Danish Research Service for Plant and Soil Science
Research Centre for Plant Protection
Department of Plant Pathology
DK-2800 Lyngby

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Validation of the threshold for eyespot *(Pseudocercosporella herpotrichoides)* in winter wheat and winter rye assessed in spring and July

Efterprøving af skadetærsklen for knækkefodsyge (Pseudocercosporella herpotrichoides) *i vinterhvede og vinterrug bedømt i foråret og i juli*

LISE NISTRUP JØRGENSEN, LARS BØDKER and HELLFRIED SCHULZ

Summary

Since the middle of the seventies control of eyespot *(Pseudocercosporella herpotrichoides* (Fron.) Deighton) has been based on a threshold, in the spring, of 15% attacked plants in winter wheat and 10% in winter rye.

Fungicide and crop rotation trials from 1978–86 including 545 trials in winter wheat and 218 trials in winter rye have been used for validation of these thresholds. The trials have been treated in the spring either with MBC products or prochloraz (Sportak 45 ec). The effect of prochloraz in separate years varies between 40–82%. The effect of MBC products has been decreasing since the beginning of the eighties because the eyespot fungus has developed resistance to the benzimidazoles.

When data from winter wheat are divided according to whether thresholds have been exceeded or not, significantly higher yield increases were found when the 15% threshold was exceeded. This is the case for both prochloraz and MBC products, when taken as an average over all the years. However, only 50% of the prochloraz treated trials and 59% of the MBC treated trials gave positive net return, when attacks were more than 15%.

In winter rye, MBC products gave significantly higher yield increases when spraying took place above the 10% threshold. This was, however, not the case for prochloraz. A positive net return was obtained at 56% of the prochloraz treated trials and 65% of the MBC treated trials where the threshold was exceeded.

The level of spring attack was divided in intervals (<5%, 5–10%, 11–15%, 16–20% and >20% attacked plants), but it was not possible to find any clear relation between level of attack in wheat or rye and yield increase after the use of prochloraz. A better correlation was found where MBC products had been used.

Due to a poor yield response for prochloraz, when controlling attacks above the 15% threshold, it has been suggested to increase the threshold to 35%, if a growth regulator is used or if the cultivar has good resistance to lodging.

The threshold in July for eyespot was for both prochloraz and MBC products found to be between 20–40% attacked straw for both winter wheat and winter rye.

Yield increases were generally higher in winter rye compared to winter wheat, which justifies the lower threshold used in rye.

Key words: Eyespot, *Pseudocercosporella herpotrichoides,* winter wheat, winter rye, prochloraz, benzimidazoles, threshold.

Resumé

Op igennem 70'erne og 80'erne har behovet for bekæmpelse af knækkefodsyge (*Pseudocercosporella herpotrichodes* (Fron.) Deighton) i Danmark været bedømt ud fra en skadetærskel på 15 pct. angrebne planter i vinterhvede og 10 pct. angrebne planter i vinterrug om foråret.

Et stort forsøgsmateriale bestående af 545 vinterhvede- og 218 vinterrugforsøg fra årene 1978–87 er brugt til at efterprøve rigtigheden af de fastsatte skadetærskler. Materialet stammer fra sædskifte og fungicidforsøg udført i anden sammenhæng.

Forsøgene har enten været behandlet med MBC-produkter eller prochloraz udbragt om foråret (primo maj). Den gennemsnitlige opnåede effekt i de enkelte år svinger for prochloraz mellem 40–82 pct. For MBC-produkterne har effekten været faldende siden begyndelsen af 80'erne som følge af, at knækkefodsygesvampen har udviklet resistens over for MBC-midlerne.

Ved opdeling af materialet, i forhold til den anvendte skadetærskel på 15 pct., var der i hvede i gennemsnit af afprøvningsårene efter brug af både prochloraz og MBC-midlerne signifikant højere merudbytte, hvor skadetærsklen var overskredet. Kun 50 pct. af de prochloraz-sprøjtede og 59 pct. af de MBC-sprøjtede forsøg gav et positivt nettomerudbytte, når skadetærsklen var overskredet. Ved anvendelse af skadetærsklen på 10 pct. i rugen var der på tilsvarende vis efter brug af MBC-midlerne signifikant højere merudbytte, hvor skadetærsklen var overskredet. Dette var ikke tilfældet, hvor prochloraz havde været anvendt. Hvor skadetærskelen var overskredet, blev der opnået et positivt nettomerudbytte i henholdsvis 56 og 65 pct. af forsøgene.

