# EuroBarley

Matzen, N.; Weigand, S.; Bataille, C.; Kildea, S.; Havis, N.; O' Driscoll, A.; Waite, K.; Jalli, M.; Rodemann, B.; Jørgensen, Ln

*Published in:*
Journal of Plant Diseases and Protection

*DOI:*
10.1007/s41348-023-00852-3

First published: 13/01/2024

*Document Version*
Publisher's PDF, also known as Version of record

Journal of Plant Diseases and Protection
https://doi.org/10.1007/s41348-023-00852-3

ORIGINAL ARTICLE

# EuroBarley: control of leaf diseases in barley across Europe

**N Matzen[1] · S Weigand[2] · C Bataille[3] · S Kildea[4] · N Havis[5] · A O' Driscoll[6] · K Waite[6] · M Jalli[7] · B Rodemann[8] · LN Jørgensen[1]**

Received: 5 October 2023 / Accepted: 9 December 2023


**Abstract**
Barley crops are at risk of being attacked by several leaf diseases. Net blotch, brown rust, Rhynchosporium and Ramularia leaf spot are among the most widespread and can cause severe attack and yield losses. Two trial protocols targeting Ramularia and net blotch, respectively, have been tested in several countries in 2021 and 2022. Ramularia trials were situated in Germany, Ireland, Scotland, and Denmark. The net blotch trials were placed in Denmark, Belgium, the UK, Germany, Finland, and France. In the two protocols, 12–13 different fungicide solutions including co-formulations of DMIs, SDHIs, QoIs, and multi-site inhibitors have been tested to compare efficacy and yield responses. Against Ramularia leaf spot, the fungicides were applied at GS 47–51 and against net blotch at GS 37–45. In six trials, the efficacy against Ramularia leaf spot was scored. The results showed a superior control from the co-formulation fluxapyroxad + metyltetraprole (78–100% control), but also solo mefentrifluconazole and the mixtures fluxapyroxad + mefentrifluconazole performed well (average 74–76% control). The mixture fluxapyroxad + metyltetraprole provided the best yield increase followed by Ascra Xpro. Folpet as a solo solution was inferior. Following the net blotch protocol, only three trials developed enough disease to rank the different fungicides; however, in five trials ranking against brown rust was also possible. Most treatments gave very good control of net blotch, and brown rust (> 80% control). The mixture fluxapyroxad + metyltetraprole delivered the best control against all diseases overall. Average yield responses from eight trials showed very similar increases from the tested fungicides.

**Keywords** Ramularia collo-cygni · Pyrenophora teres · Puccinia hordei · Fungicides · Field effects · Yield response

## Introduction

The effective control of cereal diseases is increasingly under pressure from the development of fungicide resistance, but this development is highly dependent on local disease pressure and common practices of disease control. Currently, the control of barley diseases typically relies on using 1–2 treatments with fungicide mixtures, which include both QoIs, DMIs and SDHIs. The aim of this study was to evaluate the efficacy of older and more recent chemistries against two of the main diseases in barley across Europe, namely net blotch—(*Pyrenophora teres*), and Ramularia leaf spot—(*Ramularia collo-cygni*). Additionally, the effects against brown rust (*Puccinia hordei*) were evaluated.

In barley, Ramularia is currently of the greatest concern regarding development of resistance, and substantial reductions in sensitivity to QoIs, DMIs, and SDHIs have been seen especially in western Europe (Fountaine & Fraaije 2009; Piotrowska et al. 2017; Rehfus et al. 2019). The

✉ N Matzen
nielsmatzen@agro.au.dk

1 Department of Agroecology, Aarhus University, Flakkebjerg, Slagelse, Denmark

2 Institute for Plant Protection, Bavarian State Research Center for Agriculture, Freising, Germany

3 CRA-W, Plant and Forest Health Unit, Gembloux, Belgium

4 Teagasc, Oak Park, Carlow, Ireland

5 SRUC, Edinburgh, UK

6 NIAB, Cambridge, UK

7 Natural Resources Institute Finland (Luke), Jokioinen, Finland

8 JKI, Brunswick, Germany

Published online: 13 January 2024

disease often arrives late in the season, and diagnosis can be difficult because of the resemblance between the symptoms of the disease and physiological spots. During the last decades, Ramularia has been increasingly recognized as an important yield limiting disease in barley (Havis et al. 2015).

