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Surveys of cereal diseases and pests in the Netherlands. 5. Occurrence of Septoria spp. in winter wheat

R.A. DAAMEN[1] and W. STOL[2]

[1] DLO-Research Institute for Plant Protection (IPO-DLO), PO Box 9060, 6700 GW Wageningen, the Netherlands
[2] Netherlands Grain Centre (NGC), Costerweg 5, 6702 AA Wageningen

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Abstract

Data of the annual surveys of circa 100 commercial winter wheat fields were compiled to describe epidemics of *Septoria* spp. in the Netherlands during 1974–1986. In May, during the first node stage, *S. tritici* was dominant while *S. nodorum* was virtually absent. In July, during ripening, *S. tritici* on average dominated over *S. nodorum*, though in the most continental districts of the country *S. nodorum* predominated.

In May between 1974 and 1984, on average 56% of the fields showed leaf infections by *Septoria* spp., while in July between 1975 and 1986, on average 83% of the fields showed leaf infections. Prevalence of *Septoria* spp. has increased during the surveys. Annual intensity of *Septoria* spp. in winter wheat crops was positively correlated with precipitation and negatively with average monthly sunshine duration during the harvest-month August of the previous growing season. The correlation with sunshine during August could indicate that ascospores play a major role in subsequent epidemics; but whether it is a causal relation remains to be answered.

Additional keywords: Triticum aestivum, Mycosphaerella graminicola, Phaeosphaeria nodorum, Stagonospora nodorum, epidemiology, weather.

Introduction

Systematic annual surveys of diseases and pests in commercial winter wheat fields in the Netherlands were conducted during the years 1974–1986. In previous papers, the occurrence of stem-base diseases, *Fusarium* spp. and powdery mildew and rusts have been reported (Daamen and Stol, 1990; Daamen et al., 1991, 1992). In this paper the annual epidemics of *Septoria* spp., comprising speckled leaf blotch (*Mycosphaerella graminicola*, anamorph: *Septoria tritici*) and glume blotch (*Phaeosphaeria nodorum*, anamorph: *Stagonospora (Septoria) nodorum*) are described. Both pathogens produce ascospores as well as pycnidiospores in this wheat growing area (Boerema et al., 1985; Mittelstadt and Fehrmann, 1987). The first aim of this paper is to describe the relative importance of *S. tritici* and *S. nodorum* and their distribution in the country. World-wide, epidemics of *Septoria* spp. have increased in importance (Eyal et al., 1987). Therefore the second aim is to examine whether this has also occurred in the Netherlands, and to relate the annual

* Present address: Centre for Agrobiological Research (CABO-DLO), PO Box 14, 6700 AA Wageningen, the Netherlands

variation in occurrence of *Septoria* spp. to weather conditions.

Materials and methods

Cropping practices and field selection were described in the first paper in this series (Daamen, 1990). During each survey about 100 commercial winter wheat fields were surveyed (Table 1). Intensity of *Septoria* spp. was assessed in samples of 40–50 tillers per field, during May, usually at the first to second node stage and during July, at the milky-ripe stage (Daamen and Stol, 1990). Prevalence (% field samples infected) of *Septoria* spp. on leaves (May) and on leaves and ears (July) was determined.

During the July surveys, intensity of *Septoria* spp. on leaves was also assessed, as severity during the years 1974–1980 and as incidence during 1981–1986. Between 1974 and 1978, the number of leaf layers without *Septoria* spp. and the average *Septoria* severity (% leaf surface diseased) of the first two infected leaf layers was recorded on a I–IV scale (0, 0–5, 5–25, >25). In 1979 and 1980, the severity of *Septoria* spp. (as % leaf surface) was estimated. From 1981 onwards, the number of leaves with *Septoria* and the total number of leaves in the sample was determined and *Septoria* incidence was computed (% leaves with disease). Obtained intensities were averaged over all fields to obtain mean annual *Septoria* intensity and incidence.

During the years 1974–1982 symptoms on leaves caused by *Septoria* spp. were assessed, while during 1983–1986, symptoms caused by *S. tritici* and *S. nodorum* were assessed separately. Lesion shape and colour of the pycnidia were used to distinguish between the two species. *S. avenae* is identified occasionally in the Netherlands (H.A. van Kesteren, pers. comm.). *Septoria nodorum* on ears was assessed as was described for ear blight (Daamen et al., 1991).