Ved opdeling af forårsangrebet af knækkefodsyge i intervaller (<5 pct., 5–10 pct., 11–15 pct., 16–20 pct. og >20 pct. angrebne planter) har der ikke kunnet påvises nogen tydelig sammenhæng mellem angrebsgrad og opnåede merudbytter efter behandling med prochloraz. For MBC-produkterne var der derimod en positiv sammenhæng mellem procent angrebne planter og opnåede merudbytter.

På grund af lave merudbytter for bekæmpelse med prochloraz, når skadetærsklen på 15 pct. er overskredet, foreslås det, at skadetærsklen hæves til 35 pct., hvis der vækstreguleres eller dyrkes korte og stråstive sorter.

Skadetærsklen i juli for knækkefodsyge i vinterhvede og vinterrug blev for både prochloraz og MBC-produkterne i gennemsnit overskredet ved 20–40 pct. angrebne strå.

Merudbyttet efter bekæmpelse af knækkefodsyge i forsøgene var generelt højere i rug end i hvede.

Nøgleord: Knækkefodsyge, *Pseudocercosporella herpotrichoides,* vinterhvede, vinterrug, prochloraz, benzimidazoler, skadetærskel.

Introduction

Eyespot (*Pseudocercosporella herpotrichoides* (Fron.) Deighton) is a common cereal disease in Denmark. Symptoms appear in December or early spring depending on the time of infection. In Denmark, autumn infections are thought to be more important with regard to the level of severity than spring infections. Inoculum and disease intensity in each field depends on several cultural practices (24) as well as climatic conditions (8, 9, 10). When validating the threshold for eyespot the relation between level of attack and yield response is investigated. Losses due to attack may be caused by a) early, severe attack killing individual tillers before elongation; b) lesions on the base of stems interfering with movement of water and nutrients; c) lodging – an indirect effect of lesions causing softening of the straw.

A reduction in the number of tillers by January has been found not to cause a reduction in yield. Under good growth conditions, the crop will compensate. A later thinning of the crop has been found to cause reduction in yield (4).

In Denmark, spring attack of eyespot is assessed as per cent plants infected (23). No clear relationship has, been found between attack in spring and yield loss. The 15% threshold in winter wheat and the 5–10% threshold in winter rye has been put forward as the level above which the risk of severe attack is possible (22).

In July the attack on individual tillers is divided into one of four categories: healthy, slightly, moderately or severely infected with eyespot, according to the NIAB guidelines (2). *Clarkson* (1981) summarised the effect of eyespot on yield from 8 different investigations (3, 5, 6, 7, 13, 14, 20, 25). Slight eyespot infections had no effect on yield; moderate eyespot reduced yield per ear, grain number per ear and 1000 grain weight by 9, 7 and 4% respectively; and severe eyespot caused corresponding losses of 33, 24 and 13%.

Lodging is a factor which, apart from the severity of the disease is dependent on the weather, nitrogen level, the lodging susceptibility of the varieties and the use of plant growth regulators (PGR). Early lodging is known to be most damaging. This is, in particular, known from winter rye. Yield reductions between 22 and 44% have been found in the case of severe attacks, where lodging has been serious (13, 14).

In order to validate the Danish thresholds used on eyespot in spring, results from fungicide trials carried out from 1978–1986 have been evaluated. The level of attack in July and the corresponding yield loss are discussed.

Information on disease attack related to the cultural factors in the trials has also been investigated (24).

Methods

The attack of eyespot in spring was based on a sample of plants (100–150 plants per field or treatment) collected at growth stage 22–30 (Zadoks). Per cent plants with visible eyespot attack was calculated.

Fungicide and crop rotation trials from 1978–86 included 545 winter wheat and 218 winter rye trials (Table 1). These trials were all treated with a fungicide for control of eyespot and are used for validation of the eyespot thresholds.

