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Influence of different cultural practices on distribution and incidence of eyespot *(Pseudocerocosporella herpotrichoides)* in winter rye and winter wheat

Forskellige kulturfaktorers betydning for forekomst og udbredelse af knækkefodsyge (Pseudocercosporella herpotrichoides) *i vinterrug og vinterhvede*

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Summary

Data from 1094 trials with crop rotation and control of eyespot in winter wheat and winter rye carried out at the »Landøkonomiske Foreninger« and at the Research Centre for Plant Protection have been statistically analysed with a view to explaining the importance of various cultural practices for the attack and occurrence of the eyespot disease. As the testing material is very heterogeneous, the results will only show the general tendencies. A clear yearly variation in per cent attack between the years 1978-86 at the spring and summer assessments is found, whereas only limited correlation is found between spring and summer attacks. A classification of the country in eight regions revealed differences within these as regard per cent attack in both rye and wheat in April and July. The disease is most common in the wheat growing areas. The highest attack in wheat in April was found when sowing had taken place before 1-10 September, whereas no differences were observed when sowing after 10 September. At the summer assessment the highest attack was found when sowing between 10 September and 1 October. In rye, a gradual decrease in attack was observed when postponing the sowing. In April, the highest attacks were found in clay soils compared to sandy, whereas no differences were observed in July between the two soil types. No significant difference were found in per cent attack in April as regards ploughing and no ploughing before sowing. However, significantly fewer attacks were observed in July when sowing directly. Straw burning showed an increased level of attack in July but not in April.

Crop rotation showed several significant differences in April but less in July. Grass for seed production for two years before growing wheat did not increase the level of attack, neither in April nor in July. Wheat grown after four years of spring barley stayed at a low level in spring but at a rather high level at the July assessments. When growing peas and rape as intervening crop, the attack was still at a rather high level at the spring and summer assessments, respectively, and almost at the same level as wheat grown for three years. Growing wheat for two years after rape gave a relatively high attack in spring and the highest attack at the summer assessment. Growing wheat for five years gave the highest attack in spring whereas the summer attack was at the same level as wheat grown for three years and the crop rotations in which pea, rape, barley and other crops had been grown as intervening crops as well as after growing barley for four years.

Key words: Eyespot, *Pseudocercosporella herpotricoides,* winter wheat, winter rye, cultivation methods.

Resumé

Bedømmelser for knækkefodsyge fra 1094 sædskifte- og bekæmpelsesforsøg med vinterhvede og vinterrug udført i perioden 1978-86 ved de landøkonomiske foreninger, Statens Forsøgsstationer og Planteværnscentret er blevet statistisk bearbejdet med henblik på at klarlægge de forskellige kulturtekniske faktorers betydning for angreb og udbredelse af knækkefodsyge. Da forsøgsmaterialet er meget heterogent, vil materialet kun vise generelle tendenser. Der fandtes tydelig årsvariation med hensyn til angrebsintensitet ved forårs- og sommerbedømmelsen i de enkelte år, medens der kun fandtes begrænset sammenhæng mellem forårs- og sommerangreb. Ved opdeling af landet i otte regioner fandtes både i rug og hvede forskelle med hensyn til angreb i april og juli i de forskellige regioner. Sygdommen er mest udbredt i de hvededyrkende egne. Det største angreb i hvede i april fandtes efter såning mellem den 1. og 10. september, medens der ingen forskel var ved såning efter denne dato. Ved sommerbedømmelsen fandtes ingen klar forskel mellem såning fra før 1. september til 1. oktober. I rug fandtes et jævnt fald i angreb ved såtidens udskydelse. Jordtyperne blev inddelt i 2 kategorier, JB 1-4 og JB 5-9. I april fandtes de højeste angreb i gruppe JB 5-9, medens der ingen forskel var i juli mellem de to kategorier. Der var ingen signifikant forskel ved aprilangreb med hensyn til pløjning og ikke pløjning inden såning. Men der var mindre angreb i juli ved direkte såning. Ved halmafbrænding fandtes højere angrebsprocent i juli, mens der ingen forskel var i april.

Sædskiftet havde betydelig indflydelse på angrebsniveauet i april mens forskellene var mindre ved julibedømmelsen. 2 års frøgræs som forfrugt for hvede viste det laveste angrebsniveau både i april og juli. Hvede efter 4 års vårbyg lå på et lavt niveau om foråret, men lå relativt højt ved juli-bedømmelsen. Med ærter og raps som mellemafgrøde lå angrebet stadig ret højt, ved forårs- og sommerbedømmelsen næsten på højde med 3. års hvede. 2. års hvede efter raps havde et relativt højt angreb om foråret og det højeste angreb ved sommerbedømmelsen. 5. års hvede havde de højeste forårsangreb, medens sommerangrebet lå på højde med 3. års hvede og de sædskifter, hvor ært, raps, byg og andet havde været mellemfrugt samt efter 4 års byg.

