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Control of eyespot (*Pseudocercosporella herpotrichoides* (Fron.) Deighton) using prochloraz. – Dose and timing

*Bekæmpelse af knækkefodsyge (*Pseudocercosporella herpotrichoides* (Fron.) Deighton) med prochloraz. Dosering og sprøjtetidspunkt*

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Summary

Trials were carried out in winter wheat (1986–88), in order to find the optimal time for control of eyespot *(Pseudocercosporella herpotrichoides)* using prochloraz (Sportak 45cc).

Ten trials with relatively severe eyespot attack were carried out. Prochloraz was applied at three different times in the autumn, at intervals of three weeks after full emergence. These were compared to three different times in spring, starting at GS 12–23 (Zadoks) and finishing at GS 30–31. Prochloraz was compared to a treatment using benomyl (Benlate) at GS 30–31.

Autumn control was, in all but one case, found to have kept eyespot in spring at a level below the threshold (15% attacked plants).

In July only the application at GS 30–31 was found, on average, to have significantly limited the eyespot attack relative to other treatments. The optimal time of application varied, however, between trials.

In all but one trial benomyl gave no or very little effect on eyespot. This was due to eyespot fungus being resistant to benzimidazols.

All treatments, apart from the very early spring application and the benomyl treatment, gave significant yield increases. Among the significant yield increases no differences were found.

Seven trials in winter wheat and three in winter rye were carried out to find the dose response curve for eyespot treated with prochloraz (450 g, 225 g and 113 g/ha). Control was carried out at GS 30–31. On average a linear dose response curve was found for the three dosages of prochloraz.

For comparison, split application with prochloraz (2×225 g/ha) was tested in spring at GS 12–23 and GS 30–31. A tendency towards better control was found in six out of seven trials when compared to single treatments at full dose.

In winter wheat, all treatments, on average, gave significant yield increases. A tendency towards lower yield increases was found with reduced dosages.

The relatively low levels of control (on average 46%), when using full dose of prochloraz, does not indicate that a lower dosage generally is advisable. However, the lower effect from reduced dosages did not result in any reduction in net yield. Double dose (900 g/ha), which was tested in only one season, did not indicate a large increase in level of control.

The Danish threshold for eyespot is generally low and control has only given small yield increases in most seasons. Therefore, it is suggested that attack between 15–35% can be treated with reduced dosages, if the variety has good resistance to lodging or if a growth regulator is used.

Full dose is suggested when more than 35% of the plants are attacked in spring and the variety is not resistant to lodging or a growth regulator is not used.

Key words: Eyespot, *Pseudocercosporella herpotricoides,* application time, dose response curve, prochloraz, spring application, autumn application.

Resumé

Forsøg, der havde til formål at fastlægge det optimale bekæmpelsestidspunkt af knækkefodsyge *(Pseudocercosporella herpotrichoides),* blev udført i vinterhvede i 1986–88 med prochloraz (Sportak 45ec). Ni af i alt ti forsøg var angrebet relativt kraftigt af knækkefodsyge i foråret. Tre sprøjtetidspunkter blev prøvet om efteråret valgt med tre ugers mellemrum fra kornets fulde fremspiringstidspunkt. I foråret blev ligeledes sprøjtet på tre tidspunkter fra det tidlige forår vækststadium (v.s.) 12–23 (Zadoks) til det traditionelle bekæmpelsestidspunkt på v.s. 30–31. Bekæmpelsen med prochloraz på v.s. 30–31 blev sammenlignet med en bekæmpelse med benomyl (Benlate). Efterårsbekæmpelsen reducerede forårsangrebet i ni ud af ti forsøg til under skadetærskelniveauet på 15 pct. angrebne planter.

Bekæmpelsen på v.s. 30–31 gav i gennemsnit af forsøgene signifikant bedre bekæmpelse sammenlignet med øvrige behandlingstidspunkter. Det optimale bekæmpelsestidspunkt med prochloraz varierede dog fra forsøg til forsøg. Benomyl gav i ni forsøg ringe eller ingen bekæmpelse, pga. resistensdannelse mod benzimidazolerne. Alle behandlinger, bortset fra den meget tidlige forårsbekæmpelse samt benomylbehandlingen, gav signifikante merudbytter, som dog ikke adskilte sig signifikant fra hinanden.