Table 1. No. of fungicide trials (1978–86) in winter wheat and winter rye.

Treatment	No. of trials	
	Winter wheat	Winter rye
MBC products (benomyl, carbendazim or thiophanat-methyl)	412	166
Sportak 45ec (prochloraz)	133	52
Total	545	218

The trials were treated with either MBC products (benomyl, carbendazim or thiophanat-methyl) or Sportak 45ec (prochloraz) in spring around growth stage 30–31.

In July (around growth stage 75) 100 tillers per treatment were randomly collected and each straw was placed in one of the four classes (2), listed below.

0. Healthy straw
1. Slight eyespot (one or more small lesions occupying less than half the circumference of the stem)
2. Moderate eyespot (one or more lesions occupying at least half the circumference of the stem)
3. Severe eyespot (stem completely girdled with lesions, tissue softened so that lodging would readily occur.

In these trials, per cent attack of eyespot in July is equal to the sum of per cent straw in categories 2 and 3.

Statistical analysis was carried out using general linear model procedure (21).

Estimates for the grain yield increase were calculated. The model has corrected for unbalance in the data due to variation between regions and soil type.

Results

The average per cent effect in the individual years for both MBC products and prochloraz is shown in Figs 1 and 2. A decrease in efficacy for the MBC products since the 1980's was seen. The efficacy of prochloraz fluctuates considerably from year to year.

The relation between chemical control of eyespot and yield increases in separate years is seen in Tables 2 and 3. The data are divided according to the threshold used. Big differences in level of yield response were found for separate years. This was found for both MBC products and prochloraz.

When dividing the wheat data according to the threshold of 15% in spring, the average yield increase was significantly higher when the threshold was exceeded (Table 2). This was the case for both prochloraz and MBC products. However, on average only 50% of the prochloraz treatments and 59% of the MBC treatments applied to trials with more than 15% attack gave a positive net return (application and chemical cost set to 2.5 hkg/ha for prochloraz and 1.8 hkg/ha for MBC treatments).

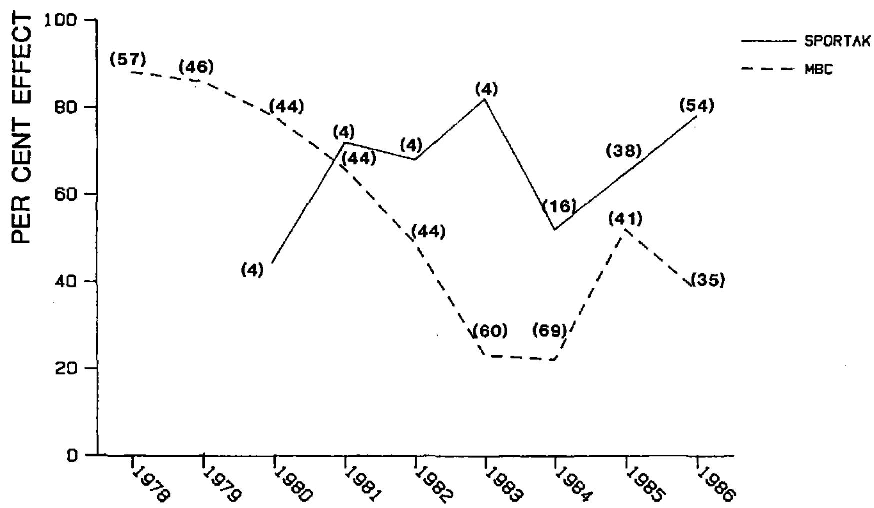

Fig. 1. Per cent effect of eyespot *(Pseudocercosporella herpotrichoides)* in winter wheat using prochloraz and MBC products. No. of trials is shown in brackets.

When dividing the winter rye trials according to threshold of 10% in spring (Table 3), no significant differences were found in average yield increase after prochloraz treatment. MBC products, however, gave significant differences. On average, 56% of the prochloraz treatments and 65% of the MBC treatments applied when the threshold was exceeded gave a positive net return.