Net blotch was the first cereal disease to develop widespread resistance to SDHI fungicides, with reduced sensitivity observed since 2012 (Rehfus et al. 2016). According to FRAC (2021), the sensitivity is moderate to high in central European countries, the UK, and Ireland, while Denmark has observed only low levels of resistance. While QoI resistance is prevalent in several cereal diseases, net blotch remains sensitive to most QoI fungicides (Jørgensen et al. 2018). DMI-resistant net blotch isolates have emerged with target site mutations like Y137F and S524T, also found in the *Zymoseptoria tritici* gene. Reduced sensitivity has been observed in specific regions of France and Germany according to FRAC in 2021. Unlike other fungicides, multi-site inhibitors like sulfur and folpet have multiple modes of action, reducing the risk of resistance. However, they generally have lower efficacy than the single-site fungicides and are considered more as supplementary products, especially useful as parts of anti-resistance strategies.

## Materials and methods

The results of this study were collected from two trial series carried out in 2021 and 2022. The trials were carried out across Europe by local scientific organizations with the aim of including diverse climate zones and agricultural practices. Trials aimed at net blotch were located in Denmark, Finland, Belgium, and Scotland, while trials aimed at Ramularia were placed in Denmark, Ireland, Scotland, and Germany. Similar procedures and a randomized plot design with four replicates and plot sizes of minimum 10 $m^2$ were used in all trials. Fungicide applications were carried out with a variety of equipment, using, for example, knapsack sprayers or self-propelled sprayers, pressures of 1.7–3.2 bar, and water volumes of 200–300 L/ha. Trials aiming at net blotch and Ramularia were sprayed at growth stage (GS) 37–45 and 47–51, respectively. In conditions with high disease pressure, a cover spray was applied to all plots including untreated to eliminate diseases like rust and net blotch, no later than 2 weeks before the estimated time for GS 37–39. Disease severity assessments were carried out following the EPPO guideline 1/26 (4)) (Oepp/Eppo, 2014). Individual leaf layers were assessed as percent symptomatic leaf area approximately every ten days after application. Grain yields were measured for each plot, which were adjusted to 85% dry matter. BASF supplied the fungicides, which were applied at full or 60%, 67%, or 80% recommended dose (Tables 1 and 2). The treatments included co-formulations of DMIs, SDHIs, QoIs, and multi-site inhibitors, and the same treatments were tested in both years.

## Results

### Field effects—net blotch and brown rust

In the net blotch trial series, only three trials developed sufficient levels of net blotch to rate the fungicide effects. Net blotch disease pressure was high ranging from 43.8–55% in the three trials (Table 3). The field effects were also quite similar across the trials with good effects on average above 80% for all treatments except prothioconazole, which also had the most variable effects ranging from 51–81% (avg. 66%) (Fig. 1). Nearly complete control was achieved by many of the solutions, and especially the solutions containing three active compounds gave excellent control, but excellent control was also seen from solutions with combinations of two active compounds fluxapyroxad + pyraclostrobin (95–100%) or fluxapyroxad + mefentrifluconazole (97–99%). However, the effects from the mixture with mefentrifluconazole and pyraclostrobin were a bit more variable ranging from 79 to 97%.

Considerable levels of brown rust developed in five trials from the net blotch trial series. The rust severity varied across the trials from 5.3 to 76.9% (avg. 26%) (Table 3). The control effects were high with averages above 80% from most treatments (Fig. 2). The solo solutions with prothioconazole and pyraclostrobin gave the lowest levels of control ranging from 48 to 98% (avg. 72) and 25–98% (avg. 74%), respectively. Solutions with mefentrifluconazole + pyraclostrobin and bixafen + fluopyram + prothioconazole and prothioconazole + trifloxystrobin gave similar ranges of effects with averages around 80%. The remaining treatments gave similar, excellent effects with average effects above 90% and little variation.

