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Surveys of cereal diseases and pests in the Netherlands. 4. Occurrence of powdery mildew and rusts in winter wheat

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Abstract

Results of annual surveys of winter wheat fields from 1974 to 1986 were compiled to describe epidemics of powdery mildew and rusts in relation to weather and cultivar resistance.

An average of 29 and 70% of fields were infected by powdery mildew in May and July, respectively. Mildew prevalence in May was positively correlated with average temperature in October and with average temperature over the months December, January, February and March. In addition, it was correlated negatively with the average grade of mildew resistance of the cultivars sown each year. Prevalence of mildew in July did not show consistent correlations with weather characteristics nor with mildew prevalence in May.

Yellow rust was usually not detected in May and on average 18% of the fields was infected in July. The occurrence of yellow rust decreased after 1977, when the farmers adopted cultivars resistant or moderately resistant to yellow rust.

Brown rust was usually not detected in May, while in July on average 48% of the fields was infected. Brown rust intensity in July was high in years with a high March temperature and high precipitation during April and May.

Black rust was rare in the Netherlands, with 3 and 1% of the fields infected in July 1977 and 1981, respectively.

Additional keywords: Triticum aestivum, Erysiphe graminis, Blumeria graminis, Puccinia striiformis, P. recondita, P. graminis, disease surveys, epidemiology, weather, resistance.

Introduction

Systematic annual surveys of diseases and pests in commercial winter wheat fields in the Netherlands were conducted during 1974–1986. A previous paper described winter wheat cropping and the surveyed fields (Daamen, 1990). This paper compiles the annual survey results to report the epidemics of powdery mildew (*Blumeria graminis* (DC.) Speer ≡ *Erysiphe graminis* DC. ex Merat), yellow rust (*Puccinia striiformis* Westend.), brown rust (*P. recondita* Rob. ex Desm.) and black rust (*P. graminis*

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Table 1. RIVRO disease resistance grades of winter wheat cultivars[a].

Cultivar[b]		1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Manella	M	5	5	5	5	5	5	5	–	–	–	–	–	–
	Y	8	8	8	8	7	6/6	6/6	–	–	–	–	–	–
	B	5	6	5	5	5	5	5	–	–	–	–	–	–
Caribo	M	4	4	4	4	4	4	4	4	4	4	–	–	–
	Y	6	7	7	7	6	6/5	6/5	6/5	6/5	6/5	–	–	–
	B	5	5	5	5	5	5	5	5	5	5	–	–	–
Lely	M	4	4	4	4	4	–	–	–	–	–	–	–	–
	Y	9	9	9	8	4	–	–	–	–	–	–	–	–
	B	7	5	5	5	5	–	–	–	–	–	–	–	–
Clement	M	8	7	5	5	4	3	3	–	–	–	–	–	–
	Y	9	6	4	4	4	4/3	4/3	–	–	–	–	–	–
	B	9	7	7	6	5	4	4	–	–	–	–	–	–
Okapi	M	–	–	–	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.5	5	5
	Y	–	–	–	7	6	6/5	6/5	6/5	6/5	6/5	6/5	6/5	5/5
	B	–	–	–	5	5	5	5	5	5	5	5.5	5.5	5.5
Arminda	M	–	–	–	7	7	6	6	6	6	6	6	6	6
	Y	–	–	–	8	8	8/7	8/7	8/7	8/7	8/7	8/7	9/7	9/7
	B	–	–	–	8	7	7	7	7	7	7	7	7	6.5
Nautica	M	–	–	–	6	6	6	6	6	6	6	6	–	–
	Y	–	–	–	7.5	8	8/8	8/6	8/6	8/6	8/6	8/6	–	–
	B	–	–	–	6	5	5	5	5	5	5.5	5	–	–
Donata	M	–	–	–	–	–	6	5	5	–	–	–	–	–
	Y	–	–	–	–	–	6/–	6/3	6/3	6/3	–	–	–	–
	B	–	–	–	–	–	6	6	6	6	–	–	–	–
Durin	M	–	–	–	–	–	7.5	7.5	7	7	–	–	–	–
	Y	–	–	–	–	–	8/6	8/6	8/6	8/6	–	–	–	–
	B	–	–	–	–	–	7	7	7	7	–	–	–	–
Marksman	M	–	–	–	–	–	–	–	7	7	7	7	7	8
	Y	–	–	–	–	–	–	–	7/6	7/6	7/6	7/6	7/6	7/6
	B	–	–	–	–	–	–	–	7.5	7.5	7	7.5	7.5	8
Saiga	M	–	–	–	–	–	–	–	–	6	6	6	6.5	6.5
	Y	–	–	–	–	–	–	–	–	7/6	7/6	7/6	7/6	7/6
	B	–	–	–	–	–	–	–	–	7.5	6.5	6.5	6.5	6.5
Citadel	M	–	–	–	–	–	–	–	–	–	6	6	6	6.5
	Y	–	–	–	–	–	–	–	–	–	7/7	7/7	7/7	7/7
	B	–	–	–	–	–	–	–	–	–	5	4	4	4
Granada	M	–	–	–	–	–	–	–	–	–	–	6.5	6	6.5
	Y	–	–	–	–	–	–	–	–	–	–	8/7	8/7	–/4
	B	–	–	–	–	–	–	–	–	–	–	8	8	8
Obelisk	M	–	–	–	–	–	–	–	–	–	–	–	–	6.5
	Y	–	–	–	–	–	–	–	–	–	–	–	–	8/7
	B	–	–	–	–	–	–	–	–	–	–	–	–	8

