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Control of leaf diseases in winter wheat using ergosterol inhibiting fungicides

Bekæmpelse af bladsygdomme i vinterhvede med ergosterolhæmmere

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Summary

In 1986 and 1987 11 different ergosterol biosynteses inhibitors (EBI) were tested for their effectiveness of control of leaf diseases in winter wheat. The tested products are all single fungicides which can be used alone or as mixing partners in coformulations. Applications were carried out at growth stage Zadoks 31-32 and 47-59.

Fenpropimorph (Corbel) was found to give the best control (99%) of powdery mildew *(Erysiphe graminis)* followed by tebuconazole (Folicur) and triadimenol (Bayfidan). The latter, however, gave considerably less control in 1986 (75%) compared to 1987 (87%). Prochloraz (Sportak 45ec) and diclobutrazol (Vigil) gave unacceptable levels of control (57-58%) whereas the rest of the tested products gave good and acceptable degrees of control (67-79%).

Only tebuconazole, fluzilazol (DPX N 6573), propiconazol (Tilt 250ec) and prochloraz, gave acceptable control (>70%) of *Septoria spp.* The 2 morpholines fenpropimorph and tridemorph (Calixin) had almost no effect at all on *Septoria spp.*

All tested products showed a relatively good protective control of yellow rust *(Puccinia striiformis)*. The long term effect of prochloraz, tridemorph and fenpropimorph was considerably shorter (3-4 weeks) than for the rest of the tested EBI's (5-6 weeks).

The yield increases obtained reflects the disease pressure in the individual trials. On average the broad spectrum fungicide tebuconazole gave the highest yield increase (24%), followed by other products with similar effects. The products which lack effect on *Septoria spp.* and other leaf spot diseases gave the lowest yield increase. About half of the increases in yield was caused by increases in grain size.

Key words: Ergosterol inhibiting fungicides, winter wheat, disease control, powdery mildew, yellow rust, *Septoria spp.*, brown rust.

Resumé

I 8 markforsøg i 1986 og 87 er 11 forskellige fungicider, alle ergosterolhæmmere, afprøvet for deres biologiske effekt på hvedesygdomme.

De testede fungicider er afprøvet i normaldosering og som enkelt produkter. Sprøjtning er udført på vækststadium 31-32 og 47-59 (Zadoks).

Fenpropimorph (Corbel) gav bedste bekæmpelse (99 pct.) af meldug *(Erysiphe graminis)*. Tebuconazole (Folicur) gav ligeledes høj grad af bekæmpelse (88 pct.). Prochloraz (Sportak 45ec) og diclobutrazol (Vigil) gav begge uacceptabel meldugbekæmpelse (57-58 pct.), mens øvrige produkter gav acceptabel bekæmpelse (67-80 pct.).

Tebuconazol, fluzilazol (DPX N 6573), propiconazol (Tilt 250ec) og prochloraz gav god og acceptabel bekæmpelse af *Septoria spp.* (>70 pct.). De to morpholiner fenpropimorph (Corbel) og tridemorph (Calixin) havde næsten ingen effekt på *Septoria spp.*

Alle de afprøvede midler viste ret god, forebyggende effekt på gulrust *(Puccinia striiformis)*. Langtidseffekten af prochloraz, tridemorph og fenpropimorph var væsentlig ringere end af de øvrige produkter. Forsøgene gav ikke mulighed for at vurdere midlernes kurative effekt på gulrust.

De høstede merudbytter i enkeltforsøgene afspejlede tydeligt størrelsen af sygdomstrykket i forsøgene. Cirka halvdelen af udbytteforøgelsen skyldtes øget kernestørrelse.

De mest bredspektrede fungicider gav i gennemsnit de højeste merudbytter. Højest lå tebuconazole med 24 pct. udbytteforøgelse. Fungicider med manglende effekt *på Septoria spp.* gav generelt de laveste merudbytter.

Nøgleord: Ergosterolhæmmere, vinterhvede, hvedemeldug, gulrust, *Septoria spp.*, brunrust.