Med henblik på fastlæggelse af doseringskurven for bekæmpelse af knækkefodsyge med prochloraz (450 g, 225 g og 113 g/ha) blev udført syv forsøg i vinterhvede og tre i vinterrug. Bekæmpelsen blev udført på v.s. 30–31. I gennemsnit af forsøgene blev fundet et liniært forhold mellem de tre doseringer og effekten på knækkefodsyge.

Til sammenligning blev en splitbehandling med prochloraz udført med udsprøjtning i foråret på henholdsvis v.s. 12–23 og 30–31. I seks ud af syv forsøg var en tendens til en forbedret bekæmpelse sammenlignet med fuld dosering udbragt ad én gang.

I hvede gav alle behandlingerne i gennemsnit signifikante merudbytter. Der var tendens til lavere merudbytte, når der blev anvendt reduceret dosering.

Den relative lave bekæmpelsesgrad ved anvendelse af normaldosering af prochloraz (46 pct.) danner ikke basis for generelt at anbefale reduktion af doseringen. Dobbelt dosering (900 g/ha), som blev afprøvet i det ene forsøgsår, viste ingen væsentlig forbedring af effekten.

Den danske skadetærskel for knækkefodsyge er lav, sammenlignet med bl.a. England, og bekæmpelse har kun givet små merudbytter i de fleste sæsoner. Det foreslås derfor at angreb mellem 15–35 pct. behandles med reduceret dosering (225 g/ha), hvis afgrøden enten er kort og stivstrået eller vækstreguleres. Hvis de sidste forhold ikke er opfyldt eller mere end 35 pct. af planterne er angrebet, anbefales fuld dosering.

Nøgleord: Knækkefodsyge, *Pseudocercosporella herpotrichoides,* bekæmpelsestidspunkt, doseringskurve, prochloraz, efterårsbekæmpelse, forårsbekæmpelse.

Introduction

Eyespot *(Pseudocercosporella herpotrichoides)* is a common disease in winter wheat and winter rye. Control has traditionally been carried out in spring around GS 30–31 (20). Since the middle of the seventies the recommended threshold in Denmark has been 15% attacked plants in winter wheat and 5–10% in winter rye in spring (18). The threshold values are based on trials with MBC products. Validation of these thresholds using prochloraz has been less convincing (12).

Trials in 1984 and 1985 showed good effect on eyespot using autumn application (10, 15). The results lead, in 1986, to a biological approval for autumn control of eyespot in winter rye. The approval was given to winter rye because of the very low threshold and the difficulties in assessing eyespot attack in rye in spring. In winter wheat, which less frequently needs eyespot control, it was decided to only recommend spring treatment, which can be applied when thresholds are passed.

In order to obtain more precise information of the optimal time of application, several different times of application have been compared, using three different times in the autumn and three different times in the spring.

According to a parliamentary decree, there should be a fifty per cent reduction in general pesticide use by 1997 relative to the mean of pesticides used in 1981–1985. This has focused attention on all methods of reducing the use of pesticides. For several of our fungicides lower dosages have provided satisfactory control against leaf diseases (11, 16). Trials were carried out in winter wheat and winter rye in 1987 and 1988 in order to test how far the dose of prochloraz could be reduced while still providing satisfactory control of eyespot.

Method

In winter wheat ten field trials were carried out in 1986, 1987 and 1988 to find the optimal time for eyespot control (experiment 1). Seven other winter wheat and three winter rye trials were carried out in 1987 and 1988 to find the dose response curve for control of eyespot using prochloraz (experiment 2). The trials were carried out according to Danish Guidelines for testing pesticides on pests and diseases in field crops (2).

The experiments were laid out as randomised blocks with four replicates. Plot size was 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.

In experiment 1, six different times of application were compared, using the recommended dose of prochloraz 450 g/ha (1.0 l Sportak 45ec/ha) from GS 10-11 to GS 30-31.

The different treatments and time of applications are shown in Table 1.