The yield increases were examined in relation to different levels of attack in spring (<5%, 5–10%, 11–15%, 16–20% and >20%). For prochloraz no significant correlation was found between level of attack and yield increases obtained in either winter rye or winter wheat (Fig. 3). For MBC products a better correlation between level of attack and yield increase was found. In winter wheat, significant differences ($P \leqq 0.05$) were found be-

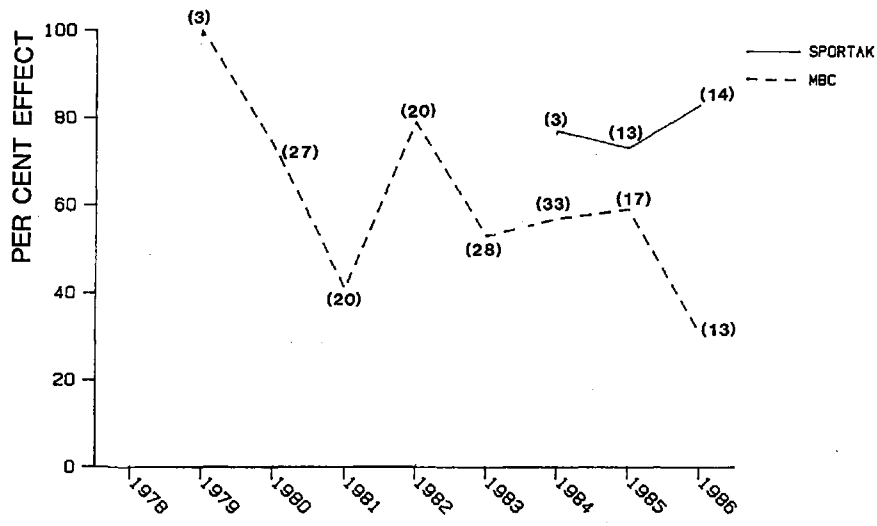

Fig. 2. Per cent effect of eyespot *(Pseudocercosporella herpotrichoides)* in winter rye using prochloraz and MBC products. No. of trials is shown in brackets.

Table 2. Yield increases (hkg/ha) after eyespot control with prochloraz and MBC products in winter wheat. Data are divided according to a 15% threshold in spring. The figures in brackets give the no. of trials.

	Yield increase after treatment with prochloraz		Yield increase after MBC treatment		% economic treatments when applied above 15% threshold	
	≧15% attack	<15% attack	≧15% attack	<15% attack	1) prochloraz	2) MBC products
1986	1.2 (33)	0.5 (27)	1.1 (27)	-0.2 (13)	27 (33)	41 (27)
1985	6.2 (14)	3.6 (27)	2.8 (17)	1.7 (29)	86 (14)	59 (17)
1984	3.8 (8)	2.1 (8)	3.4 (21)	2.7 (25)	88 (8)	57 (21)
1983	3.2 (3)	4.7 (1)	3.8 (46)	0.6 (13)	33 (3)	65 (46)
1982	3.2 (3)	2.2 (1)	3.4 (8)	3.3 (12)	33 (3)	75 (8)
1981	5.5 (3)	8.0 (1)	4.0 (11)	3.0 (11)	66 (3)	82 (11)
1980	– (0)	4.5 (4)	1.0 (10)	2.1 (41)	–	40 (10)
1979	–	–	2.8 (14)	2.9 (41)	–	78 (14)
1978	–	–	1.4 (20)	0.9 (53)	–	45 (20)
Average 3)	3.0 (64)a	2.3 (69)b	2.7 (174)a	1.9 (238)b	50 (64)	59 (174)

1) Trials with a yield increase more than 2.5 hkg/ha (cost of prochloraz product plus application).
2) Trials with a yield increase more than 1.8 hkg/ha (cost of MBC-product plus application).
3) Different letters indicate significant differences. (P ≦ 0.05)

tween attack less than 5% and attack greater than 10–15%. Similarly, in winter rye significant differences were found between attack less than 5% and attack greater than 10–15% (Fig. 4).

Control of eyespot with MBC products in winter rye has generally given a higher yield response than in winter wheat (Figs 3, 4, 5 and 6). In rye a reduction in yield increase was found when more than 20% plants were attacked in spring (Fig. 4).