Nøgleord: Knækkefodsyge, *Pseudocercosporella herpotrichoides,* vinterrug, vinterhvede, kulturforanstaltninger.

Introduction

In winter cereals, eyespot disease *(Pseudocercosporella herpotrichoides)* (Fron) Deighton) is a rather common disease in Denmark (24). In some years, spring barley can be attacked, but mostly at a very low level. However, this may cause spring barley to contribute to the transmission of the infection to a subsequent winter crop. The fungus can survive saprophytically for up to 3 years on infected stubble debris in the soil (16). When these infected stubble debris are ploughed up, a very active sporulation takes place under certain climatic conditions (5, 6, 7, 11) and infection of a susceptible crop may occur. In Denmark, this primary infection mostly takes place at the end of October and the beginning of November (28).

The first symptoms often appear in December or in early spring, depending on the weather conditions. Secondary infection from the infected plants can then take place in early spring together with a continued primary infection from straw debris in spring cereals. The spores are spread by means of water splashes and raindrops (8), but only at rather short distances (5, 6, 7). Frequency and severity of attack depend, to a very large degree, on the climatic condition.

Since the mid-sixties, a large number of assessments for take-all and eyespot disease in both spring and winter cereals from experiments with crop rotation and fungicide control have been carried out at the Research Centre for Plant Protection. Since the mid-seventies, both spring and summer assessments for attack of eyespot disease in the winter cereals under standardized conditions have been carried out in different trials located all over the country.

In order to establish which cultural factors that influence the occurrence and incidence of the attack of eyespot disease, data from 1094 trials with winter rye and winter wheat in the years 1978-86 have been statistically analysed (3).

The purpose of the statistical analyses has been to find important trends in the material and to incorporate main factors in a forecasting model for eyespot in winter wheat.

Materials and methods

In the years 1978-86, 1094 trials were carried out as crop rotation and fungicide trials with eyespot assessments at (Zadoks) growth stage 22-30 in spring and around 75 in July all over the country. Together with the samples, information on location, soil type, sowing date, previous crops (4 years), cereal variety, soil cultivation and haulm treatment of the previous crop was collected.

Sampling in spring time were performed by collecting randomly approximately 100 plants per field or treatment at growth stage 22-30 (April). The plants were slightly washed in water to which were added a detergent (sulpho). Per cent plants with visible eyespot attacks were assessed.

Assessments of samples collected in July were carried out as follows:
Approximately 100 tillers per treatment were randomly collected at growth stage 75. The tillers were cleaned for leafsheets and washed with tapwater together with compressed air.

Each straw was placed in one of the four classes listed below.

a. Healthy straw.
b. Slight eyespot attack (one or more superficial lesions occupying less than half the circumference of the stem).
c. Moderate eyespot attack (one or more lesions occupying at least half the circumference of the stem).
d. Severe eyespot attack (stem completely girdled with lesions, tissue softened so that lodging would readily occur.

Per cent attack of eyespot in July is equal to the sum of per cent straw in the categories c and d.

Statistical analyses were carried out using the general linear model procedure (25) with the following qualitative factors: year, region, cereal host, sowing time, soil type, tillage method, burning of straw and sowing time. Estimates for the disease severity for each factor level in the model is an adjusted mean value where the means are corrected for unbalance in the data.

The estimate of confidence is calculated by testing the adjusted mean values two by two using a t-test. The model takes into account the different number of observations for each factor level and the additional variation caused by the adjustment.

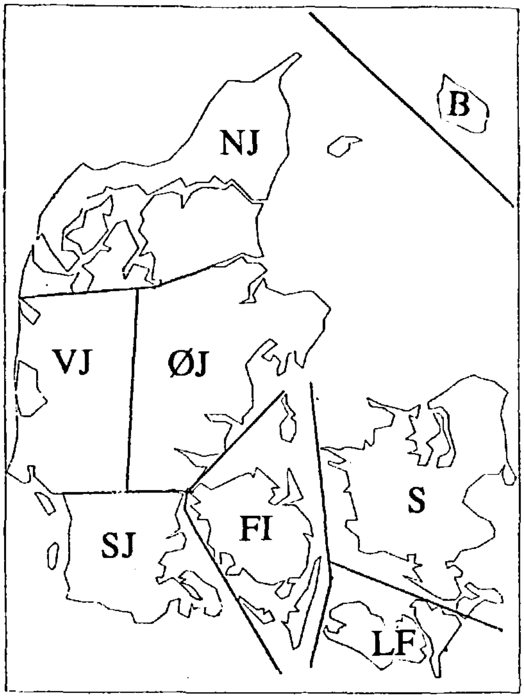


Fig. 1. Classification of the individual trials in eight regions. Nordjylland (NJ), Vestjylland (VJ), Østjylland (ØJ), Sønderjylland (SJ), Fyn and surrounding islands (FI), Sjælland and Møn (SM), Lolland-Falster (LF) and Bornholm (B).