[a] A higher grade indicates greater resistance.

[b] Resistance grades for: M mildew; Y yellow rust; B brown rust. After 1977 two ratings are given for yellow rust, the first is the grade based on field performance of the cultivars in RIVRO trials, the second is the grade based on artificial infection with the cultivar- specific rust race.

Pers. ex Pers.) and to relate their performance to weather and cultivar resistance.

The intensity of mildew and rusts in May (first–second node stage) and in July (milky–ripe) is described in terms of disease prevalence (% infected fields) and mean disease incidence (average % infected leaves).

Materials and methods

Field selection and plant sampling were described in previous papers (Daamen, 1990; Daamen and Stol, 1990). Mildew and rust intensity was estimated in the plant samples consisting of 40–50 tillers per field.

Between 1974 and 1978, the number of leaf layers without mildew and the average mildew severity (% leaf surface diseased) of the first two infected leaf layers were recorded. Severity was recorded on a I–IV scale (0, 0–5, 5–25, > 25%). The percentage of plants with rust and the average rust severity (I–IV scale) of these plants were estimated. In 1979 and 1980, the severity of leaf diseases (as % leaf surface) was estimated. From 1981 onwards, disease incidence (% leaves with mildew or rusts) was determined. The method used to assess disease intensity on ears was described by Daamen et al. (1991).

For the May and the July surveys, the disease prevalence (% fields with disease) was determined. For the July surveys the estimates of disease intensity per field (severity or incidence) were averaged over the fields.

Computations. Correlation coefficients between the disease intensities and average monthly temperature (°C), total monthly precipitation (mm) and average monthly sunshine duration (expressed as percentage of average daylength), resistance of the cultivars and intensity of fungicide use were computed. The grade of disease resistance of the cultivars was obtained from the cultivar lists of the Government Institute for Research on Varieties of Cultivated Crops (RIVRO; Table 1). Correlation coefficients were also computed between disease intensity and weather characteristics averaged over months, if successive months indicated trends. High correlations were explored using a stepwise regression procedure. The result was compared to literature data. Because weather conditions were not experimentally controlled it is emphasised that obtained relations are correlative, and, because of the explorative way relations were analysed, it is not possible to compute statistical probabilities.

A problem arose in regressing mean annual disease intensity in July on other variates, because disease intensity on leaves in July was assessed as severity during 1975–1980 and as incidence during 1981–1986. Therefore, the estimates of mean annual severity during 1975–1980 were transformed to estimates of mean annual incidence. To perform this transformation, models of the form:

$$Y_i = (\mathrm{a} + \mathrm{b}X_{1i} + \mathrm{c}X_{2i})\cdot(1 + \mathrm{d}Z_i)$$

in which i is year, Y is mean annual disease severity (1975–1980) or mean annual disease incidence (1981–1986) and Z is unity for the years 1975–1980 and zero for the other years, were fitted by using least squares, with different sets of weather variates (e.g. X_1 and X_2).

