epidemics (M is average pustule number per leaf) in treated and untreated plots of winter wheat cultivar Okapi in 1981.

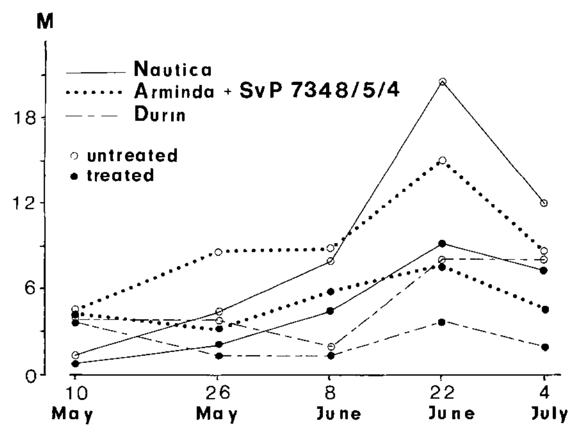
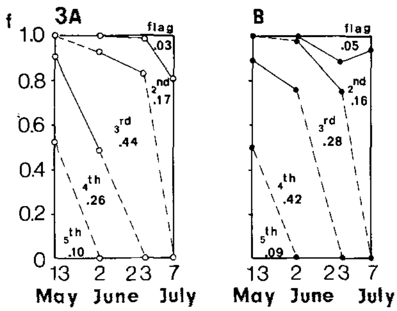


Fig. 2. Course of mildew epidemics (M is average pustule number per leaf) in treated and untreated plots of different winter wheat cultivars in 1983.

(p < 0.01), but intensity grew steadily and in July Nautica had the highest disease intensity. Durin showed the opposite trend, starting with a mildew intensity comparable to those in Arminda and the SVP-line, but decreasing in May. On 8 June, Durin had less mildew than the other cultivars ($p < 0.01$). The course of the epidemics in Arminda and the SVP-line was intermediate.

Location of mildew in the crop. Fig. 3 and 4 show the cumulative vertical distribu-



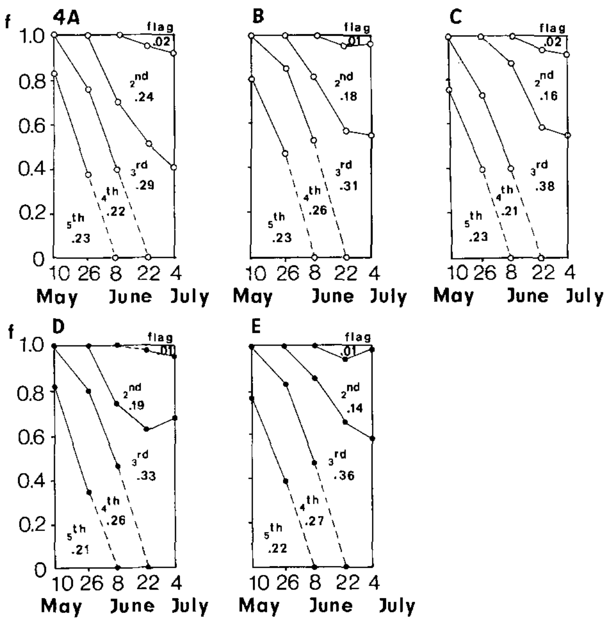


Fig. 3. Cumulative vertical distribution of mildew in an experiment with winter wheat cv. Okapi, 1981. Pustule number per leaf, expressed as a fraction (f) of the total pustule number per tiller in untreated (3a) and treated (3b) plots. Broken lines are extrapolations. The entries represent the average fraction per leaf during the observation period.

Fig. 4. Cumulative vertical distribution of mildew in an experiment with different winter wheat cultivars, 1983. Pustule number per leaf as a fraction (f) of the total pustule number per tiller in untreated plots of cv. Nautica (4a), Arminda and SVP7348/5/4 (4b) and Durin (4c) and in treated plots of cultivars Nautica and Arminda (4d) and Durin and SVP7348/5/4 (4e). Broken lines are extrapolations. The entries represent the average fraction per leaf during the observation period.