Table 1. Signification table for the attack of eyespot in wheat in April in the years 1978-86, tested two by two (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

Wheat	1978	1979	1980	1981	1982	1983	1984	1985	1986
1978		ns	ns	ns	ns	***	ns	ns	ns
1979			ns	*	ns	***	ns	ns	ns
1980				**	*	***	ns	ns	ns
1981					ns	***	*	*	**
1982						***	ns	ns	*
1983							***	***	***
1984								ns	ns
1985									ns
1986									

Due to lack of information in some of the questionnaires, often only part of the observations are included in the various models. The number of trials included in each model appears from the respective figures. The various parameter estimates for each specific factor is a corrected mean value.

All the trials were classified in eight regions (Fig. 1) partly based on climatic and soil-related conditions, traditions and experience with regard to the occurence of the disease in recent years.

Results

Yearly variation

In the years 1978-86, the level of attack of eyespot assessed in April and July varies from year to year, both in rye and wheat (Fig. 2, 3). However, in rye no significant yearly differences in the attack level are observed in April, whereas in wheat significant differences are found between some of the years (Fig. 2, Table 1). In July significant differences between some of the years occur for both wheat and rye (Fig. 3, Table 2). Especially 1983 manifests itself as an eyespot disease year. Only a limited correlation between the attack in April and July, respectively, is found (Fig. 4).

Locality variation

All trials were classified in eight regions, partly based on different climatic conditions. By classifying the trials in these regions, significant differences between some of the regions were found in the level of attack in both rye and wheat in April and July, respectively (Table 3, 4). The incidence of eyespot disease seems to be less common in Vestjylland (VJ) and most common on Lolland-Falster (LF). The remaining locations are at almost the same level, except Sønderjylland (SJ) which has also a rather high level of attack (Fig. 5). In the latter group, however, are included relatively many trials from Rønhave Research Station (at the island of Als) which notoriously has a high infection potential in its soil.

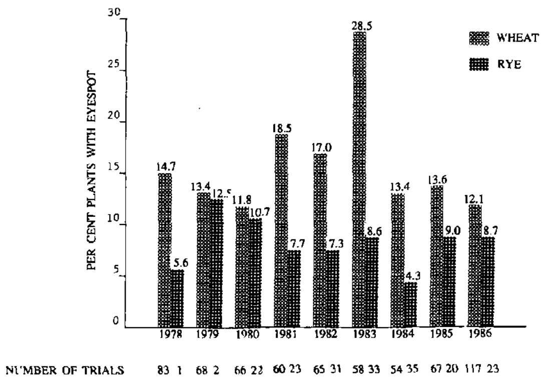


Fig. 2. Adjusted mean per cent attack of eyespot in wheat (638 trials) and rye (190 trials) in April 1978-86.

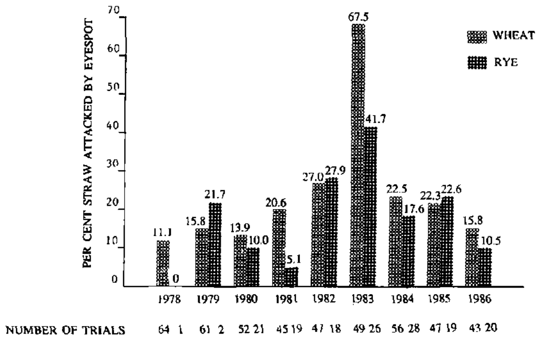


Fig. 3. Adjusted mean per cent attack of eyespot in wheat (464 trials) and rye (154 trials) in July 1978-86.

Table 2. Signification table for the attack of eyespot in July in rye and wheat in the years 1978-86, tested two by two (* P < 0.05, ** P < 0.01, *** P < 0.001).

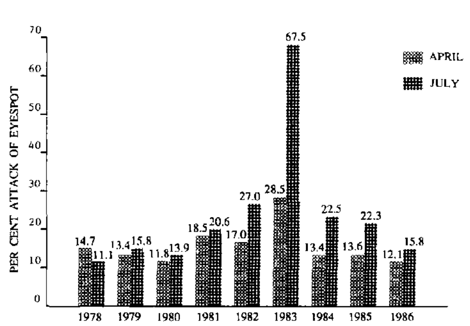
Wheat	1978	1979	1980	1981	1982	1983	1984	1985	1986
1978		ns	ns	**	***	***	***	***	ns
1979			ns	ns	**	***	*	ns	ns
1980				ns	***	***	*	*	ns
1981					ns	***	ns	ns	ns
1982						***	ns	ns	**
1983							***	***	***
1984								ns	ns
1985									ns
1986									

Rye	1978	1979	1980	1981	1982	1983	1984	1985	1986
1978		ns	ns	ns	*	**	ns	ns	ns
1979			ns	ns	ns	ns	ns	ns	ns
1980				ns	**	***	ns	*	ns
1981					***	***	*	**	ns
1982						**	*	ns	**
1983							***	***	***
1984								ns	ns
1985									*
1986									

Sowing time variation

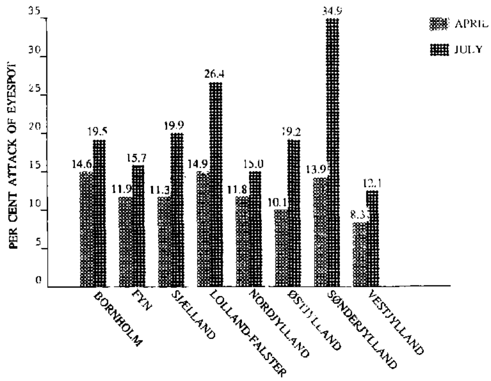
In order to evaluate the importance of the sowing date on the level of attack, the trials were grouped in six sowing time intervals. The number of observations varies much within the various sowing time intervals, as it appears from Fig. 6 and 7.