Results and discussion

Intensity of Blumeria graminis. During 1974–1984, on average 29% of the fields surveyed in May at first–second node stage were infected by mildew (Table 2). In July, between 1974 and 1986, mildew on leaves was present in on average 70% of the fields, and on ears in 27% of the fields (Table 2). The incidence of mildew on ears was low and averaged 1% glumes between 1975 and 1986. On leaves, mildew intensity in July averaged 3% leaf surface (severity) between 1975 and 1980, and on average 13% of the leaves were mildewed (incidence) between 1981 and 86 (Table 2). Mildew intensity in July was comparable to that reported by King (1977), Marin (1985) and Lagneau et al. (1986).

Table 2. Prevalence (% fields infected) and mean severity or incidence (% leaf surface or % leaves infected) of powdery mildew and rusts on winter wheat during 1974–1986, and percentage fields sprayed to control leaf and leaf and ear diseases.

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Number of fields surveyed													
May	143	88	89	105	124	305	219	132	123	107	176	–	–
July	143	88	94	105	124	129	164	138	152	143	123	94	94
Prevalence on leaves													
May													
Mildew	26	12	20	61	–	17	38	38	1	47	27	–	–
Yellow rust	–	–	0	5	–	0	0	0	0	0	0	–	–
Brown rust	–	–	0	0	–	0	1	0	0	5	0	–	–
July													
Mildew	80	75	82	74	–	47	38	72	48	71	90	88	79
Mildew, ears	70	37	55	62	–	6	5	24	8	2	38	7	11
Yellow rust	22	74	8	58	–	2	1	6	4	19	7	12	4
Brown rust	55	39	14	73	–	43	39	82	69	92	15	32	26
Black rust	0	0	0	3	–	0	0	1	0	0	0	0	0
Mean severity/incidence on leaves[a]													
July													
Mildew	–	4	3	6	2	2	0	/12	7	9	22	13	14
Mildew, ears	–	4.9	0.6	3.3	0.4	0.0	0.0	0.7	0.0	0.1	1.0	0.7	0.1
Yellow rust	–	13	0	8	0	0	0	/ 0.4	0.6	1.9	0.6	0.9	0.4
Brown rust	–	0	0	4	2	1	0	/33	11	39	1	2	2
Fields sprayed (%) to control diseases of													
Leaf	9	41	21	63	–[b]	51	19	55	22	86	51	–	–
Leaf and ear	60	77	79	89	140	48	80	84	113	160	145	–	–

[a] 1975–1980 expressed as mean percentage of leaf surface diseased (severity); 1981–1986 as mean percentage of leaves with mildew or rusts (incidence).
[b] Sprays to control diseases were not separatedly recorded and were lumped under leaf and ear diseases.
– = no observation.

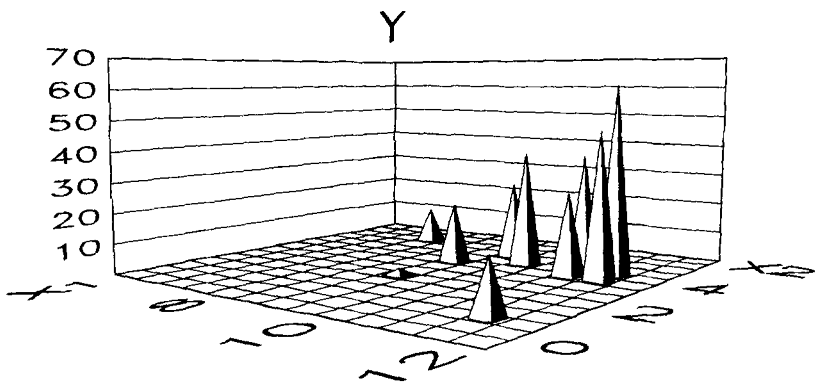

Fig. 1. Annual prevalence of mildew in May 1974–1984, 1978 missing (Y, percentage of surveyed fields with mildew), in relation to average temperature in October (X_1, °C) and average temperature over the months December, January, February and March (X_2, °C). Regression: $Y = -132 + 12X_1 + 10X_2$ ($R^2 = 0.83$)

