APPLIED CROP PROTECTION 2022

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Applied Crop Protection 2022

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Preface

The publication "Applied Crop Protection" is an annual report providing results and advice on crop protection to farmers, advisors, industry and researchers. The publication summarises data which are regarded to be of relevance for practical farming and advice. It covers information on the efficacy profiles of new pesticides, effects of implementation of IPM (integrated pest management) aiming at reducing the use of pesticides and illustrates the use of Decision Support Systems (DSS) in combination with resistant cultivars. It also includes an update on pesticide resistance to ensure that only effective strategies are used by the farmers to minimise build-up of resistance.

The series of reports was initiated in 1991 when the Danish Research Service for Plant and Soil Science (Statens Planteavlsforsøg) as part of the Ministry of Agriculture was responsible for biological testing of pesticides and provided a certificate for biological efficacy based on the level of efficacy in field trials. Later, this system was replaced by the EU's legislation for efficacy data. Efficacy testing of pesticides was opened to all trial units which had obtained a GEP certification (Good Experimental Practice) and fulfilled the requirements based on annual inspections. Since 2007 the report has been published by Aarhus University (AU) and since 2015 it has been published in English to ensure a greater outreach.

The choice of topics, the writing and the publishing of the report are done entirely by staff at AU, and the report content is not shared with the industry before publication. All authors and co-authors are from AU. The data on which the writing is based are coming from many sources depending on the individual chapter. Below is a list with information on funding sources for each chapter in this report.

Chemical companies supplied pesticides and advice on their use for the trials and plant breeders provided the cultivars included in specific trials. Trials were located either at AU's research stations or in fields owned by private trial hosts. AU collaborated with local advisory centres and SEGES on several of the projects, e.g. when assistance was needed regarding sampling for resistance or when looking for specific sites with specific targets. Several of the results were also published in shared newsletters with SEGES to ensure a fast and direct communication to farmers.

Internal scientific review of specific chapters was carried out by AU AGRO colleagues Per Kudsk, Mette Sønderskov, Niels Matzen, Annemarie Fejer Justesen, Lise Nistrup Jørgensen and Peter Kryger Jensen.

Chapter I: Climate data for the growing season 2021/2022 and specific information on disease attacks in 2022. The information was collected by AU.

Chapter II: Disease control in wheat. Trials in this chapter were financed by ADAMA, BASF, Bayer Crop Science, Corteva Agriscience, KWS, Nordic Seed, Sejet Plant Breeding and Syngenta, but certain elements were also based on AU's own funding.

Chapter III: Disease control in barley, rye and triticale. Trials in this chapter were financed by ADAMA, BASF, Bayer Crop Science, Corteva Agriscience and Syngenta, but certain elements were also based on AU's own funding.

Chapter IV: Control strategies in different cereal cultivars. Trials in this chapter were financed by income from selling the DSS system Crop Protection Online as well as input from BASF and Bayer Crop Science. Certain elements were based on AU's own funding.

Chapter V: Fungicide resistance-related investigations. Testing for fungicide resistance is carried out based on a shared cost covered by projects and the industry. In 2022 ADAMA, BASF, Bayer Crop Science, Corteva Agriscience and Syngenta were involved from the industry. The Swedish part was financed by the Swedish Board of Agriculture, and AU AGRO was involved.

Chapter VI: Integrating biological control agents and plant resistance inducers into IPM strategies to control potato early blight and late blight. The project described in this chapter was financed by the Danish GUDP (Green Development and Demonstration Programme), carried out in ECOSOL as part of the SusCrop ERA-NET Co-fund and the potato levy board (KAF). The early blight trials and all modelling work were funded as part of the ECOSOL project, while the late blight trials were funded by KAF.

Chapter VII: *Urocystis agropyri* – a new disease discovered in *Poa pratensis* in Denmark. The work described in this chapter was financed by AU.

Chapter VIII: Cercospora leaf spot – a recent disease in sugar beet; fungicide resistance and variation in strains. The work in this chapter was financed by 'Sukkerroeafgiftsfonden' through donations in 2021 and 2022.

Chapter IX: Effect of pH-adjusting adjuvants on the performance of two glyphosate formulations. The study described in this chapter was financed by 'Promilleafgiftsfonden' (SEGES).

Chapter X: Results of crop protection trials in minor crops in 2022. The projects were financed by various agricultural tax funds, GUDP, chemical companies and Swedish minor use funding.

Chapter XI: List of chemicals.

Contents

I Climate data for the growing season 2021/2022

Lise Nistrup Jørgensen, Sofie Rosengaard Nørholm & Sidsel Stein Kirkegaard

Climate

This section evaluates the overall weather conditions in Denmark during the growing season. A separate section will describe the weather conditions recorded at the weather station at AU Flakkebjerg where most Aarhus University trials were located (September 2021-August 2022).

In Denmark the autumn of 2021 was characterised by many days with precipitation. The average precipitation across the country was 223 mm, which was only 5% below the 10-year average of 2011-2020. The autumn weather was very warm compared to the other years since 1874 when measurements began. The average temperature was 10.6°C, which was 1.1°C higher than the 30-year average of 1991-2020.

During the winter of 2021/2022, there was a great deal of precipitation. Across Denmark the precipitation was 239 mm, which was 28% higher than the 30-year average (1991-2020). Most of the precipitation came in February with 121.2 mm, which made February 2022 the wettest February since 1874. The winter of 2022 had 29 frosty days and 8.5 days with snow cover. The average temperature for the country was 3.4°C, which was 1.1°C higher than the 10-year average (2011-2020).

The spring was very dry with only 83.0 mm of precipitation. March broke the record as the driest March since 1874. The spring of 2022 was full of sunny hours, and the country average was measured to be 712 sunny hours, which was a record high since 1920 and 20% higher than the 10-year average (2011-2020). The average temperature for the spring was 7.3°C across the country and near the average spring temperature (2011-2020).

In Denmark the summer of 2022 was very dry with temperatures and number of summer days higher than average. The precipitation was 51 mm, which was 32% less than the 10-year average (2011-2020). The summer in Denmark had an average temperature of 16.5°C across the country. The month of August was warm with an average temperature that was 1.2°C higher than the 10-year average for August (2011-2020).

At AU Flakkebjerg the precipitation in the autumn 2021 was 136 mm, which was 17% less than the average for AU Flakkebjerg (2011-2022). September was a dry month with 50% less precipitation than normal. The temperature in the autumn at AU Flakkebjerg was 10.8°C, which was close to the autumn average for AU Flakkebjerg.

During the winter, the precipitation at AU Flakkebjerg was 198 mm, which was 29% higher than average at AU Flakkebjerg (2011-2022). In February the precipitation was over 100% higher than average for this month at AU Flakkebjerg. The winter of 2021/2022 was warm and had an average temperature of 3.4°C, which was 1°C higher than the average for AU Flakkebjerg (2011-2022). December was colder than normal with a temperature of 1.8°C below the average temperature for December (2011-2022).

At AU Flakkebjerg the spring was dry with limited precipitation of 67 mm, which was 35% below the average for AU Flakkebjerg. The temperature was 7.5°C, which is the normal average spring temperature at AU Flakkebjerg (2011-2022).

During the dry summer of 2022, the precipitation was 118 mm, which was 23% below the summer average at AU Flakkebjerg (2011-2022). The temperature was 17.3°C, which was only 0.5°C higher than the average summer temperature at AU Flakkebjerg (2011-2022).

The overall data from AU Flakkebjerg are shown in Figures 1, 2 and 3. The drought situation across the country for the six main months is shown in Figure 4.

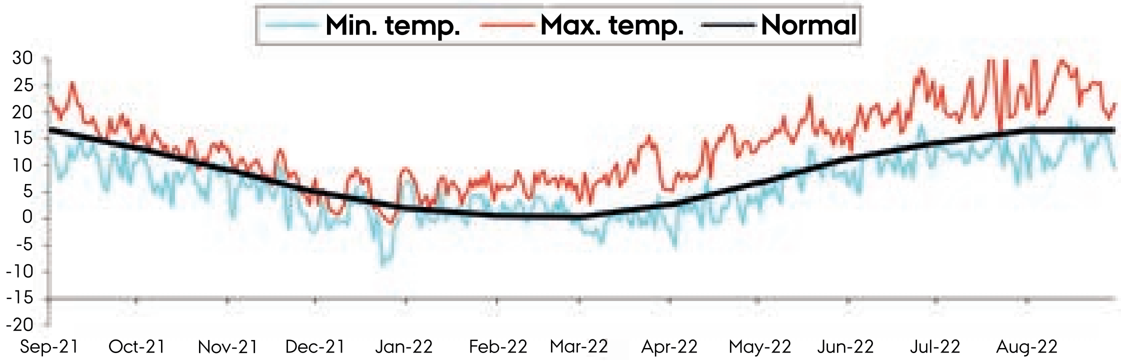


Figure 1. Climate data graph for AU Flakkebjerg for the growing season September 2021-August 2022. The temperature is in °C.

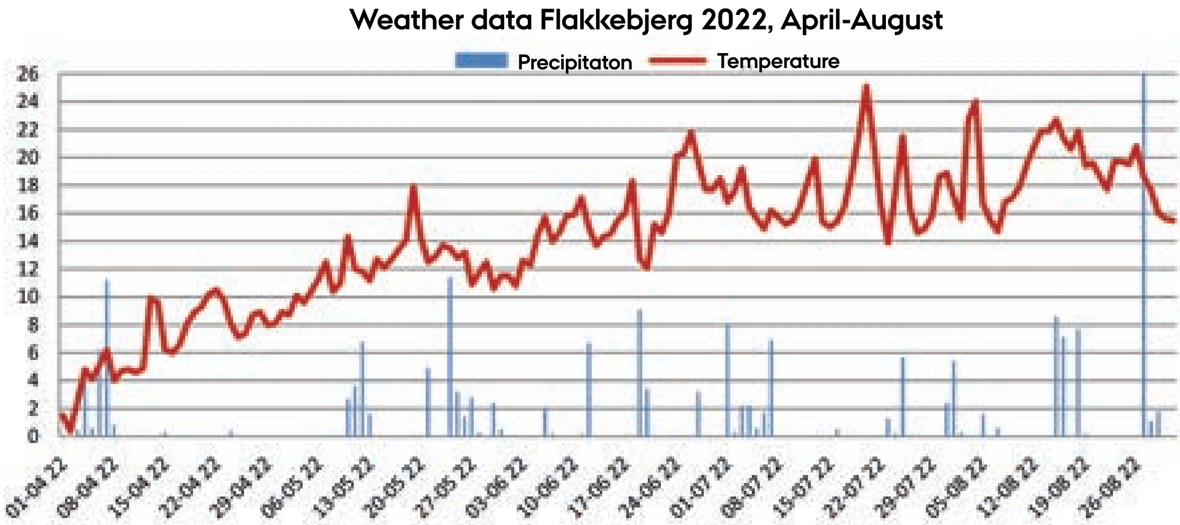


Figure 2. Climate data graph for AU Flakkebjerg for spring and summer 2022. The temperature is in °C and the precipitation is in mm.

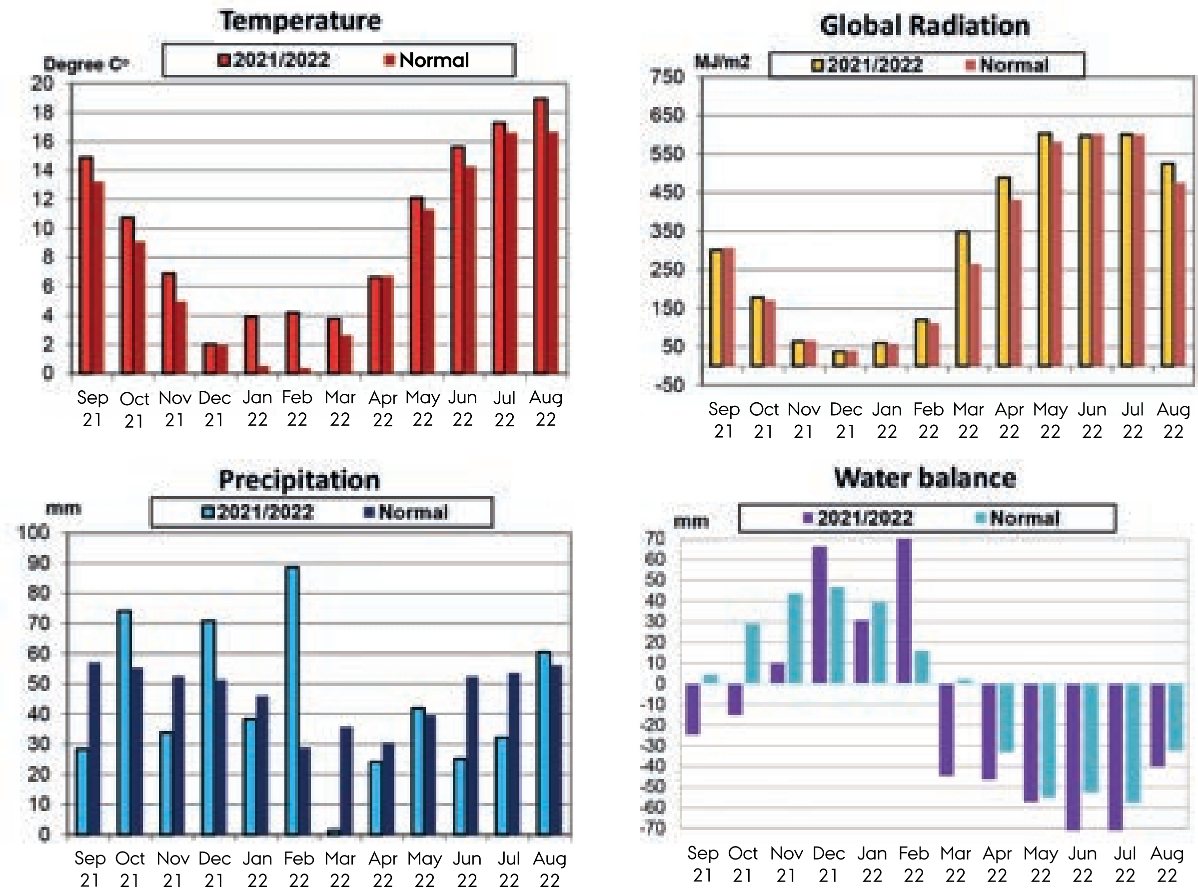
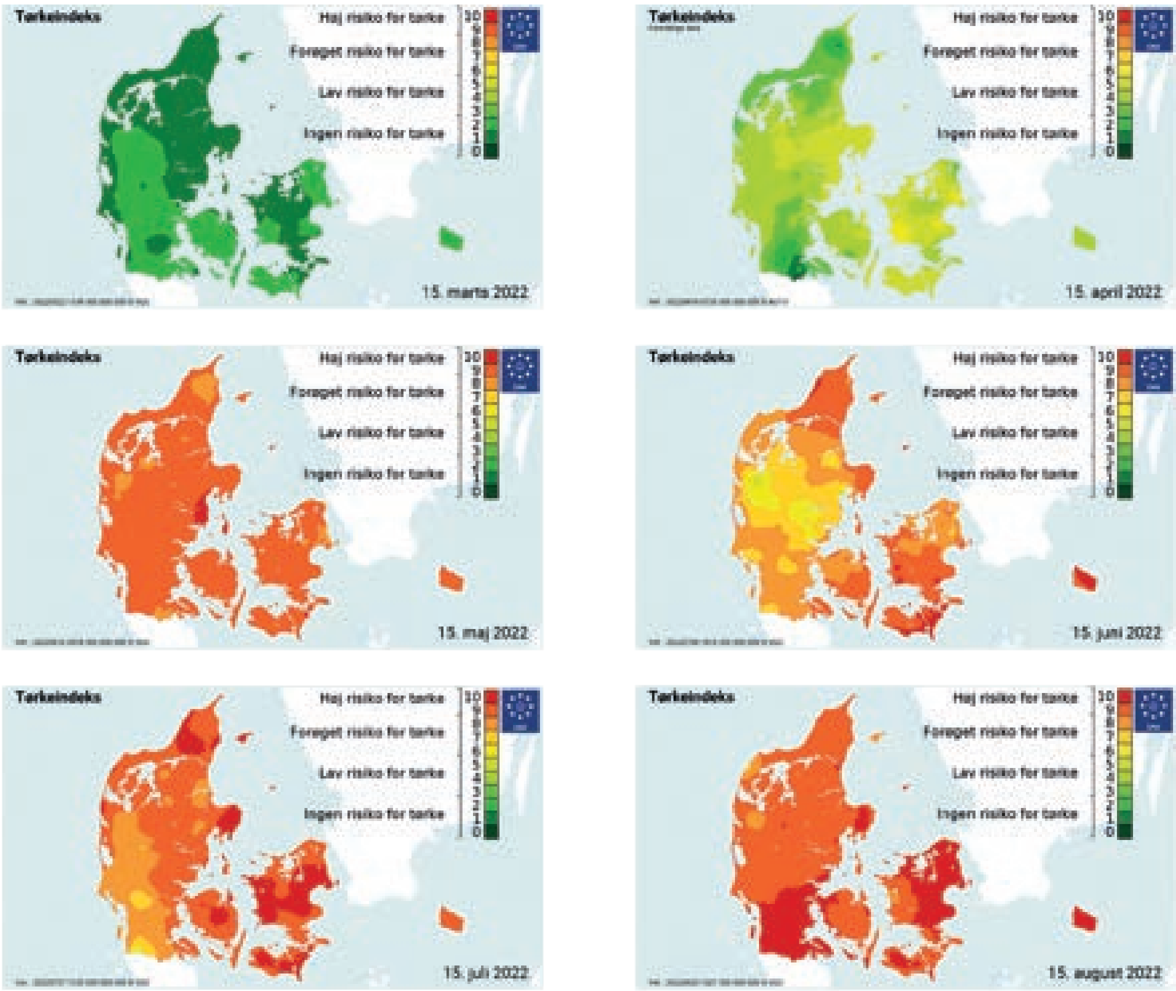


Figure 3. Climate data from AU Flakkebjerg for the growing season September 2021–August 2022. The temperature is in °C, the global radiation is measured in MJ/m², the precipitation is in mm, and the water balance is the difference between precipitation and potential evaporation.



Drought index 2022 (DMI)

- 0-2 No risk of drought (green)
- 3-5 Low risk of drought
- 6-8 Increased risk of drought
- 9-10 High risk of drought (red)

Figure 4. Drought index for May-August 2022. Danish Meteorological Institute (DMI).

1. Disease attacks in 2022

Lise Nistrup Jørgensen & Sidsel Stein Kirkegaard

This chapter describes the occurrence of diseases present in the fungicide trials in 2022. This knowledge is important for evaluation of whether the target diseases were present at significant levels. Trial efficacy assessments depend on significant disease levels to ensure representative results. Yield levels in cereal trials are ranked and compared with the previous year's responses.

Wheat

Powdery mildew (*Blumeria graminis*). Only a minor and insignificant attack of powdery mildew was recorded in trials at AU Flakkebjerg in 2022. No trials were carried out at Jyndevad, which is normally used for specific mildew trials.

Septoria leaf blotch (*Zymoseptoria tritici*). Conditions of low humidity with many days without precipitation in May and June reduced the risk of Septoria tritici blotch. Only the cultivars Hereford and Cleveland still provided good levels of *Septoria* attack and therefore gave good opportunities for ranking fungicide efficacy. Overall, the level of *Septoria* attack was low, and levels of *Septoria* attack varied depending on localities and cultivars, but in general, across the country, the attacks were at a lower level than in a normal year. At AU Flakkebjerg the trials were stimulated by 1-3 irrigations during the dry periods in May and June, and as a result of the conditions at AU Flakkebjerg the level of attack of *Septoria* reached approx. 28% on leaf 2 and 8% on leaf 1 at growth stage (GS) 71-75.

Yellow rust (*Puccinia striiformis*). In fields at AU Flakkebjerg the susceptible cultivar Benchmark was inoculated with yellow rust in late April, using spreader plants. Temperatures were normal in May, which ensured a good development of yellow rust. First clear development was recorded at the end of May, and by early June the attack was significant. Benchmark is well known for its high susceptibility, and attacks developed to a moderate to high level on the upper leaves. In Benchmark the attack increased to approx. 50% on the flag leaf and 65% on leaf 2 at GS 71. An attack of yellow rust is known to reduce yields. In Benchmark the attack of yellow rust in 2022 reduced yields by 3.2 t/ha.

Brown rust (*Puccinia triticina*). Few and only minor and insignificant attacks of brown rust were recorded in trials at AU Flakkebjerg in 2022. The brown rust symptoms developed very late in the season.

Tan spot (*Drechslera tritici repentis*). At AU Flakkebjerg minimal tillage was simulated by pre-infecting a tan spot susceptible cultivar (RGT Saki), using straw infected with tan spot. An attack of tan spot in RGT Saki developed well in the spring, but due to the dry weather and few events with precipitation only low infection levels developed. However, late in the season differences between cultivar susceptibility and fungicide treatments were seen. The assessments of tan spot at GS 69-75 showed a disease level of approx. 10% on the flag leaf and 25% on leaf 2.

Fusarium head blight (*Fusarium* spp.). To ensure attack in trials at AU Flakkebjerg, we inoculated wheat crops with *Fusarium* spores. Inoculation in combination with irrigation during flowering is an effective method to ensure attack.

A severe attack of Fusarium head blight developed in the cultivar trials where screening for cultivar susceptibility was tested. This was the case for both sets of trials, which included inoculation with infected grain placed on the soil or inoculation with a spore solution at three different timings during flowering. In field trials where we tested different biological control agents (BCA), the concentration of spores in the *Fusarium* inoculum was lower and infection also more reduced despite irrigation three times in the trials. Only a minor attack of *Fusarium* developed.

Triticale and rye

Yellow rust (*Puccinia striiformis*). Triticale trials at AU Flakkebjerg were naturally infected with yellow rust. Triticale is severely infected in most years, and 2022 was no exception. Due to the mild weather in May, yellow rust developed well, and at the beginning of June the attack increased. At GS 71, at the end of June, levels had increased to 12.2% on leaf 1 and 30% on leaf 2. The disease level gave good opportunities for ranking the performances of the fungicides.

***Rhynchosporium* (*Rhynchosporium commune*).** In rye trials, a moderate attack of *Rhynchosporium* developed during May and at the beginning of June. The disease level gave good opportunities for ranking the performances of the products. By the end of June, at GS 75, the attack of *Rhynchosporium* in rye had increased to 23.8% on leaf 2.

Winter barley

***Rhynchosporium* (*Rhynchosporium commune*)** was the most dominant disease in 2022, and the level of attack in winter barley trials was low to moderate depending on cultivar. A severe attack of *Rhynchosporium* developed mainly in the cultivar Neptun. The average attack of *Rhynchosporium* reached a level of 19% on leaves 2-3 at GS 71-75.

Brown rust (*Puccinia hordei*). Brown rust was also a dominant disease in winter barley in 2022. Almost all cultivars showed symptoms of rust. The average attack of brown rust in this year's trial at AU Flakkebjerg reached a level of 15% on leaves 2-3 at GS 75-79.

Powdery mildew (*Blumeria graminis*). Recordings carried out by the advisors in the national monitoring system organised by SEGES showed that the level of mildew attack was very low. Due to the very low level of attack of mildew at AU Flakkebjerg in 2022, it was not possible to rank the performances of the products.

Spring barley

Net blotch (*Drechslera teres*). In field trials at AU Flakkebjerg, the attack of net blotch was moderate to high due to highly susceptible cultivars such as Chapeau and RGT Planet. In trials, the susceptible cultivars provided good possibilities for ranking the performances of the fungicides. The attack of net blotch in Chapeau, Skyway and RGT Planet reached an average level of 22% on leaf 2 at GS 75-80.

Brown rust (*Puccinia hordei*). At AU Flakkebjerg, all cultivars developed an attack of brown rust although to a varying extent. The attack of brown rust developed from the middle of June, which gave good opportunities for ranking fungicide performances. The attack at AU Flakkebjerg reached an average of 18% on leaves 2-3 at GS 70-75.

Ramularia leaf spot (*Ramularia collo-cygni*). *Ramularia* developed late in 2022 and was not present in all trials at AU Flakkebjerg. The attack of *Ramularia* reached an average level of 7% on leaf 2 at GS 75-80.

Sporadic attack of *Stagonospora nodorum* could be seen in several spring barley fields.

Yield increases in fungicide trials in cereals

Weather conditions in most areas of Denmark was generally good for harvesting, and the water content in the grain was low. Average winter wheat yields in Denmark reached 87 hkg, which was 12% higher than normal. In winter wheat trials at AU Flakkebjerg, yields varied between 90 hkg/ha and 150 hkg/ha with an average of more than 100 hkg/ha. No higher yield has ever been measured at AU Flakkebjerg. Yield increases in winter wheat were on average 5.7 hkg/ha, based on national trials (Table 1). The yield response in trials carried out at AU Flakkebjerg was higher due to a dominance of more susceptible cultivars. Spring barley trials showed poor crop stands as a result of challenging cropping conditions early in the season. Most trials were irrigated twice during the growing season, but yields varied undesirably between trials and cultivars. The average national yields reached 68 hkg/ha, which was 20% above normal yields of 56 hkg/ha. Increases from standard fungicide treatments in spring barely were approx. 5.3 hkg/ha (Table 1).

Table 1. Yield increases (hkg/ha) for control of diseases using fungicides in trials. The responses are picked from standard treatments typically using two treatments per season. Numbers in brackets give the number of trials behind the figures. Data originate from SEGES and AU Flakkebjerg trials.

Year	Winter wheat	Spring barley	Winter barley
2005	6.4 (126)	5.4 (43)	4.6 (60)
2006	8.0 (106)	3.3 (63)	5.1 (58)
2007	8.5 (78)	7.2 (26)	8.9 (13)
2008	2.5 (172)	3.1 (29)	3.2 (36)
2009	6.3 (125)	5.1 (54)	6.3 (44)
2010	6.6 (149)	5.6 (32)	5.9 (34)
2011	7.8 (204)	3.9 (43)	4.3 (37)
2012	10.5 (182)	6.7 (38)	5.1 (32)
2013	10.3 (79)	5.2 (35)	5.5 (27)
2014	12.0 (82)	3.0 (19)	4.1 (18)
2015	10.9 (73 SEGES + 29 AU)	9.1 (20)	7.3 (19)
2016	10.9 (59 SEGES + 34 AU)	8.0 (16 SEGES + 13 AU)	4.0 (11 SEGES + 10 AU)
2017	15.0 (94 SEGES + 55 AU)	10.4 (11 SEGES + 16 AU)	11.9 (11 SEGES + 14 AU)
2018	4.3 (24 SEGES + 21 AU)	3.6 (4 SEGES + 12 AU)	7.5 (2 SEGES + 12 AU)
2019	15.4 (28 SEGES + 24 AU)	11.6 (10 SEGES + 9 AU)	11.5 (6 SEGES + 6 AU)
2020	6.9 (51 SEGES + 25 AU)	4.1 (11 SEGES + 12 AU)	5.8 (5 SEGES + 14 AU)
2021	9.9 (27 SEGES + 33 AU)	7.6 (8 SEGES + 23 AU)	7.8 (5 SEGES)
2022	5.7 (SEGES)	5.3 (7 SEGES + 8 AU)	7.9 (9 SEGES + 6 AU)

II Disease control in wheat

Lise Nistrup Jørgensen, Thies Marten Heick, Niels Matzen, Hans-Peter Madsen, Helene Saltoft Kristjansen, Sidsel Stein Kirkegaard, Christian Appel Schjeldahl Nielsen, Sofie Rosengaard Nørholm & Anders Almskou-Dahlgaard

Introduction

In this chapter field trials in cereals carried out with fungicides in 2022 are described in brief, and results are summarised. In graphs or tables are also included results from previous years if the trial plan covers several years. Included are main results on major diseases from both protocols with new fungicides and protocols in which products applied at different dose rates and timings are compared. Some of the trial results are used as a part of the Biological Assessment Dossier, which the companies must prepare for new products or for re-evaluations of old products. Other parts of the results aim at solving questions related to optimised use of fungicides in common control situations for specific diseases. Apart from the tables and figures providing main data, a few comments are given along with some concluding remarks. Most data summarised in this chapter are funded by the companies BASF, Bayer Crop Science, Corteva Agriscience and Syngenta, who pay to have their products tested. Data from the activity organised under the umbrella of EuroWheat financed by BASF are also presented. This activity is organised by Aarhus University (AU) in collaboration with different organisations in other countries. All data from the project are analysed by AU, which also publishes the data. In several trial plans individual treatments are included based on AU's own initiative.

Methods

All field trials with fungicides are carried out as GEP trials. Most of the trials are carried out as field trials at AU Flakkebjerg. Some trials are also located in farmers' fields, at Jyndevad Experimental Station or near Horsens in collaboration with a GEP trial unit at the advisory group Velas. Trials are carried out as block trials with randomised plots and four replicates. Plot size varies from 14 m^2 to 35 m^2, depending on the individual unit's equipment. The trials are located in fields with different, moderately to highly susceptible cultivars, specifically chosen to increase the chances of disease development. Spraying is carried out using a self-propelled sprayer and a water volume of using 150 l or 200 l per ha at a nozzle pressure of 1.7-2.2 bar.

Attack of diseases in the trials are assessed at approximately 10-day intervals during the season. Per cent leaf area attacked by the individual diseases is assessed on specific leaf layers in accordance with EPPO guideline 1/26 (4), Foliar and ear diseases on cereals. At the individual assessments the leaf layer that provides the best differentiation of the performances of the fungicides is chosen. In most cases this is the two upper leaves. In this publication only some assessments are included – mainly the ones giving the best differentiation of the efficacy of the products.

Nearly all trials are carried through to harvest and yield is adjusted to 15% moisture content. Quality parameters like specific weight, % protein, % starch and % gluten content are measured, using NIT instruments (Foss, Perten), and thousand grain weight is calculated based on 250 grains counted. In spring barley, which can potentially be used for malting, grain size fractions are also measured. For each trial LSD_{95} values or specific letters are included. Treatments with different letters are significantly different, using the Student-Newman-Keuls model. When a net yield is calculated, it is converted to hkg/ha based on deducting the cost of chemicals used and the cost of application. The cost of application has been set at DKK 70 and the cost of chemicals extracted from the database at SEGES. The grain price used is DKK 210 per hkg wheat and DKK 205 per hkg barley.

