Neth. J. Pl. Path. 97 (1991) 105-114

Surveys of cereal diseases and pests in the Netherlands. 3. Monographella nivalis and Fusarium spp. in winter wheat fields and seed lots

R.A. DAAMEN[1,9], C.J. LANGERAK[2] and W. STOL[3]

[1] Research Institute for Plant Protection (IPO), P.O. Box 9060 6700GW Wageningen, the Netherlands
[2] Centre for Variety Research and Seed Technology (CRZ), P.O. Box 32 6700AA Wageningen, the Netherlands
[3] Netherlands Grain Centre (NGC), Costerweg 5, 6702AA Wageningen; present adress: CABO, P.O. Box 14, 6700AA Wageningen, the Netherlands

Accepted 1 August 1990

Abstract

Data from surveys of winter wheat fields in the period 1974-1986 and of seed lots in the period 1962-1986 and identifications of diseases on plant samples were compiled to describe the occurrence of snow mould (*Monographella nivalis*) and *Fusarium* spp. On average, *M. nivalis* dominated over *Fusarium* spp. The complex of *Fusarium* spp. constituted mainly of *F. culmorum*, followed by *F. avenaceum* and *F. graminearum*. *M. nivalis* was dominant in May on stem-bases and in July on leaves and leaf sheaths. On seeds *M. nivalis* predominated only in years with low temperatures in July and August.

Average brown footrot infection in the field was 4% tillers in May and 5% culms in July. Brown footrot intensity in July was high in cropping seasons with high precipitation in October and with low temperatures in October, November and December. In July during the early eighties, an average of 8% of leaves and 6% of flag leaf sheaths were infected by *M. nivalis*. Average ear blight incidence was 1.2% glumes infected. Seed contamination by these pathogens averaged 16% in the years 1962-1986. The contamination was high in years with high precipitation in June, July and August. Aspects of cv. resistance and yield loss are illustrated.

Additional keywords: Triticum aestivum, *Microdochium nivale*, *Fusarium culmorum*, *Fusarium avenaceum*, *Fusarium graminearum*, epidemiology, weather, resistance

Introduction

Systematic annual surveys of diseases and pests in commercial winter wheat fields in the Netherlands were conducted from 1974 to 1986. In a previous paper the occurence of stem-base diseases was reported (Daamen and Stol, 1990).

Seedlings, stem-bases, leaves, leaf sheaths, ears and seeds of wheat may be infected by *Monographella nivalis* stat. con. *Microdochium nivale* (*Fusarium nivale*) and *Fusarium* spp. (Cook, 1981; Ubels, 1981 and Sutton, 1982). In general it is not possible to discriminate between these pathogens from their disease symptoms in the field. Identifications of the pathogens made by different Institutes in the Netherlands were available to interpret the occurrence of the complex of these pathogens in the field.

Moreover, linked with the development of standard blotter tests (De Tempe, 1963; Langerak, 1983), systematic surveys of seed fungi were carried out after 1961 in the Netherlands. In this paper, data on the occurrence of these diseases caused by *M. nivalis* and *Fusarium* spp. in the field and data on contamination of winter wheat seed lots in the Netherlands are compiled and discussed in relation to weather and cultivar resistance. The subsequent occurrence of *Fusarium* mycotoxins, was reported by Tanaka et al. (1990) and by Snijders (1990).

Materials and methods

Field surveys. Field selection, plant samples and disease assessments on stem-bases were described in a previous paper (Daamen and Stol, 1990). Snow rot caused by *Typhula incarnata* was found on stem-bases in one wheat field in May 1980 only. This disease is rare in winter wheat in the Netherlands as result of crop rotation and short duration of snow covers (Andres et al., 1987).

Disease intensity on leaves was also estimated in the plant samples. From 1981, the total number of leaves in each sample and the number of leaves with symptoms of *M. nivalis* in the green area was counted. Disease intensity was expressed as incidence: the percentage leaves with disease symptoms.

The intensity of ear blight was assessed during 1974 to 1978, by assessing in each field the percentage plants with symptoms and the average percentage glumes infected of these infected plants. In the years 1979 and 1980, a direct assessment of the percentage glumes infected by ear blight per field was made. From 1981 onwards, the number of glumes in the sample with ear blight was counted and expressed as disease incidence: the percentage infected glumes, assuming an average of 35 glumes per ear.