tion of mildew in the nitrogen and cultivar experiment, respectively. Only treatments with significant effects ($p < 0.05$) are shown. As example to read the figures, see Fig. 3a; on 2 June the fifth leaf is dead, the 4th leaf carried 0.50 proportion of the mildew of the whole culm, the 3rd carried 0.43 proportion, the 2nd 0.07 and the flag leaf was clean. In the untreated plots, both in 1981 and 1983, mildew on the third leaf was predominant within the period of measurements. In 1981 this domination was more pronounced as it was in 1983, presumably because the epidemic in 1981 was early and heavy relative to 1983. In both years, mildew treatments changed the location of mildew in the crop slightly ($p < 0.05$). In treated plots, mildew on upper leaves, the third in 1981 and flag and second in 1983, was relatively less and on the fourth leaf more than in the untreated plots. This effect was more pronounced in 1981 than in 1983. The cultivars showed small differences in the location of mildew in the crop ($p < 0.05$), corresponding with differences in growth curves of their epidemics. An early attack will infest lower leaves, a late attack upper leaves. The second leaf of Nautica and the third leaf of Durin had relatively more mildew than on Arminda and the SVP-line (Fig. 4a, b, c). The mildew epidemic in Nautica was relatively late and in Durin relatively early (Fig. 2). This effect is strengthened by differences in growth rhythm of the cultivars; Nautica is early heading and Durin late, Arminda intermediate. Accordingly the mildew epidemic in Nautica was late compared to that in Durin. In the treated plots, the same trend was observed.

Yield and disease intensities. Yields, summarised disease intensities (mean number of disease-days per leaf) and lodging are given in Tables 2 and 3 for the nitrogen and cultivar experiment, respectively. In the experiment of 1981, late nitrogen application (30 or 90 kg ha^{-1} N on 21 May) had no significant effect on yield, mildew or speckled leaf blotch intensities, while fungicide treatment was significant and prevented a damage of 6.1 kg are^{-1} (SE = 0.8). Mildew and speckled leaf blotch intensities were positively correlated ($r = 0.73$) and showed negative correlations with yield; $r = -0.83$ and $r = -0.65$ for mildew and speckled leaf blotch respectively. Nitrogen reduced the yield component kernel weight in untreated plots, presumably by an increase of the number of grains per unit area.

Table 2. Yield, grain weight, disease intensities of powdery mildew and speckled leaf blotch and percentage lodging of sprayed (F) and unsprayed (O) winter wheat at two different nitrogen levels (H = high, L = low). Entries are mean values of six replications.

Treatment	Yield[1]	Grain weight[2]	Mildew[3]	Leaf blotch[4]	Lodging
F + L	76.7a[5]	49.7a	151a	46a	23a
O + L	71.0b	48.7a	580b	117b	14a
F + H	78.8a	49.5a	156a	41a	30a
O + H	71.9b	46.3b	600b	122b	26a

[1] In kg are^{-1}.
[2] In mg.
[3] In pustule-days per leaf.
[4] In percent-days per leaf.
[5] Different letters indicate significant ($p < 0.05$) differences between treatments within colums.

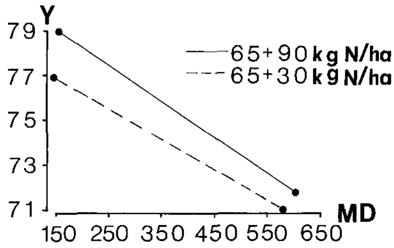
Table 3. Yield, grain weight, disease intensity of powdery mildew and of speckled leaf blotch in sprayed (F) and unsprayed (O) plots of four different cultivars of winter wheat. Entries are mean values of six replications, split plot design.

Cultivar	Treatment	Yield[1]	Grain weight[2]	Mildew[3]		Leaf blotch[4]	
Nautica	O	80.2	40.6	649	(6.5)[6]	142	(5.0)[6]
Nautica	F	86.4	40.9	332	(5.8)	108	(4.6)
Arminda	O	79.0	33.0	588	(6.4)	131	(4.9)
Arminda	F	84.7	33.9	378	(5.9)	85	(4.4)
SVP7348/5/4	O	76.6	34.8	711	(6.6)	176	(5.2)
SVP7348/5/4	F	82.4	36.5	358	(5.8)	138	(4.9)
Durin	O	85.8	36.5	395	(6.0)	159	(5.0)
Durin	F	89.1	37.4	180	(5.1)	123	(4.8)
SED between varieties		1.3	1.9		(0.14)		(0.10)
SED within a variety		1.0	1.5		(0.14)		(0.09)

Notes [1] to [4], see Table 2.
[6] log transformed disease intensities.