Comparing effects from SDHIs

As part of the EuroWheat activity, 10 trials were carried out following the same protocol and located in different countries. The focus of the trials was to investigate the efficacy of SDHIs (succinate dehydrogenase inhibitors) in areas with different climates and levels of resistance. One trial was located at AU Flakkebjerg in the cultivar Hereford and treated at growth stage (GS) 37-39 (23 May). The trial developed a moderate attack of Septoria tritici blotch. The Danish trial showed high levels of *Septoria* control from most products including both solo SDHI and solo mefentrifluconazole. Proline EC 250 gave – as also seen in previous years – only low to moderate control (Table 1). The analysis of the sensitivity of *Zymoseptoria tritici* in the trials indicated that isolates are still having a high sensitivity to SDHI fungicides in the Danish trial and that the products are still very effective.

Similar trials were conducted in other countries and showed distinct differences in levels of control, depending on the locality (Table 2). The average results from nine European trials (France, Poland, Germany, Belgium, the UK, Ireland and Denmark) carried out in 2022 are shown in Figures 1 and 2. The results in Figure 1 indicate similar levels of control as in the Danish trial. The effect in Ireland and the UK indicated less good control from SDHIs as seen in Figure 2. In all trials Revysol performed similar to or better than SDHIs. Yield responses from the trials reflected the level of disease control and are summarised in Figure 3.

Leaf samples were taken at all sites from untreated plots. *Septoria* spores were isolated from the leaves and assessed in bioassays carried out by EPILOGIC. Based on these assays EC50 values were calculated. All trials contributed with 10 isolates. Sensitivity to two azoles (desthio-prothioconazole, mefentrifluconazole) and one SDHI (fluxapyroxad) was assessed. A gradient was seen for sensitivity to fluxapyroxad and desthio-prothioconazole, while no clear differences were seen for mefentrifluconazole (Figure 4).

Table 1. Effect of applications on control of *Septoria* in wheat, using SDHIs and azoles. Treatments were applied at GS 37-39. GLA: Green Leaf Area. One trial (22328). EuroWheat.

Treatments, l/ha 22328		% *Septoria*				% GLA	Yield & yield increase hkg/ha
GS 37-39	Dose	GS 67 Leaf 3	GS 73 Leaf 2	GS 77 Leaf 1	GS 77 Leaf 2	GS 83 Leaf 1	
1. Untreated		20.5	20.8	45.0	83.8	4.3	120.1
2. Revysol	1.0	5.0	6.3	5.8	20.5	47.5	7.9
3. Revysol	1.5	6.5	3.0	5.0	17.0	50.0	10.3
4. Proline EC 250	0.8	13.0	19.0	24.3	66.3	12.0	1.8
5. Questar	2.0	3.5	1.8	2.5	12.3	75.8	13.6
6. Revystar XL	1.5	6.3	3.0	4.0	14.3	63.8	10.1
7. Revytrex	1.5	5.0	1.3	2.3	11.0	60.8	11.8
8. Elatus Era	1.0	11.5	4.8	5.3	20.5	68.8	10.9
9. Ascra Xpro	1.5	3.5	4.0	2.8	13.0	61.3	13.2
10. Imtrex	2.0	4.0	3.3	3.5	18.0	48.8	11.2
11. Thore	1.0	9.0	6.8	9.8	28.8	59.8	8.8
12. Elatus Plus	0.75	7.8	6.3	5.3	23.0	51.3	8.8
13. Luna Privilege + Thore	0.2 + 0.8	7.0	3.8	4.5	16.3	45.0	10.8
14. Revycare	1.5	9.0	6.3	7.0	26.3	50.0	10.8
LSD_{95}		3.7	2.3	4.6	7.2	17.1	3.6

Table 2. % control of *Septoria* at GS 65-85, DAA: Days After Application, flag leaf, 2022. Control effects are summarised as percentage reduction of attack relative to untreated plots. Colours signify ranking of treatment effects within trials. Green: highest rated effect. Yellow: medium rated effect. Orange: lowest rated effects. Red: Untreated. Severity is presented in untreated.

Control (%), SEPTTR, leaf 1, 2022				1	2	3	4	5	6	7	8	9	10	11	12	13
				Untr.	Revysol		Proline EC 250	Questar	Revy-star XL	Revy-trex	Elatus ERA	Ascra Xpro	Imtrex	Thore	Elatus Plus	Luna Privilege + Thore
Trial	Country	GS	DAA	-	1	1.5	0.8	2	1.5	1.5	1	1.5	2	1	0.75	0.2 + 0.8
22328-1	DK	77	46	45.0	87	89	46	94	91	95	88	94	92	78	88	90
22328-2	UK, NIAB	69	20	16.3	55	61	14	77	51	45	33	26	15	18	43	45
22328-3	UK, ADAS	65	31	9.3	42	52	13	81	44	40	36	37	26	23	22	23
22328-4	IE	75	55	100.0	51	80	28	84	74	61	25	41	41	13	41	57
22328-5	FR	85	55	39.4	84	86	43	85	89	90	65	91	76	24	51	54
22328-6	DE, LfL	75	29	6.6	66	73	33	86	76	93	65	86	78	48	51	73
22328-7	DE, JKI	75	39	0.4	25	0	0	75	25	0	0	50	25	25	0	25
22328-8	PL	73	30	5.8	52	83	67	68	82	86	100	95	87	67	80	84
22328-9	BE	83	42	2.5	87	94	70	95	100	95	92	78	74	63	58	69
22328-10	DE, LKSH	77	43	4.7	56	78	36	76	86	81	53	59	73	33	53	47
Avg. control (%)				25.5	64	77	39	83	77	76	62	67	62	41	54	60

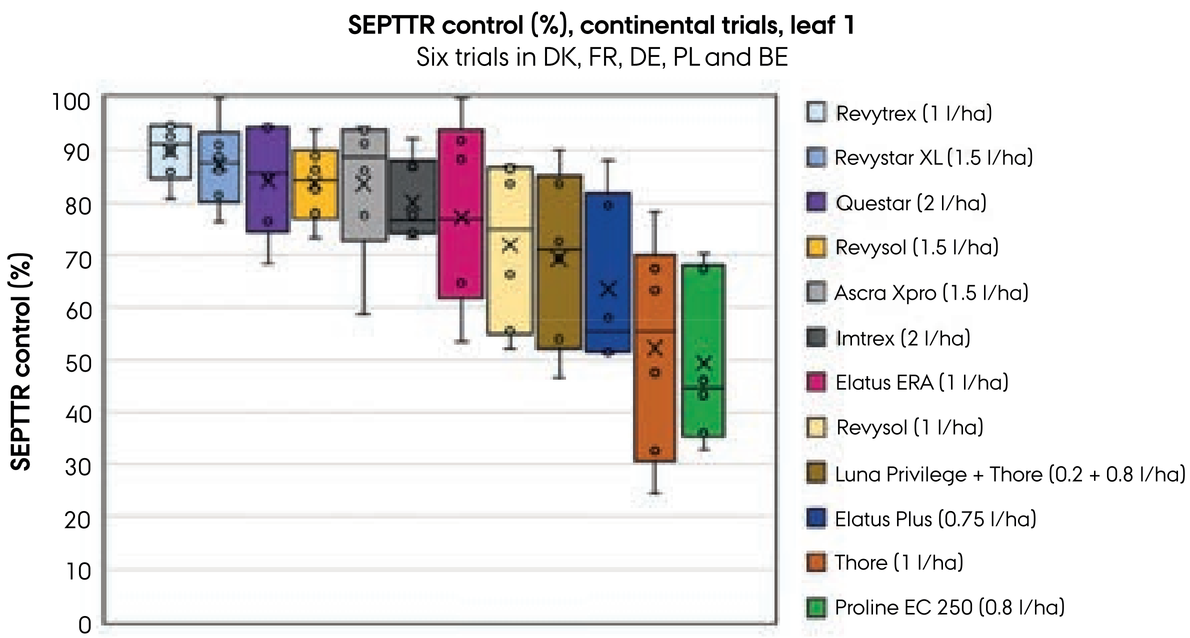


Figure 1. Control of *Septoria*, using azoles, SDHIs and mixtures. Data show values from five trials carried out in 2022 as part of EuroWheat. "X" indicates mean value. Trials were carried out in France, Germany, Poland, Belgium and Denmark.

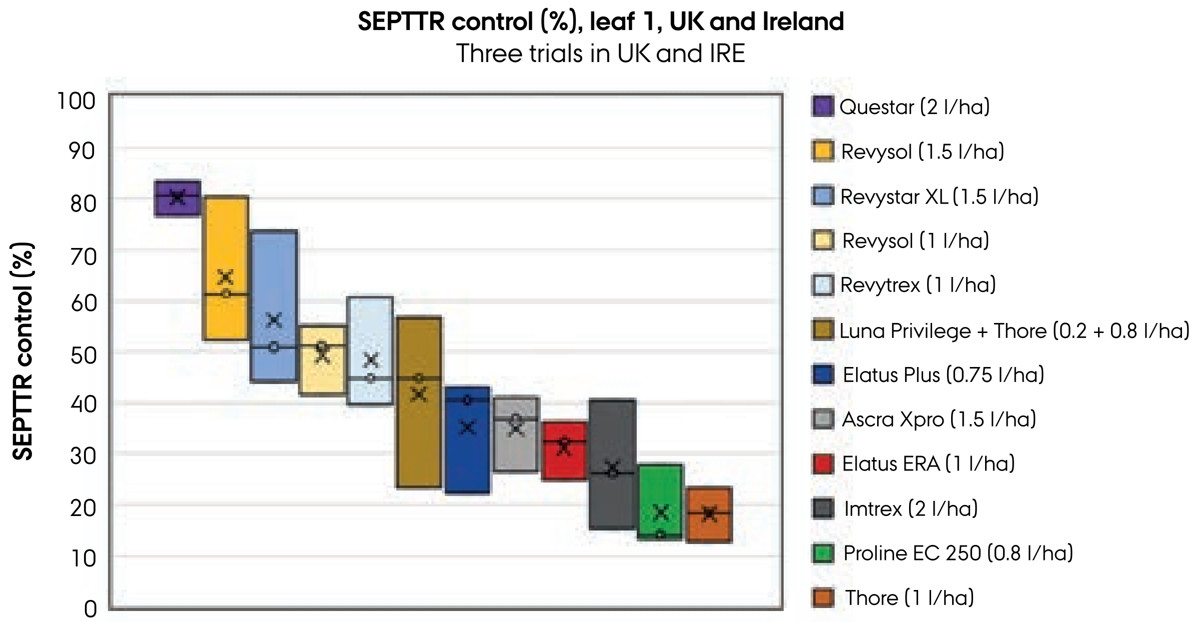


Figure 2. Control of *Septoria*, using azoles, SDHIs and mixtures. Data from three trials carried out in 2022 as part of EuroWheat. "X" indicates mean value. Trials were carried out in Ireland and the UK.

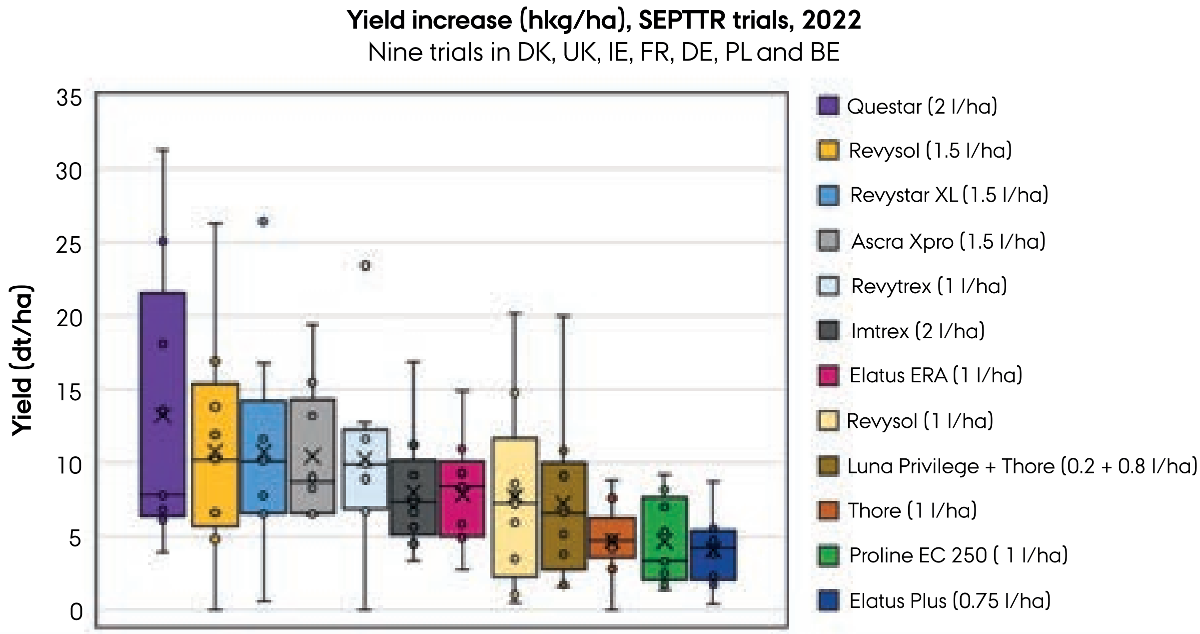
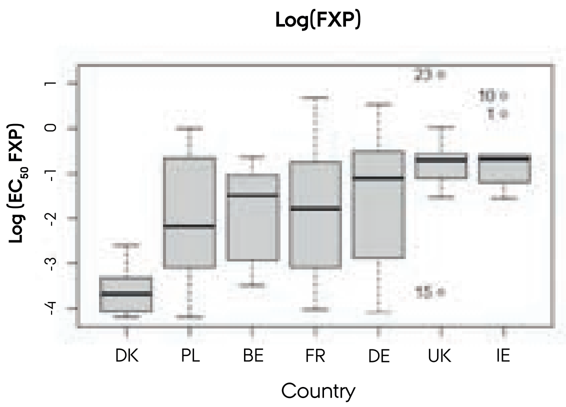
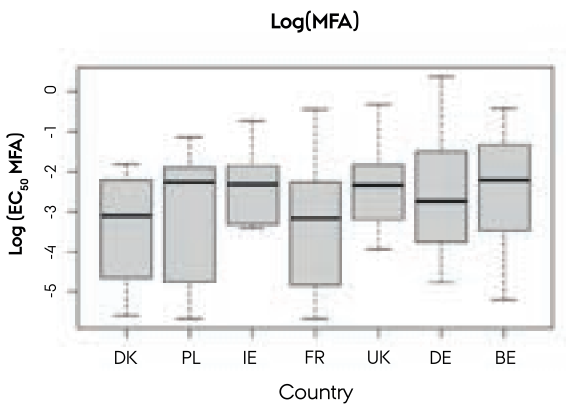


Figure 3. Yield response from treatments with azoles, SDHIs and mixtures. "X" indicates mean value. Data from nine trials carried out in 2022 as part of EuroWheat. Trials were carried out in France, Germany, Poland, Belgium, Ireland, the UK and Denmark.





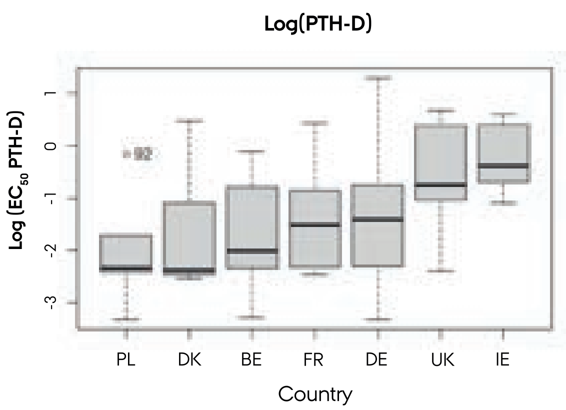


Figure 4. Sensitivity of *Zymoseptoria tritici* isolates from European trials to FXP = fluxapyroxad (SDHI), MPA = mefentrifluconazole (azole) and PTH_D = desthio-prothioconazole. EC_{50} values were calculated based on 10 isolates per site. Samples were taken in untreated plots.

Comparison of azoles (22329)

In two trials different azoles were tested in the cultivar Hereford at AU Flakkebjerg and Velas near Vejle. The trials included two treatments using two ½ recommended rates applied at GS 33 and GS 45-51. In both trials significant attacks of *Septoria* developed, and assessments showed a clear ranking of the efficacy of the products (Table 3; Figure 5). The new azole product, Revysol, has been included in the testing since 2017. In all seasons this product showed very good control (approx. 90%) compared with the old solo azoles as well as the azole mixtures, which only provided *Septoria* control in the range of 30-50%. Generally, prothioconazole is known to be significantly influenced by the current changes in mutation which have taken place in the *CYP51* gene. The strobilurin fungicide Comet Pro (pyraclostrobin) was also included in the trials with the aim of seeing if this product could still provide control in line with the old azole fungicides.

Looking at the performance of azoles during a longer period, the drop in performance began in 2014, was less pronounced in 2015 but continued in 2016 (Figure 6). Part of the yearly variation can be linked to the levels of attack, but – as discussed in chapter IV – the *Septoria* populations have changed and do now include far more mutations than previously. The mutations are known to influence the sensitivity to azoles in general but are also seen to influence specific azoles differently. The drop in the efficacy of tebuconazole has been known since about 2000. However, the drop in performance from tebuconazole used alone has changed since 2017 when tebuconazole was seen as the azole gaining some efficacy again. Similarly, difenoconazole gained slightly better efficacy. For both tebuconazole and difenoconazole, this is linked to higher proportions of the azole mutations D134G and V136A in the *Septoria* population. The mixture prothioconazole + tebuconazole has also performed better in previous seasons as the two actives are seen to support each other when it comes to controlling the different strains with different mutations. However, since 2021 all old azoles have shown very similar control, which makes it difficult to differentiate their potential control. In 2022 metconazole performed slightly better at the AU Flakkebjerg trial, while it was most inferior in the trial at Velas. As mentioned, also Comet Pro was included in the trials, and it was seen that Comet Pro performed inferiorly to the old azoles as seen in Figure 5.

Table 3. Average *Septoria* attack and yield responses from treatments in winter wheat. Two trials in 2022 (22329).

Treatments, l/ha 22329		% *Septoria*				Yield & yield increase hkg/ha	Net yield hkg/ha
GS 32-33	GS 51-55	GS 69 Leaf 3	GS 73-75 Leaf 1	GS 73-75 Leaf 2	% GLA GS 83 Leaf 1		
1. Proline EC 250 0.4	Proline EC 250 0.4	17.1	2.2	11.5	50.0	3.6	1.2
2. Juventus 90 0.5	Juventus 90 0.5	18.8	2.1	11.1	38.8	3.0	1.0
3. Folicur EW 250 0.5	Folicur EW 250 0.5	18.0	1.7	11.9	42.5	2.2	0.4
4. Proline EC 250 0.4	MCW 406-S 0.25 (difeno.)	15.3	1.6	9.4	40.0	3.5	-
5. Prosaro EC 250 0.5	Prosaro EC 250 0.5	10.4	1.5	12.6	53.8	3.9	1.7
6. Revysol 0.75	Revysol 0.75	4.5	0.0	1.8	77.5	8.5	-
7. BAS 754 00F 0.75	BAS 754 00F 0.75	7.1	0.5	2.7	80.0	8.7	-
8. Comet Pro 0.625	Comet Pro 0.625	22.1	3.0	16.1	38.8	1.2	-1.4
9. Untreated		33.1	5.9	21.1	27.5	112.7	-
No. of trials		2	2	2	1	2	2
LSD_{95}		3.0	0.5	2.5	13.0	2.8	-

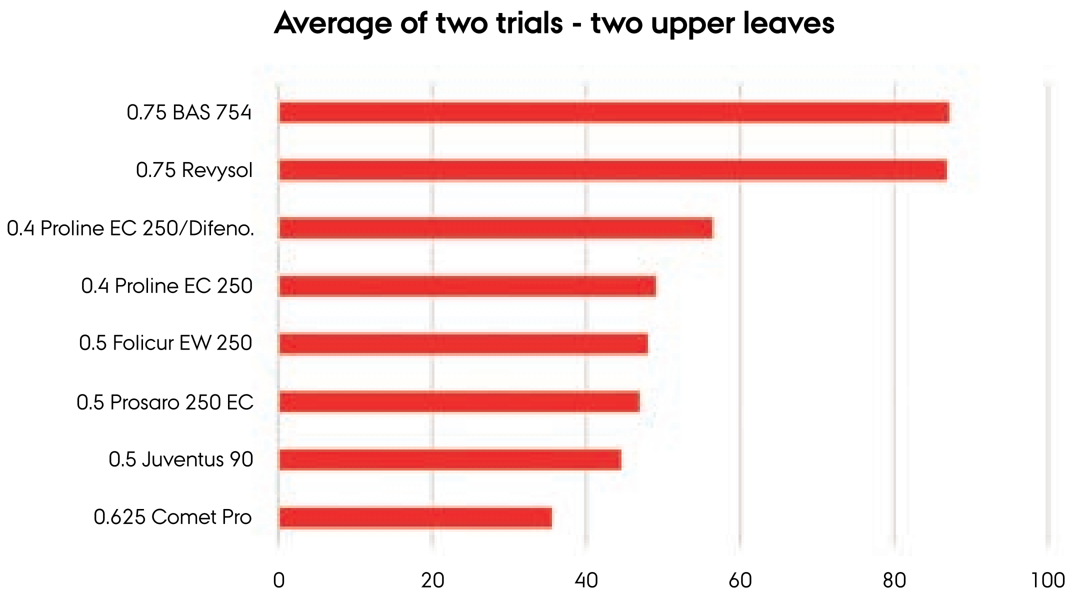


Figure 5. Per cent control of *Septoria* assessed on two upper leaves. Average of two applications at GS 32-33 and 51-55.

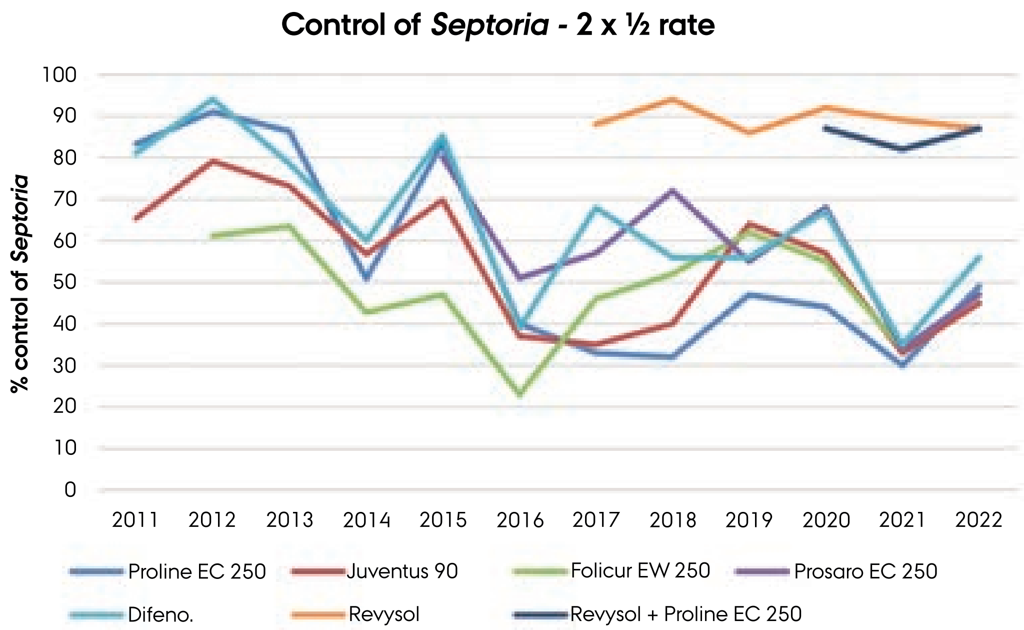


Figure 6. Per cent control of *Septoria*, using two ½ rates of different azoles. Average of two applications at GS 32-33 and 51-55. Development of efficacy across years (2011-2022).

Comparison of available solutions for ear treatments (22325)

In line with trials from previous years, treatments with different fungicides were tested when applied during heading (GS 39-40) (24-25 May) (Table 4). Three trials were carried out; two were located at AU Flakkebjerg in the cultivars Hereford and Kvium and one near Horsens in the cultivar Hereford. A cover spray was applied in most treatments at GS 32, using Proline EC 250 (0.2 l/ha).

Septoria developed a significant attack on both the 2nd leaf and the flag leaves. The control level of *Septoria* on the flag leaves varied between 42% and 85% control (Figure 7). New actives with Balaya and Univoq provided the best control, while the older chemistry with Propulse SE 250 provided slightly inferior control. Also, in this year's trials Propulse SE 250 clearly benefited from mixing with Folicur Xpert, but mixing with the sulphur product, Thiopron, also increased the level of control. The mixture of Propulse SE 250 and Balaya also performed well in the trials regarding both control and yield response.

Yields increased significantly but only moderately from treatments, varying between 5.5 hkg/ha and 10 hkg/ha. The better treatments, which all included new chemistry, increased yields more than the older chemistry. The early season treatment (GS 32) did not increase the yields, which can be seen when comparing treatments 8 and 13. Net yields were positive from all treatments (Figure 8) and was of a very similar size (approx. 5 hkg/ha).

Table 4. Effect of ear applications on control of *Septoria*, green leaf area (GLA) and yield responses in wheat when treatments were applied at GS 39-40. Three trials (22325).

Treatments, l/ha 22325		% *Septoria*				% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha	TGW g
GS 31-32	GS 39-40	GS 65-69 Leaf 3	GS 71-73 Leaf 2	GS 75 Leaf 2	GS 79-83 Leaf 1	GS 79-85 Leaf 1			
1. Proline EC 250 0.2	Propulse SE 250 1.0	7.3	3.8	16.0	23.8	30.8	5.9	3.1	50.3
2. Proline EC 250 0.2	Propulse SE 250 1.0 + Folicur Xpert 0.25	6.5	2.3	11.6	17.5	40.8	5.6	2.4	50.0
3. Proline EC 250 0.2	Propulse SE 250 0.75 + Thiopron 1.5	4.6	2.8	11.1	19.4	39.2	8.0	-	50.2
4. Proline EC 250 0.2	Univoq 0.75	5.6	2.4	9.8	12.3	45.0	8.7	5.9	49.4
5. Proline EC 250 0.2	Univoq 1.0	4.6	1.4	4.8	10.4	45.8	7.2	3.9	49.1
6. Proline EC 250 0.2	Univoq 1.25	4.3	0.7	2.5	7.1	45.0	8.8	5.0	50.0
7. Proline EC 250 0.2	Balaya 0.75	5.7	2.5	11.7	12.9	44.6	7.1	4.3	49.0
8. Proline EC 250 0.2	Balaya 1.0	5.9	1.3	7.3	9.0	45.4	7.0	3.7	50.9
9. Proline EC 250 0.2	Balaya 1.25	4.6	0.9	4.5	6.6	52.9	10.0	6.1	50.0
10. Proline EC 250 0.2	Propulse SE 250 0.4 + Balaya 0.6	4.8	0.8	5.1	9.7	50.4	9.5	6.4	49.7
11. Proline EC 250 0.2	Propulse SE 250 0.25 + Balaya 0.375	4.9	3.5	17.1	15.0	43.8	7.7	5.4	48.6
12. Proline EC 250 0.2	Greteg Star 0.5 + Propulse SE 250 0.5	6.1	3.1	12.9	19.4	35.0	5.7	3.0	48.5
13.	Balaya 1.0	4.7	1.4	6.9	12.5	51.7	7.1	4.8	50.1
14. Untreated		12.3	10.2	40.3	42.1	19.2	119.8	-	49.0
No. of trials		3	3	2	2	3	3	-	3
LSD_{95}		1.9	1.1	4.3	4.4	12.8	3.1	-	1.5

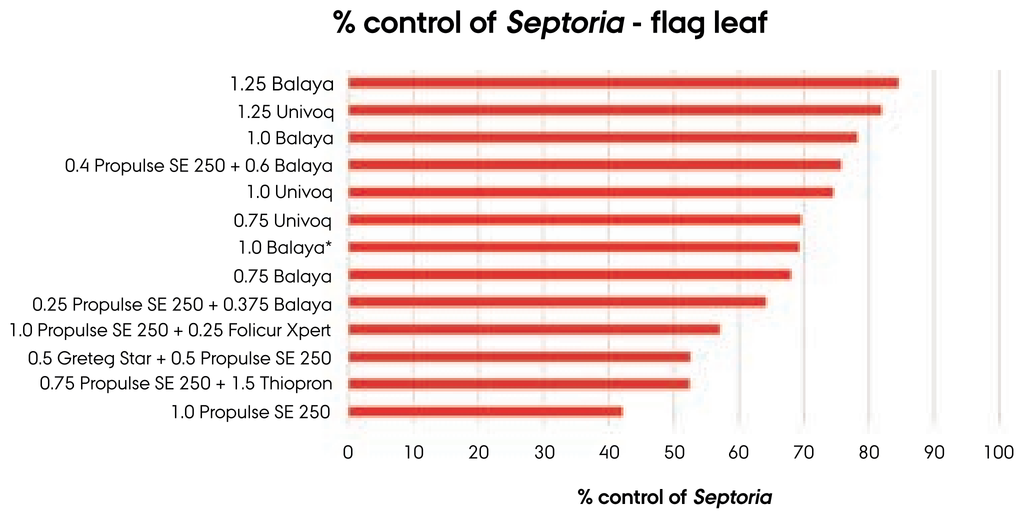


Figure 7. Per cent control of *Septoria* when treated at GS 40-51. Assessed on the flag leaf at GS 75-79. Average of three trials (22325). 28% attack in untreated. * = no cover spray.