The disease prevalence (percentage fields with the disease) and mean annual incidence (percentage infected leaves or glumes) were determined to obtain mean annual disease intensities.

Seed lots. From 1961 onwards, annually circa 40 seed lots of commercial fields were analysed by the Government Seed Testing Station. Sampling and subsampling occured according methods prescribed by the International Seed Testing Association. Standard blotter tests (De Tempe, 1963; Langerak, 1983) were used to determine the total percentage infection by *Fusarium* spp. including *M. nivalis*. Contamination with *Drechslera* spp. was rare in these years, being always below 1%.

Identifications. Identifications of the pathogens on wheat samples, mainly from commercial fields not in the surveys, were collected from the Plant Protection Service over the years 1980 to 1988 (H.A. van Kesteren, pers. comm.) and from IPO (J.W. Veenbaas-Rijks, pers. comm.) over the years 1980-1985. Identifications of the pathogens on seed lots in the years 1961-1965 were published by De Tempe and Limonard (1967). Those of 1966 were found in letters of de Tempe from the Government Seed Testing Station to Ubels (IPO). During 1980's, identifications of the fungi in seed lots were not complete, but *M. nivalis* was distinguished from *Fusarium* spp. (C.J. Langerak and R.J.H. van den Born, pers. comm.).

Table 1. Frequency of *Fusarium* spp. identified from wheat samples in the Netherlands 1980-1988. Percentages are given in brackets.

	Monographella nivalis	*Fusarium culmorum*	*Fusarium avenaceum*	*Fusarium graminearum*	Other *F.* spp.	Total samples
Seedlings	8 (62)	2 (15)	2 (15)	1 (8)	0 (0)	13
Stem-bases						
spring	31 (79)	6 (15)	2 (5)	0 (0)	0 (0)	39
summer	8 (53)	5 (33)	2 (13)	0 (0)	0 (0)	15
Leaves	12 (86)	1 (7)	0 (0)	0 (0)	1 (7)	14
Sheaths[a]	89 (97)	3 (3)	0 (0)	0 (0)	0 (0)	92
Ears	12 (32)	14 (38)	4 (11)	4 (11)	3 (8)	37
Seeds[b]						
1979-1986	(20)					
1961-1966	(59)	(5)	(12)	(14)	(11)	

[a] Inclusive 85 samples of flag leaf sheaths from the survey fields in 1982.
[b] Based on ca. 40 seed lots annually. During 1980-1987 distinction was made between *M. nivalis* (20%) and *Fusarium* spp. (80%).

Results and discussion

Species. The frequency of the pathogens involved is given in Table 1. In general *M. nivalis* dominates. *F. culmorum* was the second most important pathogen isolated between 1980 and 1988. *F. avenaceum* and *F. graminearum* were regularly isolated from seeds and also to a lesser extend from seedlings, suggesting that infections of seedlings were at least partly caused by contaminated seeds. The domination of *M. nivalis* on stem-bases decreases in the course of the growth period, confirming observations by Duben and Fehrmann (1979) in Germany. On ears and seeds (1979-1986) the relative frequency of *M. nivalis* was lowest and *Fusarium* spp. were dominating. But during ripening, *M. nivalis* was still dominant on leaves and leaf sheaths. The shift in domination in the course of the season may be attributed to the gradually increasing temperature after winter. Optimum temperature for growth is lower for *M. nivalis* than for *Fusarium* spp. In addition, *M. nivalis* is more pathogenic than *Fusarium* spp. on leaves and leaf sheaths. (Cook, 1981).

The difference in pathogen composition on seed lots in the two periods is striking (Table 1). *M. nivalis* was the dominant pathogen over the years 1961-1966, but it was replaced by *Fusarium* spp. over the years 1979-1986. Though fungicide use in the fields was much higher during the 1980's than during the 1960's, the difference in pathogen composition must be mainly attributed to average temperature in July and August in the different years (Fig. 1; Cook, 1981).