### Field effects and yields—Ramularia

Six trials from the Ramularia trial series had sufficient levels of attack to rate the effects of treatments. The disease pressure varied widely across the trials from 7.9 to 85% (avg. 34%) (Table 4). The variation of treatment effects across the trials was small, and clear patterns could be seen in the ratings of treatment effects across the trials (Table 5). The highest effects of 90% on average were delivered by the mixture fluxapyroxad + metyltetraprole. Good effects were also seen from treatments with solo mefentrifluconazole and mixtures of fluxapyroxad and mefentrifluconazole and pyraclostrobin ranging from 74 to 76% on average. The solo

**Table 1** Protocol for trials aimed at net blotch carried out in 2021 and 2022. Treatments were carried out at growth stage 37–45

| Trt. No | Treatments name | Active ingredient | Abb. | Group | Dose (L/ha) | g a.i./ha | Std. dose (%) |
|---|---|---|---|---|---|---|---|
| 1 | Untr. control | | | | – | – | |
| 2 | Revytrex | Fluxapyroxad + mefentrifluconazole | FLX + MEF | SDHI + DMI | 1.5 | 100 + 100 | 100 |
| 3 | Revytrex + comet pro | (Fluxapyroxad + mefentrifluconazole) + pyraclostrobin | FLX + MEF + PYSTR | SDHI + DMI + QoI | 1.5 + 0.5 | (100 + 100) + 100 | 100 + 40 |
| 4 | Revystar XL + Comet pro | (Fluxapyroxad + mefentrifluconazole) + pyraclostrobin | FLX + MEF + PYSTR | SDHI + DMI + QoI | 1.5 + 0.75 | (150 + 75) + 150 | 100 + 60 |
| 5 | Proline EC 250 | Prothioconazole | PTH | DMI | 0.8 | 200 | 100 |
| 6 | Elatus era | Benzovindiflupyr + prothioconazole | BNZ + PTH | SDHI + DMI | 1.0 | 75 + 150 | 100 |
| 7 | Aviator Xpro | Prothioconazole + bixafen | PTH + BIX | DMI + SDHI | 1.0 | 150 + 75 | 80 |
| 8 | Ascra XproEC260 | Bixafen + fluopyram + prothioconazole | BIX + FLU + PTH | SDHI + SDHI + DMI | 1.2 | 78 + 78 + 156 | 100 |
| 9 | Fandango S | Prothioconazole + fluoxastrobin | PTH + FLSTR | DMI + QoI | 1.75 | 88 + 175 | 100 |
| 10 | Madison | Prothioconazole + trifloxystrobin | PTH + TRSTR | DMI + QoI | 1.0 | 88 + 175 | 100 |
| 11 | Balaya/revycare | Mefentrifluconazole + pyraclostrobin | MEF + PYSTR | DMI + QoI | 1.5 | 150 + 150 | 100 |
| 12 | priaxor | Fluxapyroxad + pyraclostrobin | FLX + PYSTR | SDHI + QoI | 1.5 | 112.5 + 225 | 100 |
| 13 | Xemium + dev cpd | Fluxapyroxad + metyltetraprole | FLX + MTY | SDHI + QoI | 2.25 | 90 + 90 | 100 |
| 14 | Comet pro | Pyraclostrobin | PYSTR | QoI | 0.75 | 150 | 60 |

solutions with prothioconazole and folpet gave the lowest effects ranging from 20 to 70% (avg. 52%) and 30–82% (avg. 55%), respectively.