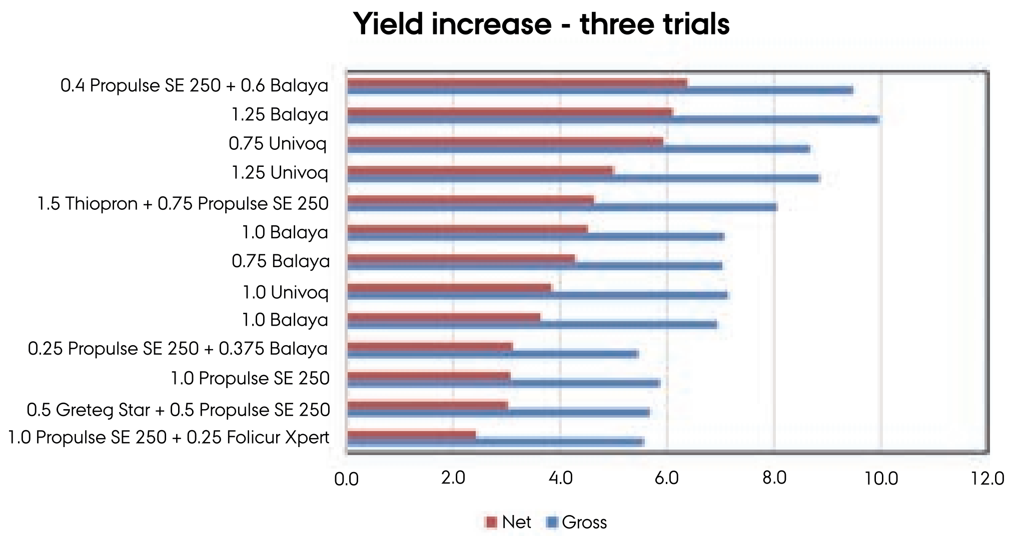


Figure 8. Yield increases (hkg/ha) in winter wheat from control of *Septoria* with treatments applied at GS 39-40. Average of three trials (22325). All treatments were also treated at T1 with 0.2 l/ha Proline EC 250. The cost of the early treatment (T1) has not been deducted for the data in the figure. LSD_{95} = 3.1 hkg/ha.

Yield data from trials across three seasons with treatments applied at GS 40-51 are shown in Figure 9. Overall, the ten solutions provided good control with limited differences and dose responses. The yield responses in the three seasons were only moderate despite most of the trials being conducted in susceptible cultivars. A minor dose response in yield responses was seen for Balaya but less so for Univoq (Figure 9).

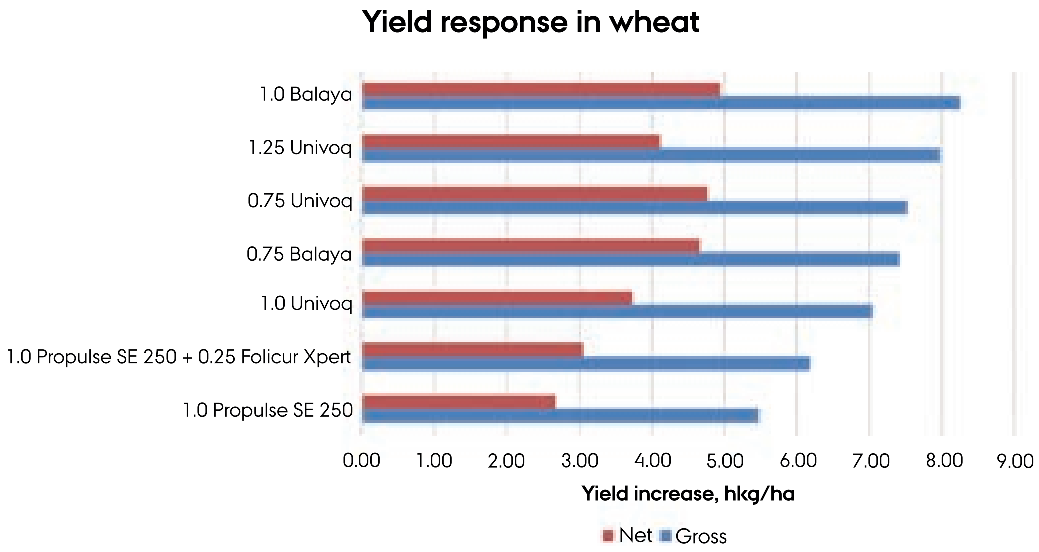


Figure 9. Yield increases (hkg/ha) in winter wheat from control of *Septoria* across 3 seasons with treatments applied at GS 40-51. Average of nine trials from three seasons (20325/21325/22325). All treatments were also treated at T1 with 0.35 l/ha Prosaro EC 250 / 0.2 l/ha Proline EC 250 and this cost was deducted for the data in the figure. LSD_{95} = 3.0 hkg/ha.

Control strategies using two treatments in winter wheat for control of *Septoria* (22326)

Three trials were initiated following the trial plan 22326 (Table 5). The trials were carried out in the cultivars KWS Scimitar and Hereford (AU Flakkebjerg) and Hereford (Velas). The trials compared different treatments using a split ear application applied at GS 37-39 (24-26 May) and GS 55-61 (9 June). Thirteen different treatments were included in the trials. All treatments including untreated had a cover spray applied at GS 32 with 0.2 l/ha Proline EC 250. Treatments included a mix of new and old chemistry (Table 5).

The trials developed moderate to severe attacks, and most treatments provided acceptable control (Figure 10). When a split ear treatment was used, Univoq or Balaya used in sequence or either of these two used in sequence with Propulse SE 250 + Folicur Xpert gave very similar control of *Septoria*. Combinations which included more of the old azoles (Greteg Star, Curbatur, Juventus 90 solo or in combination with Entargo or Pictor Active) generally gave slightly inferior control.

One of the three trials developed a late attack of yellow rust, which was well controlled by all treatments. Yield responses were moderate but significant in the range of 6-13 hkg/ha, reflecting the levels of control obtained from the different solutions (Figure 11). Net yield varied between 3 hkg/ha and 8 hkg/ha. All three trials showed a good correlation between green leaf area and yield responses. Similarly, grain weight increased following the split ear treatment (Table 5).

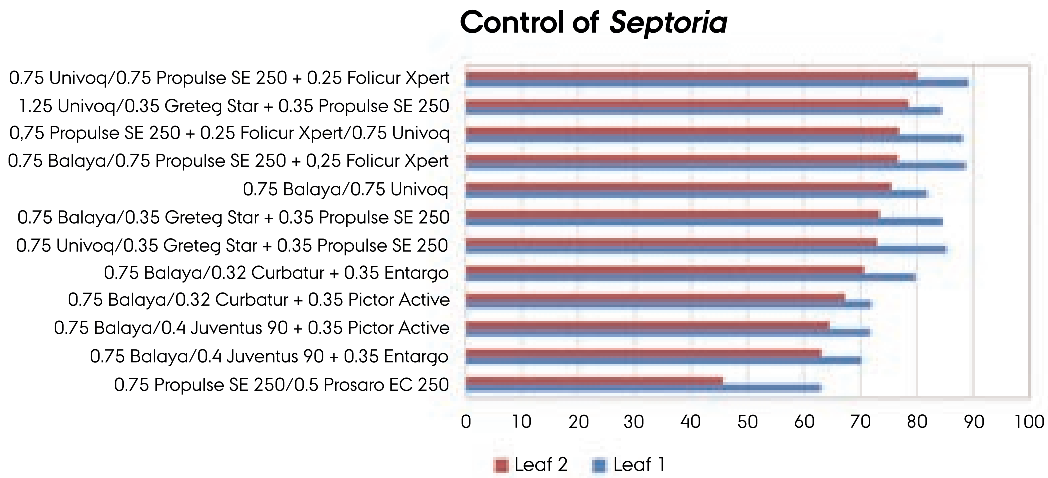


Figure 10. Per cent control of *Septoria* on the flag leaf when treated as a split ear application applied at GS 37-39 and GS 55-61. Average of three trials (22326).

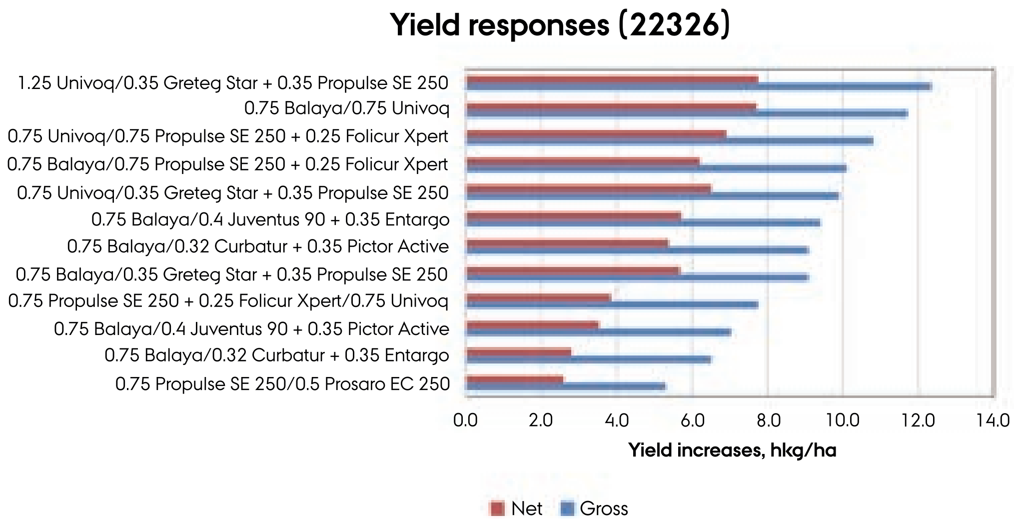


Figure 11. Yield increases in winter wheat (hkg/ha) from control of *Septoria*, using split ear treatments applied at GS 37-39 and GS 55-61. Average of three trials (22326). LSD_{95} = 3.9 hkg/ha.

Table 5. Effect of a split ear applications on control of *Septoria*, green leaf area (GLA), thousand grain weight (TGW) and yield responses in wheat. Three trials (22326). All treatments including untreated were treated with 0.2 l/ha Proline EC 250 at GS 32.

Treatments, l/ha 22326		% *Septoria*	% *Septoria*	% *Septoria*	% GLA	TGW g	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 37-39	GS 55-61	GS 67-69 Leaf 3	GS 73-75 Leaf 2	GS 79-83 Leaf 1	GS 79-85 Leaf 1			
1. Untreated	Untreated	14.2	19.0	28.1	11.3	46.0	116.9	-
2. Propulse SE 250 0.75	Prosaro EC 250 0.5	8.71	10.6	10.4	39.6	48.4	6.4	2.9
3. Balaya 0.75	Greteg Star 0.35 + Propulse SE 250 0.35	6.9	6.5	4.3	56.3	49.9	10.0	5.8
4. Univoq 0.75	Greteg Star 0.35 + Propulse SE 250 0.35	5.6	5.5	4.1	56.3	50.5	10.9	6.8
5. Propulse SE 250 0.75 + Folicur Xpert 0.25	Univoq 0.75	7.9	5.5	3.3	59.6	50.4	8.7	4.0
6. Univoq 0.75	Propulse SE 250 0.75 + Folicur Xpert 0.25	5.4	4.3	3.0	60.0	50.0	11.9	7.2
7. Balaya 0.75	Propulse SE 250 0.75 + Folicur Xpert 0.25	6.2	4.8	3.2	59.6	49.5	10.6	5.9
8. Balaya 0.75	Curbatur 0.32 + Entargo 0.35	6.0	5.5	5.7	51.3	49.8	7.8	3.4
9. Balaya 0.75	Juventus 90 0.4 + Entargo 0.35	5.3	4.8	8.4	54.2	49.5	10.3	5.9
10. Balaya 0.75	Juventus 90 0.4 + Pictor Active 0.35	6.1	6.0	7.9	51.3	49.5	8.4	4.1
11. Balaya 0.75	Curbatur 0.32 + Pictor Active 0.35	5.3	5.5	7.9	54.6	49.6	10.0	5.6
12. Balaya 0.75	Univoq 0.75	6.6	5.2	5.1	60.0	50.4	12.8	8.1
13. Univoq 1.25	Greteg Star 0.35 + Propulse SE 250 0.35	4.3	3.2	4.4	65.3	49.9	13.4	8.1
No. of trials		3	3	2	3	3	3	3
LSD_{95}		1.8	1.8	2.6	8.1	1.1	3.9	-

T1 treatments in different combinations

The two trials following the 22323 protocol were carried out in the cultivars Benchmark and Hereford. Focus in these trials was on the T1 application at GS 31-32 (3 May). The aim was to look for a replacement to Prosaro EC 250, which has been widely recommended for a T1 treatment. New triazole rules, which have been introduced to reduce leaching of 1,3,4-triazole to groundwater, will make it less attractive to apply products containing tebuconazole at this early timing as this will limit the later options for using azoles. Ten different T1 treatments were compared. The second and third treatments in the trials were more fixed and regarded as cover sprays (Table 6). All treatments resulted in very high levels of control and particularly the trial in Benchmark resulted in a very high level of yield response due to a severe attack of yellow rust.

T1 treatments based on 0.3 l/ha Propulse SE 250 or 0.42 l/ha Comet Pro did not provide full control of yellow rust and did also give slightly inferior control of Septoria tritici blotch, as seen in Figures 12 and 13. The trials indicated that several other options are available as a replacement for Prosaro SE 250.

Table 6. Effects on *Septoria*, green leaf area (GLA) and yield responses following three timings. Two trials (22323).

Treatments, l/ha 22323			% *Septoria*		% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha	TGW g
GS 31-32	GS 39	GS 55 (10-15 days after T2)	GS 69 Leaf 2	GS 71-75 Leaf 2	GS 83 Leaf 1			
1. Untreated			6.5	22.1	8.8	84.9	-	43.7
2. Propulse SE 250 0.33	Balaya 0.75	Propulse SE 250 0.5 + Folicur Xpert 0.25	3.7	2.9	51.3	30.8	25.7	50.7
3. Propulse SE 250 0.33	Balaya 0.75	Univoq 0.75	2.7	7.7	47.5	29.6	24.7	50.5
4. Juventus 90 0.2 + Pictor Active 0.2	Balaya 0.75	Univoq 0.75	2.4	3.1	59.4	30.0	25.0	50.3
5. Pictor Active 0.33 + Agropol 0.2	Balaya 0.75	Univoq 0.75	2.8	3.4	61.9	27.7	22.7	48.7
6. Comet Pro 0.42	Balaya 0.75	Univoq 0.75	3.1	6.9	47.5	25.8	20.8	50.0
7. Curbatur 0.24 + Pictor Active 0.2	Balaya 0.75	Univoq 0.75	2.6	3.9	56.3	27.9	22.7	50.1
8. Juventus 90 0.4 + Pictor Active 0.4	Balaya 0.75	Univoq 0.75	2.1	5.6	51.9	25.4	19.7	50.4
9. Propulse SE 250 0.33	Univoq 0.75	Propulse SE 250 0.5 + Folicur Xpert 0.25	3.1	4.6	53.8	27.4	23.0	50.4
10. Juventus 90 0.2 + Pictor Active 0.2	Univoq 0.75	Propulse SE 250 0.5 + Folicur Xpert 0.25	1.3	3.9	57.5	27.9	23.4	49.7
11. Comet Pro 0.42	Balaya 0.75	Propulse SE 250 0.5 + Folicur Xpert 0.25	3.4	3.3	36.3	27.2	22.7	49.7
No. of trials			2	2	2	2	2	2
LSD_{95}			1.1	1.1	12.4	4.1	-	1.5

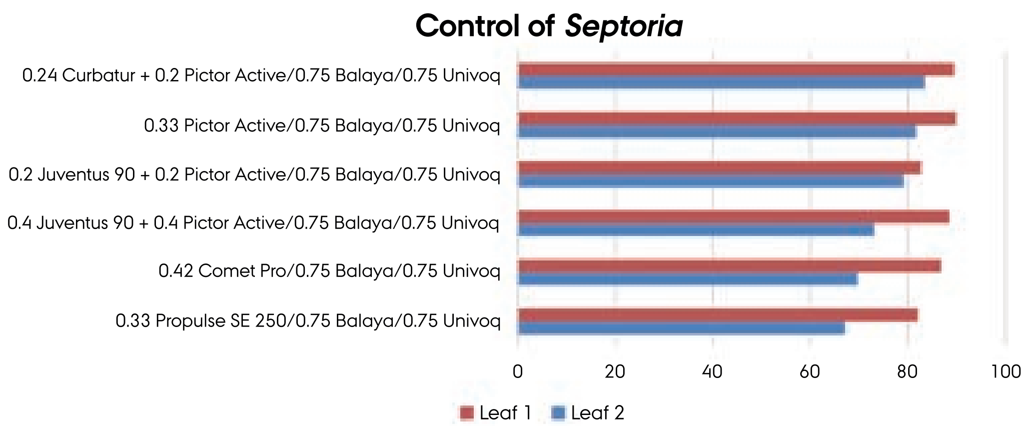


Figure 12. Per cent control of *Septoria* on the flag leaf when treated as part of a split treatment applied at GS 32, GS 37-39 and GS 55-61. Average of two trials (22323).

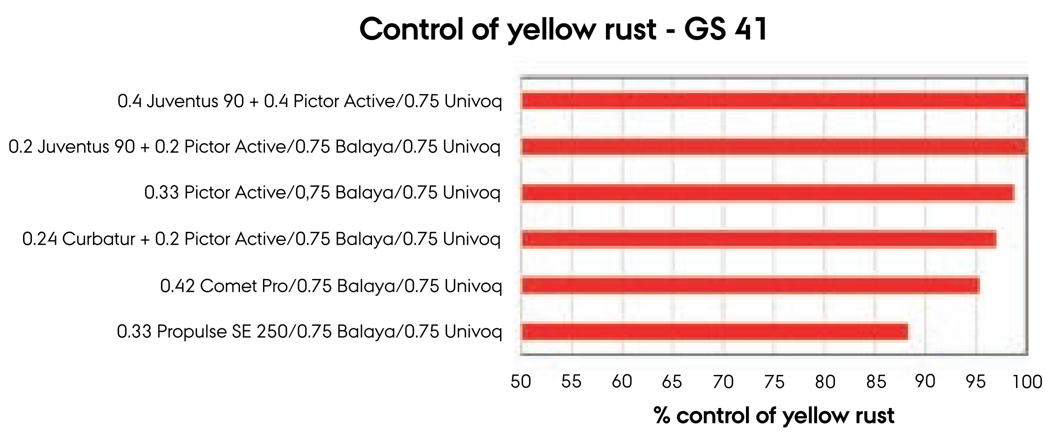


Figure 13. Per cent control of yellow rust on the flag leaf when treated as part of a split treatment applied at GS 32, GS 37-39 and GS 55-61. Data from trial in Benchmark (22323-1).

Different T1 treatments

Two trials compared several different solutions applied at T1 (GS 31-32). The trials were carried out in the cultivars KWS Scimitar and Cleveland (Table 7). Applied at T1 Pictor Active + Juventus 90 performed in line with Proline EC 250 mixed with Thiopron. Most T1 treatments improved control slightly when assessed at GS 61 (Figure 14). At later assessments the impact from the first timing could not be seen. Yield responses in the trials were significant from all treatments, giving increases between 10 hkg/ha and 15 hkg/ha. When T1 was not applied, the net yield was like the T1-treated solutions, indicating that there was a very low need for an early treatment, which seems to be the case at many sites where rust and mildew do not appear. Balaya was a better T2 treatment compared with the mixture Propulse SE 250 + Folicur Xpert. The different solutions gave similar yield responses, which did not differ significantly from each other.

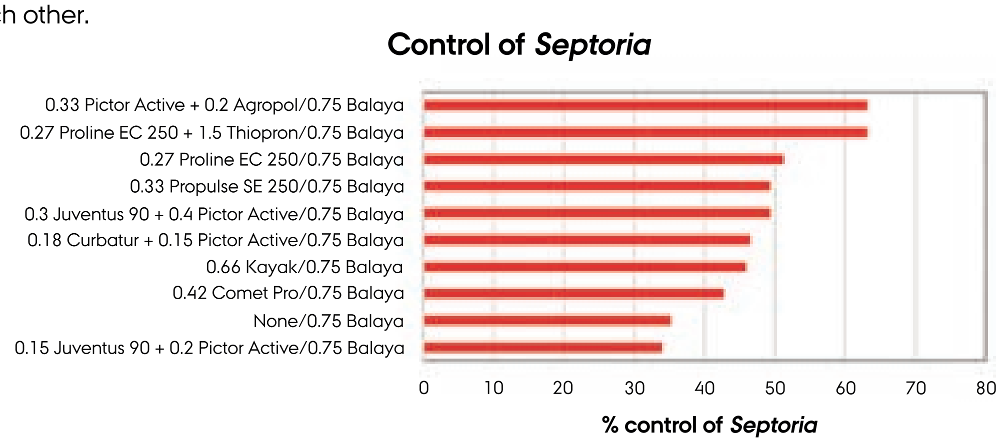


Figure 14. Per cent control of *Septoria* on leaves 2 and 3 assessed at GS 61 with focus on the effects obtained from T1 applications (GS 31-32). Average of two trials (22324).

Table 7. Effects on *Septoria*, brown rust, green leaf area (GLA), yield responses and thousand grain weight (TGW), following one timing with different *Septoria* combinations in wheat. (22324).

Treatments, l/ha 22324		% *Septoria*			% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha	TGW g
GS 31-32	GS 45-51	GS 53-60 Leaf 2-3	GS 63-65 Leaf 2-3	GS 75 Leaf 2-3	GS 79 Leaf 1			
1. Untreated		1.7	12.7	36.9	21.0	123.9		39.7
2. Proline EC 250 0.27	Propulse SE 250 0.75 + Folicur Xpert 0.25	0.1	6.3	11.1	56.3	13.7	10.9	42.7
3. Proline EC 250 0.27 + Thiopron 1.5	Propulse SE 250 0.75 + Folicur Xpert 0.25	0.1	3.1	4.9	61.3	15.1	-	42.5
4. Pictor Active 0.33 + Agropol 0.2	Propulse SE 250 0.75 + Folicur Xpert 0.25	0.1	5.1	9.5	52.5	11.6	8.6	42.5
5. Comet Pro 0.42	Propulse SE 250 0.75 + Folicur Xpert 0.25	0.1	3.8	9.8	53.8	11.4	8.5	43.3
6. Proline EC 250 0.27	Balaya 0.75	0.1	3.6	6.5	79.3	12.6	9.7	42.4
7. Proline EC 250 0.27 + Thiopron 1.5	Balaya 0.75	0.1	2.3	4.0	75.7	12.5	-	43.2
8. Pictor Active 0.33 + Agropol 0.2	Balaya 0.75	0.1	2.3	4.9	76.4	12.2	9.3	43.0
9. Comet Pro 0.42	Balaya 0.75	0.1	4.1	4.9	65.7	11.7	8.7	41.6
10. Curbatur 0.18 + Pictor Active 0.15	Balaya 0.75	0.1	4.4	4.6	71.4	13.5	10.5	42.1
11. Juventus 90 0.15 + Pictor Active 0.2	Balaya 0.75	0.1	5.5	7.0	71.4	11.9	9.0	41.7
12. Juventus 90 0.3 + Pictor Active 0.4	Balaya 0.75	0.1	4.5	6.3	74.3	11.7	8.2	43.1
13. Propulse SE 250 0.33	Balaya 0.75	0.1	4.5	5.4	77.9	11.7	8.8	43.8
14. Kayak ERA 0.66	Balaya 0.75	0.1	3.4	6.1	72.9	9.7	-	42.4
15.	Balaya 0.75	0.2	5.6	9.0	66.4	11.3	9.3	42.5
LSD_{95}		0.1	1.2	2.4	11.7	4.9	-	1.5

Testing of alternative chemistry and biological control agents (BCA)

Currently, a great deal of effort is put into finding alternative low-risk solutions to the current chemical fungicides. Many different alternative solutions are being discussed, and in two trials we tested various solutions. Data from the trials are shown in Table 8 and Figure 15. Two sulphur products were included (Thiopron and Vertipin), which both are liquid formulations which currently are not authorised as crop protection products. The same is the case for Phosphonate, which was provided by BASF. Two products included fungi: Lalstop G46 WG = *Chlonostachus rosea* and Polyversum = *Pythium oligandrum*. One product is based on the bacterium strain *Bacillus amyloliquefaciens* QST 713, which is the active ingredient in Serenade ASO. Charge is known as a biostimulant based on chitosan. Finally, Bion (benzothidiazole) is known to provide induced systemic acquired resistance (SAR), and Iodus (brown algae extract = lamarin) is known as a product stimulating the plants' own defence mechanisms.

The different solutions were compared to traditional references with chemical fungicides listed in treatments 2 and 3. Treatments were applied twice. Most treatments provided a significant reduction, but control levels were not quite in line with treatment 2, which represents a classical fungicide treatment. However, treatments, which all included sulphur products, provided control levels in line with treatment 3, which was treated with Proline EC 250.

Table 8. Effects on *Septoria*, green leaf area (GLA) and yield responses, following one timing with different product combinations in wheat. Two trials in 2022, one in Hereford and one in Kvium (22322).

Treatments, l/ha 22322 (Treatments marked with * are kg/ha) 22322		% *Septoria*			% GLA	TGW g	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 32	GS 39-45	GS 71-73 Leaf 2	GS 83-75 Leaf 1	GS 83-75 Leaf 2	GS 75 Leaf 1			
1. Untreated	Untreated	8.9	17.6	43.8	13.8	48.4	133.6	-
2. Propulse SE 250 0.5	Balaya 0.75	0.1	1.2	4.3	81.3	52.6	8.9	5.7
3. Proline EC 250 0.4	Proline EC 250 0.4	3.1	4.3	18.8	15.0	51.0	2.7	0.3
4. Thiopron 3.0	Thiopron 3.0	3.8	4.1	19.4	26.3	49.3	2.4	-
5. Phosphonate 3.0	Phosphonate 3.0	5.6	6.5	29.4	18.8	50.1	2.1	-
6. Serenade ASO 4.0 + Silwet 0.1%	Serenade ASO 4.0 + Silwet 0.1%	5.9	11.6	34.4	18.0	48.7	-1.8	-3.1
7. Charge 3.0	Charge 3.0	7.4	12.7	36.9	20.0	49.8	0.3	-
8. Phosphonate 3.0 + Thiopron 3.0	Phosphonate 3.0 + Thiopron 3.0	3.1	4.2	20.0	45.0	50.6	2.7	-
9. Iodus 1.0	Iodus 1.0	5.4	11.6	31.9	20.0	49.5	-0.2	-
10. Iodus 1.0 + Thiopron 3.0	Iodus 1.0 + Thiopron 3.0	3.1	4.5	17.6	43.9	50.3	1.6	-
11. Lalstop G46 WG 0.3*	Lalstop G46 WG 0.3* + Silwet 0.1%	4.8	6.8	24.4	25.6	49.5	0.2	-
12. Polyversum 0.1*	Polyversum 0.1*	6.4	12.3	35.0	20.0	49.8	1.0	-
13. Vertipin 5.0	Vertipin 5.0	3.3	3.9	13.2	58.9	49.0	1.9	-
14. Bion 0.06*	Phosphonate 3.0 + Thiopron 3.0	2.6	2.7	15.1	48.6	50.6	5.2	-

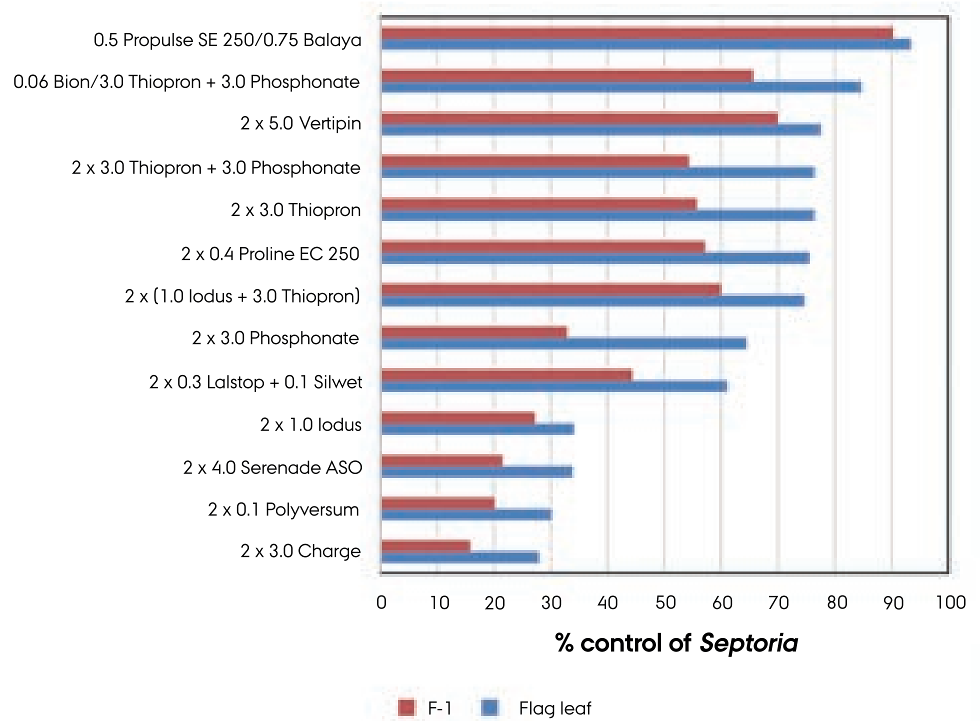
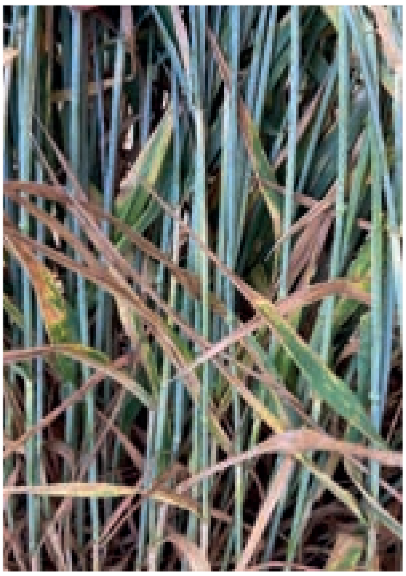
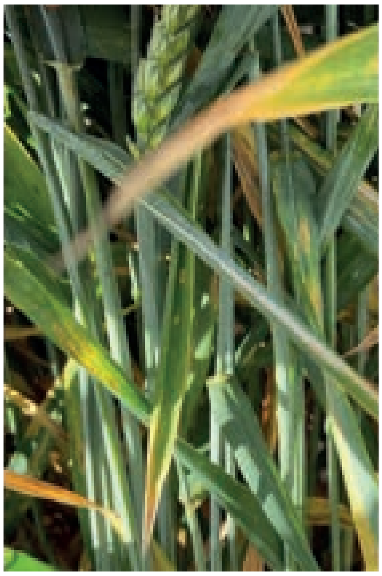


Figure 15. Control of Septoria leaf spot using different alternative substances. Assessments were done on flag leaf and F-1 (= 2nd leaf from the top). Average of two trials in winter wheat (22322).