Brown footrot. Over the years 1980-1984, incidence of brown footrot in May, mainly caused by *M. nivalis*, averaged 4% tillers and on average 68% of the fields were infested (Table 2). Both measures of disease intensity were positively correlated ($r = 0.82$). Brown footrot intensity in May was positively but not significantly correlated

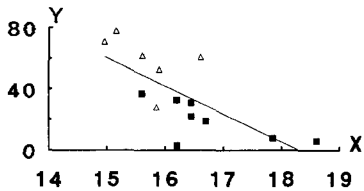

Fig. 1. *M. nivalis* on contaminated seeds as percentage of *M. nivalis* and *Fusarium* spp. (Y), in relation to the average temperature in July and August (X). Triangles: period 1961-1966; squares: period 1979-1986. Regression: $Y = 335 - 18\,X$ ($R^2 = 0.53$).

Table 2. Mean annual incidence (percentage infected tillers, leaves, glumes or seeds) and prevalence (percentage infected fields) of *M. nivalis* and *Fusarium* spp. in winter wheat fields and seed lots (–: data lacking).

Year	74	75	76	77	78	79	80	81	82	83	84	85	86
Number of fields													
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
Incidence:													
May:													
Brown footrot	–	–	–	–	–	–	4	9	8	9	1	–	–
July:													
Brown footrot	–	–	–	–	3	3	2	5	12	4	5	4	6
Snow mould	–	–	–	–	–	–	[a]	9	8	8	2	9	4
Flag leaf sheaths	–	–	–	–	–	–	–	–	29	3	1	1	7
Ear blight	–	0.1	0.0	0.1	0.1	3.8	3.2	1.4	4.6	0.3	0.0	0.3	0.1
Seeds[b]	23	3	1	2	4	11	18	20	6	1	7	37	2
Prevalence													
May:													
Brown footrot	–	–	–	–	–	–	67	64	94	89	27	–	–
July:													
Brown footrot	–	–	–	–	–	60	43	63	92	60	45	55	45
Snow mould	–	–	–	–	–	–	85	80	84	88	24	61	64
Flag leaf sheaths	–	–	–	–	–	–	–	–	99	41	5	21	33
Ear blight	51	18	0	9	–	100	95	94	96	65	15	37	31

[a] Snow mould intensity on leaves averaged 1% of leaf surface in 1980, other entries are incidences.
[b] Of ca 40 fields annually. Seed infection in the harvest years 1962-1973 averaged: 12, 29, 15, 29, 42, 8, 31, 17, 10, 32, 46, and 4% of the seeds, respectively.

with the average percentage infection in the sowing seed used ($r = 0.6$). This indicates that brown footrot in May is partly caused by contaminated seed, despite the seed disinfection commonly practiced. During the five years of this study no significant (partial) correlations of brown footrot in May with weather variables could be established.

Incidence and prevalence of brown footrot in July were positively correlated ($r = 0.79$), and averaged 5% culms and 58% fields, respectively (Table 2). Disease intensity in July was lower than recorded in Belgium (Meunier, 1984 and 1985; Lagneau et al., 1986), in England and Wales (Clarkson and Polley, 1981) and in Germany (Duben and Fehrmann, 1979). *M. nivalis* dominates over *Fusarium* spp. in these countries, excepting Germany. In Spain *F. culmorum* and *F. graminearum* dominate (Marin, 1986) due to the higher temperatures in summer, which could also explain the observation in Germany.

The correlations between brown footrot intensities in May and July were positive, but not significant. Thus, other factors in addition to brown footrot intensity in May determine brown footrot intensity in July. Brown footrot intensity in July was positively correlated with the amount of precipitation in October and negatively correlated with average temperature in October, November and December (R^2-values 0.71 and 0.85 for incidence and prevalence, respectively). However, these correlations are mainly based on the high disease intensity recorded in 1982 and may therefore not represent causal relations. They are in line however, with indications from the literature that brown footrot prevails under conditions adverse for plant growth (Bennett, 1928; Millar and Colhoun, 1969; Casell and Hering, 1982). The Dutch clay soils become water-saturated by abundant rain so that seeding and seedling growth are hampered. Moreover, crop growth is stimulated by high temperatures in autumn and early winter. In addition, above ground infections of *M. nivalis* are enhanced by high humidities (Al-Hashimi and Perry, 1986).

Snow mould. Monographella nivalis was common in winter wheat in the Netherlands (Table 1). As result of brown footrot in May, perithecia of *M. nivalis* were found on lower leaf sheaths on 43% of the culms in July 1981 (Fig. 2). Ascospores from these perithecia, dispersed by wind, may infect leaves and glumes.