In both wheat and rye the significantly highest per cent attack is found at the April evaluation with sowing between 1 and 10 September whereas there is a tendency of a slight decrease in the attack sowing after 10 October. In rye there seems to be a more gradual decrease in per cent attack



NUMBER OF TRIALS 83 64 68 61 66 52 60 45 65 47 58 49 54 56 67 47 117 43

Fig. 4. Adjusted mean per cent attack of eyespot in wheat. Per cent plants attacked in April (638 trials). Per cent straw attacked in July (464 trials).



NUMBER OF TRIALS 44 25 100 97 151 51 70 61 165 132 203 187 [illegible] 57 [illegible]

Fig. 5. Adjusted mean per cent attack of eyespot in wheat and rye in 8 different regions in 1978-86. Attack in April (775 trials) and attack in July (579 trials).

Table 3. Signification table for attack of eyespot in April in rye and wheat together in 8 different regions in the years 1978-86, tested two by two (* P < 0.05, ** P < 0.01, *** P < 0.001).

	Born-holm	Fyn	Lol.-Fal.	Sjæl-land	Nord-jyll.	Øst-jyll.	Sønd.-jyll.	Vest-jyll.
Bornholm		ns	ns	ns	ns	*	ns	*
Fyn			ns	ns	ns	ns	ns	ns
Loll.-Fal.				*	ns	**	ns	*
Sjælland					ns	ns	ns	ns
Nordjyll.						ns	ns	ns
Østjyll.							ns	ns
Sønderjyl.								*
Vestjyll.								

when postponing the sowing date (Fig. 6). But the differences are not significant.

At the summer evaluation, the highest per cent attack in wheat are found at the very early time of sowing. No significant differences in attack are found by sowing wheat between 10 September and 1 October. Sowing between 1 and 10 October gives significant less attack, compared with the earlier sowing times, whereas per cent attack rises again by sowing after 10 October. In rye, the per cent attack drops gradually when postponing the time of sowing, but only significant (PL 0.05) dif-

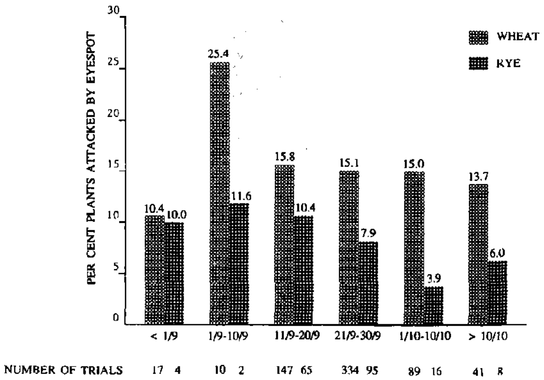


Fig. 6. Adjusted mean per cent attack of eyespot in wheat (638 trials) and rye (190 trials) in April at 6 different sowing time intervals in the years 1978-86.

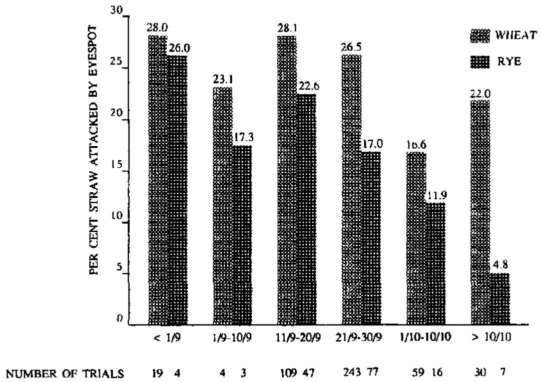


Fig. 7. Adjusted mean per cent attack of eyespot in wheat (454 trials) and rye (154 trials) in July at 6 different sowing time intervals in the years 1978-86.

Table 4. Signification table for attack of eyespot in July in rye and wheat together in 8 different regions in the years 1978-86, tested two by two (* P < 0.05, ** P < 0.01, *** P < 0.001).

	Born-holm	Fyn	Lol.-Fal.	Sjæl-land	Nord-jyll.	Øst-jyll.	Sønd.-jyll.	Vest-jyll.
Bornholm		ns	ns	ns	ns	ns	**	ns
Fyn			***	ns	ns	ns	***	ns
Loll.-Fal.				*	**	*	*	***
Sjælland					ns	ns	***	*
Nordjyll.						ns	***	ns
Østjyll.							***	*
Sønderjyl.								***
Vestjyll.								

ference in attack are found between the sowing dates 10 until 20 September and after the 10 October (Fig. 7).

