

Field efficacy of different fungicide mixtures in control of net blotch on barley

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SUMMARY

Seven fungicide mixtures (epoxiconazol + metconazole, boscalid + epoxiconazole, pyraclostrobin + epoxiconazole, prothioconazole + tebuconazole, picoxistrobin + cyproconazole, azoxystrobin + cyproconazole and spiroxamine + tebuconazole + triadimenol) were evaluated for control of net blotch of barley caused by *Drechslera teres*, as well as yield losses, over the 2010 and 2011 growing seasons. Two applications of the fungicide combination pyraclostrobin + epoxiconazole at the rate of 1.0 l ha⁻¹ were the most effective treatment in controlling the disease and improving yield in both experimental years. Treatments with the fungicide mixtures epoxiconazol + metconazole and spiroxamine + tebuconazole + triadimenol showed the least effectiveness in disease control, as well as yield increase.

Keywords: Fungicides; Chemical control; Net blotch; Barley

INTRODUCTION

Net blotch of barley (*Hordeum vulgare* L. emend Bowden) caused by *Pyrenophora teres* Drechsler (anamorph *Drechslera teres* [Sacc.] Shoem) was first reported in the 1970s, and described following its widespread detection in Denmark (Smedegard-Petersen, 1971). It is now prevalent in barley-growing regions around the world where stubble retention practices are used and susceptible barley varieties are grown. The disease can occur over a wide range of climatic conditions, but it prefers temperate conditions of high rainfall and humidity (Mathre, 1997).

Symptoms of net blotch are most prominent on the lamina and sheath of leaves but it can also be found on

flowers and grains. The first symptoms appear as small pinpoint, dark brown necrotic spots that increase in size to form elliptical or fusiform markings surrounded by chlorotic zones (Smedegard-Petersen, 1971). Symptoms associated with infection by *P. teres* are partially caused by the secretion of various toxins (Weiergang et al., 2002; Sarpeleh et al., 2007, 2008a,b).

Net blotch is an important foliar disease of barley worldwide (McLean et al., 2009; Liu et al., 2012) and can cause significant grain yield and quality loss. The disease has caused significant grain yield losses in Australia and reduced grain quality in barley, but only where conditions were ideal for epidemic development (Platz & Usher, 2006; Jayasena et al., 2007; McLean et al., 2010). Maximum yield loss recorded in Western

Australia was 44%, which was correlated to 55% of the top three leaves being affected by spot-type net blotch symptoms (Jayasena et al., 2007). Yield losses in susceptible cultivars can be up to 45% (Steffenson et al., 1991; Kangas et al., 2004).

Grain yield and quality loss can be managed effectively using a combination of crop rotation, stubble destruction methods, application of foliar fungicides and cultivation of barley varieties with host resistance (McLean, 2011).

Chemical control of net blotch of barley by foliar fungicides has been reported (Sutton & Steele 1983; Khan, 1989; van den Berg & Rossnagel, 1990; Jayasena et al., 2002; McLean, 2011). The effectiveness of control using foliar fungicides varies depending on factors such as the degree of disease pressure, mode of action of the active ingredient, application rate, timing of and number of applications, and reduced sensitivity or resistance in pathogen populations (van den Berg & Rossnagel, 1990). When correctly applied to susceptible varieties, they can provide significant reductions in disease severity (van den Berg & Rossnagel, 1990) and may have an added benefit of controlling other diseases, such as scald (*Rhynchosporium secalis*) (Scott, 1992).

The most frequently used fungicides for net blotch control are triazole-based fungicides, which inhibit the C14 demethylation step in fungal ergosterol biosynthesis and are referred to as demethylation inhibitors (DMIs) (Gisi et al., 2000). Also, the group of broad-spectrum fungicides (quinol-oxidizing inhibitor (QoI) fungicides) has been widely accepted for the control of cereal diseases (Chin et al., 2001). These fungicides affect the respiration

process by binding at the Qo-centre on cytochrome b and block electron transfer between cytochrome b and cytochrome c1.

In this study, the efficacy of different fungicide mixtures in controlling the net blotch disease of barley was compared. The effect of disease control on grain yield was measured during 2010-2011.