Yield increases relative to per cent straw with moderate and severe attack in July are shown for winter wheat and winter rye using prochloraz (Fig. 5) and MBC products (Fig. 6). Positive correlations between level of attack and yield increases have been found in both crops both for prochloraz and MBC products.

The results from July indicate, for both prochloraz and MBC products, that the economic threshold is exceeded with attacks in the range of 20–40%.

Table 3. Yield increases (hkg/ha) after eyespot control with prochloraz and MBC products in winter rye. Data are divided according to a 10% threshold in spring. The figures in brackets give the no. of trials.

	Yield increase after treatment with prochloraz		Yield increase after MBC treatment		% economic treatments when applied above 10% threshold	
	≧10% attack	<10% attack	≧10% attack	<10% attack	1) prochloraz	2) MBC products
1986	2.7 (8)	1.2 (14)	1.7 (7)	0.8 (8)	50 (8)	42 (7)
1985	6.1 (4)	3.6 (11)	3.2 (6)	1.8 (12)	100 (4)	83 (6)
1984	2.3 (1)	4.2 (7)	3.9 (7)	2.3 (27)	0 (1)	71 (7)
1983	1.9 (3)	4.9 (4)	5.4 (10)	4.0 (17)	33 (3)	50 (10)
1982	–	–	3.1 (2)	2.8 (18)	–	100 (2)
1981	–	–	6.6 (6)	3.9 (16)	–	83 (6)
1980	–	–	2.4 (8)	1.0 (18)	–	63 (8)
1979	–	–	–	5.8 (3)	–	–
1978	–	–	–	5.8 (1)	–	0 (1)
Average 3)	3.4 (16)a	2.9 (36)a	3.9 (46)a	2.6 (120)b	56 (16)	65 (46)

1) Trials with a yield increase more than 2.5 hkg/ha (cost of prochloraz product plus application).
2) Trials with a yield increase more than 1.8 hkg/ha (cost of MBC-product plus application).
3) Different letters indicate significant differences. (P ≦ 0.05)

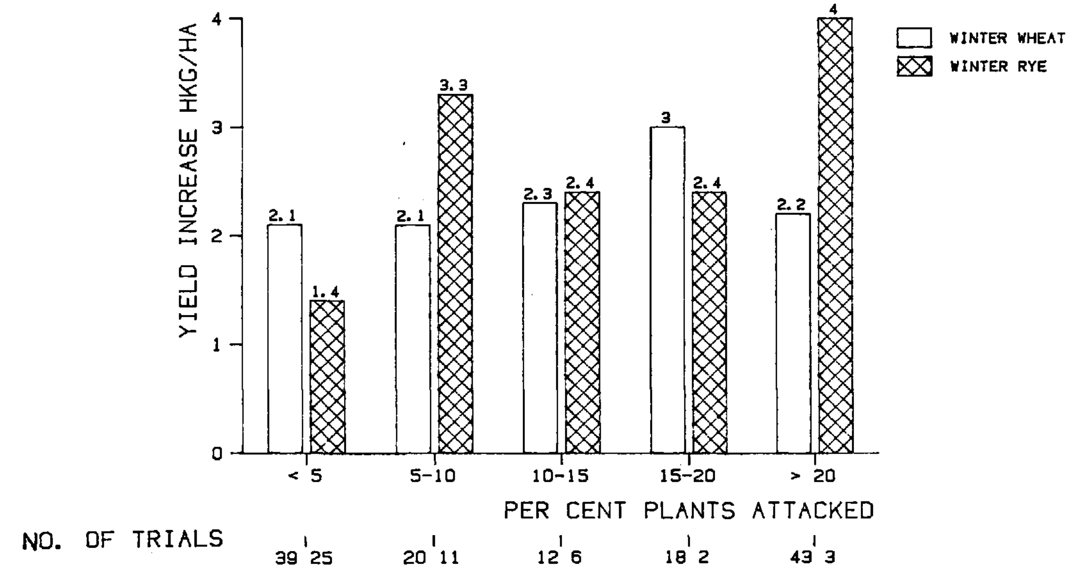

Fig. 3. Yield increase (hkg/ha) using prochloraz in relation to per cent plants attacked by eyespot *(Pseudocercosporella herpotrichoides)* in spring in the years 1978-86.