Annual variation in B. graminis intensity. Annual mildew prevalence in May was positively correlated with average temperature in October (X_1) and with the average temperature over the months December, January, February and March (X_2; Fig. 1). High temperatures in October accelerate seedling and mildew development, so that more fields become infected (Last, 1953; Turner, 1956; Smedegard-Petersen, 1967; Yarham et al., 1971). Temperatures between January and March are below optimum (15–20 °C), hence high winter temperatures stimulate mildew development. In addition to both temperatures, a third factor (X_3), the average annual weighted mildew resistance grade of the cultivars, was negatively correlated with the prevalence of mildew in May. An increase of one unit in average resistance of the cultivars grown in the Netherlands was associated with a decrease in prevalence of mildew in May of 11%, hardly changing the effect of the two other factors (see Fig. 1):

$$Y = -69 + 12X_1 + 11X_2 - 11X_3 \qquad (R^2 = 0.94)$$

Mean mildew incidence in July on leaves between 1981 and 1986 and on ears between 1975 and 1986 in July was negatively correlated with average temperature during April, May and June ($r = -0.94$ and $r = -0.54$, respectively). Annual mildew prevalence on ears between 1975 and 1986 was negatively correlated with total precipitation in March, April, May and June ($r = -0.69$). Mean mildew severity in July on leaves between 1975 and 1980 was not correlated with temperature nor with precipitation during these periods. Thus, mean annual mildew intensities in July on leaves and on ears did not show consistent correlations with weather conditions, nor with mildew prevalence in May, nor with the average annual weighted mildew resistance grade of the cultivars. The lack of consistent correlations may be due to the different types (Daamen, 1990) and amounts (Table 2) of fungicides that were used between 1974 and 1986.

Table 3. Mean incidence of mildew on leaves in July(% leaves with mildew) per cultivar in the years 1981 – 1986.

Cultivar	1981	1982	1983	1984	1985	1986
Okapi	18.0	13.4	15.8	31.5	15.4	24.5
Arminda	7.0	4.6	8.3	17.9	16.4	5.6
Nautica	7.8	–	–	–	–	–
Marksman	7.2	1.2	0.2	–	–	–
Saiga	–	1.5	5.5	7.4	–	–
Citadel	–	–	6.3	19.7	–	–
Granada	–	–	–	19.1	4.9	–
Obelisk	–	–	–	–	–	8.2

Mildew resistance. As was described above, the average annual weighted mildew resistance grade of the cultivars grown was negatively correlated with mildew prevalence in May, but not with mildew severity in July. Winter wheat cultivars vary from susceptible to moderately susceptible to mildew (Table 1). At their release, they are most often already susceptible to mildew, whilst being resistant to yellow rust. Exceptions were the cultivars Clement, Arminda, Donata and Durin, whose partial mildew resistance declined in 2 – 4 years after their release (Table 1). This is a common phenomenon in the cereal – mildew pathosystem (Wolfe, 1984; Barrett, 1988). Surveys of *B. graminis* races and information on cultivar resistance to them are not available in the Netherlands. The mean incidence of mildew in the different cultivars during July 1981 – 1986 are given in Table 3. 'Okapi', the most susceptible cultivar in that period (grade 5), was usually more mildewed than the other cultivars (grades 6 – 7), except in 1985, when the mildew intensity in 'Arminda' was comparable.

Intensity of Puccinia striiformis. Yellow rust was usually absent on the plant samples in May, except in 1977, when 5% of the fields was infected (Table 2). Between 1974 and 1986, the percentage fields infected with yellow rust in July averaged 18%. Between 1974 and 1980, yellow rust intensity in July averaged 3.5% of the leaf surface (severity) and between 1981 and 1986 1% of the leaves (incidence). This intensity was comparable to that recorded in England and Wales between 1970 and 1975 (King, 1977) and in Andalusia between 1980 and 1983 (Marin, 1985).

Annual variation in P. striiformis intensity. In May between 1976 and 1984, yellow rust was only significant in 1977. Between 1976 and 1984, the highest average temperature during February and March (5.7 °C) and the lowest in April (6.5 °C) occurred in 1977. Thus, average temperature over 3 months was slightly below 7 °C which is optimal for yellow rust development (Sharp, 1965; Coakley, 1978; Coakley et al., 1988). Moreover, in 1977, 90% of the area was sown with susceptible cultivars, which also explains the appearance of yellow rust. The most common cultivars in that year were 'Lely' (22%), whose resistance was broken by race 106E139 in 1975, 'Clement' (16%), whose resistance was broken by race 232E137 in 1974, and 'Caribo' (20%) and 'Okapi' (11%), both moderately susceptible to race 104(108)E41 which was observed for the first time in the Netherlands in 1975 (Stubbs, unpublished).