In the cultivar experiment of 1983, fungicide and cultivar treatment was significant, their interaction was not significant ($p > 0.05$). Durin yielded more than the other cultivars, whereas the SVP-line yielded less. Two times control of mildew prevented a damage of 5.2 kg are^{-1} (SE = 0.5). Arminda had relatively less speckled leaf blotch. Mildew and speckled leaf blotch were positively correlated ($r = 0.48$), mildew was negatively correlated with yield ($r = -0.68$), the correlation between yield and speckled leaf blotch was not significant ($p > 0.05$). Kernel weight of Nautica was higher than of the other cultivars. Fungicide treatment did not significantly affect kernel weight, indicating that damage by diseases occurred before kernel filling.

Different damage relations. In Fig. 5 and 6, mean yield per treatment is plotted against mildew intensity in pustule-days. Analysis of covariance were applied to study these relations, taking into account the correlation between mildew and speckled leaf blotch. Tests were performed on the significance of average relations between yield and the diseases and on the significance of different damage relations, due to nitrogen (Table 4, 1981) and cultivar (Table 5, 1983). Corrections were applied for the experimental design. In these analyses, damage relations were assumed to be linear. No tendency of heteroscedasticity or curvilinearity was detected in residuals. The combined effect of diseases on yield was significant (row 4, Tables 4 and 5) in both experiments. The partial effect of mildew on yield was significant, in both years ($p < 0.001$, row 4b). Speckled leaf blotch showed only a significant partial effect in 1983 ($p < 0.05$, Table 5, row 4a). Damage caused by the diseases is mainly attributed to mildew and not to speckled leaf blotch. Interactions of the damage relations with nitrogen or cultivar were not significant ($p > 0.05$, Table 4 and 5 row 6). In other words, the damage relations of mildew and speckled leaf blotch were independent of the nitrogen and cultivar treatment. Tests on interactions between mildew and speckled leaf blotch were not significant (row 8), so at these disease intensities the damage relations of the two diseases



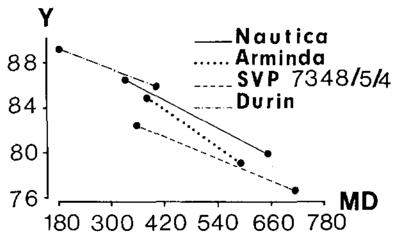


Fig. 5. (Left) Yield (Y, in kg are^{-1}) in relation to mildew intensity (MD, in pustule-days per leaf), assuming linearity, at two different nitrogen levels, 1981. Dots represent mean yields, not corrected for covariates.

Fig. 6. (Right) Yield (Y, in kg are^{-1}) in relation to mildew intensity (MD, in pustule-days per leaf) assuming linearity, for four different winter wheat cultivars, 1983. Dots represent mean yields, not corrected for covariates.

Table 4. Analysis of variance on yield to test for interactions of damage by diseases and nitrogen.

Source of variation[1]	df		SS	MS	F[2]
1. H	5		23.1	4.6	
2. N	1		6.2	6.2	
3. L	1		25.9	25.9	
4. MD + ST	2		217.0	108.7	43.3 ***
4a. ST adj. MD		1	0.1	0.1	0.0 ns
4b. MD adj. ST		1	67.9	67.9	27.0 ***
5. Residual	13		32.6	2.5	·
6. Interactions ST.N + MD.N	2		11.6	5.8	3.0 ns
6a. ST.N adj. MD.N		1	3.3	3.3	1.7 ns
6b. MD.N adj. ST.N		1	0.5	0.5	0.3 ns
7. Residual	11		21.0	1.9	
8. Interaction MD.ST	1		0.1	0.1	0.0 ns
9. Residual	10		20.9	2.1	
10. Total	22		305.1	13.9	

[1] H = replications; N = nitrogen treatments; L = % lodging; MD = pustule-days mildew; ST = %-days leaf blotch; R = cultivars.
[2] ns = not significant ($p > 0.05$); * = $p < 0.05$; *** = $p < 0.001$.

may be considered independent.

Yield estimates of the three commercial cultivars, without disease were nearly equal (ca. 94 kg are^{-1}). The high yield of Durin, compared to Nautica and Arminda, can be ascribed to its relatively high mildew resistance. Durin without protection had nearly the same mildew intensity and yield as Nautica and Arminda with two fungicide applications (Fig. 6).