Introduction

In the last 5 years most new fungicides introduced on the Danish market, for control of cereal diseases, have been coformulations. They have been introduced to the market to provide broad spectrum disease control and to minimize the risk of developing fungicide resistance (5).

Because of this trend, in future, little will be known of the efficacy and potential of the individual active ingredients used in the mixtures.

In order to obtain information on the single fungicides, it was decided to test several ergosterol inhibitors (EBI) for their efficacy on diseases in winter wheat. Apart from tridemorph (Calixin) and fenpropimorph (Corbel), which belong to the morpholines, all the tested products are 14 α – demethylation – inhibitors (DMIs).

The DMI's are generally known to inhibit fungi of the ascomycetes and basidiomycetes and some of the deuteromycetes. The DMI's inhibit the C-14 demethylation step in the biochemical pathway from lanosterol to ergosterol (9).

The morpholines, which also inhibit ergosterol biosynthesis, control fewer diseases than the DMI's, and are mainly known to be effective on powdery mildew, and to some extent also on rust diseases. The morpholines are known to inhibit sensitive fungi at two essential steps, i. e. by blocking the $\triangle$ 14 reductase, as well as the $\triangle 8 \rightarrow \triangle 7$ isomerase (4).

Materials and methods

In winter wheat, eight field trials (four on Sealand, four in Jutland) were carried out in the seasons 1986 and 1987 with four trials each year.

The trials were carried out according to Danish Guidelines for testing pesticides on pests and diseases in field crops (1).

The experimental design was a randomised complete block with four replicates and a plot size of 30 m^2. The fungicides were applied with a knapsack sprayer under low pressure (3 bar), flat fan nozzles (Hardi 4110–12) and 300 l/ha.

The fungicide treatments were applied at growth stages Zadoks 31–32 and 47–59 (10). The eleven tested products and their active ingredients are listed in Table 1. Apart from tridemorph the products were all tested at full rate.

The varieties used were:

1986: Kraka (two trials), Kanzler (one trial), Anja (one trial).

1987: Kanzler (two trials), Anja (one trial), Vuka (one trial).

Disease assessment was carried out as per cent coverage of all green leaves by the individual diseases. Powdery mildew, yellow rust, *Septoria spp.* and brown rust were assessed in the trials.

Assessments were carried out with approximately 10 days intervals, starting at first application and finishing at senescence.

Table 1. The tested ergosterol inhibitors given by their commercial or code number name and active ingredients. Products marked by a * are registered for use (1989) by National Agency of Environmental Protection.

Product	Dose per ha l	Active ingredients	g a.i/ kg or l	g a.i per ha
1. Tilt 250ec *	0.5	propiconazol	250	125
2. Bayfidan *	0.5	triadimenol	250	125
3. Folicur	1.5	tebuconazole	250	375
4. SN 108 266	0.8	cyproconazol	100	80
5. Sportak 45ec *	1.0	prochloraz	450	450
6. DPX N 6573	0.5	fluzilazol	400	200
7. PC 1002	1.0	hexaconazol	250	250
8. Vigil	1.0	diclobutrazol	125	125
9. Impact	1.0	flutriafol	125	125
10. Corbel *	1.0	fenpropimorph	750	750
11. Calixin *	0.5	tridemorph	748	374

The plots were harvested by a plot combiner and the grain yields were corrected to 15% moisture content. Thousand grain weight was measured for each plot.

The products and their active ingredients are listed in the trial plan in Table 1.

Results

1986

Disease pressure in 1986 was generally low in Denmark and fungicide treatments gave small and often uneconomic yield response (7). Severe powdery mildew attacks only occurred in one field trial with the susceptible variety Kanzler. The three other trials had very low attack. *Septoria spp.* was observed in three of the trials, but only with attacks ranging from 0.1–6.3% attack in untreated control plots.

Table 2 summarizes the results from the four trials in 1986. Fenpropimorph, tebuconazole, cyproconazol, propiconazol, flutriafol and hexaconazol all gave good control of powdery mildew, giving above 95% control, whereas triadimenol, diclobutrazol, fluzilazol, prochloraz and tridemorph were less effective.