Untreated (Hereford).



0.5 l/ha Propulse SE 250 / 0.75 l/ha Balaya.

0.06 kg/ha Bion / 3.0 l/ha Thiopron + 3.0 l/ha Phosphonate.

Photos taken in trial 22322 (Hereford).

Baltic T1 and T2 solutions for control of *Septoria*

In two trials different solutions available in the Baltic countries were compared, using a T1 (GS 32) and a T2 (GS 39-45) treatment. All solutions in 22330-1 provided high levels of control in the cultivar Hereford (Table 9). All T2 treatments included Balaya. When no T1 treatment was applied, the control of *Septoria* was generally inferior to other treatments. Most T1 treatments apart from Delaro Forte and Pecari + Amistar provided good control of *Septoria*. Balaya, applied twice, gave the best control. Yield levels in the trial were high, and again two applications of Balaya gave the best yield responses.

In another trial carried out in the cultivar Cleveland (22331-1), the level of *Septoria* attack was moderate, and the yield levels were high and responses from treatments were moderate, varying from 12 hkg/ha to16 hkg/ha (Table 10). The treatment at T1 was in all cases using 0.5 l/ha Balaya. Solutions with Revytrex and Balaya provided the best control, although most solutions did not differ significantly. Balaya resulted in a yield increase of 5.3 hkg/ha when used as a solo treatment at T1. Adding a T2 treatment increased yields by approx. 10 hkg/ha more.

A third trial carried out in the cultivar Benchmark developed both yellow rust and *Septoria*. All treatments controlled yellow rust completely. Although control of *Septoria* was less complete, all products performed acceptably. The different solutions comparing solutions from BASF, Bayer Crop Science and Syngenta showed quite similar levels of control (22332-1). As a result of the severe attack of yellow rust, yield increases were high and varied between 32 hkg/ha and 39 hkg/ha, but differences between treatments were not significant (Table 11).

Table 9. Effect of treatments at GS 32-33 and GS 45-51 on control of *Septoria*, green leaf area (GLA) and yield responses in wheat. One trial in Hereford (22330-1). Baltic countries solutions.

Treatments, l/ha 22330-1		% *Septoria*	% *Septoria*	% *Septoria*	% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 32	GS 39-45	GS 67 Leaf 3	GS 75 Leaf 2	GS 83 Leaf 1	GS 83 Leaf 1		
1. Untreated	Untreated	21.3	52.5	91.3	5.5	126.4	-
2. Balaya 0.5	Balaya 0.75	3.5	3.8	6.8	81.3	15.1	11.7
3. Verben 0.75	Balaya 0.75	7.8	12.5	11.0	75.0	11.5	-
4. Pecari 0.4 + Amistar 0.4	Balaya 0.75	7.8	22.5	20.5	65.0	9.8	-
5. Input Triple 0.75	Balaya 0.75	9.5	20.0	13.5	73.8	11.0	-
6. Cayunis 0.4 + Glacis 0.4	Balaya 0.75	7.3	7.5	10.3	73.8	12.3	-
7. Delaro Forte 1.3	Balaya 0.75	6.5	16.3	26.3	60.0	9.9	-
8. Priaxor 0.4 + Curbatur 0.4	Balaya 0.75	3.0	4.5	13.0	63.8	11.1	-
9. Balaya 0.5 + Flexity 0.25	Balaya 0.75	4.8	6.3	12.5	75.5	14.7	10.6
10. Revystar XL 0.4 + Priaxor 0.4	Balaya 0.75	2.3	2.3	8.0	78.8	13.2	-
11.	Balaya 0.75	11.8	21.3	38.0	55.0	9.0	6.9
LSD_{95}		4.4	6.3	15.1	17.7	4.5	-

Table 10. Effect of treatments at GS 32-33 and GS 45-51 for control of *Septoria*, green leaf area (GLA), yield responses and thousand grain weight (TGW) in wheat. One trial in Cleveland (22331).

Treatments, l/ha 22331-1		% *Septoria*			% GLA	Yield & yield increase hkg/ha	TGW g
GS 32-33	GS 39-45	GS 71 Leaf 3	GS 77 Leaf 1	GS 77 Leaf 2	GS 79 Leaf 1		
1. Untreated	Untreated	30.0	21.3	52.5	10.0	125.8	36.4
2. Balaya 0.5	Elatus ERA 0.75	4.4	1.1	10.0	40.0	13.0	38.1
3. Balaya 0.5	Ascra Xpro 1.0	4.4	0.8	7.5	30.0	12.0	39.0
4. Balaya 0.5	Balaya 1.0	5.3	1.5	11.3	37.5	15.3	39.7
5. Balaya 0.5	Priaxor 0.5 + Curbatur 0.5	3.6	1.0	7.5	42.5	15.3	39.0
6. Balaya 0.5	Imtrex XE 0.75 + Balaya 0.75	2.7	0.4	3.0	37.5	16.0	38.1
7. Balaya 0.5	Revytrex 1.0	2.7	0.4	6.3	40.0	15.1	38.8
8. Balaya 0.5		12.3	11.3	32.5	25.0	5.7	37.4
LSD_{95}		5.0	2.8	4.8	24.2	7.0	2.8

Table 11. Effect of treatments at GS 32 and GS 39-45 for control of *Septoria*, green leaf area (GLA), yield responses and thousand grain weight (TGW) in wheat. One trial in Benchmark (22332).

Treatments, l/ha 22332-1		% yellow rust		% *Septoria*		% GLA	Yield & yield increase hkg/ha	TGW g
GS 32	GS 39-45	GS 63-65 Leaf 2-3	GS 67-69 Leaf 2-3	GS 75-77 Leaf 2	GS 80 Leaf 1	GS 80 Leaf 1		
1. Untreated	Untreated	20.0	41.3	15.0	30.0	10.0	93.7	36.4
2. Pecari 0.4 + Amistar 0.4	Elatus Era 0.75	0.1	0.0	7.3	5.0	37.5	33.1	44.7
3. Input Triple 0.75	Ascra Xpro 1.0	0.0	0.0	3.0	2.0	37.5	36.5	46.5
4. Priaxor 0.4 + Curbatur 0.4	Balaya 1.0	0.0	0.0	3.0	1.0	42.5	32.6	47.8
5. Balaya 0.5 + Flexity 0.25	Priaxor 0.5 + Curbatur 0.5	0.0	0.1	6.5	5.0	37.5	36.2	45.4
6. Balaya 0.5 + Flexity 0.25	Revytrex 1.0	0.1	0.5	3.0	2.0	42.5	35.6	44.3
7. Priaxor 0.4 + Curbatur 0.4	Revytrex 1.0	0.0	0.0	3.0	2.5	52.5	34.5	46.8
8. Priaxor 0.4 + Curbatur 0.4	Imtrex XE 0.75 + Balaya 0.75	0.0	0.0	3.0	2.5	57.5	39.5	45.1
9. Revystar XL 0.4 + Priaxor 0.4	Revytrex 1.0	0.0	0.0	4.0	3.0	50.0	32.5	45.9
LSD_{95}		5.4	1.2	1.2	0.9	10.5	6.6	2.7

Yet another trial (22333) was carried out in Hereford testing different solutions applied at flag leaf (GS 39). The testing included several solutions expected to be available in the Baltic countries during the coming season. The trial compared Univoq with different relevant solutions (Table 12; Figure 16). Overall, the level of control was good and indicated many strong solutions for control of *Septoria*. Impact from the included doses was mainly seen on the 2nd leaf and less so on the flag leaf. Yield levels were high in the trial, but only minor but still significant increases were measured.

Table 12. Effect of treatments for control of *Septoria*, green leaf area (GLA) and yield responses in wheat. One trial in Benchmark (22332). All treatments except untreated were treated with 0.6 l/ha Verben at GS 31-32 as a cover spray.

Treatments, l/ha 22333	% *Septoria*			% GLA	Yield & yield increase hkg/ha
GS 37-39	GS 71 Leaf 3	GS 75 Leaf 2	GS 75 Leaf 1	GS 85 Leaf 1	
1. Untreated	31.3	36.3	12.5	10.0	131.3
2. Univoq 0.75	16.3	14.4	0.9	45.0	7.5
3. Univoq 1.0	16.3	11.3	0.7	35.0	6.2
4. Univoq 1.2	10.0	11.3	0.6	40.0	7.1
5. Revytrex 0.8	15.0	12.5	0.6	32.5	7.4
6. Revytrex 1.0	13.8	7.5	0.4	40.0	4.9
7. Ascra Xpro 0.8	16.3	9.4	0.5	47.5	6.8
8. Ascra Xpro 1.0	12.5	6.9	0.7	57.5	6.9
9. Questar 1.0 + Elatus Plus 0.33	9.5	4.5	0.1	55.0	8.9
10. Questar 1.2 + Elatus Plus 0.4	10.0	8.8	0.3	60.0	10.5
11. Elatus Era 0.7	13.8	18.8	2.0	42.5	5.7
12. Revystar XL 0.4 + Priaxor 0.4	12.5	9.4	0.6	42.5	7.2
13. Verben 0.75 + Questar 0.75	11.3	15.0	1.0	50.0	7.0
LSD_{95}	5.3	6.2	2.1	17.3	0.4

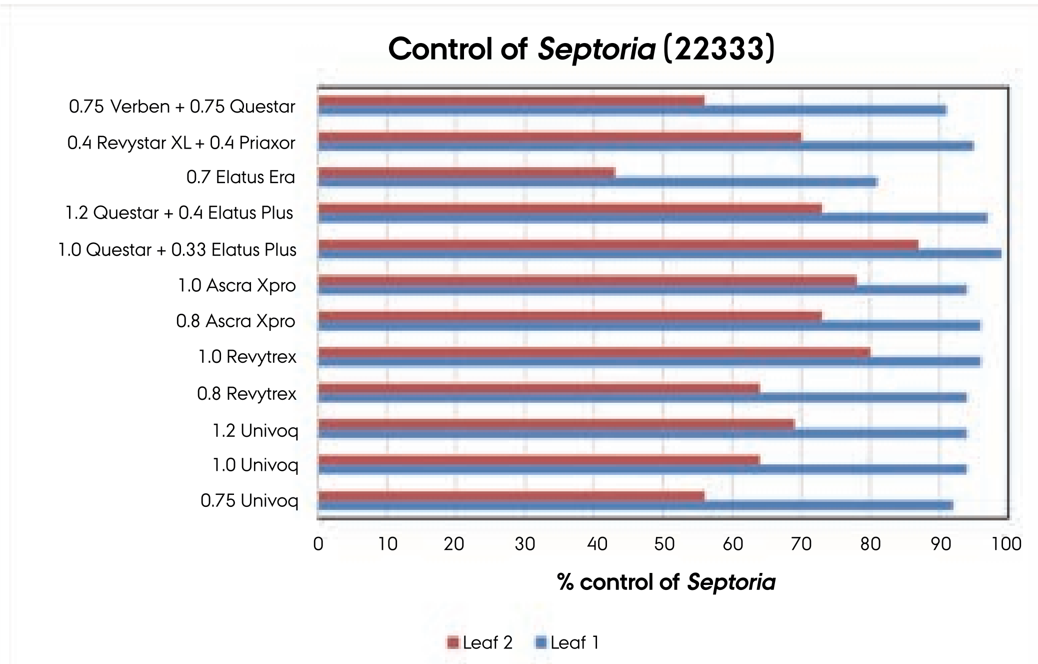


Figure 16. Control of Septoria leaf spot using different strong products – all registered or expected to be registered in the Baltic countries. Data from one trial in Hereford with focus on flag leaf treatments.

Does morning or evening spraying perform best?

It is common practice to spray early in the morning or in the evening due to lower wind speeds, higher humidity and moderate temperatures. Very few data support that this practice provide a better control compared with applications in the middle of the day. A trial in the cultivar Hereford was carried out in 2022 applying morning, midday and evening applications at two different timings. Exact timings and climate data are shown in Table 13. A water volume of 200 l/ha was used for all treatments. None of the timings were applied at extremely warm temperatures, but the relative humidity was – as expected – higher in the morning and evening. The trial tested two different fungicides, Balaya and Propulse SE 250.

The best control from both products was achieved from the early timings (19 May), while control was less good at the later timings (1 June). During the day the best control was seen from the morning and evening treatments although differences were very minor for Balaya applied at the early timing (Table 14; Figure 17). Differences were most pronounced for Balaya applied late and for Propulse SE 250 applied at both 1st and 2nd date.

All treatments increased yields significantly. Overall, Balaya increased yields by 8.8 hkg/ha and Propulse SE 250 by 4.3 hkg/ha. There was no clear and significant evidence that yields were better from morning or evening sprayings, although a tendency to lower yields were seen at the later timing (1 June). In order to compensate for more dry and hot conditions during the day, an option is to use a higher water volume.

Table 13. Spraying conditions when treatments were applied on two dates 19 May and 1 June.

	Morning	Midday	Evening
GS 37. 19 May	Temp: 15°C; RH: 90% Cloud cover: 50%	Temp: 21°C; RH: 77% Cloud cover: 80%	Temp: 17°C; RH: 84% Cloud cover: 50%
GS 51-53. 1 June	Temp: 9°C; RH: 96% Cloud cover: 100%	Temp: 15°C; RH: 55% Cloud cover: 100%	Temp: 11°C; RH: 87% Cloud cover: 100%

Table 14. Effect of applications on control of *Septoria* and yield responses in wheat. One trial (22308).

Treatments, l/ha 22308-1			% *Septoria*				Yield & yield increase hkg/ha	Net yield
GS 37 & 51		Dose	GS 65 Leaf 3	GS 71 Leaf 2-3	GS 75 Leaf 1	GS 75 Leaf 2		
1. Untreated			9.0	38.8	9.0	50.0	122.1	-
2. Balaya	GS 37 Morning	0.75	0.2	2.0	1.0	6.3	7.4	5.4
3. Balaya	GS 37 Midday	0.75	0.3	2.5	1.0	8.8	10.3	8.3
4. Balaya	GS 37 Evening	0.75	0.1	2.0	0.9	10.0	9.1	7.1
5. Balaya	GS 51 Morning	0.75	4.0	5.3	0.2	15.0	9.0	7.0
6. Balaya	GS 51 Midday	0.75	6.5	11.3	0.3	16.3	7.1	5.1
7. Balaya	GS 51 Evening	0.75	5.8	9.5	0.2	13.8	9.6	7.6
8. Propulse SE 250	GS 37 Morning	0.75	1.6	10.0	1.3	15.0	4.0	2.4
9. Propulse SE 250	GS 37 Midday	0.75	2.8	11.3	2.3	21.3	4.0	2.4
10. Propulse SE 250	GS 37 Evening	0.75	1.8	9.8	2.3	26.3	4.6	3.0
11. Propulse SE 250	GS 51 Morning	0.75	4.8	17.5	2.0	20.0	5.1	3.5
12. Propulse SE 250	GS 51 Midday	0.75	7.0	23.8	1.8	30.0	3.1	1.5
13. Propulse SE 250	GS 51 Evening	0.75	5.3	13.8	1.3	25.0	4.8	3.2
LSD_{95}			2.3	4.5	1.1	4.8	3.9	-

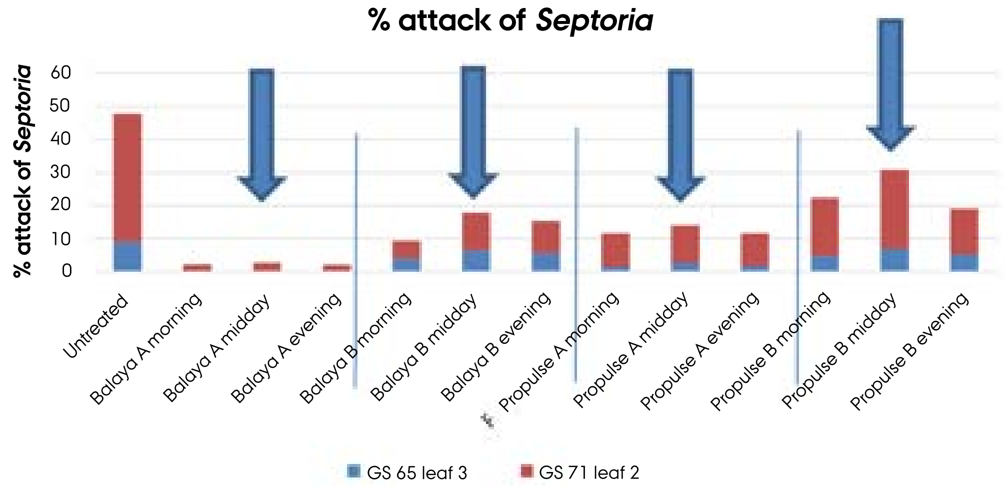


Figure 17. Per cent attack of *Septoria*, using two different fungicides and different timings. "A" represents the early timing (19 May) and "B" the later timing (1 June). Data from trial 22308.

Results with control of yellow rust

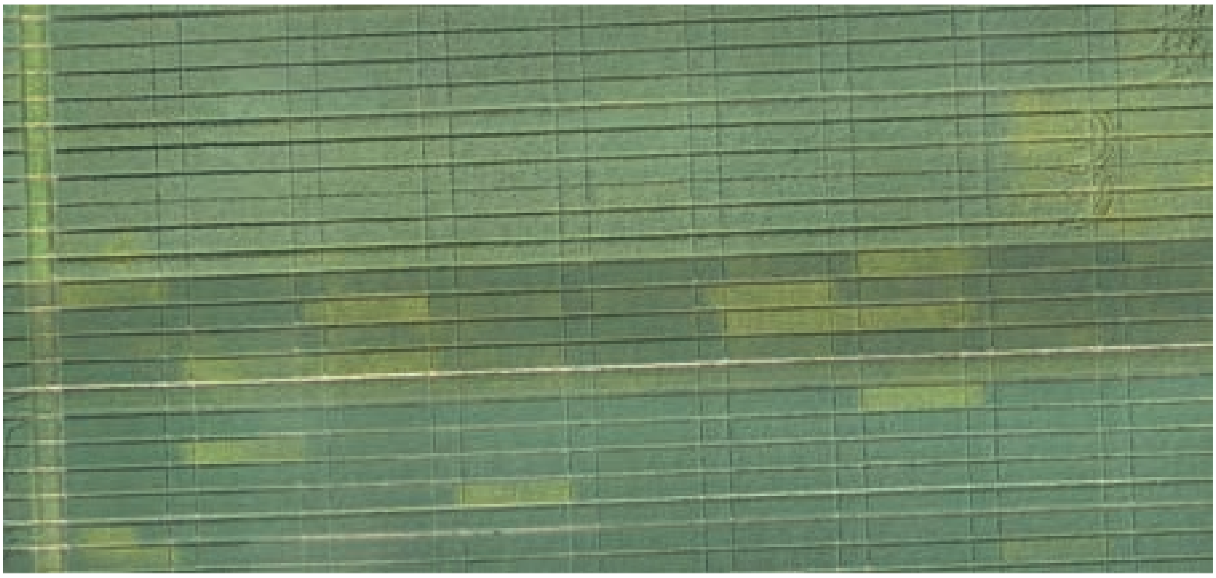
Two trials were carried out testing a small range of fungicides for control of yellow rust in the susceptible cultivar Benchmark; one was placed at AU Flakkebjerg and one at Velas. Treatments were applied at GS 33-37 and GS 51-55. The trials developed a significant attack of yellow rust, following artificial inoculations with spreader plants. The results from the trial are given in Table 15 and Figure 18.

Table 15. Effect of treatments at GS 33-37 and GS 51-55 for control of yellow rust in two fields with Benchmark. The effects are also reflected in % green leaf area (GLA), yield responses and thousand grain weight (TGW).

Treatments, l/ha 22311-1 + 22311-2			% yellow rust			% GLA	TGW g	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 33-37	GS 51-55	Cover spray (only in 311-1)	GS 41-51 Leaf 4	GS 57-65 Leaf 2	GS69-71 Leaf 2	GS			
1. Check	-	-	12.5	39.4	65.0	5.6	34.6	72.2	-
2. Comet Pro 0.313	Comet Pro 0.313	Orius Max 200 EW 0.3	4.1	2.5	16.6	19.1	41.7	22.2	19.9
3. Comet Pro 0.625	Comet Pro 0.625	Orius Max 200 EW 0.3	2.5	1.3	7.0	33.1	44.5	28.0	24.7
4. Comet Pro 1.25	Comet Pro 1.25	Orius Max 200 EW 0.3	1.0	0.2	2.4	35.6	43.2	31.0	25.8
5. Proline EC 250 0.4	Proline EC 250 0.4	Orius Max 200 EW 0.3	2.9	1.5	7.6	23.5	41.5	23.3	20.3
6. Pictor Active 0.5 + Agropol 0.1	Pictor Active 0.5 + Contact 0.1	Orius Max 200 EW 0.3	7.3	5.5	20.7	25.7	41.9	24.1	20.9
7. Check		Orius Max 200 EW 0.3	11.4	36.3	53.8	5.0	37.7		
LSD_{95}			3.3	7.1	6.8	7.3	1.8	3.7	-

Most treatments provided a high level of control, and a clear dose response was seen from Comet Pro. Half rate of Comet Pro performed in line with half rate of Proline EC 250. The efficacy of Pictor Active was slightly inferior to the two other products.

The two trials gave high and significant yield increases with the highest dose of Comet Pro giving more than 3 tonnes in yield increases. A response, which also was reflected in the measured TGW. The photo below shows a drone picture from the site. The yellow plots clearly show the severe attack of yellow rust



in the untreated plots.

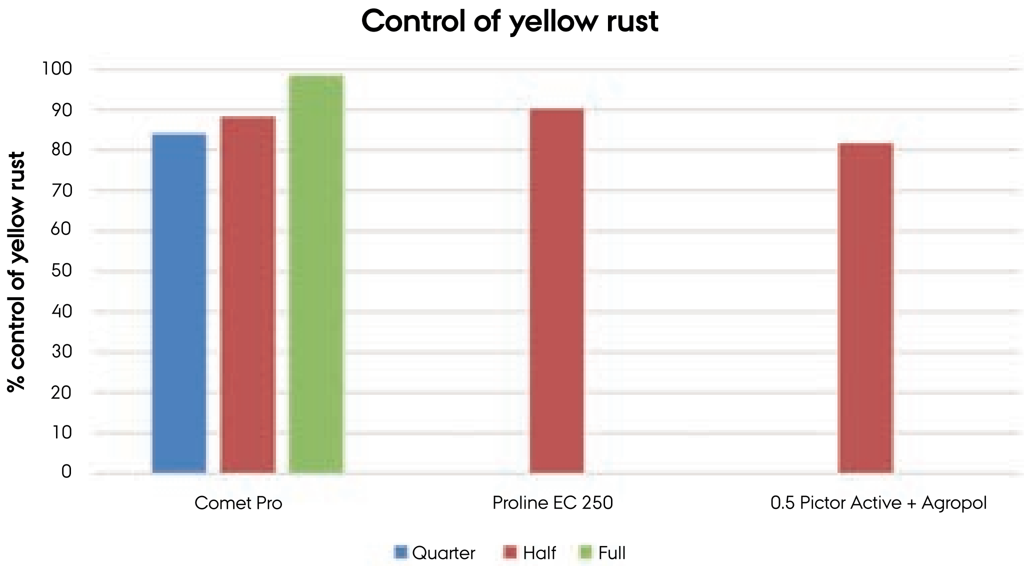


Figure 18. Per cent control of yellow rust, following two treatments applied at GS 33-37 and GS 51-55. The figure is based on data from 2nd leaf where attack was 65% as an average of the two trials.

Control of tan spot with different fungicides

One trial was carried out in the cultivar RGT Saki and inoculated with straw debris contaminated with tan spot in the autumn 2021 (22315). The trial tested different products for their ability to control tan spot. The products included Univoq, Proline EC 250, Balaya, Revytrex, Elatus Era, Input Triple and Ascra Xpro. Two dose rates were tested of Univoq, Proline EC 250, Balaya and Questar + Elatus Plus, respectively (Table 16). The products which included prothioconazole provided the best control (Figure 19), but also the mixture Questar + Elatus Plus performed well. Balaya was seen to be inferior for control of tan spot. The lower rates of the tested products performed less well. The yield responses in the trial were significant.

Table 16. Effect of applications on control of tan spot and yield responses in wheat. One trial (22315).

Treatments, l/ha 22315		% tan spot			% *Septoria*	Yield & yield increase hkg/ha	Net yield
GS 33-37	GS 49-51	GS 69 Leaf 3	GS 75 Leaf 1	GS 75 Leaf 2	GS 69 Leaf 3		
1. Untreated		9.0	11.3	40.0	31.3	110.0	-
2. Proline EC 250 0.8	Proline EC 250 0.8	3.3	3.5	13.8	14.3	10.0	6.0
3. Proline EC 250 0.4	Proline EC 250 0.4	4.5	6.3	22.5	8.3	8.0	5.7
4. Univoq 1.5	Univoq 1.5	2.5	1.8	5.8	7.3	11.0	3.7
5. Univoq 0.75	Univoq 0.75	3.5	2.0	10.5	9.5	11.0	7.0
6. Questar1.5 + Elatus Plus 0.75	Questar 1.5 + Elatus plus 0.75	3.8	0.3	1.4	5.5	15.0	-
7. Questar 0.75 + Elatus Plus 0.375	Questar 0.75 + Elatus Plus 0.375	3.8	1.5	5.0	8.5	11.0	-
8. Questar 1.0 + Verben 1.0	Questar 1.0 + Verben 1.0	2.5	1.0	5.8	6.8	14.0	-
9. Questar 0.75 + Verben 0.75	Questar 0.75 + Verben 0.75	2.3	1.8	8.8	6.8	15.0	-
10. Balaya 1.5	Balaya 1.5	3.3	3.3	18.8	8.3	13.0	5.7
11. Balaya 0.75	Balaya 0.75	3.3	4.5	21.3	5.5	10.0	6.0
12. Ascra Xpro 0.75	Ascra Xpro 0.75	2.0	1.1	3.3	5.8	14.0	-
13. Revytrex 0.75	Revytrex 0.75	2.5	2.5	13.8	6.5	13.0	-
14. Elatus Era 0.5	Elatus Era 0.5	4.3	0.8	4.5	5.8	11.0	-
15. Input Triple 0.47	Input Triple 0.47	2.8	4.0	13.0	7.8	7.0	-
LSD_{95}		2.2	2.7	5.5	6.2	0.6	-

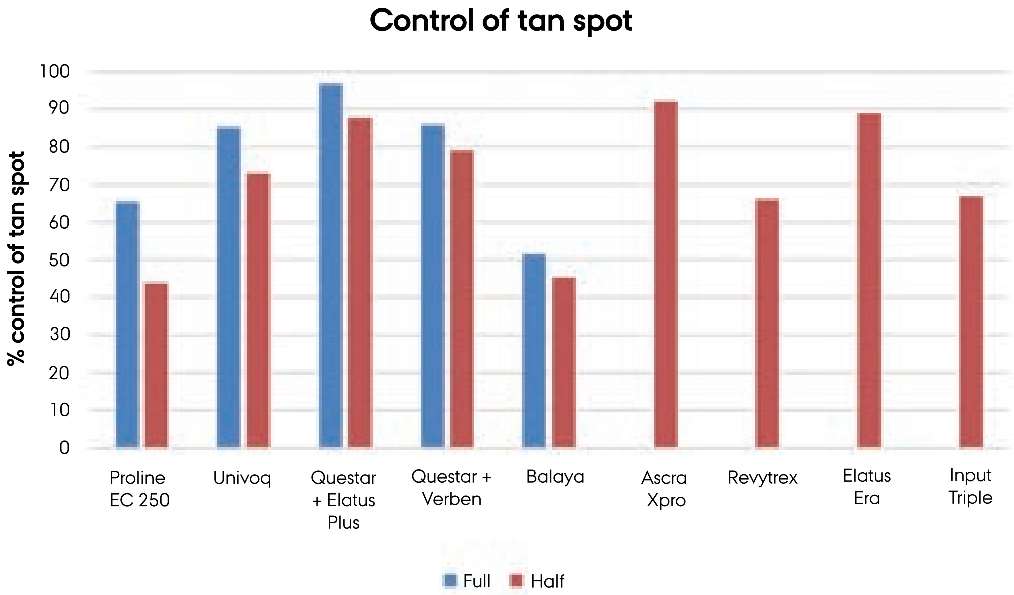


Figure 19. Control of tan spot in wheat using different fungicides assessed at GS 75 on leaf 2.

Tan spot (DTR) in wheat cultivars - ranking of cultivar susceptibility

The trial was organised with four replicates and 2 x 1 m row per plot. The area was inoculated in the autumn with debris of tan spot inoculum, which is known to provide good attack the following season. The trial in 2022 was attacked by significant infections of tan spot and almost no *Septoria*. The trial was assessed at three timings (GS 32, 73 and 77) during the season. The weather was moderately conducive to the development of attack.

Most cultivars are known to be quite susceptible to tan spot and only few of the present relevant cultivars (Creator, Informer and Pondus) had a significantly lower level of attack than average. Figure 20 shows the result for attack of % tan spot, ranking the cultivars according to susceptibility. Creator, Pondus and Informer also showed a good level of control in previous seasons.