The influence of soil type

The soil types have been roughly classified in two categories, i.e. JB 1-4 ranging from sandy soils to loam soils, and JB 5-9 which corresponds from clay soils until rather heavy clay soils. (31).

Significantly higher attacks of eyespot disease in rye and wheat are found in the clay soils at the April evaluations, whereas no significant differences in per cent attack are found at the July evaluation (Fig. 8).

The influence of soil treatment

The trials were classified in two groups – ploughing before sowing and no ploughing. No significant difference between the two types of treatment were found in April, but a significant (* = P < 0,05) lower attack in July in the non-ploughed trials was registered (Fig. 9).

The importance of straw burning

In the trials where the previous crop was a cereal crop, the effect of burning straw and stubble before tillage was analysed.

A classification of per cent attack in two groups with or without straw burning of the previous crop showed that straw burning gave no significant differences in per cent attack in April. In July there was a significantly higher attack when the straw from the previous cereals were burnt (Fig. 10).

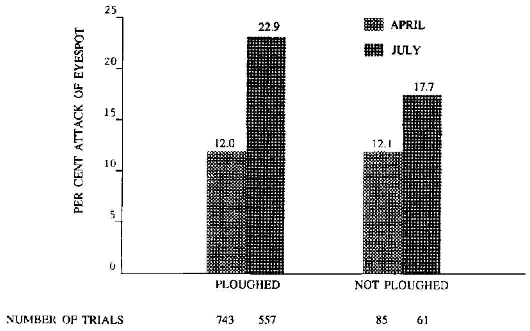


Fig. 9. Adjusted mean per cent attack of eyespot in wheat and rye in April and July in 1978-86 (1446 trials) ploughed and not ploughed.

The importance of crop rotation

Per cent attack was grouped according to the most commonly used combinations of previous crops in practice. At the plant assessment in April a significantly higher per cent attack is observed when increasing the frequency of wheat in the crop rotation.

At the spring assessment in April grass for seed production used as previous crop for two years and spring barley for four years, showed the lowest attack, while as the highest attack was found when growing wheat for five years (Fig. 11). When peas and rape are grown as previous crop, a relatively high spring attack was found, and no significant differences between these two previous crops were observed (Fig. 11, Table 5).

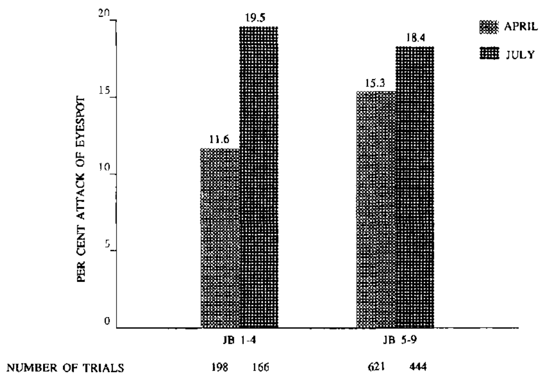


Fig. 8. Adjusted mean per cent attack of eyespot in sandy soils (JB 1-4) and clay soils (JB 5-9) in wheat and rye in April and July in the years 1978-86.

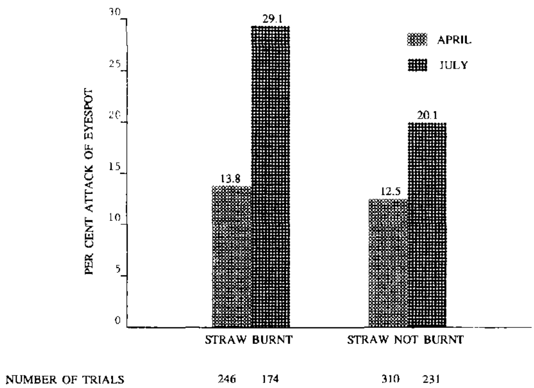


Fig. 10. Adjusted mean per cent attack of eyespot in April and July when straw from the previous crop have been burnt or not before sowing, 1978-86.

At the summer assessment fewer significant differences between the various combinations of previous crops were observed (Fig. 11, Table 5). The crop rotation with grass for seed production has a significantly lower per cent attack in July compared to nine of the crop rotation combinations, whereas the common crop rotation practice from the region Lolland-Falster (barley, wheat, beets) shows a significantly lower per cent attack compared to two years of wheat and the crop rotations which include peas and rape. No significant differences between the other combinations of crop rotations are found with regard to the per cent attack in July.

Discussion and conclusion

The estimated values have been calculated on the basis of many heterogeneous trials with the consequent interactions between the biological, chemical and physical conditions. This means that the results obtained after statistical analysis are not always unambiguous but rather show certain tendencies which to a large degree confirm the experience gained throughout the years and which until now has been used in the advisory service.