**Table 2** Protocol for trials aimed at Ramularia carried out in 2021 and 2022. Treatments were carried out at growth stage 47 – 51

| Trt. No | Treatment name | Active ingredient | Abb. | Group | Dose (L/ha) | g a.i./ ha | Std. dose (%) |
|---|---|---|---|---|---|---|---|
| 1 | Untreated | – | | | – | – | - |
| 2 | Revysol | Mefentrifluconazole | MEF | DMI | 1.0 | 100 | 67 |
| 3 | Revysol | Mefentrifluconazole | MEF | DMI | 1.5 | 150 | 100 |
| 4 | Proline | Prothioconazole | PTH | DMI | 0.54 | 133 | 67 |
| 5 | Proline | Prothioconazole | PTH | DMI | 0.8 | 200 | 100 |
| 6 | Folpan 500 SC | Folpet | FOL | Multi-site | 1.5 | 750 | 100 |
| 7 | Elatus era | Benzovindiflupyr + prothioconazole | BNZ + PTH | SDHI + DMI | 1.0 | 75 + 150 | 100 |
| 8 | Ascra Xpro | Bixafen + fluopyram + prothioconazole | BIX + FLU + PTH | SDHI + SDHI + DMI | 1.2 | 78 + 78 + 156 | 100 |
| 9 | Revytrex | Fluxapyroxad + mefentrifluconazole | FLX + MEF | SDHI + DMI | 1.5 | 100 + 100 | 100 |
| 10 | Revystar XL | Fluxapyroxad + mefentrifluconazole | FLX + MEF | SDHI + DMI | 1.5 | 75 + 150 | 100 |
| 11 | Balaya/revycare | Mefentrifluconazole + pyraclostrobin | MEF + PYSTR | DMI + QoI | 1.5 | 150 + 150 | 100 |
| 12 | Revysol + sulfur | Mefentrifluconazole + Sulfur | MEF + SLF | DMI + Multi-site | 4.0 | 100 + 2400 | 100 |
| 13 | Xemium + Dev cpd | Fluxapyroxad + metyltetraprole | FLX + MTY | SDHI + QoI | 2.25 | 90 + 90 | 100 |

The yield responses in the six Ramularia trials roughly reflected the disease data (Fig. 3). However, very similar and small yield increases were seen from the treatments in general, and in three of the trials from 2021 statistically

**Table 3** Disease severity in untreated plots on flag leaves − 1 in the net blotch trial series

| Year | Country | GS | DAA | Brown rust | Net blotch |
|---|---|---|---|---|---|
| 2021 | DNK | 79 | 34 | 30 | 50 |
| | BEL | 83 | 43 | 11.8 | – |
| 2022 | FI | 87 | 41 | – | 43.8 |
| | DK | 75 | 35 | 6 | 55 |
| | BE | 83 | 38 | 76.9 | – |
| | UK. NIAB | 75–80 | 43 | 5.3 | – |
| Avg. 2021–2022 | | | | 26 | 49.6 |

significant yield increases were not found ($P = 0.05$). The highest yields were provided by the mixture fluxapyroxad + metyltetraprole of 11.1 dt/ha on average and the lowest increases by mefentrifluconazole + sulfur, reduced dosage prothioconazole and folpet of 5.8 dt/ha, 5.2 and 3.7 dt/ha on average, respectively. The remaining treatments gave increases of 6.3–8.1 dt/ha.

## Discussion

The results from the two trial series repeated in two seasons showed distinct patterns of field effects from most fungicides across Europe. Against net blotch, most treatments had consistently high effects in all trials. Namely, the treatments with three different active compounds all gave consistently high and similar effects. Only prothioconazole solo stood out with inferior effects of 66% on average, which was 15–32% lower than those of the remaining treatments, while solo pyraclostrobin gave good effects of 81% on average. These findings corresponding to those of previous studies were