All products, apart from tridemorph, fenpropimorph, diclobutrazol and tridimenol gave acceptable control of *Septoria spp.*, although no significant differences were found.

Apart from triadimenol, fenpropimorph and tridemorph all products increased yields significantly compared to yield of the untreated control. Yield increases are reflected in increases of thousand grain weight. Generally yield increases are low, and only products giving good control of both powdery mildew and *Septoria spp.* have increased yield significantly.

1987

1987 was a year with relatively severe attacks of yellow rust (*Puccinia striiformis*), *Septoria spp.* and powdery mildew (*Erysiphe graminis*). This made it possible to obtain good evaluation of the efficacy of the tested products.

Three trials had severe powdery mildew attacks (Kanzler, Vuka). The epidemics started at the end of May. Yellow rust did not appear until late June and was found in three (Kanzler, Anja) of the four trials. The late appearance made it only possible to evaluate the preventive effect of the products on yellow rust. *Septoria spp.* – mainly *Septoria tritici* – started in the middle of June and gave relatively severe attacks (10–25% by the end of July) due to a wet and cool summer. Brown rust (*Puccinia recondita*) was found in one of the four trials (Kanzler).

Fungicide treatments in 1987, generally gave high yield increases (7).

The growth season was 7–14 days longer than in average seasons, which gave diseases longer periods to affect the crop. The prolonged season also made it possible to evaluate the long term effect of the products.

Table 3 summarizes the results from 1987. Even with high powdery mildew levels fenpropimorph

Table 2. Per cent powdery mildew *(Erysiphe graminis)* and *Septoria spp.* in four winter wheat trials treated with EBI fungicides in 1986. The fungicides were applied at growth stage Zadoks 31–32 (13–23/5) and 57–59 (10–24/6).

Product	Dose g active ingredients per ha	% Powdery mildew		% *Septoria spp.*		Yield and yield increase hkg/ha	Rel. tgw.[4]
		[1] 25/6	20/7	2/6	30/6		
		[2] 57	75	37	59		
		[3] 7–15	28–30	19	20		
Propiconazol	125	0.7	0.6	0.2	0.4	3.9	103 A
Triadimenol	125	3.7	3.2	0.3	1.0	1.3	101 AB
Tebuconazole	375	0.6	0.2	0.1	0.5	4.9	103 A
Cyproconazol	80	0.4	0.2	0.2	0.8	2.7	102 AB
Prochloraz	450	1.4	1.3	0.3	0.5	3.9	103 AB
Fluzilazol	200	1.4	1.4	0.2	0.5	3.7	101 AB
Hexaconazol	250	0.6	0.6	0.3	0.6	4.5	102 AB
Diclobutrazol	125	3.0	2.5	0.9	1.0	2.9	101 AB
Flutriafol	125	0.9	0.5	0.2	0.7	3.3	101 AB
Fenpropimorph	750	0.2	0.2	0.7	1.2	2.2	100 B
Tridemorph	374	1.0	2.1	0.8	1.3	1.5	102 A
Untreated control		14.6	13.0	1.1	1.9	58.7	100 (43.3 mg/grain)
No. of trials		3	4	3	2	4	4
LSD_{95}		3.3	2.9	0.7	n.s.	2.7	

1. Date of assessment.
2. Growth stage (Zadoks).
3. Days after application.
4. Values with the same letter do not differ significantly (P≦0.05)

Table 3. Per cent powdery mildew *(Erysiphe graminis)*, yellow rust *(Puccinia striiformis)*, brown rust *(Puccinia recondita)* and *Septria spp.* in four winter wheat trials treated with EBI fungicides in 1987. The fungicides were applied at growth stage Zadoks 31–32 (19–25/5) and 47–59 (10–24/6).