MATERIAL AND METHODS

Location and trial design

Two trials were conducted at Padinska Skela (GPS: N 44 57.997; E 20 25.597) over the 2010-2011 growing seasons. In both experimental years, barley (variety Pivan) was sown in October (240 kg seeds ha⁻¹). Fertilizers were applied in accordance with results from soil testing and 300 kg ha⁻¹ NPK (15:15:15) was applied before the sowing. An additional fertilizer (Urea) was applied at 100 kg ha⁻¹ in February.

The trials were arranged in a randomized complete block design, according to the EPPO method 1/152(4) (EPPO, 2012a). The trials were set up according to EPPO's guidelines PP 1/26(4) (EPPO, 2012b) with individual treatment plot size of 10 m² and four replicates per each treatment.

Fungicides

The fungicide combinations, formulation types, rates of active ingredients (a.i.) and application rates (l ha⁻¹) tested in this study are listed in Table 1.

Table 1. Fungicide formulations used in the trials

Proprietary name	Active ingredient	Rate of a.i. (g l ⁻¹)	Formulation type	Manufacturer	Application rate (l ha ⁻¹)
Osiris	Epoxiconazol + metconazole	37.5 + 27.5	EC	BASF	2.0
Champion	Boscalid + epoxiconazole	233 + 67	SC	BASF	1.2
Opera	Pyraclostrobin + epoxiconazole	133 + 50	SE	BASF	1.0
Prosaro	Prothioconazole + tebuconazole	125 + 125	EC	BayerCrop Science	1.0
Acanto Plus	Picoxistrobin + cyproconazole	200 + 80	SC	DuPont	1.0
Amistar Extra	Azoxystrobin + cyproconazole	200 + 80	SC	Syngenta	0.75
Falcon EC-460	Spiroxamine + tebuconazole + triadimenol	250 + 167 + 43	EC	BayerCrop Science	0.6

Application

The fungicides were applied by a knapsack sprayer (Solo 425, Germany) to simulate practical application by farmers (water volume: 400 liter/ha). Two fungicide treatments were performed, as closely as possible to the BBCH (Biologische Bundesanstalt, Bundessortenamt and Chemical Industry) growth stages BBCH 51 (first spikelet of ear just visible), and BBCH 61-65 (start of flowering - flowering half-way).

Evaluation

Two assessments of leaf infection were made: the 1st was made immediately before the first application, and the 2nd at the growth stage 75 (BBCH 75, medium milk stage). Ten randomly sampled tillers were collected from each individual treatment plot, and the percentage of leaf infection on the top three youngest fully emerged leaves of each tiller was estimated using the following scale: 0 – no disease; 1 – 1% of leaf area affected; 2 – 5% of leaf area affected; 3 – 10% of leaf area affected; 4 – 25% of leaf area affected; 5 – 50% of leaf area affected; and 6 – 75% of leaf area affected.

Disease severity (DS) was evaluated using Townsend-Heuberger's formula (Townsend & Heuberger, 1943):

$$DS (\%) = \frac{\sum(nv)}{NV} \times 100$$

where

n – degree of infection on the 6-grade scale, v – number of leaves per category, V – total number of leaves assessed, N – the highest degree of infection.

Fungicide efficacy (EF) was calculated using Abbott's formula (Abbott, 1925):

$$EF (\%) = \frac{X - Y}{X} \times 100$$

where

X – disease severity in control, Y – disease severity in treated plots.

The effects of fungicide treatments on disease severity and yield were analysed separately for each trial using ANOVA and the means were separated by Duncan's multiple range test.

RESULTS

Field trial, 2010

The assessment made before the first fungicide treatments showed there were no symptoms of net blotch on barley leaves. There was a gradual increase in disease intensity and severe disease was observed by late spring. The application of fungicides significantly reduced disease intensity when it was assessed at milk stage, BBCH 75 (Figure 1). Two sprays of the fungicide combination pyraclostrobin + epoxiconazole, applied at the rate of 1.0 l ha⁻¹, resulted in the lowest disease severity. Picoxistrobin + cyproconazole (1.0 l ha⁻¹), boscalid + epoxiconazole (1.2 ha⁻¹) and azoxystrobin + cyproconazole (0.75 ha⁻¹) treatment combinations also produced significant reductions in disease intensity, compared with the untreated control, and there were no significant differences between these fungicides.