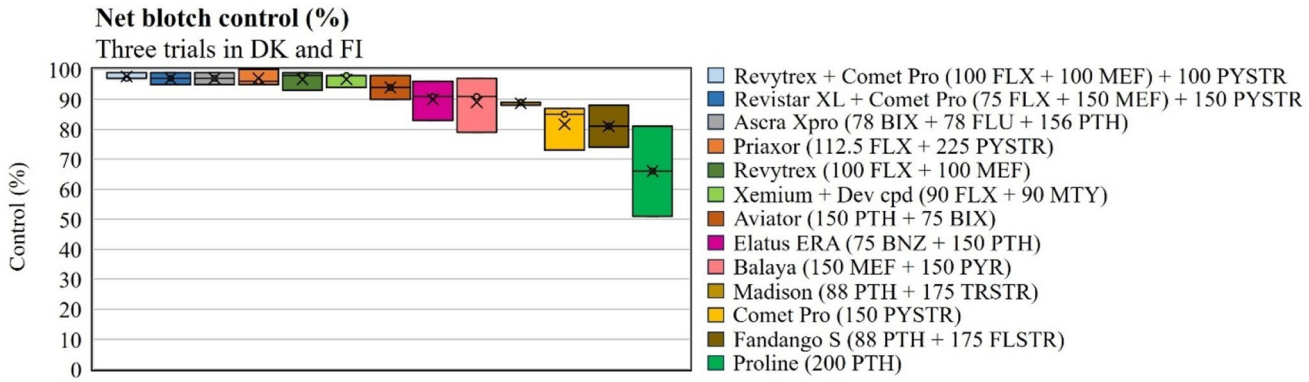


**Fig. 1** Net blotch control (%) on flag leaf -1 in three field trials from 2021 and 2022 in Denmark (2) and Finland (1). Assessments were carried out at 34–41 days after application, growth stage 75–87. Fungicide products were applied at full rates in most cases. Active compound dose rates are presented in g/L. *FLX* Fluxapyroxad, *MEF* mefentrifluconazole, *PYSTR* pyraclostrobin, *PTH* prothioconazole, *BNZ* Benzovindiflupyr, *BIX* bixafen, *FLU* fluopyram, *FLSTR* fluoxastrobin, *TRSTR* trifloxystrobin, *MTY* metyltetraprole

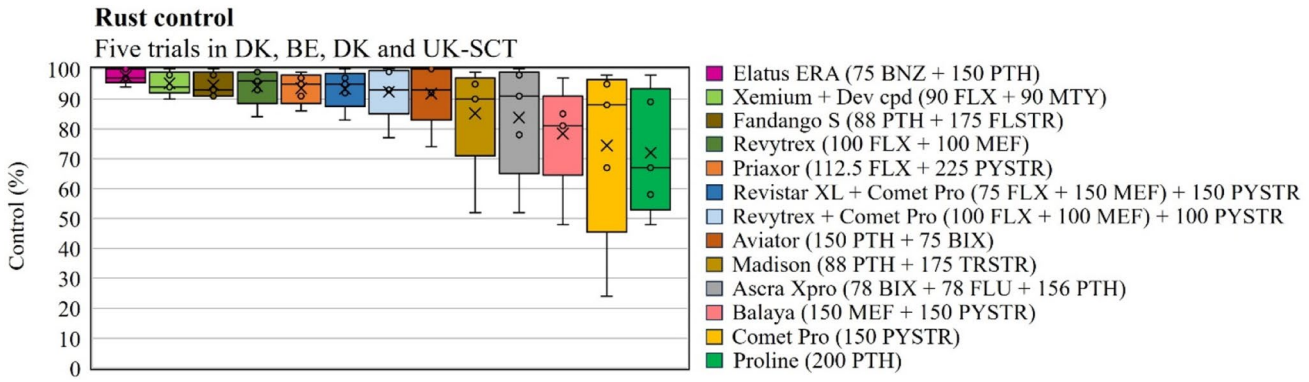


**Fig. 2** Brown rust control (%) on flag leaf − 1 in five field trials from 2021 and 2022 in Denmark, Belgium, and the UK. Assessments were carried out at 34–43 days after application, growth stage 75–83. Fungicide products were applied at full rates in most cases. Active compound dose rates are presented in g/L. *FLX* Fluxapyroxad, *MEF* mefentrifluconazole, *PYSTR* pyraclostrobin, *PTH* prothioconazole, *BNZ* Benzovindiflupyr, *BIX* bixafen, *FLU* fluopyram, *FLSTR* fluoxastrobin, *TRSTR* trifloxystrobin, *MTY* metyltetraprole