AUDPC based on three assessments

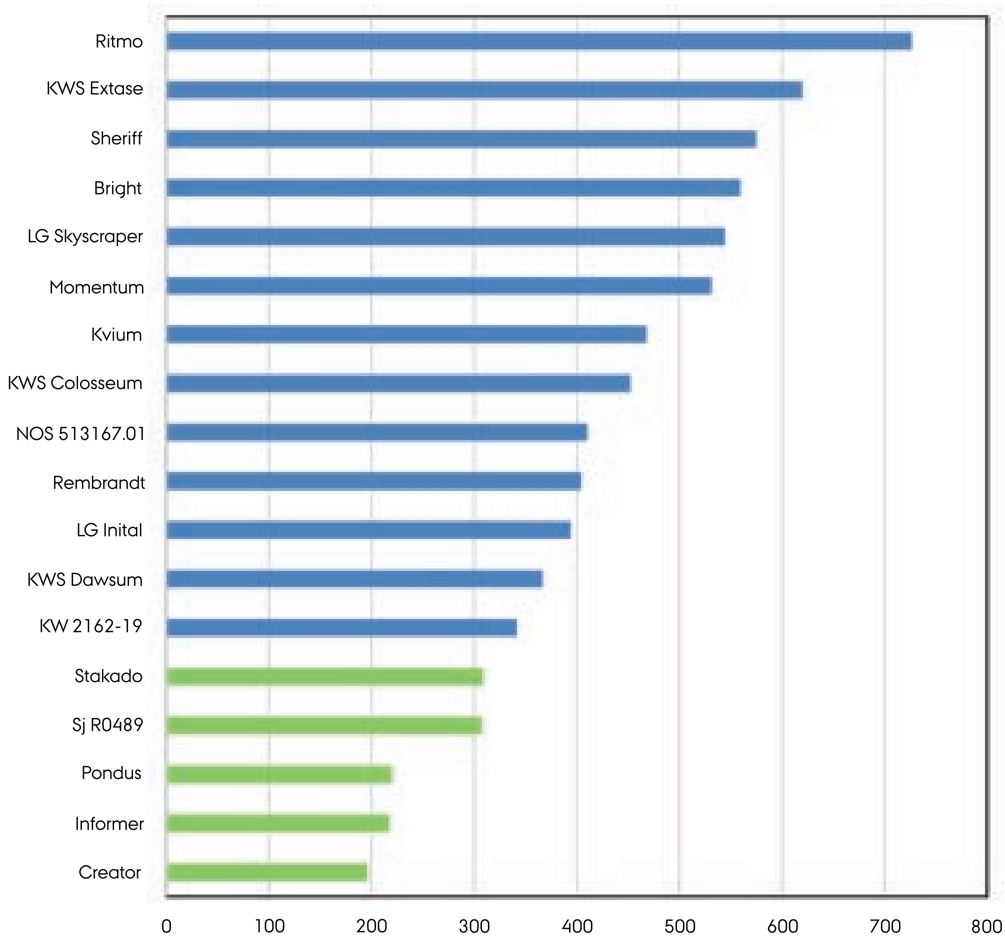


Figure 20. Per cent attack of tan spot in different winter wheat cultivars. Based on three assessments on the upper leaves (22302-1), calculating AUDPC (Area Under Disease Pressure Curve).

Control of Fusarium head blight

In four trials different fungicides against *Fusarium* were tested and assessed for their efficacy.

The trials were carried out using artificial inoculation with spores during flowering. Typically, the trials were inoculated twice following the spraying. The results from the reference treatments are shown in Table 17. The disease pressure in the trial was moderate, which also gave moderate levels of DON. The control of Fusarium head blight (FHB), using Prosaro EC 250 was in the range of 50-89%, while benefits in yields were non-significant.

Table 17. Control of Fusarium head blight and yield responses. Data generated based on four trials with different themes but with the same references.

	% Fusarium head blight				Yield & yield increase hkg/ha
	Trial 1	Trial 2	Trial 3	Trial 4	
Untreated	15 a	17 a	33 a	27 a	134.0 a
Prosaro EC 250 1.0	6 b	8 b	7 b	8 b	1.4 a

Ranking of susceptibility to Fusarium head blight in winter wheat in 2021

In line with previous years, the Department of Agroecology, Aarhus University, Flakkebjerg, investigated the susceptibility to FHB in a project partly financed by the breeders. The tested cultivars are commonly grown in Denmark or are cultivars expected to become important in the years to come. In this year's trials, 20 cultivars were included. One trial was inoculated during flowering; the other trial was inoculated with infested grain placed on the ground during elongation (GS 33-39) (19 May). Two rows of 1 metre of each cultivar were sown in the autumn, and four replicates were included. The trial was inoculated three times on 9, 13 and 15 June, respectively, using a spore solution consisting of both *Fusarium culmorum* and *Fusarium graminearum*. To stimulate the development of the disease, the trial was irrigated by a mist irrigation system two times per day. Wheat is most susceptible during flowering, and at the time of inoculation, the degree of flowering was assessed to ensure that all cultivars were inoculated during flowering. The first symptoms of FHB were seen approximately 15 days after inoculation.

Both trials were assessed counting the attack on 100 ears per cultivar per replicate. Also, the degree of attack was scored as an average of the ears attacked, using a 0-10 scale. The results from the final scoring of infection degree of the heads are shown in Figure 21 and Table 18. As seen in Figure 21, the cultivars Rembrandt, Kvium, KWS Extase, KWS Colosseum and Wheat Mix 121 had the most severe attacks. Least attack was seen in Bright, Sheriff and KW 2162-19. The cultivars Ritmo and Oakley were used as susceptible reference cultivars and Sheriff and Skalmeje as the most resistant references. Data from the two trials correlated quite well as can be seen in Figure 22.

% *Fusarium* in wheat cultivars

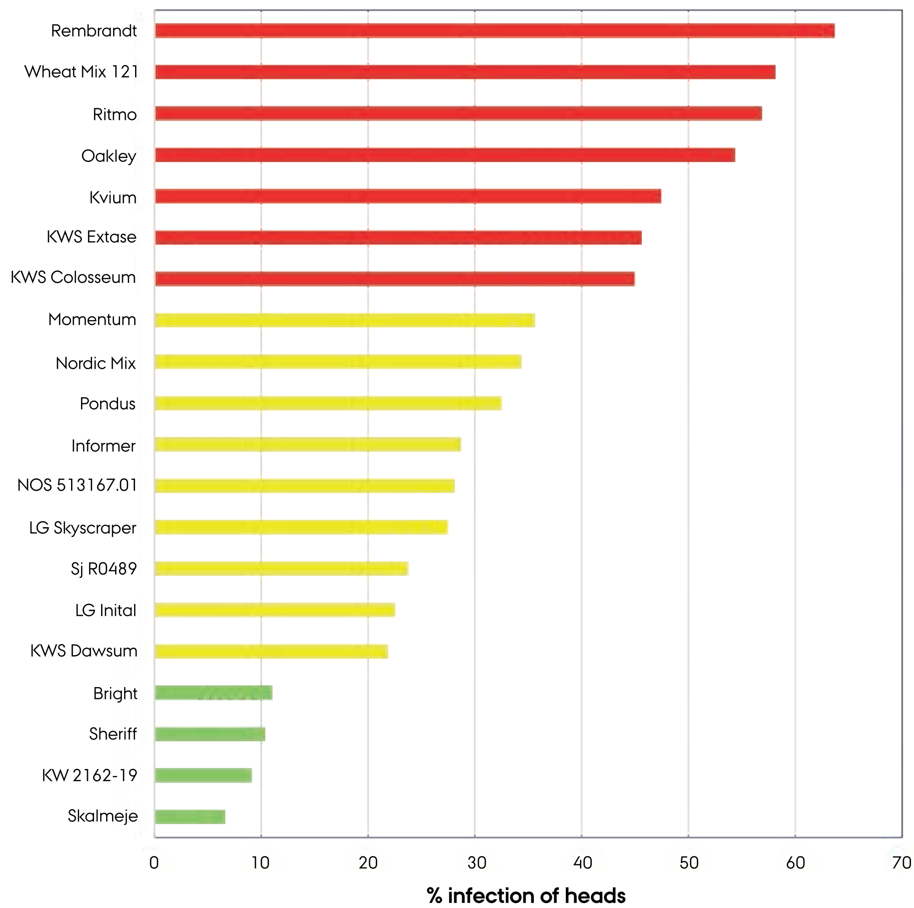


Figure 21. Per cent infection of heads with Fusarium head blight in cultivars in July 2022. Average of both trials.

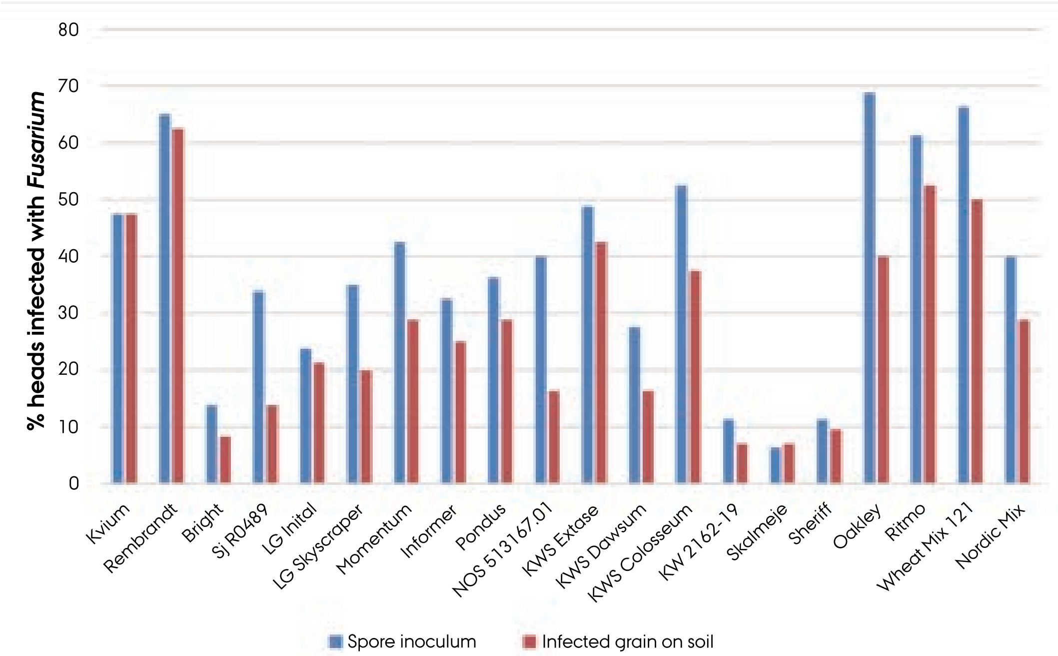


Figure 22. Per cent attack of Fusarium head blight in different cultivars tested in two wheat trials infected using different methods.

The small plots in both trials were hand-harvested, and grains were tested for the content of the mycotoxins using HPLC-MSMS. Five toxins were measured: deoxynivalenol (DON), nivalenol (NIV), zearalenone (ZEA), HT-2 and T-2. The contents of HT-2 and T-2 were very low in the trials and therefore not included. All cultivars had DON levels much higher than the maximum acceptable limit of 1250 ppb. Taking the average attack and the average DON content for the individual cultivars, a relatively good correlation was found (R^2 = 0.62) (Figure 23). The content of the different mycotoxins also correlated between them as seen for DON, NIV and ZEA (Figure 24).

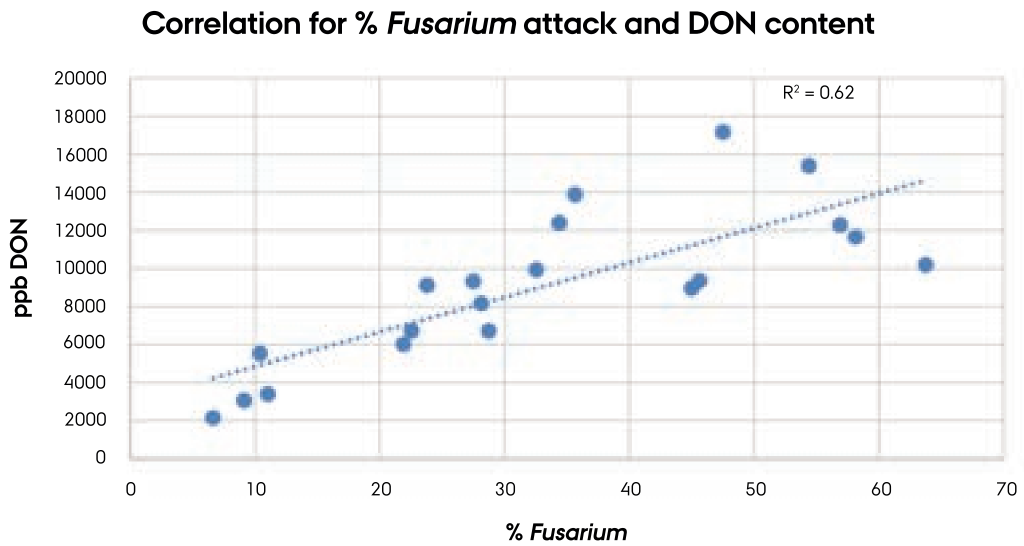


Figure 23. Correlation between % *Fusarium* attack and the DON content measured as ppb, using averages from the two trials.

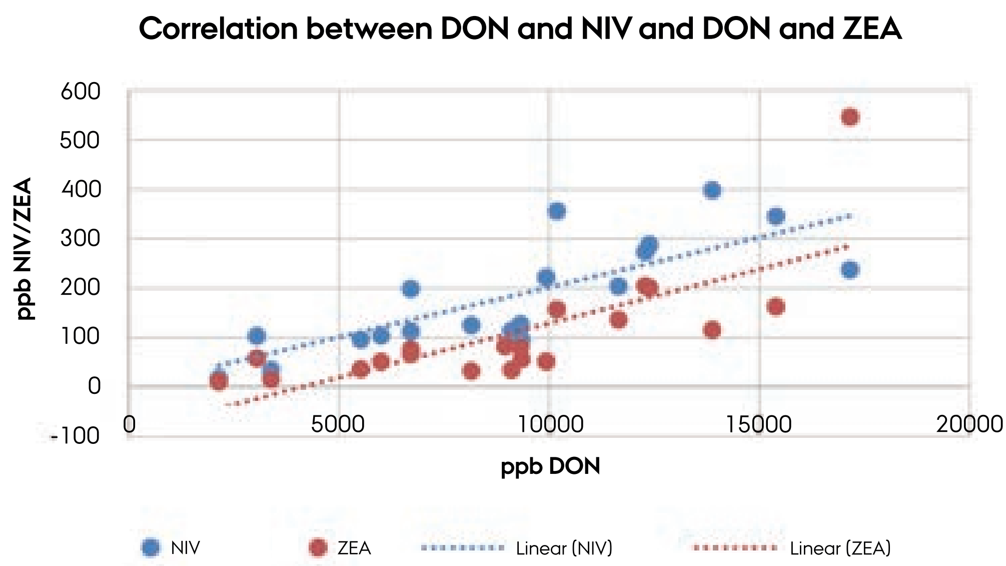


Figure 24. Correlation between DON content measured as ppb and the content of NIV and ZEA, using averages from the two trials.

Table 18. Data from the two trials with artificial inoculation of *Fusarium* in 20 wheat cultivars.

Cultivars	% *Fusarium*-infected ears		DON		NIV		ZEA	
	Spores 22301-1	Grain 22301-2	Spores 22301-1	Grain 22301-2	Spores 22301-1	Grain 22301-2	Spores 22301-1	Grain 22301-2
Kvium	48	48	11311	23009	145	329	850	242
Rembrandt	65	63	7715	12664	156	555	121	192
Bright	14	8	1224	5549	21	47	10	19
Sj R0489	34	14	4002	14211	72	155	19	49
LG Inital	24	21	3403	10015	79	145	10	123
LG Skyscraper	35	20	5916	12722	86	166	79	79
Momentum	43	29	5143	22622	225	570	118	112
Informer	33	25	3964	9455	200	196	87	65
Pondus	36	29	4080	15777	232	210	59	43
NOS 513167.01	40	16	2398	13902	48	201	18	46
KWS Extase	49	43	4776	13921	50	140	38	74
KWS Dawsum	28	16	2262	9745	78	129	33	69
KWS Colosseum	53	38	3616	14288	298	958	38	127
KW 2162-19	11	7	1336	4756	132	73	96	19
Skalmeje	6	7	586	3693	10	24	10	10
Sheriff	11	10	2224	8817	10	181	15	55
Oakley	69	40	6825	23975	248	442	114	210
Ritmo	61	53	9841	14733	313	232	333	76
Wheat Mix 121	66	50	9996	13302	144	262	214	57
Nordic Mix	40	29	4080	20688	91	483	17	384
LSD_{95}	15	11						

In Table 19 the ranking of cultivars to FHB susceptibility is summarised, including also data from previous years in the final ranking. The results from the trials were published in July together with SEGES in order to make the data available for the cultivar choice in autumn 2022.

Table 19. Ranking of cultivar susceptibility to Fusarium head blight. 2022.

Moderately resistant	Moderately to highly susceptible	Very susceptible
Creator, Sheriff, Bright (reference cultivar: Skalmeje)	Graham, Heerup, Informer, Kvium, KWS Extase, KWS Colosseum, KWS Dawsum, LG Skyscraper, LG Initial, Momentum, Pondus	Rembrandt, KWS Firefly, KWS Scimitar, Champion, RGT Saki (reference cultivars: Oakley, Ritmo)

Fusarium in wheat.

III Disease control in barley, rye and triticale

Lise Nistrup Jørgensen, Niels Matzen, Hans-Peter Madsen, Helene Saltoft Kristjansen, Sidsel Stein Kirkegaard, Sofie Rosengaard Nørholm, Christian Appel Schjeldahl Nielsen & Anders Almskou-Dahlgaard

In four trials in spring barley, different fungicide solutions using typically ½ approved rates were compared for control of specific diseases in 2022. Results from the four trials are shown in Table 1. The trials were carried out in the cultivars Chapeau, Fairway, RGT Planet and KWS Irina. All trials developed moderate attacks of net blotch (*Pyrenophora teres*) and brown rust (*Puccinia hordei*). As shown in Table 1, most of the tested solutions provided very similar and good control of the diseases. The effect on net blotch and brown rust is shown in Figure 1. Yield responses were significant but did with few exceptions not differ significantly between the different treatments (Table 1).

Three trials were also carried out in winter barley. These trials gave good opportunities for assessing efficacy on *Rhynchosporium* and brown rust. The winter barley trials were harvested and again no clear differences were recorded between the different treatments. Results are shown in Table 2.

Yield data from three seasons are summarised in Figure 2, showing net yield responses between 6 hkg/ha and 8.5 hkg/ha.

Table 1. Disease control, green leaf area (GLA), thousand grain weight (TGW) and yield responses, using different fungicides applied at half rates at GS 37 in spring barley. Four trials 2022 (22384).

Treatments, l/ha 22384		% net blotch		% brown rust	% GLA	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 37	Dose	GS 55-57 Leaf 2-3	GS 73-80 Leaf 2-3	GS 73-75 Leaf 2-3	All leaves			
1. Propulse SE 250 + Comet Pro	0.5 + 0.15	0.6	1.5	2.0	44.4	48.0	6.6	5.1
2. Propulse SE 250 + Comet Pro	0.25 + 0.3	0.6	2.1	1.6	36.6	47.4	8.1	6.8
3. Balaya + Propulse SE 250	0.5 + 0.25	1.2	2.7	2.0	43.4	47.4	7.5	5.6
4. Proline EC 250 + Pictor Active + Agropol	0.25 + 0.25 + 0.2	0.9	1.7	1.3	41.9	48.0	6.4	5.0
5. Propulse SE 250 + Pictor Active + Agropol	0.2 + 0.3 + 0.2	1.4	1.7	1.2	44.7	46.8	7.9	6.6
6. Balaya + Entargo	0.5 + 0.18	1.2	2.4	1.5	41.3	47.7	8.3	6.4
7. Kayak Era + Comet Pro	0.9 + 0.2	1.5	2.8	1.3	40.3	46.6	5.3	-
8. Untreated		6.8	25.0	7.5	25.6	45.4	84.1	-
No. of trials		3	3	3	4	4	4	4
LSD_{95}		1.0	2.6	1.2	6.7	1.6	2.2	-

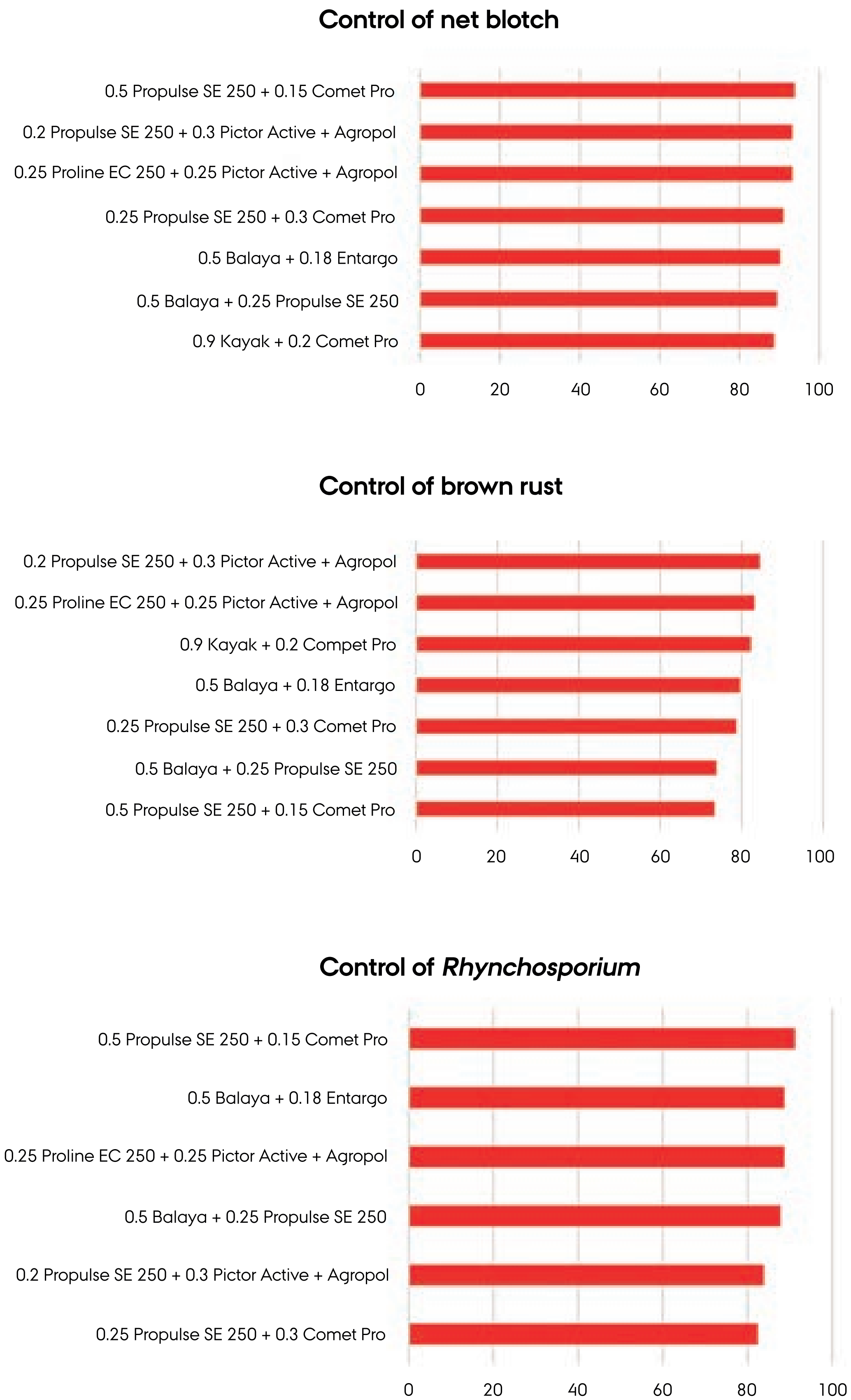


Figure 1. Per cent control of brown rust (three trials) and net blotch (four trials) in spring barley and *Rhynchosporium* (two trials) in winter barley. Leaves were assessed at GS 71-75. Attack in untreated of brown rust was 8%, net blotch 19% and *Rhynchosporium* 18%.

Table 2. Disease control, using different fungicides applied at half rates at GS 37 in winter barley. Three trials 2022 (22370).

Treatments, l/ha 22370		% *Rhynchosporium*	% rust	TGW g	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 37	Dose	GS 75 Leaf 2	GS 75 Leaf 2			
1. Propulse SE 250 + Comet Pro	0.5 + 0.15	0.9	0.2	52.4	8.8	7.3
2. Propulse SE 250 + Comet Pro	0.25 + 0.3	1.1	1.1	52.9	9.9	8.7
3. Balaya + Propulse SE 250	0.5 + 0.25	1.3	0.2	53.9	10.2	8.2
4. Proline EC + Pictor Active + Agropol	0.25 + 0.25 + 0.2	1.5	0.4	53.5	10.2	8.8
5. Propulse + Pictor Active + Agropol	0.2 + 0.3 + 0.2	1.7	0.2	52.2	8.3	7.0
6. Balaya + Entargo	0.5 + 0.18	1.1	0.3	53.0	9.9	8.0
7. Untreated		11.6	10.6	49.7	83.2	-
No. of trials		3	3	3	3	3
LSD_{95}		1.6	0.3	1.4	3.5	-

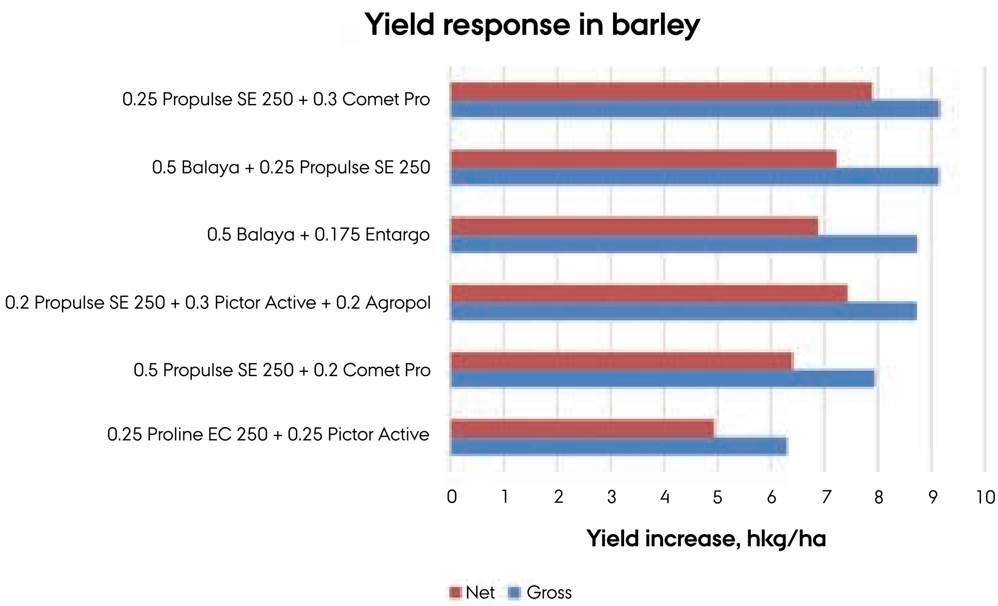


Figure 2. Yield response from fungicide treatments in seven trials carried out in spring barley 2021-22. LSD_{95} = 3.4 hkg/ha.

Control of Ramularia leaf spot (RLS) in the Eurobarley project

Ramularia leaf spot has adapted to several groups of fungicides in many regions in Western Europe, and future control is under pressure. The pathogen has been found to be highly diverse, and in many areas of Europe the control of this disease is challenged.

Ramularia leaf spot has already acquired resistance to strobilurins (QoIs), which originally had good efficacy against RLS in the past. Several mutations in the target genes of SDHIs have been detected in the population of *R. collo-cygni* (e.g. B-H266Y/R, B-T267I, B-I268V, C-N87S, C-H146R and C-H153R) with increasing frequencies since 2014. Additionally, azole-adapted isolates of *R. collo-cygni* have been found with high frequencies in several European countries.

In line with trials from 2021, specific trials with several different combinations of fungicides were also tested in 2022 when applied at GS 45-51. In the *Ramularia* trials 0.5 l/ha Comet Pro was applied during elongation to keep down attack of rust and other leaf blotch diseases.

The trial was part of the Eurobarley project where a similar trial plan was carried out in four countries. In 2022 the Danish trial did not develop any significant attack of Ramularia leaf spot and did therefore not provide good opportunities for ranking the efficacy of the products (Table 3; Figure 2). Due to significant development of brown rust in the Danish trial, significant yield benefits were still measured as a result of the good control levels achieved (Table 3).

However, trials from Ireland and Bavaria were also carried out, providing good efficacy data. Data from two seasons are shown in Table 4 and Figure 3. Solutions with Pavecto (BAS 831) and Revysol used as solo products or in combination with other actives provided very good control. Proline EC 250 provided only moderate levels of control in line with the effects achieved from Folpan 500 SC. The high level of control from the Pavecto solution (BAS 831) shows that although this product belongs to the strobilurins, the mode of activity is different and apparently has the ability to control strobe-resistant populations.

Yield increases from treatments applied for control of Ramularia leaf spot were summarised in Table 5. Data from six trials across Europe (Eurobarley) are shown. The Pavecto solutions gave the best yield responses, which nicely linked to the products also giving the best efficacy.

Table 3. Control of Ramularia leaf spot and yield responses, using different fungicides applied at GS 45-51 in spring barley (22386). Danish trial as part of the Eurobarley project.