Table 1. Prevalence (% fields infected) and mean severity or incidence (% leaf surface or % leaves infected) of leaf and ear infections by *Septoria* spp. in winter wheat during 1974–1986 (1978 is missing).

Year	1974	1975	1976	1977	1979	1980	1981	1982	1983	1984	1985	1986
Number of fields surveyed												
May	143	88	89	105	305	219	132	123	107	176	–[a]	–
July	143	88	94	105	129	164	138	152	143	123	94	94
Leaf infections by *Septoria* spp.												
Prevalence												
May	10	11	1	13	95	95	87	95	95	54	–	–
July	69	66	21	39	98	99	100	100	100	100	100	100
Mean severity/incidence[b]												
July	–	2	0	1	2	1 /	40	47	39	40	19	19
Ear infections by *Septoria nodorum* in July												
Prevalence	79	50	6	36	36	15	33	79	41	62	80	69
Severity	–	1.1	0.1	0.2	0.5	0.1	0.5	1.1	0.3	0.3	0.7	0.3

[a] No observations.
[b] 1975–1980 expressed as mean % leaf surface diseased (severity); 1981–1986 as mean % leaves infected by *Septoria* spp. (incidence).

Correlation coefficients were computed between mean annual intensities of *Septoria* spp. and weather characteristics: mean monthly temperature (°C), monthly precipitation (mm), number of days per month with precipitation above 1 mm, mean daily global radiation per month (MJ · m^{-2}) and average monthly sunshine duration (expressed as percentage of daylength). Weather characteristics were country averages. If successive months indicated trends, correlation coefficients were also computed between disease intensity and weather characteristics averaged over months. High correlations were explored using a stepwise regression procedure. Results were compared to literature data and it is stressed that this part of the study is explorative, hence computations of statistical significance were not performed.

Results

Species. From 1983 onwards, symptoms on leaves caused by *S. tritici* and by *S. nodorum* were assessed separately. In May between 1983 and 1984, *S. tritici* was common, while *S. nodorum* was rare. In July between 1983 and 1986 *S. tritici* was still predominant though *S. nodorum* increased in importance (Table 2). Despite the annual variation in occurrence, both species appeared to dominate in different parts of the country (Table 2). *S. tritici* dominated on marine clay soils in the northern, central and southwestern wheat growing areas. *S. nodorum* dominated in the most continental wheat districts of the country, viz. the northeastern (improved peat) and the southeastern (loess).

Epidemics of leaf infections by Septoria spp. during 1974–1986. In May between 1974 and 1984 and in July between 1974 and 1986, on average 56% and 83% of the fields, respectively, showed leaf infections by *Septoria* spp. (Table 1). The table shows that *Septoria* spp. has increased in importance between 1974 and 1986, both in May and in July. The prevalence of *Septoria* spp. was lower during the first four years of the survey than in the later years.

Table 2. Intensity of leaf infections by *Septoria tritici* and *Septoria nodorum*, expressed as prevalence (% fields with infection) and incidence (average % of leaves with infection) in different districts during 1983–1986 in July.

	S. tritici					*S. nodorum*				
	1983	1984	1985	1986	AV[a]	1983	1984	1985	1986	AV[a]
Prevalence	94	92	83	80	87	54	93	53	30	58
Incidence										
Northern marine clay	44	34	10	17	27	4	9	1	0	4
Central marine clay	41	38	16	5	25	1	6	2	0	7
Southwestern marine clay	19	18	13	15	16	7	20	1	0	7
Northeastern improved peat	14	1	0	2	4	42	31	53	22	37
Southern loess	3	2	6	1	3	30	24	4	42	25
Country average	30	26	9	9	19	9	14	10	10	11

[a]Average over the years.

Table 3. Correlation coefficients between annual intensities of leaf infections by *Septoria* spp. (1978 missing), year, other pathogens and selected weather variables (see Table 1 and text).

	Septoria spp. intensities			
	Prevalence May 74–84	Prevalence July 74–86	Severity July 75–80	Incidence July 81–86
Year	0.78	0.73	0.09	–0.84
Prevalence				
Mildew, May	–0.03	–	–	–
Mildew, July	–	–0.30	–0.36	–0.61
Brown rust, July	–	0.17	0.38	0.55
Precipitation				
March–April, mm	0.61	–	–	–
March–June, mm	–	0.70	0.89	0.03
% sunshine preceeding August	–0.94	–0.90	–0.54	–0.32

– = Correlation coefficient not computed.