**Table 4** Disease severity in untreated plots on flag leaves − 1 in the Ramularia trial series

| Year | Country | GS | DAA | Ramularia |
|---|---|---|---|---|
| 2021 | DK | 81 | 28 | 22.5 |
| | IE | 65 | 27 | 7.9 |
| | GB-SCT | 77 | 22 | 8.3 |
| | DE | 71 | 28 | 14.9 |
| 2022 | IE | 67 | 19 | 85.0 |
| | DE | 71 | 25 | 65.4 |
| Avg. 2021–2022 | | | | 34.0 |

mixtures between SDHIs, especially fluxapyroxad, and prothioconazole/pyraclostrobin gave good control against net blotch (Tini et al. 2022), but where the use of solo DMIs was discouraged. Semar et al. (2007) also found good effects of pyraclostrobin against net blotch and no substantial effect of F129L mutation on the effects.

The effects were also mostly high against brown rust, but the results were more variable. Unlike other cereal diseases, the rusts have remained sensitive to all major fungicide classes, and although QoI and SDHI resistance conferring mutations have been found, the impact is limited.

The field effects against Ramularia were most variable across treatments, but clear patterns were seen across the trials. Excellent effects were delivered by fluxapyroxad + metyltetraprole, which were 15-39% higher than that of all other treatments on average, which corresponds to findings of Matsuzaki et al. (2021). However, the effects were generally weaker than those seen in the net blotch trial series also for mixtures including SDHIs, QoIs, and DMIs. This corresponds the findings of Rehfus et al. (2019) who found increasing frequencies in Central Europe of haplotypes harboring mutations in the SDHI and DMI target sites leading to decreased sensitivity. In the present study, solo prothioconazole gave inferior control in most trials with an average of 51%, while mefentrifluconazole solo gave good effects of 76% on average. Previous findings on *Zymoseptoria tritici* have also shown that mefentrifluconazole and prothioconazole exhibit distinct resistance profiles, while cross-resistance was found between mefentrifluconazole, difenoconazole, and tebuconazole (Heick et al. 2020).

The yield increases from the six barley trials were small, which might reflect the fact that Ramularia attacks usually happen late in the season and application against the disease is also carried out later. Thus, for most treatments very similar yield increases were seen. However, metyltetraprole + fluxapyroxad gave clearly higher yield increases, which matched the pattern seen in the field effects.

**Table 5** Overview of Ramularia control and disease severity (%) in untreated (untr.) plots on flag leaves minus one (F-1) in six field trials located in Denmark, Ireland, Sotland, and Germany in 2021–2022. Assessments were carried out at growth stage (GS) 65–81, 19–28 days after application (DAA). Dose rates are presented in g active compound/ha, and details on active compounds are presented in Table 2