Mean annual yellow rust intensity in July was positively correlated with average temperature during November–March (r = 0.67) and tended to be negatively correlated with average temperature in April. The same result was obtained when mean annual yellow rust intensity was corrected for the area grown with completely yellow rust resistant cultivars. Though the R^2-value is low (0.4), the correlation with temperature is in agreement with other studies (Zadoks, 1961; Sharp and Hehn, 1963; Burleigh and Hendrix, 1970; Shaner and Powelson, 1971; Coakley, 1978; De la Rocque, 1986; Coakley et al., 1988; Conner et al., 1988). High temperatures during November–March shorten the latent period of yellow rust, thus leading to infections of new leaves before lowest infected leaves die. The highest prevalence (76%) occurred in 1975 when 'Clement', sown on 55% of the winter wheat area, was seriously affected by race 232E137.

Precipitation during July, August, September or October of the previous summer–autumn was not correlated with yellow rust intensities in July, which indicates that overwintering and not oversummering (Zadoks, 1961; Priestley, 1978; Zadoks and Bouwman, 1985; Park, 1990; Ellison and Murray, 1992) was the critical factor for survival of yellow rust between 1974 and 1986.

Yellow rust resistance. In the Netherlands, yellow rust has been studied intensively after the epidemic in 'Heines VII' in 1955 (Zadoks, 1961). A survey of races has been made annually and cultivars were thoroughly tested for their degree of resistance before introduction. Also, breeders put much emphasis on developing resistant cultivars. Prior to the introduction of fungicides against rusts in 1978, growing resistant cultivars (grade 8 or 9, Table 1) was the only way of controlling the disease. However, these resistances appeared to have a relatively short duration, due to the appearance of new virulent races. In the past 40 years about 75% of the commercially grown cultivars lost their resistance within 1–5 years. Only a few, such as 'Arminda', maintained their resistance (Tables 1, 2, 4). On average, two new races are identified each year.

After 1978, the possibility of controlling the disease with effective chemicals allows the cultivation of cultivars which are moderately susceptible to moderately resistant (grades 5 to 7, Table 1). An example is 'Okapi', which was sown on 30–40% of the winter wheat area in 1979–1986. The relatively high incidence of yellow rust in this cultivar (Table 4) is due to high prevalence of race 104(108)E41. This race is avirulent

Table 4. Mean incidence of yellow rust in July (% infected leaves) per cultivar in the years 1981–1986.

Cultivar	1981	1982	1983	1984	1985	1986
Okapi	0.7	1.3	4.8	1.4	0.9	0.1
Arminda	0	0	0	0	0	0
Nautica	0	–	–	–	–	–
Marksman	0.2	0.1	2.5	–	–	–
Saiga	–	0	0	0	–	–
Citadel	–	–	0	0	–	–
Granada	–	–	–	1.3	1.0	–
Obelisk	–	–	–	–	–	0

to the cultivars Saiga and Citadel, which explains the absence of yellow rust in both (Table 4). However, on a small area highly susceptible cultivars not included in the Descriptive List of Cultivars for Agricultural Crops (such as 'Vuka', 'Kanzler' and later 'Slejpner') are cultivated, requiring extremely large amounts of chemicals. The first infections in spring are usually observed in these cultivars. It is evident that such cultivars are sources of inoculum spread and, likely, of new virulent races.

Intensity of Puccinia recondita. Brown rust was usually not detected in May (Table 2), except in 1980 when one leaf with rust was found, and in 1983 when 5% of the field samples was infected. Between 1974 and 1986, the prevalence of brown rust in July averaged 48% of the fields. Brown rust intensity in July averaged 1% of the leaf surface (severity) between 1975 and 1980, and on average 15% of the leaves was infected between 1981 and 1986 (Table 2). The highest intensity was recorded in 1983, when 5% of the fields was already infected in May (Table 2). These values are comparable to those recorded in England and Wales between 1970 and 1975 (King, 1977), in Switzerland between 1983 and 1986 (Forrer, 1987) and in Andalusia between 1980 and 1983 (Marin, 1985), but lower than recorded in France (Curé and Caron, 1986).

Annual variation in P.recondita intensity. In May between 1976 and 1984, brown rust was only significant in 1983. This was preceded by high temperatures during autumn–winter. Between 1976 and 1984, temperature during October–April was highest in 1982–1983 (viz. 6.2 °C). High temperatures in autumn stimulate primary infections by brown rust and high temperatures in winter enhance brown rust development and reduce mortality due to frost.