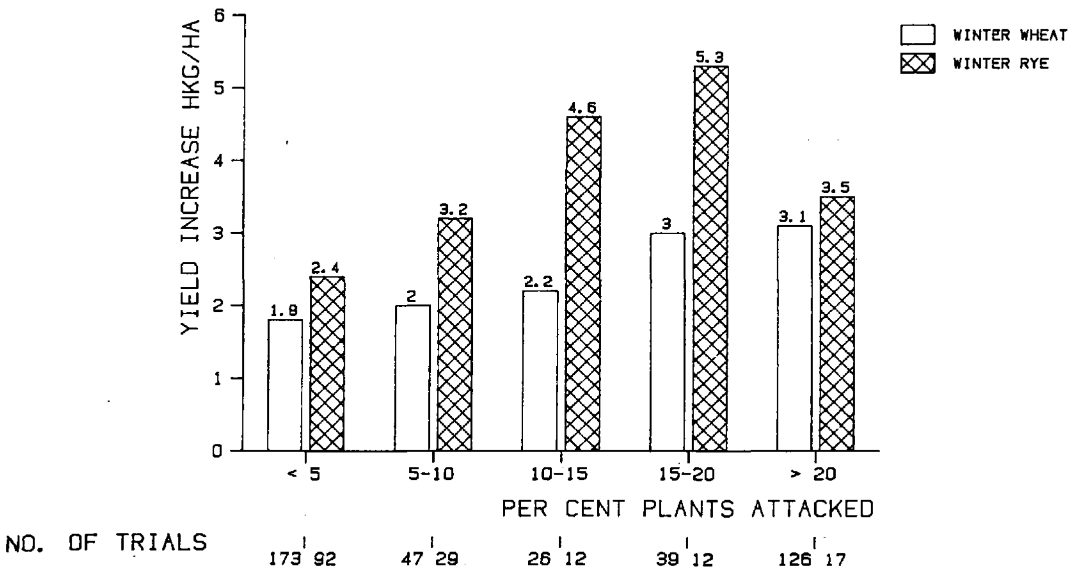

Fig. 4. Yield increase (hkg/ha) using MBC-products in relation to per cent plants attacked by eyespot *(Pseudocercosporella herpotrichoides)* in spring 1978-86.

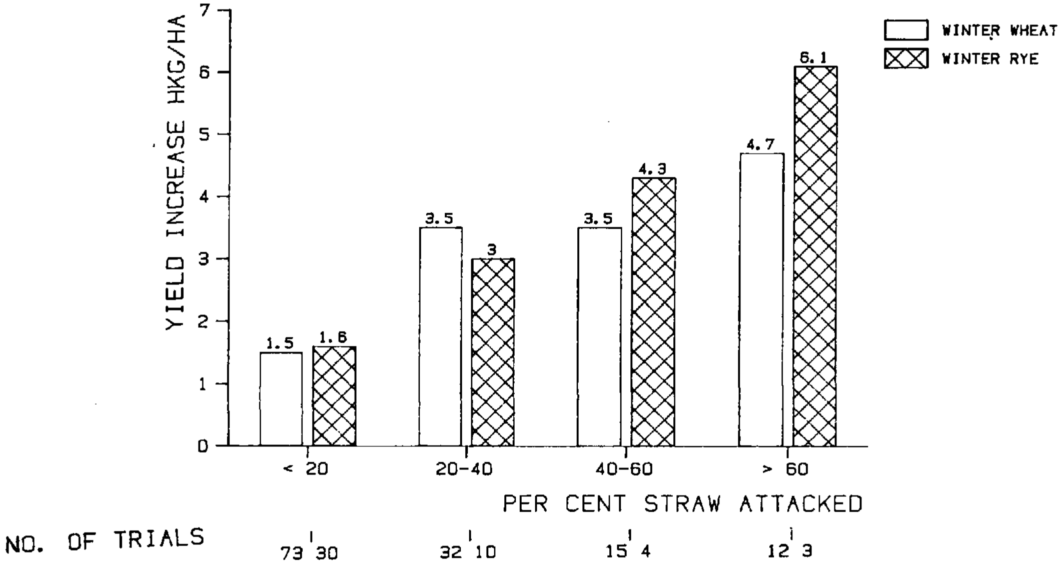

Fig. 5. Yield increase (hkg/ha) using prochloraz in relation to per cent straw attacked straw by eyespot *(Pseudocercosporella herpotrichoides)* in July 1978-86.