| Ramularia control (%), leaf 2 | | | Untr. | Revysol | | Proline | | Folpan | Elatus ERA | Ascra Xpro | Revy Trex | Revystar XL + Comet | Balaya | Revysol + sulfur | Xemium + metyl-tetraprole |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [a] | | | | MEF | | PTH | | FOL | BNZ +PTH | BIX+ FLU+ PTH | FLX+ MEF | (FLX+ MEF)+ PYSTR | MEF+ PYST R | MEF+ SLF | FLX+ MTY |
| Year | Ctry. | GS DAA - | | 100 | 150 | 133 | 200 | 750 | 75+ 150 | 78+ 78+ 156 | 100+ 100 | (75+ 150)+ 150 | 150+ 150 | 100+ 2400 | 90+ 90 |
| 2021 | DK | 81 28 | 22.5 | 93 | 94 | 54 | 60 | 63 | 74 | 74 | 92 | 92 | 87 | 87 | 98 |
| 2021 | IE | 65 27 | 7.9 | 63 | 77 | 57 | 58 | 82 | 33 | 68 | 72 | 65 | 41 | 52 | 89 |
| 2021 | SCT | 77 22 | 8.3 | 84 | 78 | 64 | 70 | 78 | 70 | 78 | 82 | 82 | 78 | 78 | 100 |
| 2021 | DE | 71 28 | 14.9 | 65 | 72 | 42 | 66 | 42 | 77 | 80 | 87 | 82 | 72 | 68 | 91 |
| 2022 | IE | 67 19 | 85.0* | 48 | 64 | 28 | 20 | 34 | 49 | 51 | 56 | 58 | 72 | 28 | 78 |
| 2022 | DE | 71 25 | 65.4 | 61 | 71 | 32 | 41 | 30 | 55 | 54 | 63 | 67 | 57 | 56 | 87 |
| Avg., 2021 | | | 13.4 | 76.5 | 80.6 | 54.2 | 63.6 | 66.5 | 63.4 | 75.2 | 83.2 | 80.1 | 69.3 | 71.2 | 94.4 |
| Avg., 2022 | | | 75.2 | 54.9 | 67.5 | 29.8 | 30.2 | 32.1 | 52.1 | 52.1 | 59.7 | 62.6 | 64.8 | 42.0 | 82.5 |
| Avg., 2021-2022 | | | 34.0 | 69.3 | 76.2 | 46.0 | 52.5 | 55.0 | 59.6 | 67.5 | 75.3 | 74.3 | 67.8 | 61.4 | 90.4 |

[a]FLX = fluxapyroxad, MEF = mefentrifluconazole, PYSTR = pyraclostrobin, PTH = prothioconazole, BNZ = Benzovindiflupyr, BIX = bixafen, FLU = fluopyram, FOL = folpet, SLF = sulfur, MTY = metyltetraprole.

*FLX* fluxapyroxad, *MEF* mefentrifluconazole, *PYSTR* pyraclostrobin, *PTH* prothioconazole, *BNZ* Benzovindiflupyr, *BIX* bixafen, *FLU* fluopyram, *FOL* folpet, *SLF* sulfur, *MTY* metyltetraprole

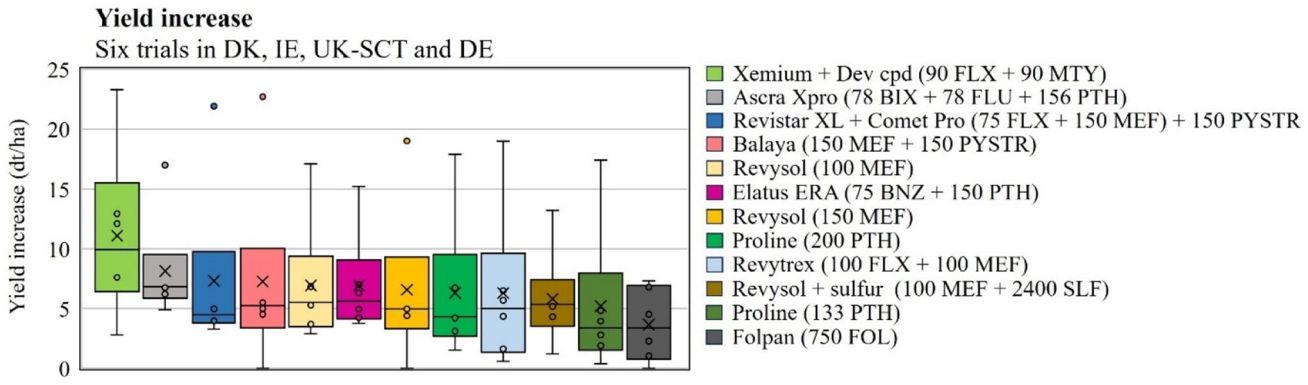


**Fig. 3** Yield increases in six field trials attacked by Ramularia from 2021 and 2022 in Denmark, Ireland, Scotland, and Germany. Active compound dose rates are presented in g/L. *FLX* fluxapyroxad, *MEF* mefentrifluconazole, *PYSTR* pyraclostrobin, *PTH* prothioconazole, *BNZ* Benzovindiflupyr, *BIX* bixafen, *FLU* fluopyram, *FOL* folpet, *SLF* sulfur, *MTY* metyltetraprole

**Acknowledgements** Thank you to the partners and technicians who have been involved in this activity and especially to BASF for funding this work and for collaboration with Dr. Rosie Bryson and Mr. Dieter Strobel from BASF.