In Table 3 simple correlation coefficients are given between *Septoria* spp. intensity on leaves during the years 1974–1986 (1978 missing) and other variables. Annual prevalence (% fields infected) of *Septoria* spp. on leaves in May and July was positively correlated with year. Average annual severity in July, during 1975–1980 did not show a correlation with year, while average annual incidence during 1981–1986 was negatively correlated, due to the low incidences recorded during 1985 and 1986. Because severity was assessed during the first six years and incidence during the following five years, no indication is obtained of an increased severity or incidence of *Septoria* spp. as was found for the prevalence of *Septoria* spp.

Other pathogens or weather may also affect the intensity of *Septoria* spp. The annual intensity of *Septoria* spp. did not show consistent correlations with that of other widespread leaf pathogens, mildew and brown rust (Table 3). Thus, the annual variation and the increase in prevalence of *Septoria* spp. is not associated with that of other important leaf pathogens. Annual prevalence of *Septoria* spp. on leaves in May 1974–1984 was positively correlated with cumulative precipitation over the months March and April. Annual prevalence in July 1974-86 and average annual severity in July 1975–1980 was positively correlated with cumulative precipitation over the months March–June, although average annual incidence during 1981–1986 did not show positive correlations with precipitation. Exploration of other weather variables than precipitation revealed that annual prevalence of *Septoria* spp. both in May and in July was negatively correlated with average sunshine duration in August of the previous growing season. Average annual severity and incidence were also negatively, though less pronounced, correlated with average sunshine duration in the month August before sowing.

In further analyses, year and weather variables were stepwise regressed on annual intensities of *Septoria* spp. on leaves. When analysing prevalence in both May and July, the correlations with average sunshine duration during the preceding harvest-month August always dominated. Year and sunshine duration in August explained statistically the greater part of the variation in prevalences for both May and July (R^2 = 0.9).

Precipitation in combination with year did not show better correlations than year alone. Thus in explaining the variation in prevalence of *Septoria* spp. in May and July, sunshine duration during August was statistically most important, followed by year, and precipitation was not important. Analysing the average annual severity during July 1975–1980 statistically, revealed that precipitation during March–April was most important. Addition of year or sunshine duration in August did not improve the correlation. Average annual incidence during July 1981–1986 did not reveal correlations, consistent with the earlier observations (Table 3).

Glume blotch. Between 1974 and 1986, on average 49% of the fields showed ear infections by *S. nodorum* (Table 1). Unlike *Septoria* spp. on leaves, the intensity of glume blotch did not increase in importance between 1974 and 1986. Glume blotch incidence was low, on average 0.5% of the glumes was infected during 1975–1986. Annual glume blotch intensities did not correlate with weather variables, as nearly all correlation coefficients were below 0.5.

Discussion

Occurrence and distribution of *S. tritici* and *S. nodorum* in the Netherlands correspond to those in neighbouring countries. *S. nodorum* dominates in Germany, except in the coastal districts (Verreet et al., 1990). In France, the tendency is that *S. tritici* dominates in the northwestern part, both species occur in the central and southeastern part, though in the latter *S. tritici* is replaced by *S. nodorum* in the course of the season (De la Rocque, 1986). However, in the United Kingdom both species occurr and their dominance varies annually (Royle et al., 1986), though *S. tritici* was predominant from 1985 to 1988 especially in the West and the South-West (Polley and Thomas, 1991).

The relative dominance of the different pathogens is presumably the result of the interaction of weather and crop development. *S. nodorum* is more virulent on adult plants than *S. tritici*, and *S. tritici* requires lower temperatures than *S. nodorum* (Holmes and Colhoun, 1974; Wainshilbaum and Lipps, 1991). Moreover, the latent period of *S. tritici* is considerably longer than that of *S. nodorum* and pycnidiospores of *S. tritici* require a longer period of leaf wetness to complete infection than those of *S. nodorum* (Holmes and Colhoun, 1974; Shearer and Zadoks, 1974; Jeger et al., 1981, 1983; Thomas et al., 1989; Shaw, 1990). This implies that if both pathogens cause primary infections in autumn, *S. tritici* predominates in winter and spring. When temperatures increase during stem elongation, leaf formation and leaf death increase concurrently. High temperatures and short leaf durations promote *S. nodorum* relative to *S. tritici*. The faster temperature increases during stem elongation and the higher the subsequent temperatures, the more *S. nodorum* will be predominant (Holmes and Colhoun, 1974; Hart et al., 1984). The domination of the pathogens at the end of the season determines subsequent sources of primary inoculum for the next crop. Whether ascospore flights in spring (Mittelstadt and Fehrmann, 1987; Shaw and Royle, 1989) determine intensity of both pathogens in summer is unknown. In the Netherlands, presumably both regional climate and soil type and its associated crop microclimate determine the occurrence of both species. E.g. in Wageningen, on sandy soils, *S. nodorum* dominates in summer, whereas at 1 km distance, on heavy river clay, *S. tritici* dominates.