The yearly variation is rather clear, especially at the spring assessment (Fig. 2). The level of attack depends very much on the infection pos-

Table 5. Signification table for the attack of eyespot in wheat in April/May and July with different combinations of previous crops in the years 1978-86, tested two by two (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

April/May	BA BA BA BA	WH BA	BA BE WH BA	RA BA	SG SG	VE WH	PE WH	BA WH	WH WH	WH WH WH WH	RA WH	WH RA
BA BA BA BA		*	*	ns	ns	ns	**	*	***	***	*	***
WH BA			ns	*	***	ns	ns	ns	ns	***	ns	*
BA BE WH BA				*	***	ns	ns	ns	ns	***	ns	*
RA BA					ns	ns	*	*	***	***	*	***
SG SG						ns	***	**	***	***	***	***
VE WH							ns	ns	ns	**	ns	*
PE WH								ns	ns	*	ns	ns
BA WH									ns	**	ns	ns
WH WH										*	ns	ns
WH WH WH WH											**	ns
RA WH												ns
WH RA												

July	BA BA BA BA	WH BA	BA BE WH BA	RA BA	SG SG	VE WH	PE WH	BA WH	WH WH	WH WH WH WH	RA WH	WH RA
BA BA BA BA		ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
WH BA			ns	ns	*	ns	ns	ns	ns	ns	ns	*
BA BE WH BA				ns	ns	ns	ns	ns	*	ns	ns	**
RA BA					*	ns	ns	ns	ns	ns	ns	**
SG SG						ns	*	**	**	**	**	***
VE WH							ns	ns	ns	ns	ns	ns
PE WH								ns	ns	ns	ns	ns
BA WH									ns	ns	ns	ns
WH WH										ns	ns	ns
WH WH WH WH											ns	ns
RA WH												ns
WH RA												

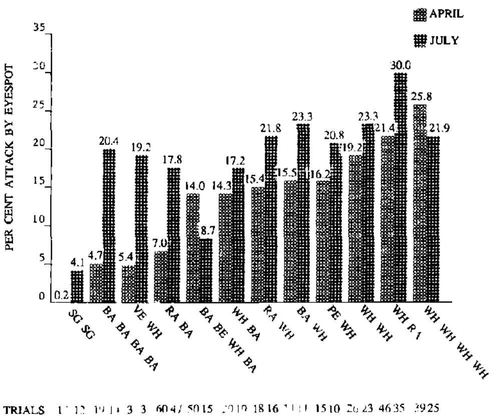


Fig. 11. Adjusted mean per cent attack of eyespot in April and July in winter wheat with different combinations of previous crops in the period 1978-86. RA = oilseed rape (winter and spring), SG = grass for seed production, WH = winter wheat, VE = vegetables, PE = peas, BA = spring barley, BE = sugar beets.

sibilities after emergence of the winter cereals and on the climatic possibilities for sporulation and infection during the winter (5, 6, 7). The level of attack at the summer assessment also shows significant differences between some of the years (Fig. 3, Table 2), but only poor correlation between the assessments of attacks in the spring and in the summer (Fig. 4). This poor correlation is mainly dependent on climatic conditions in the intervening period. The disease development compared to the growth of the plants seems to be important for the final result of the incidence of the attack (*9*). Humid and cool conditions promote the growth of the fungus, whereas dry and warm conditions promote the plant growth. As a consequence the plant may grow faster than the fungus and the exterior infected leafsheets dry out before infection to the stem occur (29).

Control of the disease can, however, only be based on the level of attack in spring (12, 28) as the coming climatic conditions in May and June, which are decisive for the importance of the attack, cannot be predicted. The yearly average of attack in the period 1976-86 shows that 35-50 per cent of the wheat fields have had attacks above the 15% threshold (*H. Schulz* unpubl.).

A classification of the trials in 8 regions (Fig. 1) revealed significant differences in eyespot attack both in April and July between some of the regions (Fig. 5, Table 3, 4). To a large degree, these differences are probably due to variations in climate. It appears from these results that a control strategy may have to be planned on a more specific regional prognosis.

Danish and foreign investigations have shown that early sowing has resulted in the highest attack of eyespot disease (9, 20, 22, 27, 30). When grouping the results in six sowing time intervals the highest level of attack was found at the April assessment with sowing between 1 and 10 September. When sowing after 10 September no significant differences were found in wheat. In rye a decreasing attack was found when the sowing time was postponed. At the summer assessment the strongest attacks were found when sowing before 1 September and between 10 September and 1 October, but the differences are far from significant in all cases. Unfortunately, the number of observations within the various sowing time intervals varies a lot (Fig. 6, 7). This may explain why the differences in level of attack do not appear as clear as was the case with specific trials (20). Late sowing to avoiding attack can, however, not be recommended as it negatively affects the yield due to other reasons. On the other hand, too early sowing increases the risk for widespread strong attacks, which has also been the case for take-all (3, 20).