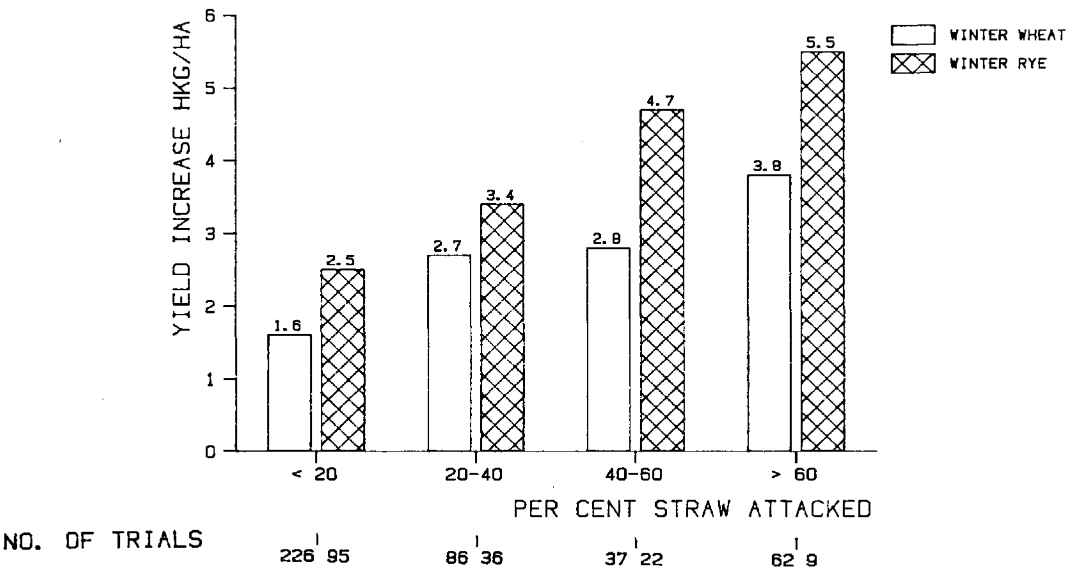

Fig. 6. Yield increase (hkg/ha) using using MBC products in relation to per cent straw attacked straw by eyespot *(Pseudocercosporella herpotrichoides)* in July 1978-86.

In both spring and July the results of prochloraz are less reliable than those of MBC products due to lack of data.

Discussion and conclusion

As a result of the increase in the area of winter cereal, which took place in the beginning of the eighties, the use of MBC products became more widespread (17). This increased the selection pressure of MBC products on eyespot. In 1983–84 widespread MBC resistance to eyespot was discovered in field samples tested in the laboratory (19).

This confirmed that the reduction in efficacy seen in the trials was caused by resistance. An overall increase in efficacy was found as an average of all wheat trials in 1985. This was probably caused by winter wheat being introduced to new areas of Jylland, where this crop had not been grown previously.

The reason for the fluctuation of the efficacy of prochloraz cannot easily be explained. Trials have, however, shown that the optimal timing of prochloraz treatments varies considerably from year to year (15), indicating that advanced attacks are only poorly controlled. Few trials in 1980–83 also makes the efficacy data uncertain.

The specific MBC fungicides gave a better correlation between level of attack in spring and yield increases (Fig. 4), than the broad-spectrum fungicide prochloraz (Fig. 3). The reduction in yield increase in rye, when more than 20% plants are attacked in spring, might indicate that high levels of attack are connected to advanced attacks in the plants. These are difficult to control and therefore yield response remains at a lower level. The effect of prochloraz is partly obscured by its effect on other diseases (*Septoria spp.* and powdery mildew *(Erysiphe graminis)*). The thresholds for use in winter rye (10%) and winter wheat (15%) appear to be reasonable for the MBC products. The thresholds give less acceptable results when used for prochloraz, although it should be noted that less data exist for prochloraz and therefore the validation is less reliable. When considering results from separate years (Tables 2 and 3), it can, however, be seen that the succes of the thresholds for both MBC products and prochloraz varies considerably from year to year. This is most pronounced for winter wheat.