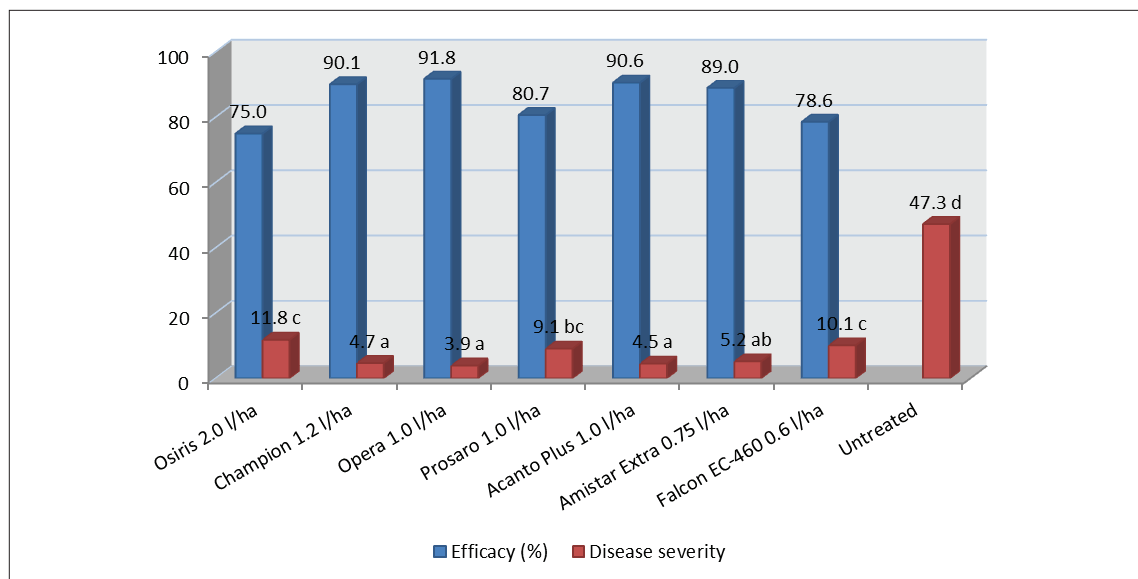


Figure 1. Disease severity on barley leaves (mean of top three leaves) and fungicide efficacy (location: Padinska Skela, 2010). (*Means marked by different letters are significantly ($p < 0.05$) different according to Duncan's test).

Three fungicide combinations, prothioconazole + tebuconazole, spiroxamine + tebuconazole + triadimenol and epoxiconazole + metconazole, were the least effective with efficacy reaching only 80.7%, 78.6% and 75.0%, respectively.

All treatments significantly increased the yield (Figure 2). Plots treated twice with the fungicide combination pyraclostrobin + epoxiconazole increased the yield 35.3%, compared to the untreated plots. The other six tested fungicide combinations also significantly increased the yield (19.5-30.0%) compared to the control.

Field trial, 2011

Infection was observed before the first fungicide application, indicating that there were no symptoms of net blotch on barley leaves. The effects of fungicide treatments became evident at the second assessment, made at the milk stage BBCH 75 (Figure 3). The most effective of all tested fungicides was the combination pyraclostrobin + epoxiconazole, applied at the rate of 1.0 l ha⁻¹, which reached 97.0% efficacy. Treatments with