Mean annual brown rust intensity in July was positively correlated with average temperature in March and with cumulative precipitation in April and May (Fig. 2). This indicates that temperatures in early spring rather than in winter are critical for brown rust epidemics in July, confirming the critical period concept of Chester (1943). The dependence of brown rust epidemics on early spring temperatures, even when the winter wheat is infected in autumn and when winter is mild or severe, has been observed also by others (Overlaet, 1958; De la Rocque, 1986; Eversmeyer et al., 1988). Brown rust may survive winter whenever winter wheat survives (Hassan et al., 1986). High temperatures in March may lead to sporulation of brown rust and infection of young leaves, before it dies with the older leaves (Parlevliet and Van Ommeren, 1976; Roelfs, 1986). The observed correlation with precipitation during April and May (Fig. 2) seems in conflict with the critical period defined by Chester (1943). He concluded that temperature during only one month, March, was critical for brown rust epidemics in Oklahoma. However, during April–May the crop in the Netherlands develops from DC 30 (pseudo stem erection) to DC 40 (booting). In Oklahoma, development proceeds much faster and this phase takes place mainly during March (Chester, 1943). Whether the correlation of brown rust intensity in July with precipitation in April and May (Fig. 2) is the result of higher spore deposition, prolonged periods of leaf wetness and/or increased leaf duration remains unclear; moreover, it may be a spurious correlation due to the high intensity of brown rust in 1983.

Brown rust resistance. The data in Table 2 show that brown rust was more prevalent than yellow rust. Between 1974 and 1986, 48% of the fields were infected by brown

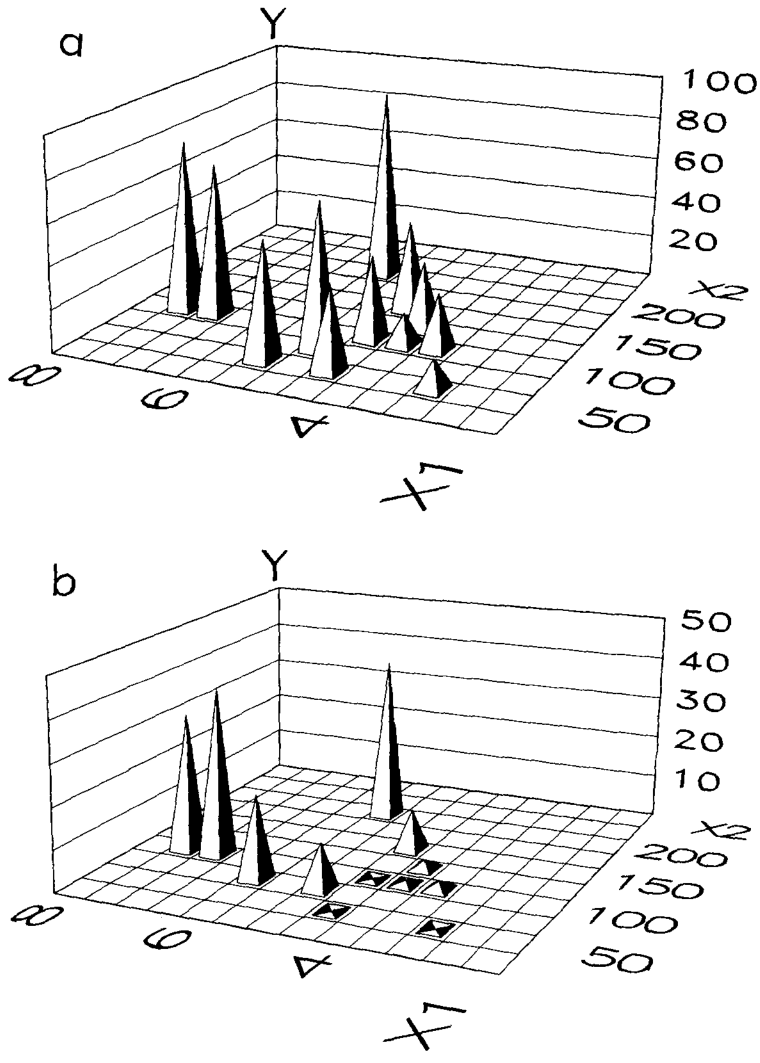

Fig. 2. Annual brown rust prevalence (a, Y = % infected fields) and mean annual incidence (b, Y = % infected leaves) both in July 1974–1986, one year missing, in relation to average temperature in March (X_1, °C) and cumulative precipitation in April and May (X_2, mm). The estimates of mean brown rust severity during 1975–1980 were transformed to mean brown rust incidence by d = 9, see methods.
Regression a: $Y = -45 + 16X_1 + 0.16X_2$ ($R^2 = 0.82$)
Regression b: $Y = -45 + 9X_1 + 0.13X_2$ ($R^2 = 0.85$)