Product	Dose g active ingredients	% Powdery mildew			% Yellow rust		% Brown rust	% *Septoria spp.*		Yield and yield increase hkg/ha	Rel. tgw[4]
		[1] 2–4/6	3–17/7	14–28/7	3–17/7	23–28/7	23/7	3–17/7	23–27/7		
		[2] 37	65	75	55	75	85	65	85		
		[3] 9–13	16–23	27–34	23–27	32–43	43	16–23	40–43		
Propiconazol	125	3.7	8.9	8.4	0	0.1	0.3	2.0	4.1	15.9	120 ABC
Triadimenol	125	2.5	4.4	2.7	0	0.1	0.1	4.1	7.1	15.3	117 BCD
Tebuconazole	375	2.5	4.2	5.0	0	0	0	1.0	3.5	20.5	122 BCD
Cyproconazol	80	2.3	7.4	6.6	0	0	0	2.9	6.0	17.8	120 ABC
Prochloraz	450	4.9	14.4	10.2	0.3	9.0	0.9	2.1	3.5	14.4	119 ABC
Fluzilazol	200	4.4	11.0	7.8	0	0.3	0.1	1.8	2.5	18.2	125 A
Hexaconazol	250	3.1	11.0	6.9	0	0.6	0.3	3.8	6.5	13.7	117 BCD
Diclobutrazol	125	5.8	13.3	7.1	0	1.3	0.5	5.4	8.9	10.8	111 DE
Flutriafol	125	3.6	10.4	7.4	0	0.5	0.2	3.1	5.2	16.5	121 AB
Fenpropimorph	750	1.0	0.3	1.5	0.1	5.5	0.1	6.8	11.4	12.4	114 CDE
Tridemorph	374	2.6	9.3	7.7	0.6	12.8	1.0	7.2	10.6	8.6	108 E
Control		11.5	23.5	21.3	4.9	23.1	3.0	7.2	17.5	46.7	100(35.9 mg/grain)
No. of trials		3	4	4	3	3	1	4	2	4	4
LSD_{95}		3.4	4.6	4.8	0.5	12.3	0.7	2.4	7.2	4.8	

1. Date of assessment
2. Growth stage (Zadoks)
3. Days after application
4. Values with the same letter do not differ significantly (P≦0.05)

gave above 90% control in 1987. Triadimenol gave better control in 1987 than in 1986 trials and was as effective as tebuconazole. Cyprocanozol, propiconazol, flutriafol, tridemorph, hexaconazol and fluzilazol gave reasonable mildew control whereas prochloraz and diclobutrazol in general gave poor control.

Most products gave very effective preventive control of yellow rust. Prochloraz and tridemorph gave the poorest control, which was particularly noticeable in the long term effect. Fenpropimorph also showed less long term effect compared to the DMI products.

A low level of brown rust appeared in one trial just before senescence. Apart from prochloraz and tridemorph all products gave acceptable control.

Septoria spp. were controlled well by tebuconazol, fluzilazol, propiconazol and prochloraz. Flutriafol, cyproconazol and hexaconazol gave a somewhat lower level of control, although still not significantly different from the best products. Tridemorph, fenpropimorph, triadimenol and diclobutrazol gave an unacceptable control of *Septoria spp.*

All the products increased grain yield significantly. Big differences in yield increases were found between products. The broad spectrum fungicides giving the highest yield increases. About 50% of the yield increases were due to increase in thousand grain weight.

Results from 1986 and 1987 are summarized in Figs. 1–6.

Discussion and conclusion

The 11 EBI fungicides tested showed different effectiveness on the three major diseases in winter wheat (Figs 1–4).