In July during 1980-86, prevalence and incidence of snow mould on leaves were positively correlated (r^2 = 0.79) and averaged 69% of the fields and 7% of the leaves, respectively (Table 2). The intensity of snow mould on leaves was positively correlated with brown footrot intensity in May, mainly as a result of the low intensity of both diseases in 1984.

During 1970's, snow mould on leaves in July was rare or not mentioned at all, but from 1979 onwards it became common. Also in Germany (Ahrens and Fehrmann, 1984) and Switzerland (Forrer et al., 1982) the symptoms appeared, presumably partly as the result of the increased use of fertilizers (Ellen and Langerak, 1987). Moreover, this coincided with the development of resistance by *M. nivalis* against carbendazim-generating fungicides. On the other hand, however, in 1974 Häni (1981) found high intensities of *M. nivalis* on leaves late in the season in Switzerland. In the Netherlands, during prolonged humid conditions in the ripening phase, the fungus grows superfici-

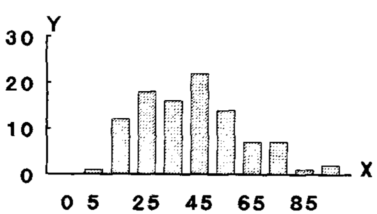

Fig. 2. Frequency distribution (*Y*, % fields) of the occurence of perithecia of snow mould (*M. nivalis*) on basal leaf sheaths (*X*, % tillers with perithecia) in July 1981.

ally and rapidly over the leaf epidermis, presumably initiated by the abundance of ascospores (Fig. 2) and spores are formed in stomata. Then necrosis follows, which is hard to distinguish from senescence, especially in dry weather conditions because distinctly visible fruiting bodies appears only later. In this way the disease is often not noticed, while the straw is already invaded.

In the July months from 1982 to 1986, incidence and prevalence of diseased flag leaf sheaths averaged 8% culms and 40% fields, respectively (Table 2). Both intensities were positively correlated ($r = 0.95$), mainly as a result of the high disease intensity in 1982. Under high disease intensity in some fields, flag leaves completely disappeared from the plants, so that the crop in July only had an active second leaf layer. Diseased flag leaf sheaths of 121 fields were sampled in 1982 and placed in petri dishes on moist filter paper at about 20 °C. One to three days later spores had been formed and identifications were made at low magnification. On average 70% of the symptoms on leaf sheaths was attributed to *M. nivalis* and 30% to *Leptosphaeria nodorum*. In two samples, also *Mycosphaerella graminicola* and *F. culmorum* were identified. Prevalence and incidence of diseased flag leaf sheaths was positively correlated with disease intensity on stem bases and leaves, both in July (correlation coefficients > 0.9).

Ear blight. Incidence and prevalence of ear blight averaged 1.2% of the glumes and 51% of the fields, respectively (Table 2), and were positively correlated ($r = 0.85$). Ear blight was caused by *F. culmorum* and *M. nivalis* mainly, but also *F. avenaceum* and *F. graminearum* were recorded (Table 1). No significant correlation was obtained between ear blight intensities and prevailing weather. However, ear blight incidence and prevalence were positively correlated with precipitation in June (R^2-values 0.57 and 0.61, for incidence and prevalence, respectively), if data of 1985 with high precipitation in June (121 mm) were excluded from the analysis. The effect of rain during flowering on ear blight intensity during ripening is well-known (Cook, 1981). The survey in 1985 was carried out earlier than usual, mid-July instead of end of July. The development of the crop was slow in 1985, due to the prevailing low temperatures. Flowering, which usually occurs mid-June took place at the end of June. Moreover, the first half of July was dry. The combination of these factors may explain the observed deviation of 1985.