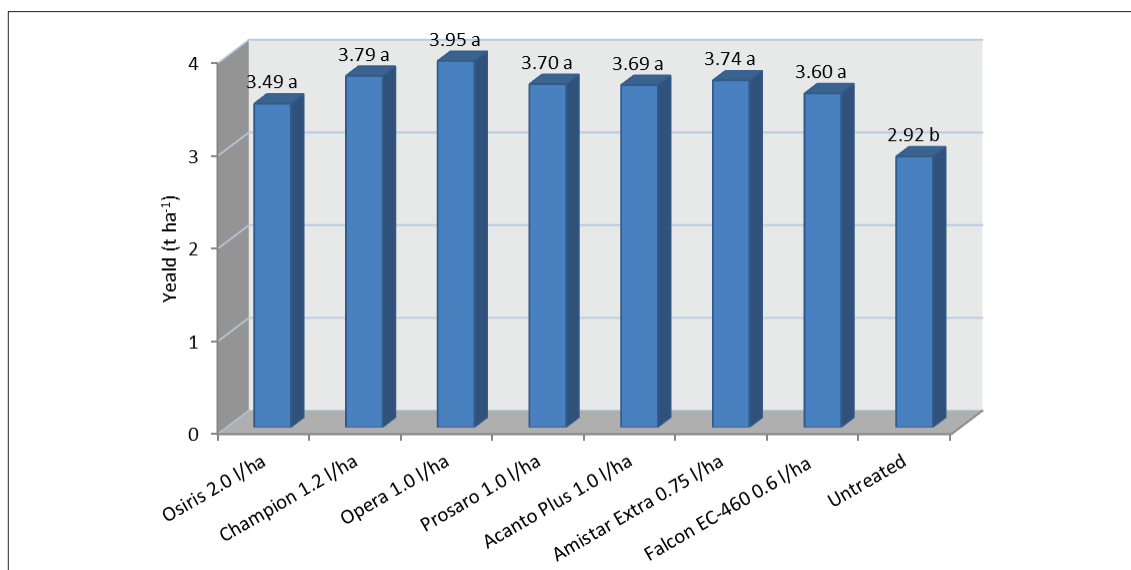


Figure 2. Effects of different fungicides on the yield of barley affected by net blotch, Padinska Skela 2010. (*Means marked by different letters are significantly ($p < 0.05$) different according to Duncan's test).

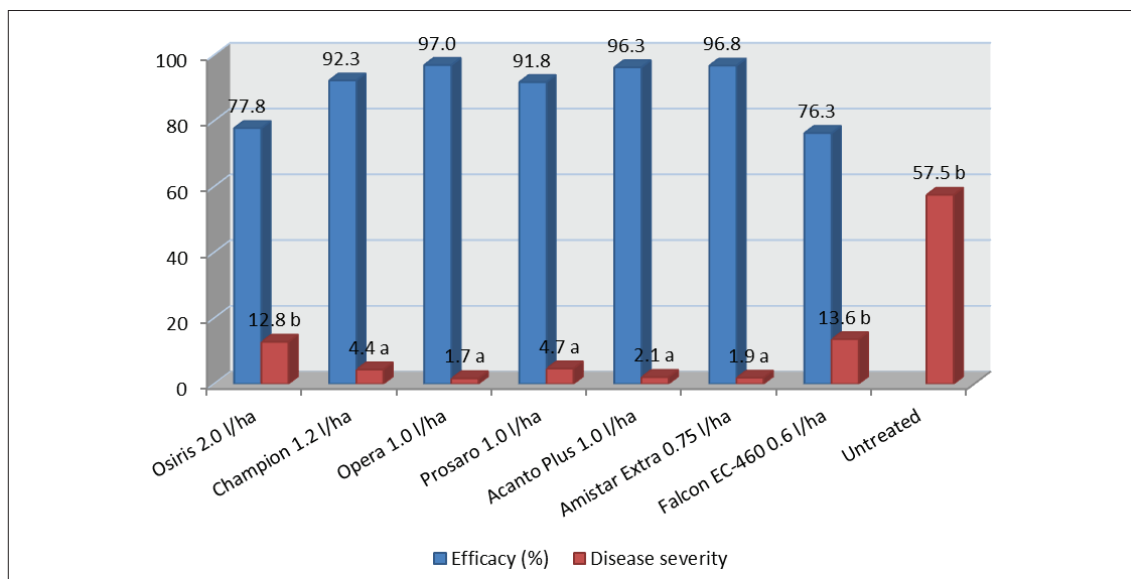


Figure 3. Disease severity on barley leaves (mean of top three leaves) and fungicide efficacy (location: Padinska Skela, 2011). (*Means marked by different letters are significantly ($p < 0.05$) different according to Duncan's test).