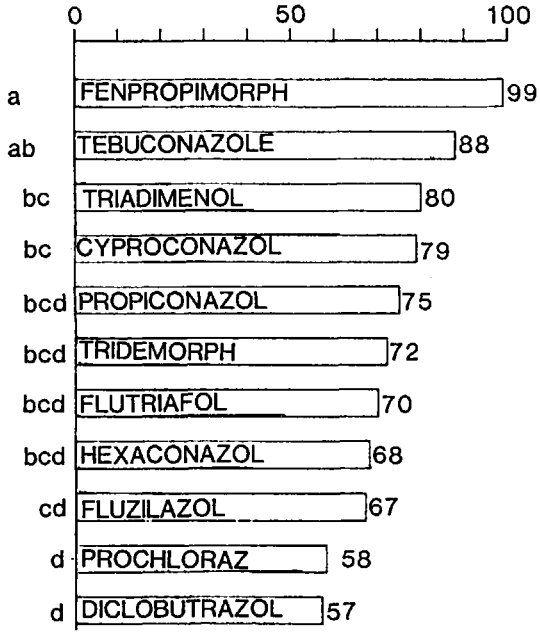

Fig. 1. Per cent control of mildew *(Erysiphe graminis)* in winter wheat by EBI fungicides. Average of seven trials from 1986 and 1987. Assessed 3–4 weeks after 2nd application. Attack in control: 20.4%. Values with the same letter do not differ significantly (p≦0.05).

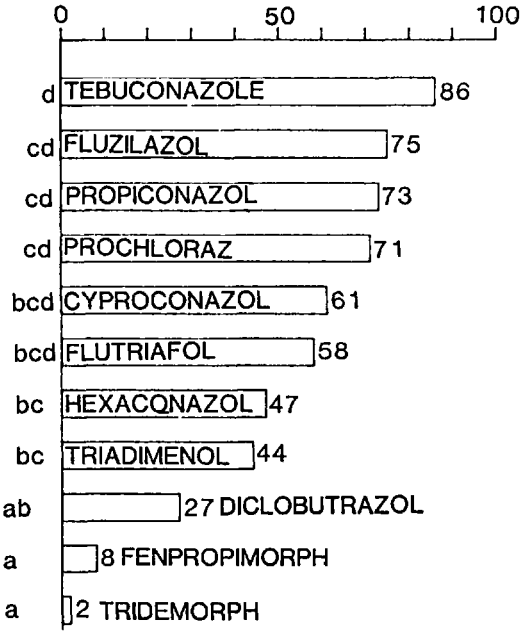

Fig. 2. Per cent control of *Septoria spp (Septoria tritici* and *Septoria nodorum)* in winter wheat by EBI fungicides. Average of five trials from 1986 and 1987. Assessed three weeks after 2nd application. Attack in control: 5.9%. Values with the same letter do not differ significantly (p≦0.05).

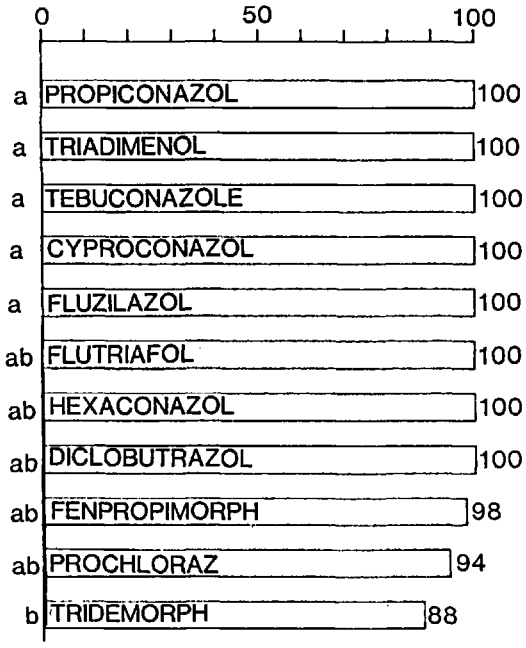

Fig. 3. Per cent control of yellow rust *(Puccinia striiformis)* in winter wheat by EBI fungicides. Average of three trials in 1987. Assessed 2–3 weeks after 2nd application. Attack in control: 4.9%. Values with the same letter do not differ significantly ($p \leqq 0.05$).