In experiment 2, three dosages of prochloraz were tested (113 g, 225 g and 450 g/ha). In 1988, 900 g of prochloraz was included in three trials. The treatments were applied at GS 30-31. Split treatment of prochloraz (2 × 225 g/ha) applied at GS 12-21 and 30-31 were compared to single treatments.

Both experiments 1 and 2 were treated with the broad spectrum fungicide Tilt Turbo (propicona-

Table 1. Effect of prochloraz and benomyl on eyespot *(Pseudocercosporella herpotrichoides)* and yield in winter wheat when using different times of application. Results from 1986-1988.

	Dose g a.i. per ha	Time of Application Zadoks	Date	% plants attacked in spring	Eyespot Index in July	Yield and yield increase hkg/ha	Yield and yield increase rel.	1000 grain weight g rel.
Untreated				37	47	65.2	100	100 (42,9)
Prochloraz	450	10–11 autumn	(7/10–2/11)	9	34	2.5	104	101
Prochloraz	450	11–13 autumn	(31/10–30/11)	10	32	2.3	104	101
Prochloraz	450	12–23 autumn	(17/11–21/12)	12	31	2.6	104	101
Prochloraz	450	12–23 spring	(6/4–28/4)	–	34	1.1	102	100
Prochloraz	450	23–30 spring	(18/4–6/5)	–	31	2.5	104	102
Prochloraz	450	30–31 spring	(6/5–22/5)	–	26	2.1	103	102
Benomyl	250	30–31 spring	(6/5–22/5)	–	39	1.1	102	101
No. of trials				10	10	10	10	8
LSD_{95} (incl. control)				8	5	1.4		N.S.

zol 125 g/l, tridemorph 350 g/l) or Tilt Top (propiconazol 125 g/l, fenpropimorph 375 g/l) at the time around earing.

Eyespot assessments were carried out in the spring at the end of April. Approximately 100 plants per treatment were randomly collected. Per cent plants with eyespot were assessed. In July approximately 100 straws were collected per treatment and assessed according to NIAB guidelines (1). The disease index was calculated for each treatment:

$$\text{Eyespot index} = \frac{(0 \times a) + (1 \times b) + (2 \times c) + (3 \times d)}{a + b + c + d} \times \frac{100}{3}$$

Where a, b, c and d are the number of tillers examined which fall into the categories 0 (healthy), 1 (slight attack), 2 (moderate attack) and 3 (severe attack), respectively.

The plots were harvested by a plot-combine and the grain yield was corrected to a 15% moisture content. Thousand grain weight was assessed for each plot.

Results

Experiment 1.

The results from the ten wheat trials carried out in 1986 to 1988 are shown in Table 1.

The level of eyespot was generally high in the trials and only one trial had an attack level below the threshold of 15% in the spring. In all but one trial, autumn treatment limited attack to below the threshold when assessed in the following spring. No significant differences could, however, be found between the threshold and level of attack after autumn treatment. Similarly, there were no significant differences between the three autumn treatments, when assessed in the spring. The treatment which gave the best control, varied between trials.

Despite the differences found in spring between the three timings of autumn treatments, no difference could be detected when assessed in July.

In July, no significant differences were found between either the three autumn applications or the two first applications in spring. Only the application at GS 30-31 resulted in significantly lower attacks.

The treatment with benomyl, reduced the eyespot attack significantly compared to the untreated control, but gave less control than prochloraz irrespective of time of application.

Average yield increases varied between 1.1 – 2.6 hkg/ha. All but two treatments gave significantly higher yields than untreated.

Experiment 2.

The dose responses of prochloraz on eyespot in winter wheat and winter rye are shown in Tables 2 and 3 respectively. The level of eyespot attack has generally been high in these trials as well.

In spring all trials in winter wheat had attack

Table 2. Control of eyespot *(Pseudocercosporella herpotrichoides)* in winter wheat when using different dosages or split application of prochloraz in spring. Results with the same letter are not significantly different (P≤0.05).