The importance of the soil type on eyespot attack (Fig. 8) does not appear clearly. This is probably due to the classification of soil types into sandy and clay soils being somewhat too rough. Furthermore, wheat more often forms part of the crop rotation on clay soils, so that the infection potential in these soils is maintained. The results obtained from spring assessment however do correspond to other experiences which show more clearly that the highest incidence of eyespot disease is found on the medium to heavy clay soils (JB 6-7) (18, 23). In the summer assessments there are no significant differences between the two categories.

Concerning influence of soil treatment the number of observations varies much, as by far the largest number of fields have been ploughed before sowing of the winter cereals (Fig. 9). However, a significant higher attack, but only in July, by traditional ploughing is observed. This is probably due to the ploughing-up of infected stubles. *Herman* and *Wiese* (10) also found that traditional soil treatment with plough or disk harrow gave the highest attack of eyespot disease compared to reduced soil cultivation. A classification of the fields according to previous straw burning showed no significant differences in attacks in April, but in July there was a significantly higher attack when the straws from the previous cereals were burnt (Fig. 10). This result corresponds to other trials (2, 4, 5, 21). When burning the straw the eyespot disease is only slightly reduced and there will always be so much infection potential left that new attacks may occur.

As expected, important significant differences between some of the combinations of crop rotation were found, especially when wheat forms part of the crop rotation on a regular basis. The highest and most significant differences between the various combinations of previous crops were found particularly at the spring assessments (Fig. 11, Table 7). No difference were found between peas and rape grown as previous crop, and the level of attack was relatively high after growing them as previous crops. Grass for seed production for two years did not increase the severity of eyespot in a following wheat crop. *Maenhout* (17) showed, however, that Italian rye grass could maintain the infection level at a relatively high level. Several years with barley grown as previous crop will probably not reduce the eyespot disease very much, but strong attacks when growing barley and wheat as previous crops have been observed.

Only few significant differences between the combinations of previous crops at the July assessment were found (Table 5). This is probably due to the big influence of climatic conditions from the time of infection until the assessment of attack in July.

It can not be excluded that different types of the eyespot fungi (19) with varying aggressiveness are involved (13, 14, 15) or that there appears to be an antagonism between the various types of the eyespot fungi (26) or other fungi such as *Fusarium spp.* and *Rhizoctonia spp.* These conditions have not been examined in these trials.

The variety variation has been excluded from the statistically analysis due to uneven distribution of varieties over the years. Foreign trials show that no variety variation is found at the seed leaf stage (1). Danish observations from practice only shows small variety variation as regards to attack of eyespot fungus.

References

1. *Batemann, G. L. & G. S. Taylor,* 1976. Seedling infection of wheat cultivars by *Pseudocercosporella herpotrichoides*. Trans. Br. mycol. Soc. 67, 95-101.
2. *Bockmann, H.,* 1965. Wirksamkeit des Stoppelbrennens auf die Fusskrankheiten des Weizens. Biologische Bundesanstalt für Land- und Forstwirtsschaft in Berlin und Braunschweig (Jahresbericht) A74, 1 p.
3. *Bødker, L. & Jensen, B.* 1988. Knækkefodsyge og goldfodsyge, forebyggelse, prognose/varsling og bekæmpelse. Hovedopgave, Plantepatologisk Institut, KVL. 158 pp.
4. *Dueholm, S. & Jørgensen, J.* 1974. Halmens indflydelse på kerneudbyttet og fodsyge ved ensidig korndyrkning 1967-1973. Statens Forsøgsvirksomhed i Plantekultur, Meddelelse nr. 1159.
5. *Fehrmann, H. & Schrödter, H.* 1971a. Ökologische Untersuchungen zur Epidemiologi von *Cercosporella herpotrichoides*. I. Die jahreszeitliche Abhängigkeit von Weizeninfektionen im Freiland. Phytopath. Z. 71, 66-82.
6. *Fehrmann, H. & Schrödter, H.* 1971b. Ökologische Untersuchungen zur Epidemiologi von *Cercosporella herpotrichoides*. II. Die Abhängigkeit des Infektionserfolges von einzelnen meteorologischen Faktoren. Phytopath. Z. 71, 97-112.
7. *Fehrmann, H. & Schrödter, H.* 1971c. Ökologische Untersuchungen zur Epidemiologi von *Cercosporella herpotrichoides*. III. Die relative Bedeutung der meteorologischen Parameter und die Komplexe Wirkung ihrer Konstellationen auf den Infektionserfolg. Phytopath. Z. 71, 203-222.
8. *Fitt, B. D. L. & Bainbridge, A.* 1983. Recovery of *Pseudocercosporella herpotrichoides* spores from rain splash samples. Phytopath. Z. 106, 177-182.
9. *Frahm, J. & Knapp, A.* 1986. Ein einfaches Model zur Optimierung von Fungicidbehandlungen gegen *Pseudocercosporella herpotrichoides* in Weizen. Gesunde Pflanzen 38, 139-150.
10. *Herrman, T. & Wiese, M. V.* 1985. Influence of cultual practices on incidence of foot rot in winter wheat. Plant Disease 69, 948-950.
11. *Jørgensen, J.* 1964. Some observations on the effect of temperature on the sporulation of *Cercosporella herpotrichoides* Fron. Acta agric. Scand. 14, 126-128.
12. *Jørgensen, L. Nistrup, Bødker, L. & Schulz, H.* 1990. Validation of the threshold for eyespot *Pseudocercosporella herpotrichoides* (Fron.) Deighton in spring and July. Tidsskr. Planteavl 94, 223-232.
13. *Lange-de la Camp, M.* 1966a. Die Wirkungsweise von *Cercosporella herpotrichoides* Fron, dem Erreger der Halmbruchkrankheit des Getreides. I. Feststellung der Krankheit. Beschaffenheit und