Seed contamination. On contaminated seeds *Fusarium* spp. dominated or were important in addition to *M. nivalis* (Table 1), mainly depending on the average temperature in July and August (Fig. 1). Over the period 1962-1986, on average 16% of the seeds was contaminated (Table 2). Contamination of harvested seed was not correlated with disease intensity of sown seeds ($r = 0.04$) due to the effect of weather during the

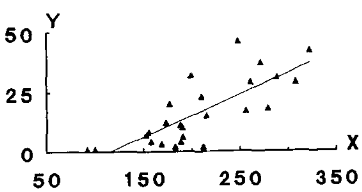

Fig. 3. Percentage of seeds (Y) contaminated with *Fusarium* spp. and *M. nivalis* in the years 1962-1986, in relation to cumulative precipitation (X, mm) in June, July and August. Regression: $Y = -21 + 0.18 X$ ($R^2 = 0.59$)

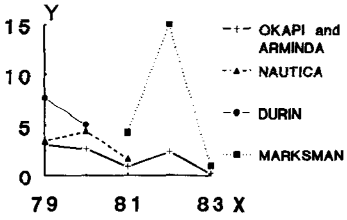

Fig. 4. Incidence of ear blight in July (*Y*, % infected glumes) in the years 1979-1983 (*X*) in different winter wheat cultivars.

cropping season. Seed contamination was positively correlated with cumulative precipitation during the months June, July and August (Fig. 3). Wet conditions may stimulate ear infection and disease development directly. In addition, crop ripening and harvest is delayed during such periods, so that infection of the seeds can continue.

Cultivar resistance and yield. The dwarf cvs. Durin and particularly Marksman showed a higher incidence of ear blight than the tall and semi-dwarf cvs. Okapi and Arminda (Fig. 4). Ear blight incidence in the semi-dwarf cv. Nautica was intermediate. That in the semi-dwarf cv. Saiga was comparable to that in cvs. Okapi and Arminda. These field observations correspond with the disease resistance ratings of the cvs. established after artificial inoculations (Ubels and Van der Vliet, 1984a;b). Yields of the survey fields, corrected for region and cv. were strongly correlated with their degree of ear blight incidence in 1980 (Daamen, 1981), indicating that *Fusarium* spp. was a major contraint to yield in commercial fields. The effect of ear blight on yield could also be illustrated with the results of the cultivar trials of RIVRO (Government Institute for Research on Varieties of Cultivated Crops). In Fig. 5, yields of the susceptible cvs. Durin and Marksman and the moderately resistant cvs. Arminda and Okapi attained in cultivar trials, in which fungicides were applied on marine clay soils in the northern, central and southern part of the country are plotted against ear blight incidence in these regions in 1979, 1980 and 1981. These data illustrate that yields of the various cvs. in the absence of ear blight are similar. The susceptible cvs., however, show a stronger yield reduction than the moderately resistant cvs. at higher ear blight incidence. Weather conditions favouring ear blight may also affect yield directly, but that effect is presumably similar for the cvs.

Intensity of brown footrot and snow mould on leaves did not show such distinct resistance patterns. Cv. Marksman, the most susceptible cv. to ear blight in the survey, showed significantly more brown footrot than the other cvs.. In 1981 and 1983, cv. Arminda, one of the least susceptible cvs. in the survey, was less affected by snow mould on leaves than the other cvs.

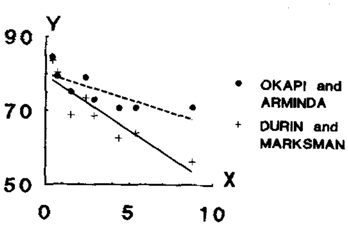

Fig. 5. Yields (*Y*, kg are^{-1} at 16% moisture) on northern, central and southwestern clay soils (RIVRO trials), in relation to mean incidence of ear blight in 1979-1981 in these regions (*X*, % glumes infected, survey data) for the moderately susceptible cvs. Okapi and Arminda and for the susceptible cvs. Durin and Marksman.

Fungicides. No effective fungicide seems to be available yet to protect the crop in the field (Mielke, 1988). Seed disinfection is common practice in the Netherlands, but as already indicated, it does not prevent brown footrot and other infections during the cropping season. Moreover, Ubels (1984) and Daamen et al. (1988 and 1989) suggest that brown footrot intensity on Dutch clay soils may increase after seed disinfection with fungicides. It is not clear whether this increase is caused by elimination of antagonistic organisms (Al-Hashimi and Perry, 1986) or whether diseased plants survive winter more easily thus promoting carry-over of the disease (Hewett, 1983).