Slope of the damage relations. The estimates of the partial effects of mildew and speckled leaf blotch which deviated signifcantly from zero ($p < 0.05$) are given in Table

Table 5. Analysis of variance on yield to test for interactions between damage by diseases and varieties.

Source of variation[1]	df		SS	MS	F[2]
1. H	5		27	5.4	
2. R	3		402	134.1	
3. H.R	15		113	7.5	
4. ST + MD	2		307	153.5	33.4 ***
4a. ST adj. MD		1	20	19.8	4.3 *
4b. MD adj. ST		1	71	70.6	15.4 ***
5. Residual	22		101	4.6	
6. Interactions ST.R + MD.R	6		33	5.5	1.2 ns
6a. ST.R adj. MD.R		3	22	7.5	1.8 ns
6b. MD.R adj. ST.R		3	12	3.9	0.9 ns
7. Residual	16		68	4.2	
8. Interaction MD.ST	1		0	0.1	0.0 ns
9. Residual	15		68	4.5	
10. Total	47		950	20.2	

Notes [1] and [2], see Table 4.

Table 6. Estimated damage (kg are^{-1}) per pustule-day mildew per leaf and percent-day speckled leaf blotch per leaf, assuming linearity and their standard errors.

	Experiment 1981	Experiment 1983
All leaves:		
mildew	0.013 (0.002)	0.012 (0.003)
leaf blotch	ns	0.040 (0.019)
Top three leaves:		
mildew	0.014 (0.003)	0.013 (0.003)
leaf blotch	ns	ns

ns = not significant ($p > 0.05$).

6, for all and for the top three leaf positions. Comparison of the estimates of the damage per pustule-day mildew, assuming a linear damage relation, show that they did not differ significantly when all leaves or top three leaves were compared. The estimates of 1981 in cv. Okapi did not differ significantly from those of 1983, in cultivars Nautica, Arminda, Durin and the SVP-line.

Neglecting other effects of fungicides. The analyses above assume that fungicide treatment affect yield only by reducing intensities of mildew and speckled leaf blotch. Other diseases, phytotoxic or stimulating effects of fungicides are neglected. An impression of the validity of these assumptions can be obtained when the effect of fungicides on yield in anova design is compared with the effect of diseases on yield in analysis of covariance. If triadimefon determines yield not only through mildew and speckled leaf

Table 7. R^2 values of the yields explained by the fungicide treatments (anova) or by the main diseases (linear regression of mildew and speckled leaf blotch).

	Experiment 1981	Experiment 1983
Fungicides	0.84	0.93
Diseases	0.89	0.89

blotch, then a greather percentage of the yield variation should be explained by mildew treatment compared to disease intensity (Table 7). The R^2 values were high, ranging from 0.84 to 0.93, and did not differ much between both types of analyses. Thus it can be concluded that the diseases mildew and speckled leaf blotch and the fungicide treatment explained in statistical terms an equal part of the yield differences.

Discussion

Two applications of triadimefon gave nearly complete mildew control in 1981, despite the high mildew intensity at onset of the epidemic. In 1983 the spraying was not that successfull, even though mildew intensity was lower. This effect was also observed in commercial fields and attributed to a decrease in mildew sensitivity to triadimefon in 1983 (De Waard et al., 1986). Moreover the effectivity of triadimefon was lower due to the cold and wet weather in spring 1983 compared to 1981 (Kuck, 1987).

Darwinkel (1980) found effects of different nitrogen applications on winter wheat yield and on mildew intensity, in field experiments in the Netherlands. No significant effects of different late nitrogen applications on yield and mildew intensity were found in the experiment described above. It is likely that the fertilizer was available for the crop, as precipitation in May after the 21th was 38 mm. The nitrogen treatment showed a significant effect on grain weight, indicating that the treatment resulted in a different uptake of nitrogen by the crop. Total nitrogen supply was high, 175 kg ha^{-1} N in the low and 235 kg ha^{-1} N in the high nitrogen treatment. In commercial fields of the Netherlands, total nitrogen supply (including available nitrogen in the soil) was about 220 kg ha^{-1} N in 1983. Presumably, the effect of nitrogen on mildew is negligible at these high application levels, but no firm conclusion can be drawn from the nitrogen experiment, as nitrogen concentration and distribution in the crop were not measured. In 1983, the cultivars sustained three different mildew epidemics, reflecting the differences in partial resistance to the local mildew population. The cultivars did not show significant different damage relations to mildew.