		Eyespot									
		% plants with attack in spring			Index in July			Yield and yield increase hkg/ha			1000 grain weight g rel.
		1987	1988	Average	1987	1988	Average	1987	1988	Average	
Untreated		52	48	50	61	51	57	70.2	85.0	76.5	A100 (43.7)
Prochloraz	900				–	32	–	–	3.3	–	–
Prochloraz	450				27	37	31	3.5	2.5	3.2	B103
Prochloraz	225				43	41	41	3.4	1.1	2.4	B103
Prochloraz	113				47	41	45	2.6	0.7	1.8	B102
Prochloraz	2×225				29	30	29	5.6	1.7	4.0	B103
No. of trials		4	3	7	4	3	7	4	3	7	7
LSD_{95} (incl. control)					5	8	7	2.6	3.5	1.5	

Table 3. Control of eyespot *(Pseudocercosporella herpotrichoides)* in winter rye using different dosages or split application of prochloraz in spring.

	Dose g a.i. pr. ha	Eyespot Index in July	Yield and yield increase hkg/ha	1000 grain weight g rel.
Untreated		51	59.4	100 (31.6)
Prochloraz	450	38	1.2	103
Prochloraz	225	40	1.9	104
Prochloraz	113	42	1.2	101
Prochloraz	2×225	29	1.8	103
No. of trials		3	3	3
LSD_{95}		17	N.S.	N.S.

above threshold values. A clear dose response effect was found in the trials. On average the relation was found to be linear, between 450, 225 and 113 g.a.i/ha (Fig. 1). The differences found in rye were small and insignificant.

The use of split application of prochloraz generally gave better control compared to 450 g/ha used at GS 30-31. A similar tendency was found in both winter wheat and winter rye in all but one trial.

In winter wheat, yield increases were significantly higher after all treatments compared to untreated. There was a tendency towards higher yields when using full rate either as single or split application compared to using reduced rates. All treatments increased thousand grain weight slightly.

In winter rye no significant differences were found between yields.

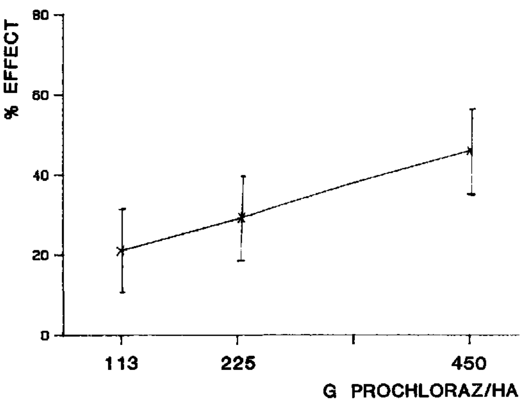

Fig. 1. Dose response curve for eyespot *(Pseudocercosporella herpotrichoides)* in winter wheat with prochloraz at GS 30-31. Average effect from seven trials in 1987 and 1988. – Assessed in July. 95% interval of confidence is specified.

Discussion and conclusion

Prochloraz is a broad spectrum fungicide, which apart from controlling eyespot gives good control of powdery mildew (*Erysiphe graminis*, D. C. ex. Merat) in barley; Scald *(Rhynchosporium secalis*, (Oud) J. J. Davis), leaf blotch (*Pyrenophora teres*, Drechsler) and *Septoria spp. (Septoria nodorum*, Berk. and *Septoria tritici*, Rob. and Desm.). The effect of the product on other diseases means that yield increase might not be solely due to the control of eyespot. As a result of widespread MBC resistance (17), prochloraz is almost the only eyespot product sold in Denmark.

Prochloraz is non systemic but has translaminar movement (4). This fact is recognized to be an advantage for the effect on eyespot as the product is not thought to be diluted as a result of transport to other parts of the plant.

The results indicate that the optimal time of application is in the spring around GS 30-31. Five trials gave best control of eyespot when applied in spring, whereas the five other trials showed no distinct differences between spring or autumn application. Application carried out later than GS 31 has, so far, not been tested in Denmark.

In 20 trials carried out by The Danish Advisory Service slightly better control was achieved when application was made at GS 30-31, when compared to a spring application at GS 23-29 (14). *Jørgensen* (8) found as an average of 20 trials from 1985-87, that autumn application has given 33% control and spring treatments 42% control. Yield increases were 4.2 hkg/ha and 3.4 hkg/ha, respectively.