Treatments, l/ha 22386		% rust	% rust	% GLA	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 45-51	Dose	GS 69 Leaf 3	GS 75 Leaf 2	GS 75 Leaf 2			
1. Untreated		5.3	22.5	17.5	45.4	81.9	-
2. Revysol	1.0	0.1	2.0	30.0	47.9	3.9	-
3. Revysol	1.5	0.0	1.0	32.5	46.4	9.0	-
4. Proline EC 250	0.54	0.0	2.3	31.3	48.2	5.2	3.7
5. Proline EC 250	0.8	0.0	0.8	31.3	46.4	7.1	5.0
6. Folpan 500 SC	1.5	3.0	15.0	20.0	46.1	2.7	1.2
7. Elatus Era	1.0	0.0	0.1	37.5	49.1	9.0	-
8. Ascra Xpro	1.2	0.0	0.4	43.8	49.7	11.1	-
9. Revytrex	1.5	0.0	0.0	47.5	49.1	15.5	-
10. Revystar XL	1.5	0.0	0.0	37.5	49.2	9.4	-
11. Balaya/Revycare	1.5	0.0	0.3	36.3	48.3	5.9	2.2
12. BAS 768 00F	4.0	1.9	9.5	31.3	48.3	5.9	-
13. BAS 831 00F	2.25	0.0	0.1	43.8	46.9	10.8	-
LSD_{95}		1.0	3.7	8.5	3.1	6.9	-

Table 4. Control of Ramularia leaf spot and other diseases, using different fungicides applied at GS 45-51 in spring barley. Efficacy data were ranked using a colour gradient for each individual trial; the ranking should therefore be read horizontally and not vertically. Green: highest rating. Yellow: medium rating. Orange: lowest rating.

Control (%), RAMUCC, leaf 2, 2021 and 2022, protocol 386				Untr.	Revysol		Proline EC 250		Folpan 500 SC	Elatus ERA	Ascra Xpro	Revy-trex	Revy-star XL	Balaya	Revysol + sulphur	Xemium + metyl-tetraprole
Year	Country	GS	DAA	-	1	1.5	0.54	0.8	1.5	1	1.2	1.5	1.5	1.5	4	2.25
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	UK-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. control, 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
Avg. control, 2022				75.2	55	68	30	30	32	52	52	60	63	65	42	83
Avg. control, 2021-2022				34.0	69	76	46	53	55	60	68	75	74	68	61	90

Table 5. Yield increases from trials where control of Ramularia leaf spot was the main target, using different fungicides applied at GS 45-51 in barley. Six trials across Europe (Eurobarley). Efficacy data were ranked using a colour gradient for each individual trial; the ranking should therefore be read horizontally and not vertically. Green: highest rating. Yellow: medium rating. Orange: lowest rating.

Y-incr. (hkg/ha), 2021, protocol 386		Untr.	Revysol		Proline EC 250		Folpan 500 SC	Elatus ERA	Ascra Xpro	Revy-trex	Revy-star XL	Balaya	Revysol + sulphur	Xemium + metyl-tetraprole	+Untr.	-Untr.
Trial	Country	-	1	1.5	0.54	0.8	1.5	1	1.2	1.5	1.5	1.5	4	2.25		
2021	DK	37.3	2.9	4.4	0.4	3.1	6.8	7.0	6.2	0.6	4.0	5.0	1.2	7.6	NS	NS
2021	IE	90.6	5.7	5.0	4.0	6.7	4.5	3.8	7.0	4.4	5.0	4.5	5.5	7.8	NS	NS
2021	UK-SCT	77.3	5.3	0.0	2.8	1.5	2.3	4.3	4.9	1.6	3.3	0.0	5.2	2.8	NS	NS
2021	DE	93.0	6.8	6.1	4.8	4.4	1.0	5.0	6.7	5.7	4.0	5.8	4.3	12.9	3.3	7.1
2022	IE	80.8	17.1	19.0	17.4	17.9	7.3	15.2	17.0	19.0	21.9	22.7	13.2	23.3	5.4	5.5
2022	DE	94.4	3.7	5.0	1.9	4.2	0.0	6.3	7.0	6.5	5.7	5.5	5.5	12.1	2.7	2.5
Avg. 2021		74.5	5.2	3.9	3.0	3.9	3.7	5.0	6.2	3.1	4.1	3.8	4.0	7.8	2.4	2.4
Avg. 2022		87.6	10.4	12.0	9.7	11.1	3.7	10.8	12.0	12.8	13.8	14.1	9.4	17.7	4.1	3.3
Avg. 2021-2022		78.9	6.9	6.6	5.2	6.3	3.7	6.9	8.1	6.3	7.3	7.3	5.8	11.1	3.3	2.3

The cultivar KWS Irina developed a significant attack of Ramularia leaf spot late in the season, which gave good opportunities for differentiating the efficacy of the products.

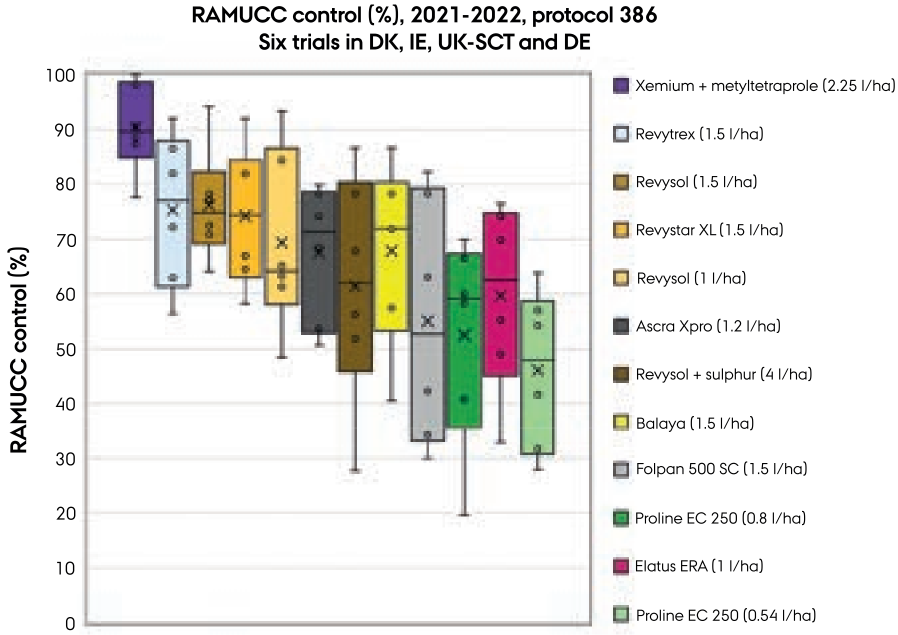


Figure 3. Control of *Ramularia* based on six trials from two seasons originating from Denmark, Germany, Ireland and Scotland. "X" indicates mean value.

Control of net blotch and rust in barley (Eurobarley)

The attack of net blotch was significant in only few trials. Also, against net blotch a wide range of products was tested and provided a highly variable level of control. In the Danish trial, solutions based on BAS 831 00F (Pavecto solution), Priaxor, Revytrex and Ascra Xpro gave the best performances (Table 6). The results are summarised from two seasons in Table 7 and Table 8. All treatments apart from Proline EC 250 gave very high levels of control. Yield data are summarised in Table 9, showing average yield responses between 5.9 hkg/ha and 10 hkg/ha. Proline EC 250, Elatus Era and Comet Pro gave the overall smallest yield responses (Table 9).

Table 6. Control of brown rust, net blotch and Ramularia leaf spot in spring barley (21385 and 22385). Trial in the cultivar Chapeau as part of the Eurobarley project.

Treatments, l/ha 21385 and 22385		% brown rust	% net blotch	% *Ramularia*	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 37-49	Dose	GS 75- 79 Leaf 2	GS 73-75 Leaf 2	GS 75-79 Leaf 2			
1. Untreated		18.0	52.5	10.9	42.1	55.1	-
2. Revytrex	1.5	2.5	0.8	0.5	47.4	12.7	-
3. Revytrex + Comet Pro	1.5 + 0.5	3.7	1.0	0.7	45.6	9.9	-
4. Revystar XL + Comet Pro	1.5 + 0.75	2.6	1.0	0.5	46.9	8.9	-
5. Proline EC 250	0.8	7.3	18.1	4.4	43.7	4.3	1.7
6. Elatus ERA	1.0	0.5	3.3	2.9	47.8	9.6	-
7. Aviator Xpro	1.0	4.1	2.1	3.0	46.6	8.5	-
8. Ascra Xpro	1.2	3.3	1.0	3.0	46.5	11.0	-
9. Fandango S	1.75	1.6	11.9	5.8	46.8	10.2	-
10. Madison	1.0	1.6	5.8	4.3	47.2	9.8	-
11. Balaya	1.5	3.5	3.0	1.3	47.0	8.4	3.0
12. Priaxor	1.5	2.3	1.0	1.6	47.7	12.2	-
13. BAS 831 00F	2.25	1.6	1.0	1.3	46.7	13.0	-
14. Comet Pro	0.75	5.4	7.3	6.8	45.3	8.4	6.5
LSD_{95}		2.0	2.6	1.0	-	-	-

Table 7. Control of net blotch, using different fungicides applied at GS 45-51 in spring barley. Efficacy data originating from Denmark and Finland were ranked using a colour gradient for each individual trial; the ranking should therefore be read horizontally and not vertically. Green: highest rating. Yellow: medium rating. Orange: lowest rating.

Control (%), PYRNTE, leaf 2, 2021-2022, protocol 385				1 Untr.	2 Revy-trex	3 Revy-trex + Comet Pro	4 Revy-star XL + Comet Pro	5 Pro-line EC 250	6 Elatus ERA	7 Aviator Xpro	8 Ascra Xpro	9 Fan-dango S	10 Madi-son	11 Balaya	12 Priaxor	13 Xemium + metyl-tetraprole	14 Comet Pro
Trial	Ctry.	GS	DAA	-	1.5	1.5 + 0.5	1.5 + 0.75	0.8	1	1	1.2	1.75	1	1.5	1.5	2.25	0.75
21385-1	DK	79	34	50.0	98	97	97	81	91	94	97	81	89	91	96	98	87
22385-1	DK	57	19	55.0	99	99	99	51	96	98	99	74	89	97	100	98	85
22385-2	FI	87	41	43.8	93	97	95	66	83	90	95	88	88	79	95	94	73
Average control (%), 2022				31.5	97.8	97.8	97.2	61.6	87.0	93.3	96.4	82.4	88.8	89.0	92.7	95.0	83.9
Average control (%), 2021-2022				39.2	96.7	97.4	96.7	67.5	87.2	92.7	96.1	83.4	88.7	87.1	94.3	95.5	82.1

Table 8. Control of brown rust, using different fungicides applied at GS 45-51 in spring barley. Efficacy data originating from Denmark, Belgium and the UK were ranked using a colour gradient for each individual trial; the ranking should therefore be read horizontally and not vertically. Green: highest rating. Yellow: medium rating. Orange: lowest rating.

Control (%), PUCCHD, leaf 2, 2021-2022, protocol 385				1 Untr.	2 Revy-trex	3 Revy-trex + Comet Pro	4 Revy-star XL + Comet Pro	5 Proline EC 250	6 Elatus ERA	7 Aviator Xpro	8 Ascra Xpro	9 Fan-dango S	10 Madi-son	11 Ba-laya	12 Pria-xor	13 Xemium + metyl-tetraprole	14 Comet Pro
Trial	Ctry.	GS	DAA	-	1.5	1.5 + 0.5	1.5 + 0.75	0.8	1	1	1.2	1.75	1	1.5	1.5	2.25	0.75
21385-1	DK	79	34	30.0	84	77	83	58	97	74	78	91	90	81	86	90	67
21385-3	BE	83	43	11.8	99	99	100	98	100	100	100	98	99	97	99	100	98
22385-1	DK	75	35	6.0	96	93	97	67	97	93	98	93	95	81	97	98	88
22385-3	BE	83	38	76.9	93	93	92	89	94	92	91	91	90	85	91	94	24
22385-6	UK	75-80	43	5.3	99	100	95	48	100	100	52	100	52	48	95	94	95
Avg. control (%), 2021				20.9	91.6	87.9	91.7	78.3	98.7	87.0	89.2	94.5	94.6	89.1	92.4	95.0	82.5
Avg. control (%), 2022				29.4	96.2	95.3	94.3	67.8	97.1	94.8	80.5	94.9	79.1	71.1	94.1	95.1	68.8
Avg. control (%), 2021-2022				26.0	94.4	92.3	93.3	72.0	97.7	91.7	84.0	94.7	85.3	78.3	93.4	95.1	74.3

Table 9. Yield increases from trials where control of Ramularia leaf spot was the main target, using different fungicides applied at GS 45-51 in barley. Six trials across Europe (Eurobarley). Efficacy data were ranked using a colour gradient for each individual trial; the ranking should therefore be read horizontally and not vertically. Green: highest rating. Yellow: medium rating. Orange: lowest rating.

Y-incr. (hkg/ha), 2021-2022, protocol 385		1	2	3	4	5	6	7	8	9	10	11	12	13	14	LSD	LSD
		Untr.	Revy-trex	Revy-trex + Comet Pro	Revy-star XL + Comet Pro	Proline EC 250	Elatus ERA	Avia-tor Xpro	Ascra Xpro	Fan-dango S	Madi-son	Ba-laya	Priaxor	Xemium + metyl-tetraprole	Comet Pro		
Trial	Ctry.	-	1.5	1.5 + 0.5	1.5 + 0.75	0.8	1	1	1.2	1.75	1	1.5	1.5	2.25	0.75	+Untr.	-Untr.
21385-1	DK	29.5	9.0	7.4	6.7	3.7	9.3	5.5	9.3	8.9	10.1	7.1	8.4	11.7	7.5	5.3	NS
21385-2	UK	81.7	0.3	6.4	10.9	6.1	1.8	5.9	7.9	4.3	5.1	8.8	8.7	6.6	2.9	4.9	4.9
21385-3	BE	83.5	3.8	4.6	5.1	3.1	3.7	3.7	3.5	5.5	5.8	4.4	6.4	4.4	5.4	2.5	NS
22385-1	DK	80.7	16.5	12.4	11.1	4.8	9.9	11.4	12.7	11.5	9.5	9.7	15.9	14.2	9.3	6.2	5.9
22385-2	FI	65.8	7.2	5.7	5.8	6.7	5.4	8.1	9.3	7.4	8.5	6.1	8.2	5.9	5.3	4.5	NS
22385-3	BE	72.2	14.0	15.7	13.2	13.6	17.5	14.9	14.0	18.1	17.9	19.4	17.1	16.8	10.6	6.3	NS
22385-5	DE	105.8	5.2	4.4	7.0	3.1	5.3	7.0	10.0	7.0	5.8	4.4	7.6	11.7	2.0	NS	NS
Y-incr. (hkg/ha), 2021		64.9	4.4	6.1	7.6	4.3	4.9	5.0	6.9	6.2	7.0	6.8	7.8	7.6	5.3	3.0	3.0
Y-incr. (hkg/ha), 2022		81.1	10.7	9.6	9.3	7.1	9.5	10.4	11.5	11.0	10.4	9.9	12.2	12.2	6.8	2.9	2.6
Y-incr. (hkg/ha), 2021-2022		74.2	8.0	8.1	8.6	5.9	7.5	8.1	9.5	8.9	9.0	8.6	10.3	10.2	6.1		

Does morning or evening spraying perform best?

It is common practice to spray either early in the morning or in the evening due to lower wind speeds and more moderate temperatures. Very few data support that this practice provides a better control compared with applications in the middle of the day. A trial in the cultivar Skyway was carried out in 2022, applying morning, midday and evening applications at two different timings. Exact timings and climate data are shown in Table 10. A water volume of 200 l/ha was used for all treatments. None of the timings were applied at extreme warm temperatures, but the relative humidity was – as expected – higher in the morning and evening (Table 10). The trial tested the fungicide Propulse SE 250.

No clear differences from the different timings could be spotted for control of rust and net blotch (Table 11). The last of the two timings showed slightly less control of rust and net blotch compared with the first timing. Also with respect to yield responses no significant differences could be measured.

Table 10. Spraying conditions when treatments were applied on two dates, 1 and 10 June.

	Morning	Midday	Evening
GS 45-49. 1 June	Temp: 9.2°C; RH: 96% Cloud cover: 100%	Temp: 15°C; RH: 55% Cloud cover: 100%	Temp: 11.3°C; RH: 87% Cloud cover: 100%
GS 55. 10 June	Temp: 12.4°C; RH: 94% Cloud cover: 100%	Temp: 18.6°C; RH: 74% Cloud cover: 25%	Temp: 13.1°C; RH: 86% Cloud cover: 80%

Table 11. Effect of applications on control of *Septoria* and yield responses in spring barley. One trial (22380).

Treatments, l/ha 22380-1			% brown rust		% net blotch		% *Ramularia*	% GLA	Yield & yield increase hkg/ha	Net yield
GS 45-49 & 55		Dose	GS 69 Leaf 3	GS 75 Leaf 2-3	GS 69 Leaf 2-3	GS 75 Leaf 2-3	GS 75 Leaf 2	GS 75		
1. Untreated			5.8	31.3	5.3	8.8	5.0	6.3	87.4	-
8. Propulse SE 250	GS 45-49 Morning	0.75	0.1	2.0	0.2	0.6	1.0	30.0	5.2	3.5
9. Propulse SE 250	GS 45-49 Midday	0.75	0.0	2.0	0.2	0.6	1.0	35.0	10.0	8.3
10. Propulse SE 250	GS 45-49 Evening	0.75	0.0	1.5	0.2	0.6	1.0	27.5	9.4	7.7
11. Propulse SE 250	GS 55 Morning	0.75	0.8	3.3	1.6	0.6	0.8	28.8	8.5	6.9
12. Propulse SE 250	GS 55 Midday	0.75	0.6	4.0	1.3	1.3	1.0	42.5	7.6	5.9
13. Propulse SE 250	GS 55 Evening	0.75	0.5	1.8	1.5	0.6	0.8	27.5	5.8	4.2
LSD_{95}			0.6	3.5	1.2	1.4	0.4	12.0	8.9	-

Testing of alternative chemistry and biological control agents (BCA)

Currently a great deal of pressure is put on finding alternative low risk solutions to the current chemical fungicides. Many different alternative solutions are being discussed and in two trials we tested various solutions. Data from the trials are shown in Table 12. Two sulphur products were included (Thiopron and Vertipin), which both are liquid formulations which are currently not authorised as crop protection products in Denmark. The same is the case for Phosphonate, which was provided by BASF. One product is based on the bacterium strain *Bacillus amyloliquefaciens* QST 713, which is the active ingredient in Serenade ASO. Charge is known as a biostimulant based on chitosan. Finally, Bion (benzothidiazole) is known to provide induced systemic acquired resistance (SAR), and likewise Iodus (brown algae extract = lamarin) is known as a product stimulating the plants' own defence mechanisms.

The different solutions were compared to traditional chemical fungicides listed in treatments 2 and 3 as references. Treatments were applied once and followed by a later cover spray using Balaya. Most treatments provided a significant reduction in disease attack. It was difficult to separate performances, but generally both treatments 2 and 3 performed slightly better than the other alternative treatments regarding control of brown rust. The cover spray generally provided a high effect, which made it difficult to evaluate the effect of the first treatments with the alternative products.

Table 12. Effects on leaf diseases and yield responses, following one timing with different alternative products in spring barley and a common cover spray with Balaya. One trial in 2022 in KWS Irina (22382).

Treatments, l/ha 22322 (Treatments marked with * are kg/ha)		% rust			% GLA	TGW g	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 32	GS 51-55	GS 59 Leaf 2-3	GS 69 Leaf 3	GS 75 Leaf 2	GS 75 Leaf 1			
1. Untreated		1.6	5.3	30.0	17.5	46.2	95.7	-
2. Propulse SE 250 0.5	Balaya 0.5	0.2	0.1	0.3	63.8	49.3	8.8	6.1
3. Proline EC 250 0.4	Balaya 0.5	0.1	0.1	0.5	62.5	49.6	10.2	7.6
4. Thiopron 3.0	Balaya 0.5	0.4	0.5	2.3	43.8	48.9	6.0	-
5. Phosphonate 3.0	Balaya 0.5	0.5	0.5	1.8	40.0	50.4	8.9	-
6. Serenade ASO 4.0 + Silwet 0.1%	Balaya 0.5	0.2	0.6	1.6	52.5	48.5	8.2	4.5
7. Charge 5.0	Balaya 0.5	0.3	0.3	2.0	52.5	49.3	7.6	-
8. Phosphonate 3.0 + Thiopron 3.0	Balaya 0.5	0.5	0.7	1.4	51.3	48.6	5.9	-
9. Iodus 1.0	Balaya 0.5	0.4	0.4	1.3	50.0	48.6	10.7	-
10. Iodus 1.0 + Thiopron 3.0	Balaya 0.5	0.4	0.6	2.4	42.5	49.0	9.5	-
11. Vertipin 5.0	Balaya 0.5	0.3	0.4	1.4	47.5	49.1	7.1	-
12. Bion 0.06*	Balaya 0.5	0.9	1.1	1.4	46.3	49.2	7.6	-
LSD_{95}		0.7	1.1	1.3	19.1	1.4	4.6	-

Results from fungicide trials in rye and triticale

Two trials were carried out in 2022 – one in winter rye (KWS Tayo) and one in triticale (Neogen), testing different commonly used fungicides (22364).

The trial carried out in triticale (22364-1) was treated twice as the attack of yellow rust in the cultivar began very early and was driven by natural infection. The attack also spread to the ears. All treatments provided high levels of control. Also, glume blotch (*Stagonospora nodorum*) developed to some extent in the trial. The yield responses were large and significant and varied between 29 hkg/ha and 34 hkg/ha (Table 13). The different solutions gave very comparable levels of rust control and yield responses.

Table 13. Control of diseases in triticale, GLA and yield responses, using different fungicides applied at GS 32-33 and GS 51-55 (22364-1).

Treatments, l/ha 22364-1		% yellow rust			% GLA	TGW g	Yield & yield increase hkg	Net increase hkg
GS 32-33 & 51-55	Dose	GS 69 Leaf 2	GS 69 Ear	GS 80 Leaf 2	GS 80			
1. Prosaro EC 250 + Comet Pro	2 x (0.25 + 0.3)	0.03	0.0	2.5	55.0	48.2	27.8	25.4
2. Propulse SE 250 + Comet Pro	2 x (0.35 + 0.2)	0.03	0.0	3.0	55.0	48.1	34.4	31.7
3. Propulse SE 250 + Comet Pro	None / 0.35 + 0.2	0.0	0.0	1.0	60.0	46.6	29.1	27.8
4. Juventus 90 + Comet Pro	2 x (0.25 + 0.3)	0.0	0.0	1.0	70.0	47.2	29.5	27.0
5. Curbatur + Comet Pro	2 x (0.2 + 0.3)	0.0	0.0	3.5	45.0	47.7	33.9	31.1
6. Comet Pro	2 x 0.6	0.5	0.0	2.5	60.0	50.2	29.2	26.5
7. Untreated		33.8	11.3	50.0	22.5	43.8	103.6	-
LSD_{95}		7.0	2.7	1.0	12.1	2.8	5.5	-

The rye trial (22364-2) was treated twice. The trial developed mainly an attack of *Rhynchosporium* and only a very minor attack of brown rust. Data from two seasons are summarised in Table 14. The five different treatments provided significant and almost similarly good control of *Rhynchosporium*. The yields increased moderately and provided positive net yields.

Rust in triticale ears.

Rust on leaves of triticale.

Table 14. Control of *Rhynchosporium* in rye, GLA and yield responses, using different fungicides applied at GS 32 and GS 51-55 (22364-2 + 21364-2).

Treatments, l/ha 22364-2 + 21364-2		% *Rhynchosporium*		% rust	TGW g	Yield & yield increase hkg	Net Increase hkg/ha
GS 32 & 51-55	Dose	GS 65-69 Leaf 1	GS 73 Leaf 2	GS 73 Leaf 2			
1. Prosaro EC 250 + Comet Pro	2 x (0.25 + 0.3)	6.9	15.2	0.0	28.2	7.5	4.4
2. Propulse SE 250 + Comet Pro	2 x (0.35 + 0.2)	4.3	15.2	0.0	28.1	6.7	3.5
3. Propulse SE 250 + Comet Pro	None / 0.35 + 0.2	5.0	0.3	0.0	30.5	5.0	3.8
4. Juventus 90 + Comet Pro	2 x (0.25 + 0.3)	5.0	0.3	0.0	30.7	9.4	7.2
5. Curbatur + Comet Pro	2 x (0.2 + 0.3)	5.0	0.3	0.0	30.7	13.7	11.2
6. Comet Pro	2 x 0.6	5.3	18.3	0.0	29.9	11.4	8.1
7. Untreated		14.3	33.2	2.0	27.4	88.6	0
No. of trials		2	2	1	2	2	2
LSD_{95}		-	-	0.5	-	-	-

Ranking of cultivar susceptibility to ergot

In a project partly financed by the breeders, the Department of Agroecology, Aarhus University, Flakkebjerg, has investigated the susceptibility to ergot among the winter rye cultivars most commonly grown in Denmark. In this year's trials, 15 cultivars, sown in 1-m^2 plots, were tested in two replicates with buffer zones of triticale between all plots (21303). The trial was inoculated three times on 3, 6 and 9 June, respectively, using a spore solution of ergot prepared in the lab. Rye is most susceptible during flowering, and at the time of inoculation the degree of flowering was assessed to ensure that all cultivars were inoculated during flowering. Approximately 15 days after inoculation, the first symptoms of ergot were seen. The trial was assessed counting the number of ergots on 100 heads, which provides a ranking of the tested cultivars.

A major variation in level of infections were seen in the trial (Figure 4). Helltop and Stannos were the two cultivars, which had the most severe attack of ergots. Durinos and DHEK073 were the two most resistant cultivars, which are now known to have specific resistant genes. Cultivars from KWS which are based on pollen-plus systems showed a variable level of attack. KWS Jethro, KWS Tutor and KWS Inspirator had least attack, while KWS Tayo and KWS Berado had a higher level of attacked heads.

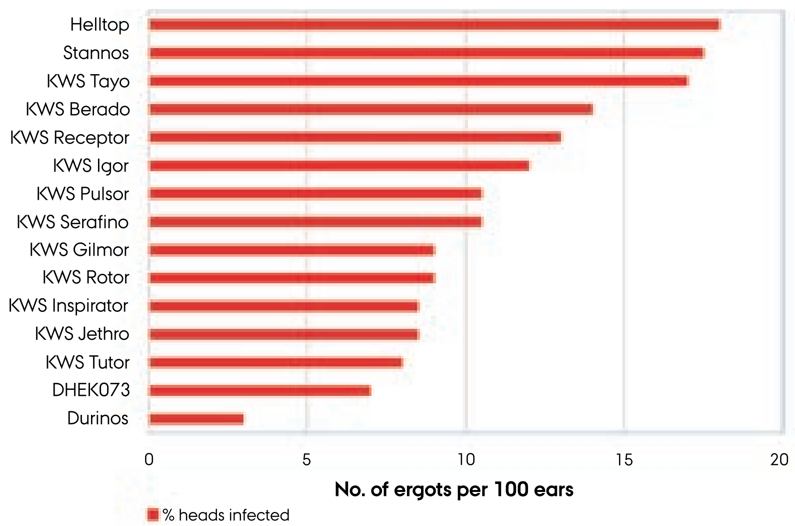


Figure 4. Number of ergots per 100 ears heads of rye inoculated with ergot during flowering (22303). LSD_{95} = 6.8.

IV Control strategies in different cereal cultivars

Lise Nistrup Jørgensen, Niels Matzen, Sidsel Stein Kirkegaard & Anders Almskou-Dahlgaard

Data from six wheat cultivars

Eight different control strategies were compared in six different wheat cultivars (5 solo cultivars and one mixture). The cultivars reflect some of the most commonly grown cultivars in Denmark. The cultivar mixture included three fairly resistant cultivars (Kvium, Informer and Pondus). One of the treatments included the use of the decision support system Crop Protection Online (CPO) to evaluate the need for treatments. The trials were placed at two sites – one at AU Flakkebjerg and one near Fredericia at Velas. At AU Flakkebjerg a treatment was also based on treating the crop when the qPCR method showed signs of *Septoria* DNA. The following strategies were tested:

1. Untreated
2. 1.25 l/ha Balaya (GS 40)
3. 0.75 l/ha Propulse SE 250 + 0.25 l/ha Proline Xpert (GS 40)
4. 0.75 l/ha Balaya / 0.75 l/ha Univoq (GS 37-39 / GS 55-61)
5. 0.5 l/ha Balaya / 0.5 l/ha Univoq (GS 37-39 / GS 55-61)
6. 0.33 l/ha Propulse SE 250 / 0.5 l/ha Balaya / 0.5 l/ha Univoq (GS 32 / GS 37-39 / GS 55-61)
7. Treatments according to qPCR; only relevant for AU Flakkebjerg
8. Treatments according to Crop Protection Online (Table 1)

The trials initially only developed low to moderate levels of *Septoria* attack. Only the cultivars Rembrandt and Chevignon had an attack earlier in the season. All treatments reduced the disease attack adequately. The exception was the treatments applied according to qPCR. DNA from *Zymoseptoria tritici* was not detected until late in the season, and as a result both per cent *Septoria* and yield responses were lower compared with other treatments.