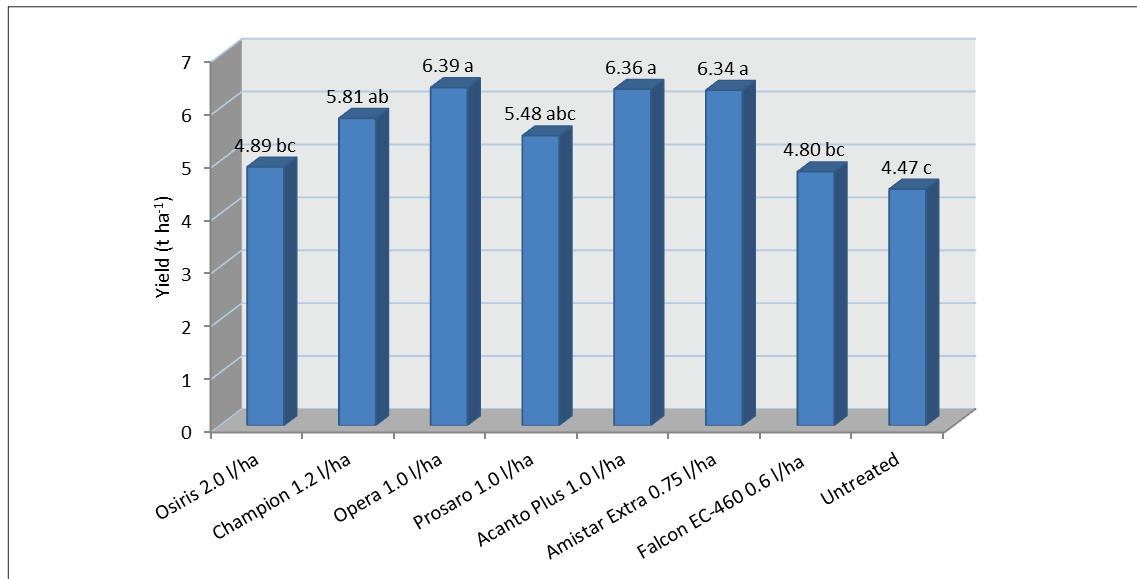


Figure 4. Effects of different fungicides on the yield of barley affected by net blotch, Padinska Skela 2011. (*Means marked by different letters are significantly ($p < 0.05$) different according to Duncan's test).

picoxistrobin + cyproconazole, azoxystrobin + cyproconazole and boscalid + epoxiconazole were as effective as in the field trial of the previous year, while the combination prothioconazole + tebuconazole decreased disease severity more than in the field trial in 2010. Epoxiconazol + metconazole and spiroxamine + tebuconazole + triadimenol were the least effective treatments with 77.8% and 76.3% efficacy, respectively.

Two applications of the mixture pyraclostrobin + epoxiconazole produced a significantly higher yield than the control, but it was not significantly different from the yield that followed the application of picoxistrobin + cyproconazole, azoxystrobin + cyproconazole, boscalid + epoxiconazole and prothioconazole + tebuconazole. These fungicide treatments increased the yield 22.6–43% compared to the untreated plots. Plots treated with epoxiconazol + metconazole and spiroxamine + tebuconazole + triadimenol increased the yield 7.4% and 9.4%, respectively, compared to the untreated plots.

DISCUSSION

Net blotch was the most prevalent and severe foliar disease of barley crops in the experimental field trials conducted during the 2010 and 2011 growing seasons. The time and intensity of disease infection in the field depends on the susceptibility of a variety, so that the resistance of any variety has a great importance in controlling plant disease (Carmona et al., 1999). Fungicides are needed to

avoid yield reduction by disease infection, and to increase economic profits. The results of a study by Sooväli and Koppel (2010) indicate that chemical control is the most profitable control method for moderately susceptible barley varieties and that the best spot-type net blotch control effect was achieved with two treatments per season.

The results of the current study show that different foliar fungicide treatments resulted in different degrees of reduction in disease severity. The fungicides used in these experiments belong to two groups, according to their mode of action. The fungicides epoxiconazole, metconazole, prothioconazole, tebuconazole, cyproconazole, spiroxamine and triadimenol are inhibitors of sterol biosynthesis in cell membranes, while boscalid, pyraclostrobin, picoxistrobin and azoxystrobin inhibit mitochondrial respiration in fungi. The results of our experiments show that the most effective were mixtures containing fungicides from each of these two groups. Treatments with the fungicide pyraclostrobin + epoxiconazole at 1.0 l ha⁻¹ rate resulted in the lowest disease severity in both experimental years. The efficacy of this fungicide mixture was 91.8% in 2010, and 97.0% in the 2011 growing season. The other tested fungicide combinations of inhibitors of mitochondrial respiration and sterol biosynthesis inhibitors, i.e. picoxistrobin + cyproconazole (1.0 l ha⁻¹), boscalid + epoxiconazole (1.2 l ha⁻¹) and azoxystrobin + cyproconazole (0.75 l ha⁻¹), were also effective in net blotch control and there were no significant differences among these three fungicide combinations. The mixture prothioconazole + tebuconazole, applied at the rate of 1.0 l ha⁻¹, was more