The big variation in yield increases between years reflects a difference in weather conditions.

The final severity of eyespot attack largely depends on the weather conditions in May and June, the two months when elongation takes place. Warm and dry weather for long periods during these two months does not allow the disease to grow rapidly enough through leaf sheaths to catch up with the growth of the plant. In particular, when eyespot only occurs on the outermost leaf sheaths, the disease might stop completely due to the dying of these leaf sheaths (11).

The long term weather prognosis is not yet reliable enough to use for an accurate prediction of eyespot development. It is, therefore, of little use when considering treatment with prochloraz, which must be applied at the latest at growth stage 31. This growth stage occurs in most years in the beginning of May (17).

The spring assessment of attacked plants has other disadvantages. The symptoms of eyespot are difficult for the farmers to recognise and they can easily be mistaken for other diseases such as sharp eyespot *(Rhizoctonia cerealis)* and *Fusarium spp.* The assessment in spring only indicates the proportion of the crop affected by eyespot. Variation in severity of lesions can be seen in spring, but is not included in the assessment.

In rye the spring symptoms of eyespot are more unreliable than in wheat. In practice control is often carried out regardless of the threshold due to the fact that winter rye is often grown in crop rotations where rye has a high frequency and a considerable amount of inoculum is expected to be present.

In England, a 20% threshold in wheat is used, but this is based on per cent infected shoots (1), not per cent infected plants. If each plant has 1.5–2.0 shoots, on average, the English threshold is equal to 30–40% plants if only one shoot of each plant is attacked. This is considerably higher than the Danish threshold of 15% plants.

The eyespot assessment in July shows a good correlation between level of attack and yield increase after treatments with MBC products as well as prochloraz (Figs 5 and 6). When 20–40% of the straw was attacked in July, use of both MBC products and prochloraz gave an economic yield increase. This was found for both winter wheat and winter rye. German results (18) have shown that 40–60% attacked wheat straw in July resulted in positive yield increases with spring treatment. An earlier paper (12) mentioned, however, the economic threshold to be approximately 40%.

Whether 15% attacked plants in spring will develop to 40% attacked straw in July depends primarily on the weather. Other crop husbandry factors, along with attack and control level of leaf diseases, have an influence on how much of the potential yield increase resulting from eyespot control, will be gained at harvest.

Generally, the yield increases are higher in winter rye than in winter wheat. This justifices the use of a lower threshold in winter rye (10%) than in winter wheat (15%). As a result of the common practice of using plant growth regulators (PGR), lodging rarely occurs even under severe eyespot attacks. This helps to prevent dramatic losses due to eyespot. The threshold, as suggested by *Scott* and *Hollins* (26), should probably be higher for cultivars which are resistant to lodging, either naturally or by the use of PGR.

For the 1990 spring assessment the Danish threshold in winter wheat is suggested increased to 35% attacked plants, if a growth regulator is used or if the cultivar has good resistance to lodging. Fields with attacks between 15 and 35% are suggested controlled with half-rate prochloraz. Half-rate has in trials shown no reduction in net return, despite a reduction in effect (15).

Due to the widely developed resistance in eyespot fungus to MBC products in Denmark, prochloraz is, at present, almost the only product used for eyespot control.

In relation to the public and political pressure to reduce the use of pesticides, the need for a better forecasting system should be emphazised, bearing in mind the relatively large number of trials indicating that eyespot control with prochloraz has given uneconomic yield increases when using the existing threshold of 15%. The lack in relationship between thresholds in the spring and yield increases for prochloraz, plus the uncertainty related to assessments, suggest that models for prediction of eyespot attack should be based on cultural factors and weather conditions.

Information on the eyespot attack related to cultural factors in this trial material has been investigated and reported by *Schulz et al.* (24).

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