Table 1. Treatments applied following recommendations from Crop Protection Online (CPO), treatment frequency index (TFI) and costs of treatments including cost of application (22350-1/2)

Cultivars (22350-1)	Date and GS	Products, l/ha	TFI	Costs, hkg/ha
Cultivar mixture (Kvium, Pondus, Informer)	03-06-2022 GS 53-55	0.5 Propulse SE 250 + 0.25 Orius Max	0.72	1.40
Rembrandt	20-05-2022 GS 37-39 15-06-2022 GS 65-69	0.5 Balaya 0.4 Propulse SE 250 + 0.15 Folicur Xpert	1.14	2.66
Kvium	20-05-2022 GS 37-39 15-06-2022 GS 65-69	0.5 Balaya 0.4 Propulse SE 250 + 0.15 Folicur Xpert	1.14	2.66
Pondus	03-06-2022 GS 53-55	0.5 Propulse SE 250 + 0.25 Orius Max	0.72	1.40
Informer	20-05-2022 GS 37-39 15-06-2022 GS 65-69	0.5 Balaya 0.4 Propulse SE 250 + 0.15 Folicur Xpert	1.14	2.66
Chevignon	20-05-2022 GS 37-39 15-06-2022 GS 65-69	0.6 Balaya 0.4 Propulse SE 250 + 0.15 Folicur Xpert	1.25	2.88

Cultivars (22350-2)	Date and GS	Products, l/ha	TFI	Costs, hkg/ha
Cultivar mixture (Kvium, Pondus, Informer)	14-06-2022	0.4 Propulse SE 250 + 0.15 Prosaro EC 250	0.62	1.32
Rembrandt	14-06-2022	0.5 Propulse SE 250 + 0.2 Prosaro EC 250	0.79	1.50
Kvium	14-06-2022	0.5 Propulse SE 250 + 0.2 Prosaro EC 250	0.79	1.50
Pondus	14-06-2022	0.4 Propulse SE 250 + 0.15 Prosaro EC 250	0.62	1.32
Informer	14-06-2022	0.5 Propulse SE 250 + 0.2 Prosaro EC 250	0.79	1.50
Chevignon	14-06-2022	0.5 Propulse SE 250 + 0.2 Prosaro EC 250	0.79	1.50

Control of *Septoria* from the different treatments is shown in Figure 1. Control strategies which included both two and three treatments provided the best control, while strategies using only one treatment and CPO provided slightly inferior control. Yield levels were generally high, and increases following fungicide applications were low to moderate (Figure 2; Table 2). All treatments in the six different cultivars gave relatively even levels of net responses. Only one of the two trials included treatments according to the use of a qPCR reading. In this trial leaf samples were taken at six timings; both top leaves and second leaves were sampled. The positive measurements of DNA of *Z. tritici* only occurred very late (Figure 3). This resulted in a late timing of the treatments, which again resulted in lower disease control and lower yield responses compared with for instance CPO, which recommended one to two treatments at an earlier timing (Figure 4).

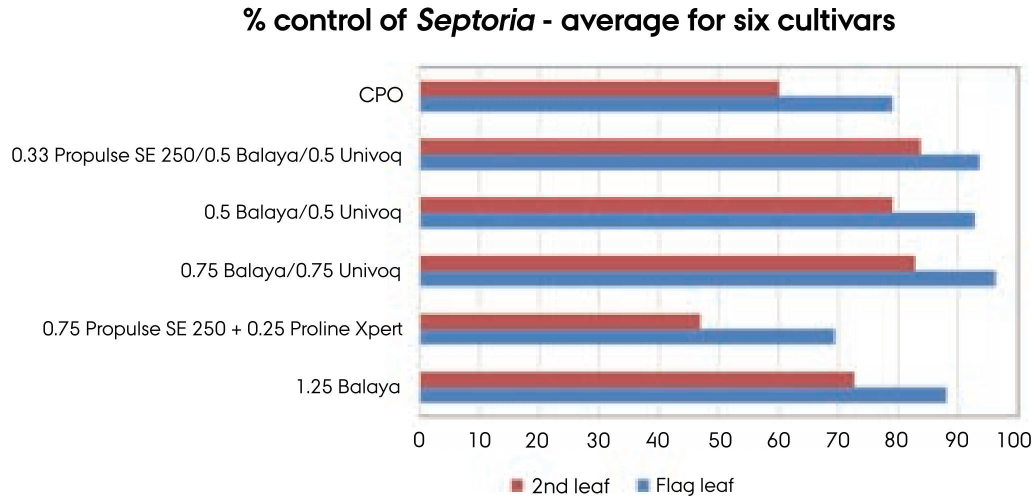


Figure 1. Attack of *Septoria* assessed on the flag leaf and second leaf at GS 75. All treatments reduced the attack. The level of attack varied very much between the cultivars. Average of two trials.

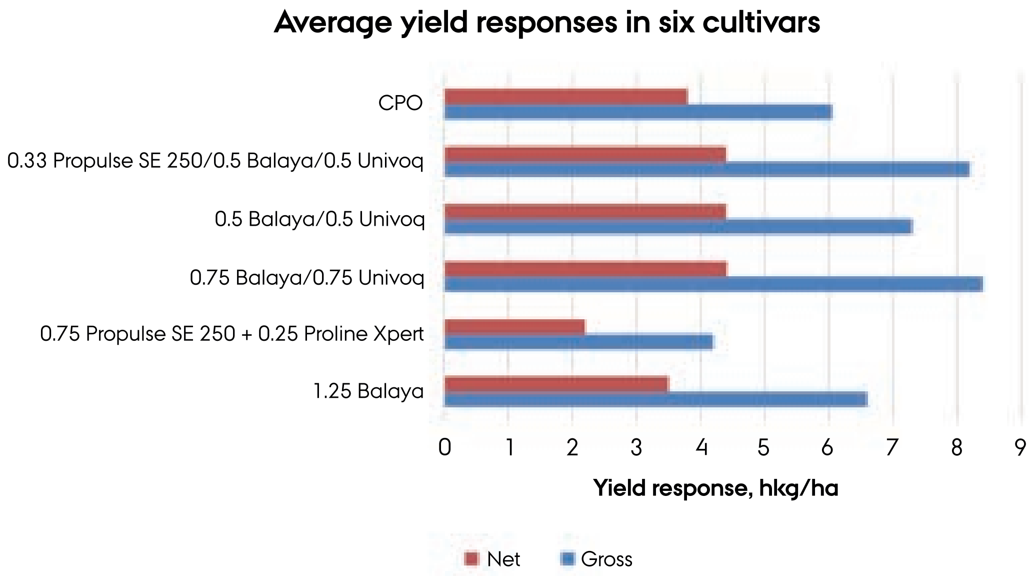


Figure 2. Gross yield and net yield following treatments with different treatments. Average of six different cultivars and two trials.

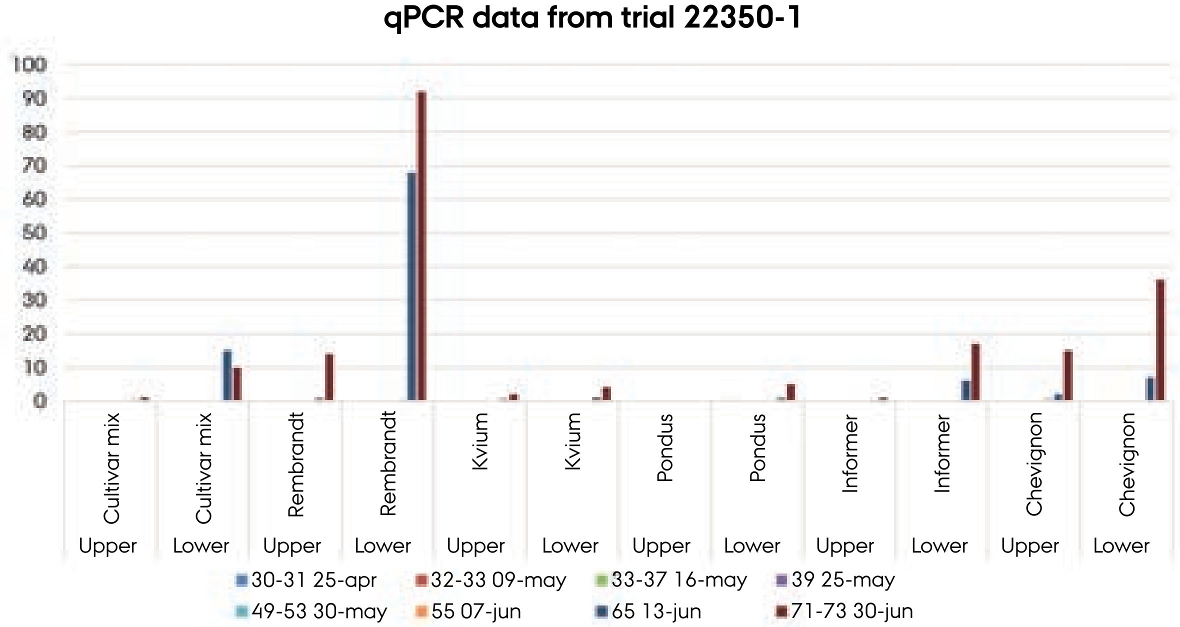


Figure 3. Results from a qPCR testing in trial 22350-1, based on leaf samples from eight sampling dates. The season had a late and minor *Septoria* attack in most cultivars. The qPCR method only gave positive readings from approx. 13 June in Rembrandt and Chevignon, while the more resistant cultivars were not treated until after a positive reading on 24 June.

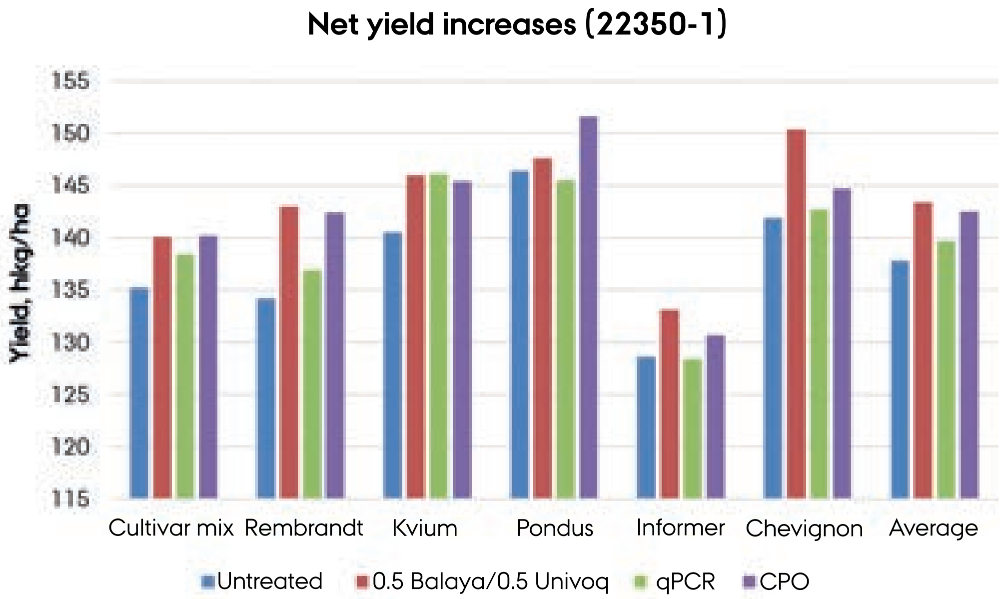


Figure 4. Net yield (hkg/ha) in the AU Flakkebjerg trial (22350-1), comparing four of the eight tested solutions.

Untreated Rembrandt.

Rembrandt treated with 0.5 l/ha Balaya followed by 0.5 l/ha Univoq.

Untreated Pondus.

Pondus treated with 0.5 l/ha Balaya followed by 0.5 l/ha Univoq.

Table 2. % *Septoria*, yellow rust, green leaf area (GLA) and yield responses. One trial at Velas in Jutland and one trial at AU Flakkebjerg with six winter wheat cultivars, using seven of eight different fungicide treatments (22350). (Continues on the next page).

Cultivars	% *Septoria*, leaf 2, GS 73-75							% *Septoria*, leaf 3, GS 73-75						
	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO
Cultivar mixture	1.9	0.1	0.6	0.1	0.0	0.1	0.4	7.2	3.0	4.0	1.7	2.3	2.3	4.2
Rembrandt	20.3	6.7	8.0	2.6	4.7	2.9	11.0	59.2	19.7	34.8	7.0	20.2	8.3	39.8
Kvium	2.8	0.4	0.9	0.1	0.7	0.2	0.8	8.8	3.8	5.8	2.0	2.7	2.3	5.0
Pondus	1.8	0.1	0.2	0.0	0.0	0.2	0.6	6.0	1.5	2.7	1.1	1.7	2.0	3.2
Informer	3.7	0.5	1.3	0.0	0.3	0.2	1.2	14.3	4.5	6.0	2.7	4.8	4.2	7.2
Chevignon	9.0	1.8	3.2	1.7	1.4	1.3	3.0	27.5	9.3	12.5	7.3	5.8	5.7	9.8
Average	6.6	1.6	2.4	0.8	1.2	0.8	2.8	20.5	7.0	11.0	3.6	6.3	4.1	11.5
No. of trials	2							2						

Cultivars	% *Septoria*, leaf 1, GS 77-83							% *Septoria*, leaf 2, GS 77-83						
	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO
Cultivar mixture	8.5	0.5	1.6	0.3	0.4	0.6	0.9	22.5	3.0	5.8	1.7	1.7	2.3	7.0
Rembrandt	44.2	4.7	15.8	0.9	2.8	1.5	13.3	81.7	23.7	41.7	20.0	20.3	12.8	41.2
Kvium	19.2	0.8	4.0	0.6	1.7	1.7	3.8	31.7	4.7	12.8	2.2	5.5	4.7	10.7
Pondus	9.0	0.7	3.2	0.1	0.8	0.3	1.1	18.3	2.9	11.3	1.3	2.7	1.7	5.0
Informer	8.5	1.0	2.8	0.6	0.7	0.6	0.8	28.3	6.3	17.8	3.7	5.2	5.0	5.7
Chevignon	67.5	11.0	20.8	3.3	5.2	5.3	12.8	83.3	32.5	51.7	17.3	20.3	17.3	36.7
Average	26.2	3.1	8.0	1.0	1.9	1.7	5.5	44.3	12.2	23.5	7.7	9.3	7.3	17.7
No. of trials	2							2						

Table 2. % *Septoria*, yellow rust, green leaf area (GLA) and yield responses. One trial at Velas in Jutland and one trial at AU Flakkebjerg with six winter wheat cultivars, using seven of eight different fungicide treatments (22350). (Continued).

Cultivars	% green leaf area, leaf 1, GS 77-83							% green leaf area, leaf 2, GS 77-83						
	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO
Cultivar mixture	87.3	94.0	94.3	94.0	95.3	94.3	93.3	69.2	85.3	82.0	86.0	89.0	86.0	80.7
Rembrandt	50.0	76.7	81.7	88.3	88.2	77.8	80.0	14.2	66.7	46.7	78.3	80.0	68.3	46.7
Kvium	75.7	87.5	88.8	95.8	93.2	89.2	88.0	55.0	85.0	77.0	89.5	87.0	86.7	75.0
Pondus	81.8	93.5	90.5	97.3	94.3	95.2	92.7	70.8	89.2	80.8	92.8	88.8	90.0	85.0
Informer	92.2	92.2	90.2	96.5	80.8	96.0	96.3	61.7	80.0	78.3	90.5	85.8	87.5	88.8
Chevignon	24.5	80.8	65.8	82.8	79.2	84.5	71.7	11.7	50.8	37.5	67.5	60.8	67.5	48.3
Average	68.6	87.5	85.2	92.5	88.5	89.5	87.0	47.1	76.2	67.1	84.1	81.9	81.0	70.8
No. of trials	2							2						

Cultivars	Yield & yield increase, hkg/ha							Net increase, hkg/ha					
	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO
Cultivar mixture	116.6	5.7	4.9	9.3	6.4	6.7	7.3	2.6	2.8	5.3	3.5	2.9	5.9
Rembrandt	113.7	10.4	5.7	10.4	12.5	9.7	8.1	7.3	3.6	6.4	9.6	5.9	6.0
Kvium	122.0	5.1	4.0	8.1	7.3	7.2	5.8	2.0	1.9	4.1	4.4	3.4	3.7
Pondus	124.7	7.7	3.4	10.8	5.2	6.9	7.2	4.6	1.3	6.8	2.3	3.1	5.8
Informer	109.4	3.5	3.8	4.4	6.6	7.8	3.2	0.4	1.7	0.4	3.7	4.0	1.1
Chevignon	117.6	6.5	3.7	6.7	6.2	10.4	4.0	3.4	1.6	2.7	3.3	6.6	1.8
Average	117.3	6.5 ab	4.3 a	8.3 b	7.4 ab	8.1 b	5.9	3.4	2.2	4.3	4.5	4.3	4.1
No. of trials	2							2					

Table 2. % *Septoria*, yellow rust, green leaf area (GLA) and yield responses. One trial at Velas in Jutland and one trial at AU Flakkebjerg with six winter wheat cultivars, using seven of eight different fungicide treatments (22350). (Continued).

Cultivars	TGW (g)						
	Untr.	1.25 Balaya	0.75 Propulse SE 250 + 0.25 Proline Xpert	0.75 Balaya / 0.75 Univoq	0.5 Balaya / 0.5 Univoq	0.33 Propulse SE 250 / 0.5 Balaya / 0.5 Univoq	CPO
Cultivar mixture	51.4	49.8	52.7	50.9	53.5	51.8	52.3
Rembrandt	49.4	51.1	50.9	51.3	51.4	50.6	49.7
Kvium	51.7	51.9	53.1	52.6	53.8	54.5	52.6
Pondus	49.6	52.7	51.4	53.0	52.4	52.2	51.8
Informer	54.3	55.9	55.0	53.9	54.3	53.7	55.6
Chevignon	49.3	48.9	49.2	51.2	50.8	52.7	49.6
Average	51.0	51.7	52.1	52.2	52.7	52.6	51.9
No. of trials	2						

Untr. = Untreated; 1.25 l/ha Balaya, GS 45-51 (costs = 3.1 hkg/ha); 0.75 l/ha Propulse SE 250 + 0.25 l/ha Proline Xpert, GS 40 (costs = 2.1 hkg/ha); 0.75 l/ha Balaya, GS 37-39 / 0.75 l/ha Univoq, GS 55-61 (costs = 4.0 hkg/ha); 0.5 l/ha Balaya, GS 37-39 / 0.5 l/ha Univoq, GS 55-61 (costs = 2.9 hkg/ha); 0.33 l/ha Propulse SE 250, GS 32 / 0.5 l/ha Balaya, GS 37-39 / 0.5 l/ha Univoq, GS 55-61 (costs = 3.8 hkg/ha); qPCR (costs = 0.7 hkg/ha); CPO = Crop Protection Online.

Control strategies in different winter barley cultivars

In four winter barley cultivars (three solo cultivars and one mixture of the three), five different control strategies including control and a decision support system (CPO) for crop protection were tested. The treatments given below were tested in one trial at AU Flakkebjerg.

1. Untreated
2. 0.25 l/ha Balaya + 0.1 l/ha Entargo / 0.5 l/ha Pictor Active + 0.25 l/ha Proline EC 250 (GS 32 / GS 51)
3. 0.5 l/ha Balaya + 0.2 l/ha Propulse SE 250 (GS 37-39)
4. 0.2 l/ha Proline EC 250 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro (GS 32 / GS 51)
5. Treatments according to Crop Protection Online (Table 3)

The cultivars Neptun, Bordeaux and Valerie and the cultivar mix developed attacks of *Rhynchosporium*, and all treatments reduced the attacks significantly, particularly when assessed at the later timing (Table 4). Only a minor attack of brown rust was seen in the trial, and all the standard treatments gave significant control of rust. All treatments had a good impact on the green leaf area. Only two (Bordeaux and Valerie) of the four cultivars were treated according to CPO. CPO did not perform very well in the trial and monitoring for risk assessments was not optimal, which resulted in insufficient control.

Both yield levels and increases in all cultivars were quite high and gave overall good net yield increases.

Table 3. Treatments applied following recommendations from Crop Protection Online, treatment frequency index (TFI) and cost of the treatments (22351-1).

Cultivars (22351-1)	Date and GS	Products, l/ha	TFI	Costs, hkg/ha
Neptun	-	-	-	-
Bordeaux	25-05-2022 GS 65	0.25 Propulse SE 250 + 0.25 Comet Pro	0.48	1.2
Valerie	25-05-2022 GS 65	0.25 Propulse SE 250 + 0.25 Comet Pro	0.48	1.2
Cultivar mix (Neptun, Bordeaux, Valerie)	-	-	-	-

Table 4. Control of diseases in winter barley and yield response (22351-1).

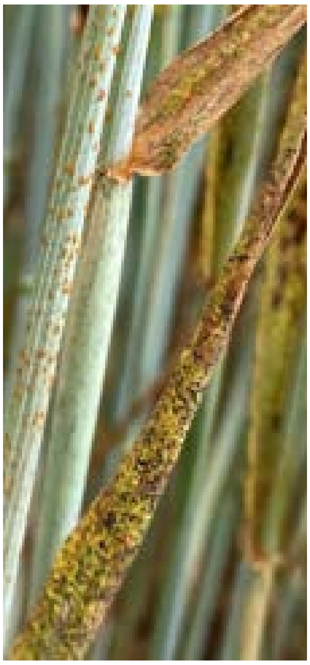
Cultivars	% *Rhynchosporium*, leaf 2, GS 69					% *Rhynchosporium*, leaf 2, GS 83				
	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.25 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.25 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Neptun	8.0	4.3	2.8	3.0	8.0	2.5	0.4	0.9	0.3	1.5
Bordeaux	4.3	1.2	1.6	1.5	3.0	2.7	0.6	3.7	3.0	3.3
Valerie	0.7	0.5	0.5	0.5	0.7	33.3	3.5	12.0	3.0	11.3
Cultivar mix	3.7	0.5	1.0	0.5	1.4	21.7	2.5	6.0	5.7	16.7
Average	4.2	1.6	1.5	1.4	3.3	15.1	1.8	5.7	3.0	8.2

Cultivars	% brown rust, leaf 2, GS 69					% GLA, leaf 2, GS 83				
	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.25 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.25 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Neptun	0.3	0.0	0.0	0.0	0.3	36.7	56.7	53.3	60.0	16.7
Bordeaux	0.4	0.1	0.2	0.1	0.4	8.3	30.0	33.3	33.3	31.7
Valerie	7.7	0.5	0.4	0.5	5.0	2.7	35.0	36.7	30.0	11.7
Cultivar mix	2.3	0.4	0.2	0.3	3.7	11.7	40.0	20.0	26.7	10.0
Average	2.7 a	0.3 b	0.2 b	0.2 b	2.4 a	14.9 a	40.4 b	35.8 b	37.5 b	17.5a

Table 4. Control of diseases in winter barley and yield response (22351-1). (Continued).

Cultivars	Yield & yield increase, hkg/ha					Net increase, hkg/ha			
	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.25 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.25 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Neptun	70.4	8.4	15.4	10.6	3.7	5.6	13.6	8.4	3.7
Bordeaux	79.8	16.8	19.3	15.1	8.9	14.0	17.5	12.9	7.7
Valerie	69.3	6.4	24.8	16.4	11.9	3.6	23.0	14.2	10.7
Cultivar mix	84.8	9.3	6.0	8.4	3.4	6.5	4.2	6.2	3.4
Average	76.1 b	10.2 ab	16.4 a	12.6 a	7.0 b	7.4	14.6	10.4	4.6

Untr. = Untreated; 0.25 l/ha Balaya + 0.1 l/ha Entargo, GS 32 / 0.5 l/ha Pictor Active + 0.25 l/ha Proline EC 250, GS 51 (costs = 2.85 hkg/ha); 0.5 l/ha Balaya + 0.2 l/ha Propulse SE 250, GS 37-39 (costs = 1.83 hkg/ha); 0.2 l/ha Proline EC 250, GS 32 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 51 (costs = 2.21 hkg/ha); CPO = Crop Protection Online.



Control of strategies in different spring barley cultivars

In four spring barley cultivars (three solo cultivars and one mixture of the three), different control strategies were tested. Three single cultivars were used as well as a mixture of the three cultivars. The trial was located at AU Flakkebjerg. The treatments given below were tested in the trial.

1. Untreated
2. 0.25 l/ha Balaya + 0.1 l/ha Entargo / 0.5 l/ha Pictor Active + 0.2 l/ha Proline EC 250 (GS 32 / GS 51)
3. 0.5 l/ha Balaya + 0.2 l/ha Propulse SE 250 (GS 37-39)
4. 0.2 l/ha Proline EC 250 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro (GS 32 / GS 51)

The trial developed only a moderate attack of net blotch. Regarding control of net blotch there was no significant difference between the fungicide treatments; this was also the case for the assessed green leaf area. The trial also included testing of the CPO models – but due to mistakes, the crops were not monitored closely enough during the season and no treatments were recommended.

When the untreated plots were compared, the cultivar mixture showed the highest yield and was superior to the individual cultivars (Table 5). When the cost of treatments with one or two fungicide applications was deducted, the yield in the cultivar Skyway and the cultivar mixture performed best (Figure 5). Thousand grain weight was measured in all plots, and the level increased significantly from all fungicide treatments.

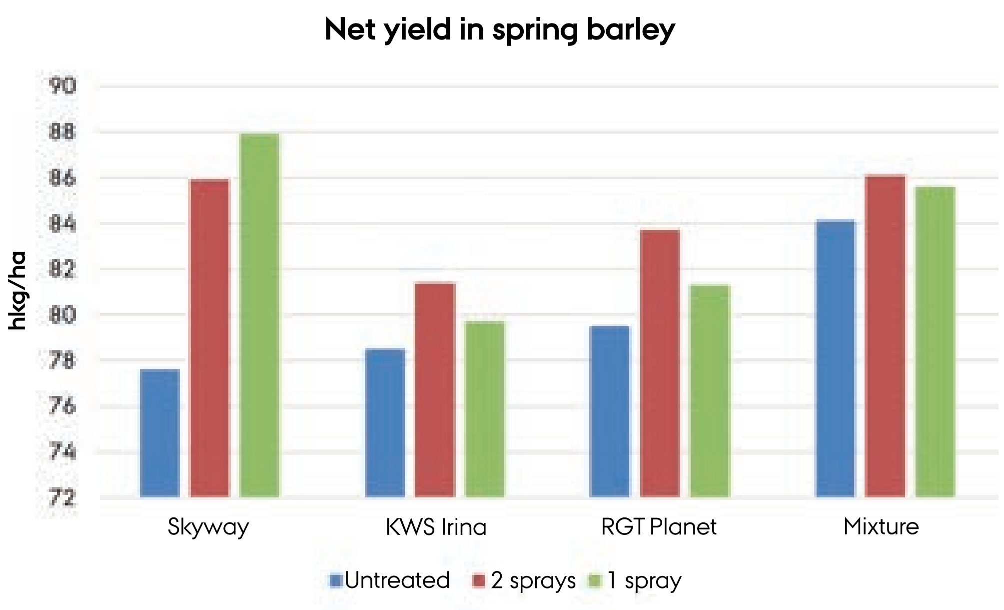


Figure 5. Net yield following one- or two-spray strategies in three cultivars plus the mixture of the three cultivars.

Table 5. Control of diseases in spring barley, green leaf area (GLA) and yield responses from one trial in four different spring barley cultivars, using four different strategies. Untr. = untreated. (22352-1).

Cultivars	% net blotch, leaf 2, GS 80			
	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.2 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro
Skyway	9.0	0.4	2.2	0.7
KWS Irina	6.0	0.1	0.2	0.3
RGT Planet	6.3	0.4	0.4	1.2
Cultivar mix (Skyway, KWS Irina, RGT Planet)	5.0	0.1	0.4	0.3
Average	6.6 a	0.3 b	0.8 b	0.6 b

Cultivars	% GLA, GS 80				TGW, g/1000			
	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.2 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.2 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro
Skyway	23.3	43.3	46.7	40.0	48.2	51.7	53.7	51.1
KWS Irina	23.3	40.0	30.0	40.0	47.6	51.5	50.2	49.9
RGT Planet	20.0	33.3	40.0	43.3	49.6	52.3	51.9	51.7
Cultivar mix (Skyway, KWS Irina, RGT Planet)	26.7	36.7	36.7	40.0	48.5	51.8	51.8	50.7
Average	23.3 a	38.3 b	38.4 b	40.8 b	48.5 a	51.8 b	51.9 b	50.9 b

Cultivars	Yield & yield increase, hkg/ha				Net increase, hkg/ha		
	Untr.	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.2 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	0.25 Balaya + 0.1 Entargo / 0.5 Pictor Active + 0.25 Proline EC 250	0.5 Balaya + 0.2 Propulse SE 250	0.2 Proline EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro
Skyway	77.6	11.1	12.1	12.1	8.3	10.3	9.9
KWS Irina	78.5	5.7	3.0	3.7	2.9	1.2	1.5
RGT Planet	79.5	7.0	3.6	5.1	4.2	1.8	2.9
Cultivar mix (Skyway, KWS Irina, RGT Planet)	84.1	4.8	3.3	5.2	2.0	1.5	3.0
Average	79.9 a	7.2 b	5.5 b	6.5 b	4.4	3.7	4.3
Untr. = Untreated; 0.25 l/ha Balaya + 0.1 l/ha Entargo, GS 32 / 0.5 l/ha Pictor Active + 0.2 l/ha Proline EC 250, GS 51 (costs = 2.85 hkg/ha); 0.5 l/ha Balaya + 0.2 l/ha Propulse SE 250, GS 37-39 (costs = 1.83 hkg/ha); 0.2 l/ha Proline EC 250, GS 32 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 51 (costs = 2.21 hkg/ha); CPO = Crop Protection Online.							

V Fungicide resistance-related investigations

Thies Marten Heick, Niels Matzen, Birgitte Boyer Frederiksen, Anja Maribo Larsen & Lise Nistrup Jørgensen

The development of fungicide resistance in Danish and Swedish *Z. tritici* populations is monitored each year in a collaboration between Aarhus University (AU), SEGES, local advisers and several agrochemical companies in Denmark and Jordbruksverket in Sweden. Leaf samples with clear symptoms of Septoria tritici blotch are collected around growth stages 73-77 and forwarded for analysis at AU, AGRO. The aim was to collect 10 isolates from each location, which was not always possible. Thus, the sensitivity to prothioconazole, which was tested in the form of the metabolites prothioconazole-desthio (PTH-D) and fluxapyroxad (FLX), was analysed for 176 isolates from 24 Danish locations and 225 isolates from 28 Swedish locations in 2022 (Tables 1 and 3). The disease pressure of Septoria tritici blotch was generally moderate.