In the seventies, isolates of *M. nivalis* showed ED50 values of ca. 0.1 ppm carbendazim, and some of the isolates reached ED50 values of 10 ppm. after artificial selection in vitro (Van Tuyl, 1977). Also Van der Hoeven and Bollen (1980) have reported ED50 values below 0.5 ppm for strains of *M. nivalis* and of 1-2 ppm. for strains of *Fusarium* spp. to carbendazim-generating fungicides in 1970-1974. In later years, ED50-values of some strains of *M. nivalis* from seeds harvested in 1979 were above 100 ppm. (Langerak and Bollen, 1980) and some strains of *M. nivalis* from 1982 had ED50-values above 1000 ppm. (De Jong, 1982).

In 1980, the common seed disinfectant was natrium-dimethyl-dithiocarbamate and fuberidazol (used in 77% of the fields) and guazatine was used in only 8% of the fields. After 1980 guazatine became the common seed disinfectant. Seed disinfection allows higher seedling survival of contaminated seeds, but the survey data and those of the field experiments (Ubels, 1984) show that seed disinfection does not protect the crop against infection by *M. nivalis* and *Fusarium* spp. after the seedling stage.

Acknowledgements

We thank professor H. van Keulen for critically reading the manuscript.

References

Ahrens, W. & Fehrmann, H., 1984. Weizenbefall durch *Septoria nodorum* und Ährenfusariosen. 1. Schadenanalyse. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz 91: 42-58.

Al-Hashimi, M.H. & Perry, D.A., 1986. Survival and saprobic ability of *Monographella nivalis* in soil. Transactions of the British Mycological Society 86: 373-379.

Andres, H., Hindorf, H., Fehrmann, H. & Träger-Born, J., 1987. Untersuchungen zum Auftreten und zur Verbreitung von *Typhula*-Arten an Wintergetreide im östlichen Franken und Bayrischen Wald. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz 94: 491-499.

Bennett, F.T., 1928. On two species of *Fusarium, F. culmorum* and *F. avenaceum*, as parasites of cereals. Annals of Applied Biology, 15: 213-244.

Cassell, D. & Hering, T.F., 1982. The effect of water potential on soil-borne diseases of wheat seedlings. Annals of Applied Biology 101: 367-375.

Clarkson, J.D.S. & Polley, R.W., 1981. Assessment of losses caused by stem-base and root diseases in cereals. Proceedings 1981 British Crop Protection Conference on Pests and Diseases: 223-231.

Cook, R.J., 1981. *Fusarium* diseases of wheat and other small grains in North America. In: P.E. Nelson; T.A. Tousson and R.J. Cook (eds), *Fusarium*: Biology and Taxonomy. Pennsylvania State University Press. 39-52.

Daamen, R.A., 1981. Surveys of diseases and pests of winter wheat in the Netherlands, 1979-1980. Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent 46: 933-937.

Daamen, R.A. & Stol, W., 1990. Surveys of cereal diseases and pests in the Netherlands. 2. Stem-base diseases in winter wheat fields. Netherlands Journal of Plant Pathology 96: 251-260.

Daamen, R.A., Wijnands, F.G. & Vliet, G. van der, 1988. Disease and pest development in different winter barley cropping systems. In: M.L. Jorna and L.A.J. Slootmaker (Eds), Cereal breeding related to integrated cereal production, 38-43. PUDOC, Wageningen.

Daamen, R.A., Wijnands, F.H. & Vliet, G. van der, 1989. Epidemics of diseases and pests of winter wheat at different levels of agrochemical input. Journal of Phytopathology 125: 305-319.

Duben, J. & Fehrmann, H., 1979. Vorkommen und Pathogenität von *Fusarium*-Arten an Winterweizen in der Bundesrepublik Deutschland. 1. Artenspektrum und jahreszeitliche Sukzession an der Halmbasis. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz 86: 638-652.

Ellen, J. & Langerak, C.J., 1987. Effects of plant density and nitrogen fertilization in winter wheat (*Triticum aestivum*). 2. Incidence of *Gerlachia nivalis* and *Fusarium* spp. related to yield losses. Netherlands Journal of Agricultural Science 35: 155-162.

Forrer, H.R., Rijsdijk, F.H. & Zadoks, J.C., 1982. Can mildew assist the entry of *Fusarium* fungi into wheat leaves? Netherlands Journal of Plant Pathology 88: 123-125.

Häni, F., 1981. Zur Biologie und Bekämpfung von Fusariosen bei Weizen und Roggen. Phytopathologische Zeitschrift 100: 44-87.