Control of eyespot in trials, when using prochloraz has generally not given rise to big yield increases. Yields have increased by 3,0 hkg/ha as an average of 64 trials (1981-84), when the threshold in spring was exceeded (12). The common use of plant growth regulators is thought to minimize the risk of yield reductions from severe eyespot attacks.

Results from England have shown that an application of prochloraz between November (GS 22) and mid May (GS 37) decreased the severity of eyespot in varying degrees (3, 7). Yield response between these timings have, however, not differed significantly (7). The strategy of applying prochloraz at GS 37 has been found to make penetration through the crop canopy, difficult, when sprayed conventionally (3). New spraying techniques which displace the crop during spraying, are suggested for improvement of the treatment at GS 37. Redistribution of prochloraz by rain is another factor, which has proved to increase the efficacy of prochloraz when applied at GS 37 (5).

The advantages of late application should be an improved reliability of forecast, where amount of infection reaching the stem during stem extension could be included. Late application also offers a valuable possibility of prochloraz being used as a combined eyespot and *Septoria* treatment.

Frahm and *Knapp* (6) mention that effective eyespot control by prochloraz should be carried out before the temperature sum has exceeded 400°C, measured at a soil depth of 10 cm, from the first opportunity for inoculation or at the beginning of tillering. A base temperature of 4°C is used. The authors expect at that stage, the disease to be so advanced in the plants that a further delay in spraying will not enable prochloraz to reach and stop an eyespot attack.

Sporulation counts from autumn sprayed plots containing plants and infected straw have shown that prochloraz reduce conidia production both in autumn and spring. From December to June the number of spores were reduced to 8–12% relative to untreated plots (19).

The importance of early control for obtaining high effectiveness of prochloraz, along with the fact that the disease is active over a long period of time, is confirmed by new results. These have shown that a combined autumn and spring control (2 × 225 g/ha) give a considerably better effect on eyespot than spring or autumn control alone. The increase in effect has not resulted in any further yield increase (11).

Autumn-control using prochloraz has been thought of as a combined control of eyespot and snow mould *(Gerlachia nivale)*. Snow mould is, however, rarely a significant problem in Denmark and trials have not been able to justify general autumn control because of snow mould attacks alone.

Autumn application, using a single treatment, has not shown any advantages compared to spring application. Spring application is still thought to be more desirable because it enables spraying to be carried out after a risk evalution. The relatively low yield responses which eyespot control has given points towards minimizing a general preventive use of eyespot control.

Therefore, only farmers, with a known high risk of eyespot, should consider autumn application using half dose prochloraz, if it can be combined with a herbicide treatment. Application of the other split treatment can be considered in spring after evaluation of the eyespot risk.

As a result of the relatively low efficacy which the normal dose of prochloraz has given in the trials, further reduction in dosage can not generally be recommended. Lower dosages have given lower effect which is again reflected in a lower yield increase. The net returns are however almost identical (net return is calculated using 130 Dkr/hkg wheat, 250 Dkr/l of Sportak 45ec, 120 Dkr/application). Because of net returns being similar and the danish threshold being low (12), farmers with a low level of attack (15-35%) are recommended to use half rate, if a growth regulator is used or if the variety has good resistance to lodging.

Double dose (900 g of prochloraz/ha) did not, in the 1988 trials, give a significant increase in effect and seems not to be advisable.

The relatively low effects which have been found in trials from both experiment 1 and 2 can not be related to a build up of resistance to prochloraz. Laboratory tests have not, shown any change in the sensitivity to prochloraz (9).

The very low effect of benomyl, in nine out of ten trials, indicates MBC resistance in the fields. This is in line with previous experiences on MBC resistance from field trials and laboratory tests. (13, 17).

References

1. *Anonymous* 1985a. Disease assessment manual for crop variety trials. NIAB Cambridge.