The question is whether this conclusion can be extrapolated to all commercial cultivars in the country, in the scope of integrated control. In literature on disease management, no connection with this question was found. In resistance breeding this question concerns the concept of tolerance and the conclusion above state that cultivars were equal in tolerance (Schafer, 1971) to mildew. Gaunt (1981) discussed the concept and questioned whether true tolerance (Schafer, 1971) in fact exists. He suggests to measure disease by several different parameters, including chlorosis, senescence, leaf area and other plant fysiological functions; the whole syndrome. I agree with Gaunt, that the term tolerance to disease (the whole syndrome) is then redundant and the term tolerance to pathogens may be restricted to the study of the relation between the pathogen and the syndrome. As only pustule number was determined in this study, no conclusion on tolerance to mildew (interpretation Gaunt, 1981) of the tested cultivars can be made. Whichever terminology is used, the cultivars did not show significant different damage relations to powdery mildew intensity and the above raised question remains to be answered.

Kramer et al. (1980) give support for this extrapolation. One may reason that plant breeders select high yielding cultivars which are exposed to mildew. As a consequence, they select indirectly for less negative slopes of damage relations and differences between slopes are eliminated. Therefore, it seems reasonable to assume that all partially resistant commercial cultivars in the country have the same damage relation to their mildew strains. One might speculate, that completely resistant cultivars escaped such an indirect selection and might show more negative slopes of their damage relation when attacked by a new mildew strain.

The slopes of the two measured damage relations in both years, assuming linearity, did not differ significantly and averaged 0.0125 kg are^{-1} per pustule-day mildew per leaf, from first node stage onwards, at yields of 70-90 kg are^{-1} in the Netherlands. The measured damage cannot be explained by a reduction of weight per kernel, as in the cultivar experiment no significant effect of diseases on grain weight was found. Further analysis showed that the partial effects of the main diseases on yield adjusted for grain weight were significant ($p < 0.001$) in both experiments. So it is indicated that the damage by mildew and speckled leaf blotch is caused by a reduction of the grain number per unit area, in these experiments.

The vertical distribution of mildew depended on cultivar, but this was not exclusively a cultivar effect. It was indicated that the mildew location in the crop depended mainly on the moment of mildew infection in the ontogeny of the crop. In integrated control systems, the choice of resistant or partially resistant cultivars is a prerequisite. Inputs such as fertilisers and fungicides are minimized, maximizing net yield. All input factors can affect yield directly and also indirectly through effects on disease intensity. The study of the impact of all these factors and their interactions on yield in field experiments is complicated (Walters et al., 1984 and Widdowson et al., 1982). The present study indicates that the direct effects of cultivars, and presumably also of late nitrogen application at high fertilization levels, on yield do not interact with their indirect effects through powdery mildew. The fungicide triadimefon affected yield only through its effect on diseases in this study. Crop models, which describe or explain the quantitative effects of inputs on yield, and epidemiological models, which describe the effects of these cultural practives on mildew, can then be connected by a simple damage function, to optimize the integrated control system.

Acknowledgements

The author wishes to thank professors R. Rabbinge and J.C. Zadoks for discussing and critically reviewing the manuscript and for the assistance of Mr G. van der Vliet, Mr A.K. van Harxen and Mr W.A. Wietsma during the field work. The field work was financed by the Netherlands Grain Centre (NGC).

Samenvatting

Effecten van stikstofbemesting en ras op de schaderelatie van meeldauw (Erysiphe graminis) in wintertarwe

In 1981 en 1983 werd in veldproeven met wintertarwe de relatie tussen schade (in kg are^{-1}) en meeldauw onderzocht. Of de relatie onafhankelijk is van de stikstofbemesting (175 en 235 kg ha^{-1} N totaal), kon niet met zekerheid worden vastgesteld. De schaderelatie werd niet significant beïnvloed door de vier getoetste rassen. In de twee jaren werd een vergelijkbare schade van gemiddeld 0.0125 kg are^{-1} per puistdag meeldauw per blad gemeten, bij een opbrengstniveau van 70-90 kg are^{-1}. Tevens werd de locatie van meeldauw in het gewas beschreven.

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