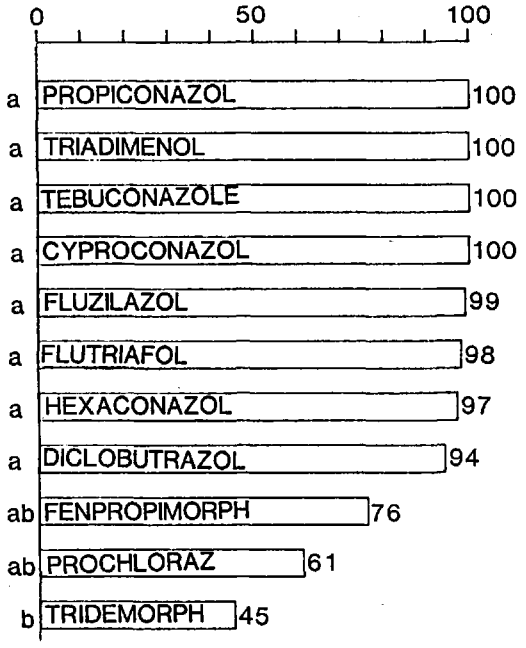

Fig. 4. Per cent control of yellow rust *(Puccinia striiformis)* in winter wheat by EBI fungicides. Average of three trials in 1987. Assessed 5–6 weeks after 2nd application. Attack in control: 23.1%. Values with the same letter do not differ significantly ($p \leqq 0.05$).

Fenpropimorph gave an outstanding effect (99%) on powdery mildew and showed a considerably better effect than other products. Half rate of fenpropimorph has in other trials, shown similar high effectiveness (6).

The big difference in effectiveness found for mildew control with triadimenol in 1986 and 1987 cannot be explained. A similar lack in effect has also been seen on barley powdery mildew (8).

Fenpropimorph, tebuconazole, triadimenol, propiconazol and tridemorph have an approval for treatment of mildew in winter wheat (2). Tridemorph, however, is only recommended until growth stage 32 because of the risk of causing phytotoxicity.

The trials only enabled evaluation of the protective effect of the products on yellow rust. They all showed good protective effect at low infection level (Fig. 3), but the long term effect of the products were shorter for tridemorph, prochloraz and fenpropimorph (Fig. 4). Despite the relatively poor long term effect, fenpropimorph is known to have a good curative effect on yellow rust (3). Fenpropimorph, propiconazol, triadimenol, tebuconazole and fluzilazol have an approval for treatment of yellow rust, whereas prochloraz and tridemorph are tested, but not approved for control of this disease (2).

In the two seasons, *Septoria tritici* was the dominating *Septoria* disease. The control of *Septoria spp.* varied a great deal between the products. The two morpholines tridemorph and fenpropimorph had almost no effect on this disease. In mixture with *Septoria* active fungicides the two products have, however, proved to increase control of this disease which indicates a synergistic effect (6). Tebuconazole, fluzilazol, propiconazol and prochloraz gave best control of *Septoria spp.* The four products all have an approval for treatment of *Septoria spp.* in winter wheat.

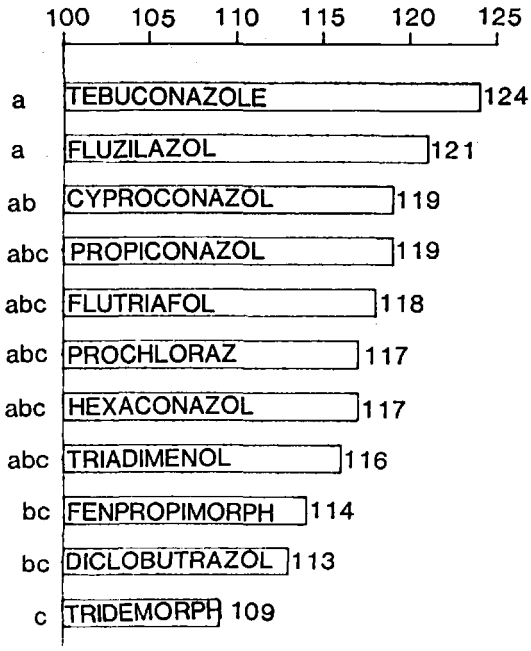

Fig. 5. Relative yield increase in winter wheat after two applications with EBI fungicides. Average of eight trials in 1986 and 1987. Yield in control: 52.8 hkg/ha. Values with the same letter do not differ significantly ($p \leqq 0.05$).