2. *Anonymous* 1985b. Retningslinier for afprøvning af midler mod sygdomme og skadedyr på landbrugsafgrøder. Statens Planteavlsforsøg.
3. *Bateman, G. L.* 1987. Comparison of the effects on eyespot in wheat of fungicides applied to the foliage or shoot bases at different times. J. Agric. Sci. 109, 601-604.
4. *Cooke, B. K., Pappas, A. C., Jordan, V. W. L. & Western, N. M.* 1979. Translocation of benomyl, prochloraz and procymidone in relation to control of Botrytis cinerea in strawberries. Pesticide Sci. 10, 467-472.
5. *Cook, B. K., Hislop, E. C., Jordan, W. W. L., Western N. M. & Hennington, P. J.* 1989. Redistribution of foliar surface deposits of prochloraz by simulated rainfall and the control of eyespot disease of winter wheat. Crop Protection 8, 373-379.
6. *Frahm, J. & Knapp, A.* 1986. Ein einfaches Model zur Optimierung von Fungicidbehandlungen gegen *Pseudocerosporella herpotrichoides* in Weizen. Gesunde Pflanzen 38, 139-150.
7. *Jordan, V. W. L., Hunter, T., & Fielding, E. C.* 1988. Interaction of fungicides with nitrogen and plant growth regulators for cost-effective control of wheat diseases. Proceedings 1988 British Crop Protection Conference – Pest and Diseases, 873-880.
8. *Jørgensen, L. N.* 1987 a. Bekæmpelse af knækkefodsyge. Landbonyt maj, 60-63.
9. *Jørgensen, L. N.* 1987 b. Sensitivity of eyespot *(Pseudocercosporella herpotrichoides)* in Denmark to sterol inhibitors. Växtskyddsrapporter, Jordbruk 48, 97-102.
10. *Jørgensen, L. N. & Strøh, J.* 1985. Efterårsbekæmpelse af knækkefodsyge *(Pseudocercosporella herpotrichoides)* med Sportak 45ec. 2. Danske Planteværnskonference, Sygdomme og Skadedyr, 162-176.
11. *Jørgensen, L. N. & Nielsen, B. J.* 1990. Bekæmpelse af svampesygdomme i hvede, 1989. 7. Danske Planteværnskonference, Sygdomme og Skadedyr, 201-217.
12. *Jørgensen, L. N., Bødker, L. & Schulz, H.* 1990. Validation of the threshold for eyespot *(Pseudocercosporella herpotrichoides)* in spring and July. Tidsskr. Planteavl 94, 223-232.
13. *Jørgensen, L. N., Nielsen, B. J., Petersen, E. F. & Elbek-Pedersen, H.* 1987. Fungicide resistance. Present situation and fungicide strategies for benzimidazoles in Denmark. Växtskyddsrapporter, Jordbruk 48, 59-69.
14. *Kristensen, H. & Elbek-Pedersen, H.* 1989. Plantebeskyttelse. Oversigt over Landsforsøgene 1988, 128-203.
15. *Nielsen, B. J. & Jørgensen, L. N.* 1986. Bekæmpelse af knækkefodsyge og bladsvampe på korn, 1985. 3. Danske Planteværnskonference, Sygdomme og Skadedyr, 98-129.
16. *Nielsen, B. J. & Jørgensen, L. N.*, 1989. Bekæmpelse af svampesygdomme i byg, 1988. 6. Danske Planteværnskonference, Sygdomme og Skadedyr, 119-137.
17. *Nielsen, B. J., Schulz, H. & Jørgensen, L. N.* 1986. Carbendazimresistens hos knækkefodsygesvampen *(Pseudocercosporella herpotrichoides)* i Danmark 1984. 3. Danske Planteværnskonference, Sygdomme og Skadedyr, 149-177.
18. *Schulz, H. & Hansen, K. E.* 1977. Knækkefodsyge i vintersæd. Biologi og bekæmpelse. Statens Planteavlsforsøg, Meddelelse nr. 1343.
19. *Sindberg, S. & Schulz, H.* 1986. Prochloraz og MBC-midlernes indflydelse på sporuleringen hos knækkefodsygesvampen ved en efterårssprøjtning. 3. Danske Planteværnskonference, Sygdomme og Skadedyr, 133-148.
20. *Zadoks, J. C., Chang, T. T., Konzak, C. F.* 1974. A decimal code for the growth stage of cereals. Weed Research 14, 415-421.

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