Increased intensity of *Septoria* spp. over time, associated with increased wheat production (Eyal et al., 1987) has also been observed in the Netherlands, where average grain production increased from 5 to 7 tonnes dry matter per hectare between 1974 and 1986. The observed increase in intensity of *Septoria* spp. in different parts of the world has been attributed to the increased use of early-maturing short-strawed cultivars, caused by changes in resistance as well as changes in canopy structure and dynamics (Bahat et al., 1980; Scott et al., 1985; Baltazar et al., 1990; Eyal and Talpaz, 1990). Although crop stature gradually changed in the Netherlands between 1974 and 1986, it is unlikely that this caused the observed increase in prevalence of *Septoria* spp. during these years. The old cvs Manella, Lely and Clement, cultivated between 1974 and 1978, were on average two grades more susceptible to *S. nodorum* and *S. tritici* than the later cvs Okapi and Arminda (E.Ubels, pers. comm.; Ubels et al., 1980). Therefore, other changes in crop management during this period must have promoted epidemics of *Septoria* spp. Presumably changes in several practices concurrently caused the increase in leaf infections by *Septoria* spp. in the Netherlands. In the early 1970s, stubble ploughing was a common sanitation practice, especially to control weeds. During the 1980s weeds were controlled mainly by herbicides and an increased presence of stubble in the field resulted. This was also stimulated by the increased practice of undersowing grasses. The consequence is that emerging winter wheat crops are more easily infected by ascospores. In addition, increased production was realised by increasing nitrogen application from circa 100 to 160 kg N/ha, so that leaf death, straw and kernel ripening and harvest have been delayed. To avoid late harvests, farmers tend to sow earlier. Both shorten the fallow period. Hence, increased carry-over of *Septoria* spp., especially of *S. tritici*, may result. The gradual increased use of fungicides apparently hardly affected the prevalence of *Septoria* spp. A direct effect of fungicides would have resulted in a decrease in *Septoria* spp., while an indirect effect, through decreased competition by other widespread pathogens like mildew and brown rust, was not observed. It is unlikely that the widespread and recent occurrence of strains of *S. tritici* resistant to carbendazim generating fungicides (Polley and Thomas, 1991) caused the increased importance of *Septoria* spp., as the use of carbendazim generating fungicides decreased (Daamen, 1990).

Weather. Once a crop is infected, rain and high air humidity stimulate *Septoria* epidemics (Rapilly and Jolivet, 1976; Tyldesley and Thompson, 1980; Coakley et al., 1985; Hess and Shaner, 1987; Shaw, 1987; Khoury and Kranz, 1989; Thomas et al., 1989; Murray et al., 1990; Djurle and Yuen, 1991). Also in this study precipitation was positively correlated with *Septoria* spp. intensity. However, with respect to the annual prevalence of *Septoria* spp. this correlation was not strong and not additional to the correlation with year. From the weather variables, sunshine duration in the harvest month August before sowing gave the highest (negative) correlation with prevalence of *Septoria* spp. No references were found in literature confirming this correlation and, moreover, many weather variables were explored using correlations only, so that this correlation might be coincidental. On the other hand, the quantitative role of ascospores in epidemics of *Septoria* spp. is not yet clear. Ascospores, formed on wheat stubble and crop residues, are an important primary inoculum for emerging wheat (Brown et al., 1978; Mittelstadt and Fehrmann, 1987; Sanderson and Hampton, 1978; Scott et al., 1988; Shaw and Royle, 1989) and for long distance dispersal. The onset, duration and intensity of ascospore flights vary considerably between years, due to unknown factors (Brown et al., 1978; Sanderson and Hampton, 1978; Shaw and Royle, 1989) as do epidemics of *S. tritici* and *S. nodorum* (Royle et al., 1986; Verreet and Hoffmann, 1990; Polley and Thomas, 1991). We may hypothesise that much sunshine during the harvest-month August decreases the availability of ascospores due to earlier and less variable times of harvest and stubble management in the country.

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