rust, compared to only 18% by yellow rust. The high prevalence of brown rust may be ascribed to the relatively low resistance grade of the cultivars mostly sown during that period, viz. 'Manella', 'Caribo', 'Lely', 'Clement', 'Okapi' and 'Arminda' (Table 1). In contrast to yellow rust, brown rust has received little attention with regard to the survey of races and the evaluation of cultivar resistance to those races. Breeding

Table 5. Mean incidence of brown rust in July (% infected leaves) per cultivar in the years 1981 – 1986.

Cultivar	1981	1982	1983	1984	1985	1986
Okapi	42.7	13.6	38.6	1.0	1.1	0.7
Arminda	25.7	5.7	28.3	0.4	3.1	0.2
Nautica	48.1	–	–	–	–	–
Marksman	10.8	4.9	22.2	–	–	–
Saiga	–	17.7	45.0	0.1	–	–
Citadel	–	–	72.8	3.0	–	–
Granada	–	–	–	0.1	0	–
Obelisk	–	–	–	–	–	0.1

for resistance as well as grading the resistance of the cultivars (Table 1) were dependent on natural occurrence of the disease in experimental fields. A brief study on the pathogenicity of brown rust in the Netherlands showed that brown rust, like yellow rust, consists of field races (Zadoks, 1966). Another study by Stubbs (unpublished) in the period 1983 – 1988 showed, among others, that virulences observed by Zadoks (1966), such as virulence to 'Felix' and to 'Flamingo', were still present in the isolates collected from farmers' fields 20 years later. New virulences were those to 'Clement', highly resistant in 1974 (Table 1), to 'Granada' and to 'Obelisk'. The resistance of the latter two was broken in 1986 and 1988, respectively.

The resistance of 'Clement' is based on Lr26 (McIntosh, 1988); however, Denissen and Van der Putten (1991) did not mention the absence of virulence to Lr26 in their 'Clement' isolate. The resistance of 'Granada' was also based on Lr26 in combination with an additional gene (Bartos and Stuchlíková, 1987). Von Kröcher (1990) suggests Lr14a as additional gene; however, this seems unlikely, as all isolates tested in the Netherlands, including old isolates, showed virulence to Lr14a (Denissen and Van der Putten, 1991). Moreover, the 'Clement' isolate with virulence to Lr26 was avirulent on 'Granada' (Stubbs, unpublished data). Genes of resistance in 'Obelisk', originating from a composite cross, are not yet been identified.

In race nurseries with isolates collected between 1984 and 1987, most of the cultivars commercially grown in the Netherlands appeared to have a race-specific resistance. The cultivars Caribo and Okapi were susceptible to all isolates (races) used in the tests. The incidence of brown rust in the various cultivars (Table 5) agrees with their level of resistance/susceptibility. 'Nautica' is specifically susceptible to races with 'Clement' virulence, and 'Saiga' to races with 'Felix' virulence. The 'boom and bust' cycle in brown rust is much less pronounced than in yellow rust.

Puccinia graminis. Black rust was rare in the Netherlands. The prevalence of black rust was 3% of the fields in July 1977 and 1% of the fields in July 1981; it was not detected in the other years. In 1977 and 1981 average temperature in March was high, which could indicate that the limiting factor for brown rust epidemics may limit black rust development too.

Fungicides. Fungicide use in the surveyed fields is given in Table 2. More detailed statistics have been reported earlier (Daamen, 1990). In EPIPRE fields, after 1978, the percentage of fields in which fungicides were used to control leaf diseases before flowering was positively but not significantly (r = 0.61) correlated with the prevalence of mildew and rusts in May. The percentage of fields in which fungicides were used before and after flowering was also positively but not significantly (r = 0.75) correlated with the prevalence of mildew and rusts in July. This indicates that about 50% of the variation in annual use of fungicides may be due to the annual variation in occurrence of these leaf diseases.

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