**Funding** Open access funding provided by Aarhus Universitet.



## References

Fountaine JM, Fraaije BA (2009) Development of QoI resistant alleles in populations of *Ramularia collo-cygni*. Asp Appl Biol 92:123–126

FRAC (2021) SDHI working group. https://www.frac.info/frac-teams/working-groups/sdhi-fungicides/recommendations-for-sdhi. Accessed september 2022

Havis ND, Brown JKM, Clemente G, Frei P, Jedryczka M, Kaczmarek J, Kaczmarek M, Matusinsky P, McGrann GRD, Pereyra S, Piotrowska M, Sghyer H, Tellier A, Hess M (2015) *Ramularia collo-cygni*—an emerging pathogen of barley crops. Phytopathology 105(7):895–904. https://doi.org/10.1094/PHYTO-11-14-0337-FI

Heick TM, Matzen N, Jørgensen LN (2020) Reduced field efficacy and sensitivity of demethylation inhibitors in the Danish and Swedish *Zymoseptoria tritici* populations. Eur J Plant Pathol 157:625–636. https://doi.org/10.1007/s10658-020-02029-2

Jørgensen LN, Oliver RP, Heick TM (2018) Occurrence and avoidance of fungicide resistance in cereal diseases. In: Oliver R (ed) Integrated disease management of wheat and barley, 1st edn. Burleigh Dodds Science Publishing, Sawston, pp 235–259. https://doi.org/10.1201/9780429201219

Matsuzaki Y, Yoshimoto Y, Arimori S, Iwahashi F (2021) Chapter 27 - The discovery of metyltetraprole: reconstruction of the quinone outside inhibitor extended pharmacophore to overcome QoI-resistant strains. In: Maienfisch P, Mangelinckx S (eds) Recent highlights in the discovery and optimization of crop protection products. Academic Press, Cambridge, pp 425–432

Oepp/Eppo (2014) Foliar and ear diseases on cereals Vol. 44 (EPPO Bulletin)

Piotrowska MJ, Fountaine JM, Ennos RA, Kaczmarek M, Burnett FJ (2017) Characterisation of *Ramularia collo-cygni* laboratory mutants resistant to succinate dehydrogenase inhibitors. Pest Manag Sci 73:1187–1196. https://doi.org/10.1002/ps.4442

Rehfus A, Miessner S, Achenbach J, Strobel D, Bryson R, Stammler G (2016) Emergence of succinate dehydrogenase inhibitor resistance of *Pyrenophora teres* in Europe. Pest Manag Sci 72:1977–1988. https://doi.org/10.1002/ps.4244

Rehfus A, Matusinsky P, Strobel D et al (2019) Mutations in target genes of succinate dehydrogenase inhibitors and demethylation inhibitors in *Ramularia collo-cygni*. Europe J Plant Dis pro 126:447–459. https://doi.org/10.1007/s41348-019-00246-4

Semar M, Strobel D, Koch A, Klappach K, Stammler G (2007) Field efficacy of pyraclostrobin against populations of *Pyrenophora teres* containing the F129L mutation in the cytochrome b gene/feldwirkung von pyraclostrobin gegen populationen von *pyrenophora teres* mlt F129L mutation im cytochrom-b-Gen. J Plant Dis Prot 114(3):117–119

Tini F, Covarelli L, Ricci G, Balducci E, Orfei M, Beccari G (2022) Management of pyrenophora teres f. teres, the causal agent of net form net blotch of barley, in a two-year field experiment in central Italy. Pathogens 11(3):291. https://doi.org/10.3390/pathogens11030291