effective in the second experimental year, when the disease pressure was higher. Two fungicide combinations, spiroxamine + tebuconazole + triadimenol (0.6 l ha^{-1}) and epoxiconazol + metconazole (2.0 l ha^{-1}), were the least effective. The results presented in this study are similar to those reported by Pereyra and Castro (2011). Pyraclostrobin + epoxiconazole was the most effective fungicide mixture in their experiments conducted from 2008 to 2010. They also found that fungicide combinations of trifloxystrobin + tebuconazole, azoxystrobin + tebuconazole and kresoxim-methyl + epoxiconazole were effective in controlling net blotch in a single application, improving grain physical quality. Jayasena et al. (2002) evaluated ten fungicides (pyraclostrobin, tebuconazole, flutriafol, epoxiconazole, propiconazole, triadimefon, azoxystrobin, trifloxystrobin, difenoconazole and a mixture of propiconazole with iprodione) in single applications for control of net blotch of barley at three locations during the 1999 and 2000 growing seasons. They reported that pyraclostrobin, propiconazole and the mixture of propiconazole with iprodione were the most effective in controlling disease, and azoxystrobin, trifloxystrobin, difenoconazole and epoxiconazole also provided disease control.

All treatments significantly increased grain yield. Two applications with the fungicide combination pyraclostrobin + epoxiconazole improved disease control and increased the yield compared to untreated plots in the 2010 and 2011 growing seasons (35.3% and 43%, respectively). Jayasena et al. (2002) reported that yield losses under moderate disease severity ranged from 17-19%, depending on location, while losses reached 32% under high disease severity. They also found that individual pyraclostrobin and epoxiconazole treatments also resulted in reduced disease severity. Also, single applications of these fungicides increased the yield up to 24%. Under higher disease pressure, pyraclostrobin performed better than epoxiconazole in controlling disease and increasing the yield. A single application of propiconazole fungicide applied at $62\text{-}125 \text{ g ai ha}^{-1}$ around the early flag leaf emergence stage of the crop is a commercial practice to control net blotch (Jayasena et al., 2007). The effect of a single application at around the late stem elongation growth stage on disease control and grain yield was assessed in an earlier study at Wellstead, Australia, in 2001 (Jayasena et al., 2002). That fungicide treatment provided a partial disease control and resulted in $0.8\text{-}1.0 \text{ t/ha}$ yield increase.

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Efikasnost različitih kombinacija fungicida u suzbijanju prouzrokovala mrežaste pegavosti ječma

REZIME

Ispitivana je efikasnost sedam različitih kombinacija fungicida (epoksikonazol + metkonazol, boskalid + epoksikonazol, piraklostrobin + epoksikonazol, protiokonazol + tebukonazol, pikoksistrobin + ciprokonazol, azoksistrobin + ciprokonazol i spiroksamin + tebukonazol + triadimenol) u suzbijanju prouzrokovala mrežaste pegavosti ječma *Drechslera teres*, kao i njihov uticaj na prinos tokom 2010. i 2011. godine. Najveću efikasnost u obe ispitivane godine ispoljila su dva tretmana kombinacijom fungicida piraklostrobin + epoksikonazol primenjenom u količini 1.0 l ha⁻¹. Kombinacije fungicida epoksikonazol + metkonazol i spiroksamin + tebukonazol + triadimenol su pokazale najslabije delovanje na prouzrokovala mrežaste pegavosti ječma, kao i najmanje povećanje prinosa u poređenju sa kontrolom.

Ključne reči: Fungicidi; Hemijsko suzbijanje; Mrežasta pegavost; Ječam