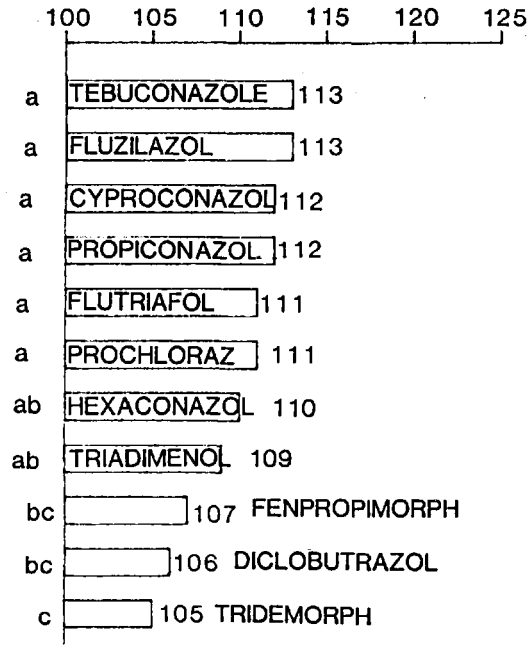

Fig. 6. Relative grain weight in winter wheat after two applications with EBI fungicides. Average of eight trials in 1986 and 1987. Grain weight in control: 39.6 mg. Values with the same letter do not differ significantly ($p \leqq 0.05$).

The same four products have generally been found to give good control of other leaf spot fungi like *Drechslera teres* and *Rhynchosporium secalis* in barley (8).

The grain yield increases for two applications varied considerably between the two seasons. In 1986 disease levels were low and treatments generally gave small or even negative economic results. In 1987, two applications gave significant and very economic yield increases (7).

About half of the yield increases were caused by increases in thousand grain weights.

The results from two years field trials with EBI – fungicides have given a knowledge of the individual active ingredients, which in the future can help to evaluate the potential of the components in coformulations.

References

1. *Anonymous* 1985. Retningslinier for afprøvning af midler mod sygdomme og skadedyr på landbrugsafgrøder. Statens Planteavlsforsøg.
2. *Anonymous* 1989. Plantebeskyttelsesmidler. Anerkendt til bekæmpelse af plantesygdomme, skadedyr og ukrudt, til nedvisning af frøafgrøder og kartoffeltop samt til vækstregulering. Statens Planteavlsforsøg, 97 pp.
3. *Atkin, J. C., Parsons, R. G., Reiley, C. E., Waterhouse, S. & Siegle, H.* 1981. Control of cereal diseases with fenpropimorph and fenpropimorph mixtures in the United Kingdom. Br. Crop Prot. Conf. – Pest and Diseases, 307–315.
4. *Baloch, R. I., Mercer, E. I., Wiggins, T. E., & Baldwin, B. C.* 1984. Where do morpholines inhibit sterol biosynthesis? Br. Crop. Prot. Conf. – Pest and Diseases, 893-898.
5. *Bolton, N. J. E. & Smith, J. M.* 1988. Strategies to combat fungicide resistance in barley powdery mildew. Br. Crop Prot. Conf. – Pest and Diseases, 367-378.

6. *Jørgensen, L. N. & Nielsen, B. J.* 1986. Fungicidblandinger – en ny udvikling inden for bekæmpelse af svampesygdomme i korn. 3. Danske Planteværnskonference – Sygdomme og Skadedyr, 291-316.
7. *Jørgensen, L. N.* 1989. Behov og faktisk forbrug af fungicider i korn. 6. Danske Planteværnskonference – Sygdomme og Skadedyr, 197-209.
8. *Nielsen B. J. & Jørgensen, L. N.* 1988. Bekæmpelse af svampesygdomme i byg 1987. 5. Danske Planteværnskonference – Sygdomme og Skadedyr, 153-172.
9. *Ragsdale, N. N.* 1977. Inhibitors of lipid synthesis. In: Antifungal compounds volume 2, *M. R. Siegel* and *H. D. Sisler* (eds), 333-363. Marcel Dekker Inc., New York, USA.
10. *Zadoks, J. C., Chang, T. T. & Konzak, C. F.* 1974. A decimal code for the growth stages of cereals. Weed Research 14, 415-421.

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