Hewett, P.D., 1983. Seed-borne *Gerlachia nivalis* (*Fusarium nivale*) and reduced establishment of winter wheat. Transactions of the British Mycological Society 80: 185-186.

Hoeven, E.P. van der & Bollen, G.J., 1980. Effect of benomyl on soil fungi associated with rye. 1. Effect on the incidence of sharp eyespot caused by *Rhizoctonia cerealis*. Netherlands Journal of Plant Pathology 86: 163-180.

Jong, C. de., 1982. Bladaantasting door *Gerlachia nivalis* in wintertarwe. Doctoraal Verslag RUU, WCS and IPO. 112pp.

Lagneau, C., Dandois, J., Bastin, V., Poncelet, J. & Maraite, H., 1986. Evolution et sévérite des maladies sur froment d'hiver et escourgeon en 1985. Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent 51: 603-616.

Langerak, C.J., 1983. Annual report 1982/1983 of Government Seed Testing Station, Wageningen 35: 55-56.

Langerak, C.J. & Bollen, G.W., 1980. Annual report 1979/1981 of Government Seed Testing Station, Wageningen 31: 42-43.

Marin, J.P., 1986. Hongos asociados con el mal del pie del trigo en Andalucia occidental. Investigacion Agraria: Produccion y Proteccion Vegetales 1: 409-431.

Meunier, S., 1984. Inventaire des maladies du pied chez le froment d'hiver en 1983 et incidence sur les composantes du rendement. Parasitica 40: 27-40.

Meunier, S., 1985. Evaluation de l'importance des maladies du pied sur froment d'hiver en Belgique. Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent 50: 1125-1134.

Mielke, H., 1988. Untersuchungen über *Fusarium culmorum* als Fuss- und Ährenkrankheitserreger beim Weizen. Mitteilungen aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft Berlin-Dahlem. Heft 238. 101 pp.

Millar, C.S. & Colhoun, J., 1969. *Fusarium* diseases of cereals. VI. Epidemiology of *F. nivale* on wheat. Transactions of the British Mycological Society 52: 195-204.

Snijders, C.H.A., 1990. Aspects of resistance to Fusarium head blight caused by *Fusarium culmorum* in wheat. Dissertation, Agricultural University Wageningen, 115 pp.

Sutton, J.C., 1982. Epidemiology of wheat head blight and maize ear rot caused by *Fusarium graminearum*. Canadian Journal of Plant Pathology 4: 195-209.

Tanaka, T., Yamamoto, S., Hasegawa, A., Aoki, N., Besling, J.R., Sugiura, Y. & Ueno, Y., 1990. A survey of the natural occurrence of *Fusarium* mycotoxins, deoxynivalenol, nivalenol and

zearalone, in cereals harvested in the Netherlands. Mycopathologia 110: 19-22.
Tempe, J. de, 1963. The blotter method for seed health testing. Proceedings of the International Seed Testing Association 28: 133-151.
Tempe, J. de & Limonard, T., 1967. Enkele aspecten van de *Fusarium* infectie van tarwezaad. In: S. Broekhuuizen (Ed.), Collected papers on cereal diseases (1). Stichting Nederlands Graancentrum. Technisch Bericht no. 17, Wageningen. 35-42.
Tuyl, J.M. van. 1977. Genetics of fungal resistance to systemic fungicides. Dissertation, Agricultural University, Wageningen. 137 pp.
Ubels, E., 1981. *Fusarium* in tarwe. Gewasbescherming 12: 105-124.
Ubels, E., 1984. Effecten van enkele zaadontsmettingsmiddelen en aarbescherming met een fungicide in wintertarwe uit zwaar met *Monographella* (*Gerlachia*) *nivalis* besmet zaaizaad. IPO rapport april 1984, Wageningen. 29 pp.
Ubels, E., & Vliet, G. van der, 1984a. Vatbaarheid van enkele tarwerassen voor aaraantasting door *Fusarium culmorum* en *Gerlachia nivalis*. 1. Rassentoetsing door aarinfectie met *F. culmorum*. Gewasbescherming 15: 31-39.
Ubels, E. & Vliet, G. van der, 1984b. Vatbaarheid van enkele tarwerassen voor aaraantasting door *Fusarium culmorum* en *Gerlachia nivalis*. 2. Vergelijking van rasreacties op *F. culmorum* met die op *G. nivalis*. Gewasbescherming 15: 63-71.