Infektionsweise ihres Erregers. Phytopath. Z. 55, 34-66.
14. *Lange-de la Camp, M.* 1966b. Die Wirkungsweise von *Cercosporella herpotrichoides* Fron, dem Erreger der Halmbruchkrankheit des Getreides. II. Aggressivität des Erregers. Phytopath. Z. 56, 155-190.
15. *Lange-de la Camp, M.* 1966c. Die Wirkungsweise von *Cercosporella herpotrichoides* Fron, dem Erreger der Halmbruchkrankheit des Getreides. III. Art und Ausmass des Schadens – Bekämpfungsmöglichkeiten. Phytopath. Z. 56, 363-392.
16. *Macer, R. C. F.* 1961. Survival of *Cercosporella herpotrichoides* Fron in wheat straw. Ann. appl. Biol. 49, 165-172.
17. *Maenhout, C. A. A. A.* 1975. Eyespot in winter wheat: Effects of crop rotation and tillage, and the prediction of incidence. EPPO Bull. 5, 407-413.
18. *Naumann, K. & Lange-de la Camp, M.* 1975. Dauer der Infektionsfähigkeit halmbruchkranker Getreidestoppeln. II. Zbl. Bakt. Abt. II. 130, 171-194.
19. *Nirenberg, H. I.* 1981. Differenzierung der Erreger der Halmbruchkrankheit I. Morphologie. Z. PflKrankh. PflSchutz. 88, 241-248.
20. *Olsen, C. C.* 1984. Såtid og såmængde i vinterhvede og vinterbyg. Tidsskr. Planteavl. 88, 547-569.
21. *Olsen, C. C.* 1985. Halmhåndteringens indflydelse på kerneudbyttet og goldfodsygen ved ensidig dyrkning af vårbyg. Statens Planteavlsforsøg, Meddelelse nr. 1845.
22. *Pedersen, P. N. & Jørgensen, J.* 1960. Knækkefodsygens og goldfodsygens afhængighed af sædskifte og andre dyrkningsfaktorer. Tidsskr. Planteavl 64, 369-416.
23. *Petersen, H. I.* 1960. Knækkefodsygens og goldfodsygens afhængighed af sædskifte og andre dyrkningsfaktorer. Tidsskr. Planteavl 64, 369-416.
24. *Petersen, H. I.* 1963. Landsomfattende undersøgelser over forekomst af fodsyge i kornmarker i 1961 og 1962. Ugeskrift for Landmænd. 31, 487-492.
25. *SAS Users Guide* 1982. Statistics Version, 5 Edition SAS Institute Inc. Cary, NC USA. 960 pp.
26. *Schreiber, M. T. & Prillwitz, H. G.* 1989. Untersuchungen zum Antagonismus von *Pseudocercosporella anguioides* gegenüber den Halmbrucherregern *Pseudocercosporella herpotrichoides* var. *acuformis* und *Pseudocercosporella herpotrichoides* var. *herpotrichoides*. Z. Pfl. Krankh. PflSchutz 96, 408-427.
27. *Schulz, H.* 1970. Angreb af fodsyge (*Pseudocercosporella herpotrichoides* Fron og *Ophiobolus graminis* Sacc.) ved forskellige såtider, så- og kvælstofmængder i vinterrug og vinterhvede. Tidsskr. Planteavl 74, 412-418.
28. *Schulz, H. & Hansen, K. E.* 1977. Knækkefodsyge i vintersæd. Biologi og Bekæmpelse. Statens Planteavlsforsøg, Meddelelse nr. 1343.
29. *Scott, P. R.* 1971. The effect of temperature on eyespot (*Cercosporella herpotrichoides*) in wheat seedlings. Ann. appl. Biol. 68, 169-175.
30. *Siebrasse, G. & Fehrmann, H.* 1987. Ein erweitertes Model zur praxisgerechten Bekämpfung des Erregers der Halmbruchkrankheit *Pseudocercosporella herpotrichoides* in Winterweizen. Z. PflKrankh. PflSchutz. 94, 137-149.
31. *Skriver, K.* 1988. Planteavlsarbejdet i de landøkonomiske foreninger 1988, 252.

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