The *Z. tritici* isolates were collected by scraping off six-day-old spores from individual pycnidia, which were transferred into Milli-Q water, and the spore suspensions were then homogenised and adjusted to a spore concentration of 2.4 x 10^4 spores/ml. The sensitivity testing was then carried out on microtitre plates with technical duplicates for each isolate. The isolates IPO323 and OP15.1 were used as references. The active ingredients prothioconazole-desthio and fluxapyroxad were dissolved in 80% ethanol. These fungicide stock solutions were mixed with 2 x potato dextrose broth (PDB). The PDB fungicide solutions were added to the microtitre plates with the final concentrations of (mg/l): 6.0, 2.0, 0.67, 0.22, 0.074, 0.025, 0.008 and 0 (prothioconazole-desthio) and 3.0, 1.0, 0.3, 0.1, 0.04, 0.01, 0.004 and 0 (fluxapyroxad). A total of 100 µl spore suspension and 100 µl PDB fungicide solution was added to the 96-deep well microtitre plates. The plates were then wrapped in tinfoil and incubated at 22°C for 6 days in a dark room. The plates were analysed using an ELISA reader at 620 nm. The fungicide sensitivity was found by determining the fungicide concentration, which inhibited *Z. tritici* growth by 50% (EC_{50}). This value was determined by a non-linear regression using Graphpad Prism (Version 9.5.0 (730), November 9, 2022). Resistance factors were calculated by dividing EC_{50} values of isolates with those of the sensitive reference IPO323, which were 0.01 for prothioconazole-desthio and 0.15 for fluxapyroxad.

The results presented here are a continuation of resistance monitoring for prothioconazole and fluxapyroxad, which has been carried out in Denmark since 2016 and 2018, respectively, and in Sweden since 2017 and 2018, respectively.

Results – Denmark

For prothioconazole-desthio, the average EC_{50} value was 0.30 ppm in Denmark in 2022, which is comparable to the sensitivity measured in previous years, 2021 (avg. 0.32 ppm) and 2020 (avg. 0.44 ppm) (Table 2; Figure 1). The resistance factor was 30 in 2022, which was also in line with previous years' findings of 32 in 2021 and 44 in 2020. However, the sensitivity varied widely among sites, with resistance factors ranging from 4 to 172. The findings suggest that the sensitivity of the Danish *Z. tritici* population overall has shifted but also stabilised at a reduced sensitivity level.

Similarly, the sensitivity of Danish *Z. tritici* to fluxapyroxad in 2022 (avg. 0.46 ppm) was in line with the findings of 2021 (avg. 0.44 ppm) and 2020 (avg. 0.36 ppm) (Table 2; Figure 2). This was also reflected by the resistance factor for fluxapyroxad, which was 3 in 2022 and 5 in 2021. The resistance factor remains low, which means that the Danish *Z. tritici* population remains sensitive to fluxapyroxad. However, the results also indicate a tendency to slightly decreasing sensitivity across the period.

In summary, the sensitivity of Danish *Z. tritici* population towards the two active ingredients did not shift substantially in 2022.

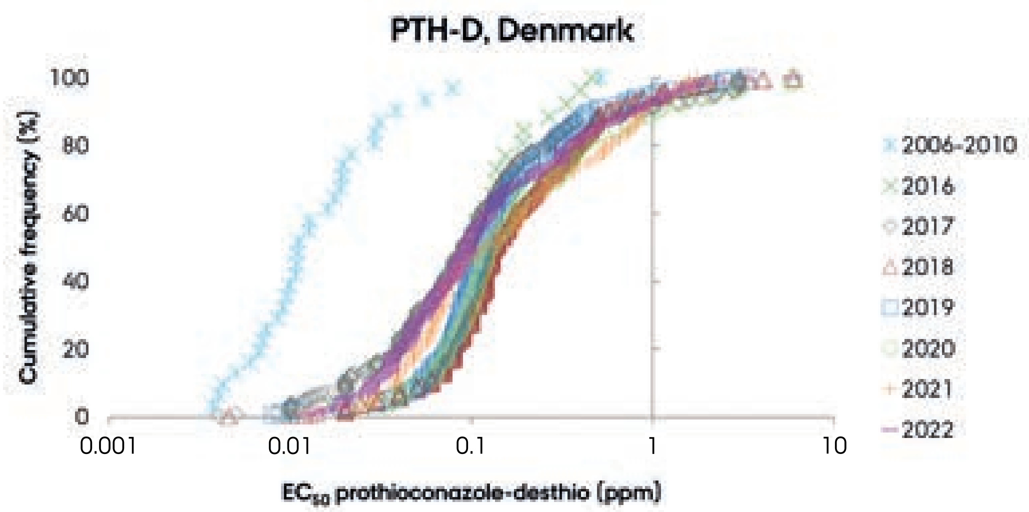


Figure 1. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Danish *Z. tritici* populations from 2016 to 2022. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

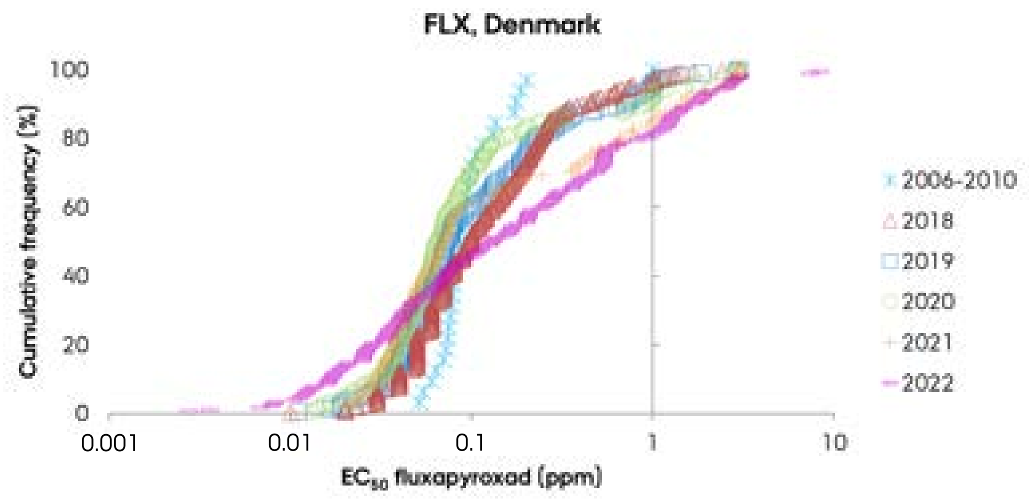


Figure 2. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Danish *Z. tritici* populations from 2016 to 2022. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

Table 1. Mean EC_{50} values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for 176 *Z. tritici* isolates from 24 Danish locations in 2022.

Location		EC_{50} (ppm)						Number of isolates
		PTH-D	RF	Range	FLX	RF	Range	
22-ZT-DK-01	Flakkebjerg, Slagelse	0.16	16	0.02-0.46	0.36	2	0.03-1.15	10
22-ZT-DK-02	Otterup	0.35	35	0.03-0.66	0.20	1	0.03-0.37	2
22-ZT-DK-05	Årslev, Aabenraa	0.16	16	0.04-0.72	0.71	5	0.02-2.70	10
22-ZT-DK-06	Blans, Sønderborg	0.38	38	0.05-1.59	0.61	4	0.02-1.92	9
22-ZT-DK-07	V. Sottrup, Sønderborg	0.32	32	0.02-1.32	0.77	5	0.01-2.30	7
22-ZT-DK-08	Haderslev	0.07	7	0.04-0.19	0.59	4	0.03-1.73	9
22-ZT-DK-09	Børkop	0.35	35	0.09-0.83	0.75	5	0.04-1.95	5
22-ZT-DK-10	Spøttrup, Skive	0.50	50	0.08-1.50	0.07	0	0.04-0.11	5
22-ZT-DK-11	Roslev, Skive	0.17	17	0.07-0.29	0.17	1	0.02-0.54	4
22-ZT-DK-12	Vester, Fyn	0.34	34	0.02-1.76	0.64	4	0.05-2.00	10
22-ZT-DK-13	Mørke, Fyn	0.15	15	0.06-0.31	0.30	2	0.02-1.90	10
22-ZT-DK-14	Gabøl, Vojens	0.24	24	0.04-0.63	1.40	9	0.13-2.70	7
22-ZT-DK-15	Lintrup, Vojens	0.56	56	0.04-2.42	0.69	5	0.10-1.85	6
22-ZT-DK-17	Holeby	0.19	19	0.07-0.39	0.97	7	0.27-3.00	6
22-ZT-DK-18	Lintrup, Vojens	0.77	77	0.09-1.88	0.16	1	0.03-0.41	3
22-ZT-DK-19	Vrå, Brønderslev	1.72	172	0.15-3.29	0.09	1	0.07-0.11	2
22-ZT-DK-20	Rønde	0.21	21	0.02-0.87	0.39	3	0.03-2.44	8
22-ZT-DK-22	Fløjstrup, Randers	0.29	29	0.03-1.07	0.57	4	0.06-1.87	10
22-ZT-DK-24	Storvorde	0.43	43	0.02-1.17	0.18	1	0.01-0.99	8
22-ZT-DK-25	Køge	1.22	122	0.01-5.88	0.31	2	0.00-1.80	6
22-ZT-DK-26	Slimminge, Ringsted	0.05	5	0.04-0.10	0.13	1	0.01-0.54	5
22-ZT-DK-27	Kongstedvej, Ringsted	0.15	15	0.02-0.81	0.20	1	0.01-0.64	10
22-ZT-DK-28	Årre	0.04	4	0.01-0.06	0.23	2	0.03-0.52	10
22-ZT-DK-29	Hjerm	0.17	17	0.02-1.15	0.23	2	0.01-1.22	9
22-ZT-DK-30	Fredericia	0.21	21	0.02-0.73	0.18	1	0.01-0.54	5

Table 2. Summary of mean EC_{50} (ppm) values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad assessed for *Z. tritici* in Denmark. The total number of isolates tested are given in brackets.

Year	Prothio-desthio	RF	Fluxapyroxad	RF
2016	0.13 (26)	17	-	-
2017	0.32 (263)	32	-	-
2018	0.33 (155)	35	0.26 (155)	2
2019	0.26 (209)	26	0.27 (209)	2
2020	0.44 (110)	44	0.36 (110)	3
2021	0.32 (127)	32	0.44 (127)	5
2022	0.30 (176)	30	0.46 (176)	3
Ref. IPO323	0.01	-	0.15	-

Results - Sweden

The average EC_{50} value was 0.11 for prothioconazole-desthio in Sweden in 2022, which is comparable to the previous years' findings in 2021 (0.14 pmm), 2020 (0.15 ppm), 2019 (0.17 ppm) and 2018 (0.35 ppm) (Table 4; Figure 3), but with indications of slightly increased sensitivity across the period. However, when comparing the current sensitivity with isolates from 2006 to 2010, it is still clear that a shift has taken place. The sensitivity of the Swedish *Z. tritici* populations was higher than the sensitivity of the Danish populations, and the resistance factor of 11 in 2022 for the Swedish populations compared to 30 for the Danish populations also illustrates this. Resistance factors varied from 1 to 49 in Sweden in 2022 (Table 3).

For fluxapyroxad, the average EC_{50} value was 0.20 in Sweden in 2022 (Table 4), which is comparable to the findings of previous years in 2021 (0.22 ppm), 2020 (0.14 ppm), 2019 (0.09 ppm) and 2018 (0.19 ppm) (Figure 4), but with indications of decreasing sensitivity across the period. As mentioned earlier, a similar pattern was observed in Denmark. Although the Danish *Z. tritici* populations remain sensitive to fluxapyroxad, the results also indicate that the sensitivity of the Swedish *Z. tritici* populations is higher, with resistance factors of 1-2 in Sweden compared with 2-5 in Denmark in 2018-2022.

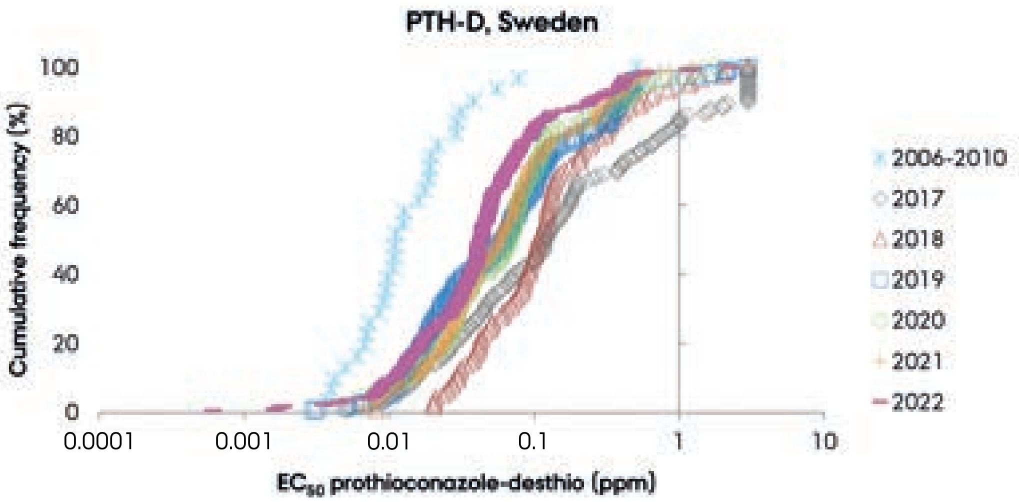


Figure 3. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Swedish *Z. tritici* populations from 2017 to 2022. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

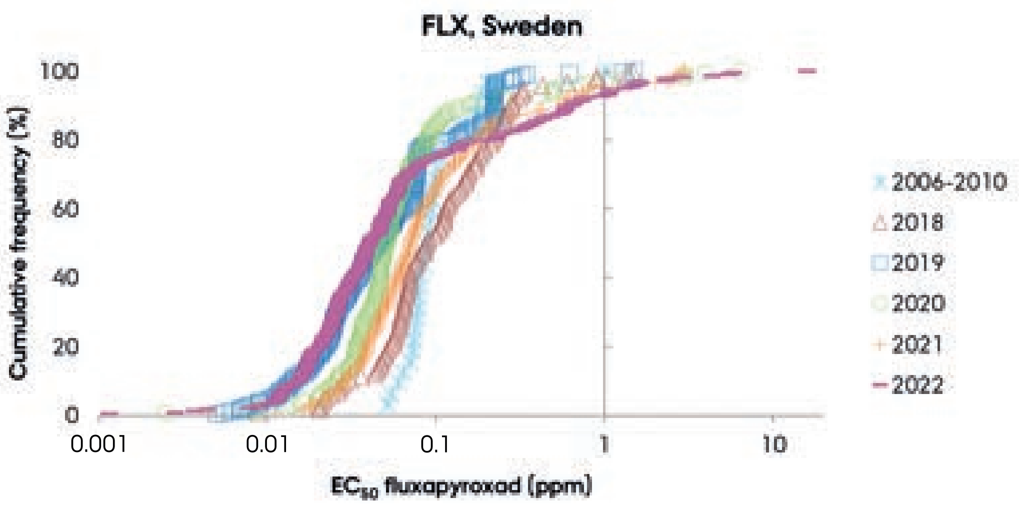


Figure 4. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Swedish *Z. tritici* populations from 2018 to 2022. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

Table 3. Mean EC_{50} values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for 225 *Z. tritici* isolates from 28 Swedish locations in 2022.

Location		EC_{50} (ppm)						Number of isolates
		PTH-D	RF	Range	FLX	RF	Range	
22-ZT-SW-02	Söderköping	0.036	4	0.008-0.066	0.02	0	0.01-0.04	5
22-ZT-SW-03	Äsköping	0.009	1	0.004-0.018	0.09	1	0.02-0.23	3
22-ZT-SW-04	Skällby	0.032	3	0.009-0.052	0.03	0	0.01-0.08	10
22-ZT-SW-05	Hagby, Borgholm	0.151	15	0.001-1.250	0.12	1	0.01-0.66	10
22-ZT-SW-06	Nyköping	0.159	16	0.009-0.483	0.11	1	0.01-0.59	7
22-ZT-SW-07	Sollebrunn	0.080	8	0.080-0.080	0.08	1	0.08-0.08	1
22-ZT-SW-08	Skofteby, Lidköping	0.041	4	0.002-0.095	0.09	1	0.01-0.31	10
22-ZT-SW-09	Fimmerstar, Töreboda	0.433	43	0.002-2.242	0.30	2	0.00-1.50	6
22-ZT-SW-10	Flakeberg, Grästorp	0.031	3	0.007-0.076	0.02	0	0.00-0.05	10
22-ZT-SW-11	Eliisgård, Vara	0.047	5	0.008-0.128	0.10	1	0.02-0.54	8
22-ZT-SW-12	Håberg, Grästorp	0.053	5	0.051-0.054	0.03	0	0.02-0.03	2
22-ZT-SW-13	Kyrkheddinge, Staffanstorp	0.231	23	0.041-1.167	0.21	1	0.02-0.79	10
22-ZT-SW-14	St Isie, Anderslöv	0.155	16	0.032-0.413	0.34	2	0.01-1.44	9
22-ZT-SW-15	Fröslöv Ystad	0.198	20	0.050-0.424	0.72	5	0.03-1.60	10
22-ZT-SW-16	Övedskloster, Sjöbo	0.246	25	0.060-0.432	0.36	2	0.09-0.64	2
22-ZT-SW-17	Haglösa, Trelleborg	0.495	49	0.034-3.500	0.18	1	0.02-0.97	10
22-ZT-SW-18	Borrby, Simrishamn	0.108	11	0.014-0.410	0.39	3	0.01-1.06	9
22-ZT-SW-19	Råbelöv, Kristianstad	0.074	7	0.005-0.263	0.77	5	0.04-2.90	10
22-ZT-SW-20	Klockrike	0.093	9	0.002-0.389	0.23	2	0.01-1.63	10
22-ZT-SW-21	Fjugesta	0.055	6	0.010-0.189	0.09	1	0.00-0.43	10
22-ZT-SW-22	Visby, Källunge	0.072	7	0.009-0.254	0.04	0	0.02-0.06	10
22-ZT-SW-23	Bålsta, Uppsala	0.029	3	0.008-0.094	0.05	0	0.04-0.06	6
22-ZT-SW-24	Uppsala	0.037	4	0.009-0.121	0.04	0	0.01-0.08	7
22-ZT-SW-26	Kavlas, Tidaholm	0.022	2	0.003-0.044	0.17	1	0.01-0.74	10
22-ZT-SW-27	Mörarp, Bjuv	0.060	6	0.017-0.083	0.05	0	0.00-0.15	10
22-ZT-SW-28	Råbelöv, Kristinastad	0.127	13	0.016-0.591	0.40	3	0.02-2.37	10
22-ZT-SW-29	Uppsala	0.020	2	0.008-0.046	0.13	1	0.02-1.06	10
22-ZT-SW-30	Hedemora	0.059	6	0.012-0.283	0.04	0	0.01-0.11	10

Table 4. Summary of mean EC_{50} (ppm) values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad assessed for *Z. tritici* in Sweden. The total numbers of isolates tested are given in brackets.

Year	Prothio-desthio	RF	Fluxapyroxad	RF
2017	0.58 (150)	71	-	-
2018	0.35 (127)	35	0.19 (127)	2
2019	0.17 (341)	17	0.09 (341)	1
2020	0.15 (157)	15	0.14 (157)	1
2021	0.14 (210)	14	0.22 (210)	2
2022	0.11 (225)	11	0.20 (225)	1
Ref. IPO323	0.01	-	0.15	-

Mutation occurrences based on leaf samples (Eurores)

During the spring and summer period in 2022, leaf samples with *Septoria* were collected in Denmark and Sweden. Samples were gathered at AU Flakkebjerg, and pieces of leaves with attack of *Septoria* were cut out and analysed for four specific *CYP51* and *Sdh* mutations by Walloon Agricultural Research Centre in Belgium with the aim of getting an overall view on the frequencies of mutations. The method described by Hellin et al. (2021) was used. The data from Sweden and Denmark are included below in Table 5 and Figures 5 and 6. The 18 Danish samples were picked in untreated plots, while the Swedish samples were primarily picked from fungicide-treated plots.

The CYP51 mutation S524T was found in 31% and 25% of the Danish and Swedish samples, respectively, indicating that this mutation today is common and widespread. Investigations from 2020 showed a similar level of occurrence based on single isolate-based testing (Vestergaard et al., 2023).

Regarding the three Sdh mutations (Table 5), the levels of particularly C-N86S have clearly increased. In 2020, the level of this mutation was still below 5% in both Sweden and Denmark. C-T79N was below 3% in Denmark and 1% in Sweden, while H152R was not previously detected (Vestergaard et al., 2023). Low findings of C-H152R were seen in 2022, but particularly one spring sample had a very high occurrence of this mutation (80%). This sample will be further investigated.

Table 5. Mutation frequencies in leaf samples with *Zymoseptoria tritici*. The CYP51 mutation S524T and 3 Sdh-C mutations occurred in leaf samples collected from Denmark and Sweden during 2022 and analysed using qPCR by Belgian colleagues.

Location	S524T		C-H152R		C-T79N		C-N86S		Number of sites
	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	
Denmark	31	6-80	5	0-80	4	0-12	28	0-76	18
Sweden	25	6-50	2	0-8	6	2-12	36	17-65	11

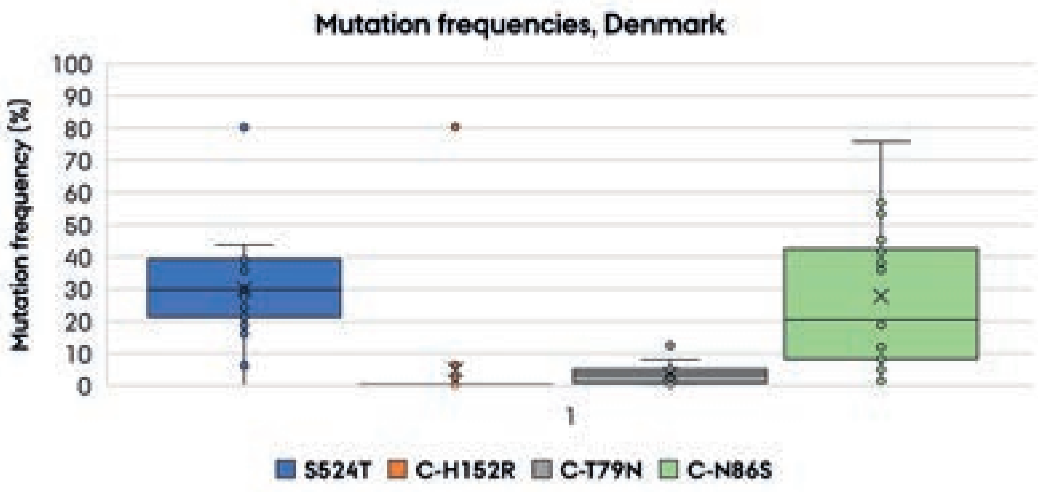


Figure 5. Mutation frequencies in Danish leaf samples attacked by *Z. tritici*. Based on leaf samples collected in 2022.

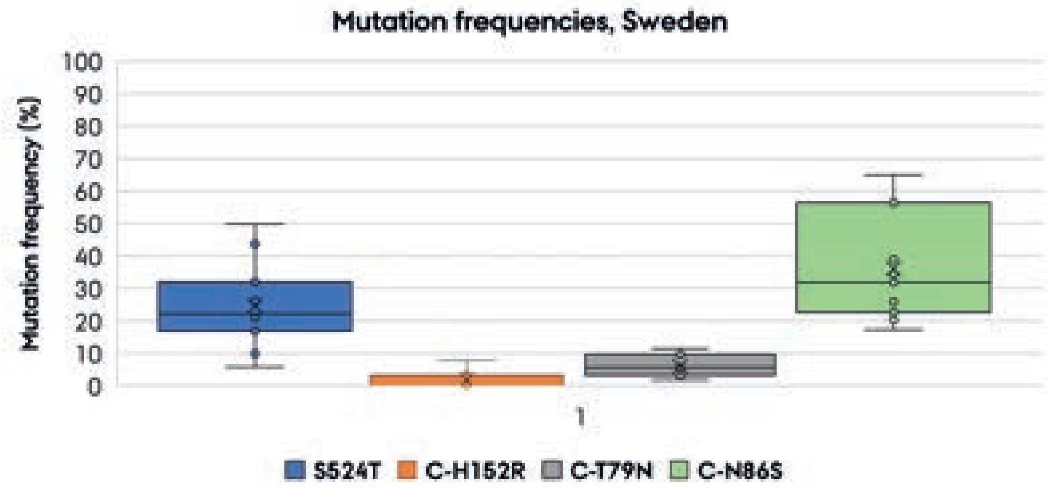


Figure 6. Mutation frequencies in Swedish leaf samples attacked by *Z. tritici*. Based on leaf samples collected in 2022.

Cross-resistance and sensitivity of mefentrifluconazole, tebuconazole and fluopyram

Two isolates were picked from each locality in Denmark and Sweden and tested for sensitivity to two further azoles and one more SDHI. These data are shown in Table 6 and show a steady level of resistance to these three actives.

Cross-resistance between mefentrifluconazole and tebuconazole is shown in Figure 7, and data for cross-resistance between mefentrifluconazole and prothioconazole-desthio are shown in Figure 8. A high correlation between mefentrifluconazole and tebuconazole has previously been shown by Heick et al. (2022) and others and is confirmed in this study. A poor correlation between mefentrifluconazole and prothioconazole-desthio has previously been shown and is also confirmed by data from 2022.

Table 6. Sensitivity to *Z. tritici* from two azoles and one SDHI carried out on a subset of isolates from the general testing in 2022. Data from 2022 are compared with data from 2021.

Location	Year	EC_{50}			Number of sites
		Fluopyram	Mefentrifluconazole	Tebuconazole	
Denmark	2021	-	0.30	4.92	20
	2022	2.15	0.44	8.57	23
Sweden	2021	-	0.07	1.54	26
	2022	1.73	0.06	3.01	28

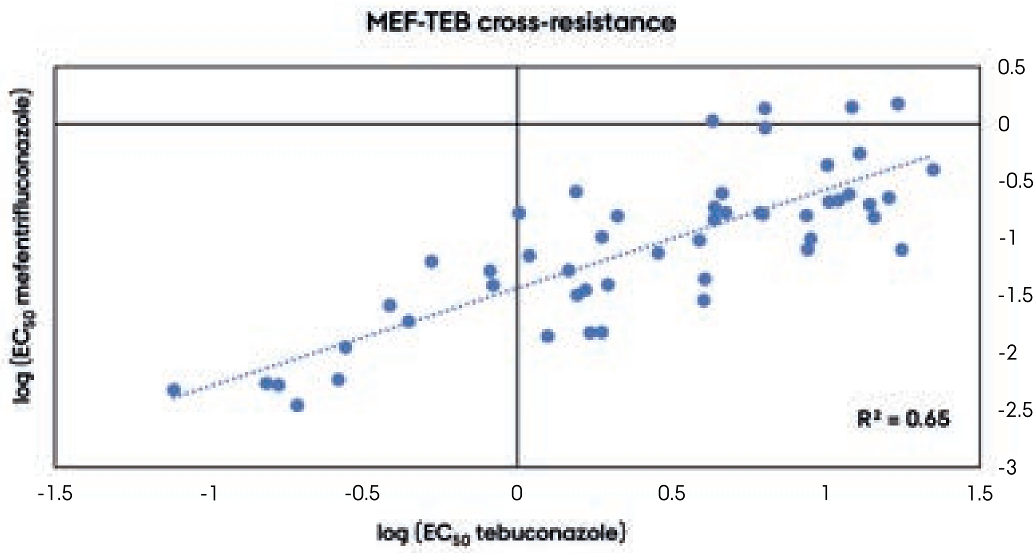


Figure 7. Cross-resistance analysis between mefentrifluconazole and tebuconazole, using *Z. tritici* isolates from Denmark and Sweden from 2022.

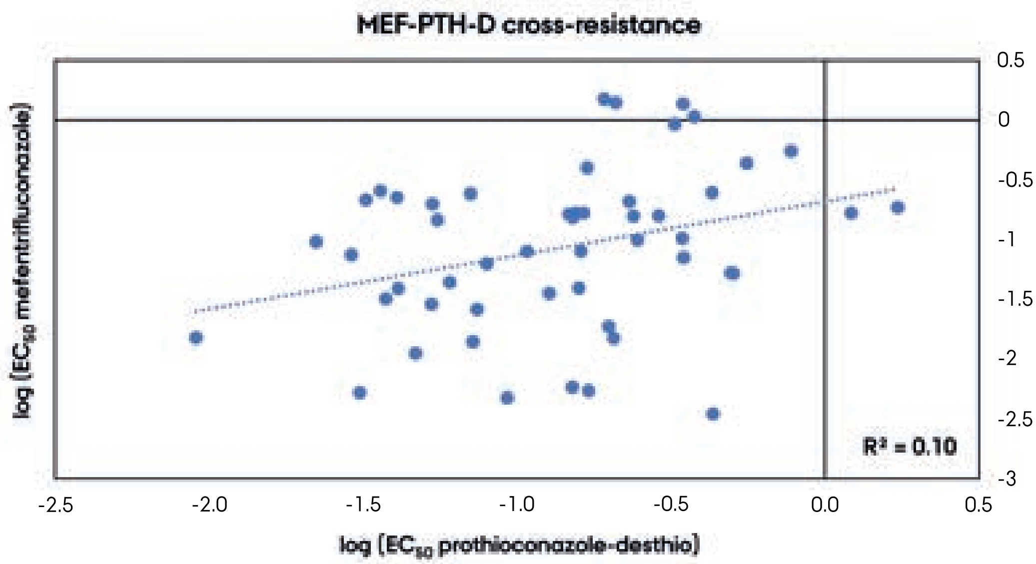


Figure 8. Cross-resistance analysis between mefentrifluconazole and prothioconazole-desthio using *Z. tritici* isolates from Denmark and Sweden from 2022.

Net blotch (*Pyrenophora teres*) resistance to strobilurin and SDHI fungicides

Strobilurin resistance

In 2022, nine Danish net blotch samples were investigated for the frequency of QoI resistance mutation F129L. The mutation F129L is known to be a mutation that only partly influences the field performances of strobilurins. The leaf samples originated from untreated plots in field trials. The investigation for F129L was carried out by BASF. The data from 2022 showed that the level of F129L in the population of *P. teres* remains high, which also is in accordance with information from other countries. Six samples from Sweden showed similarly high levels of F129L in the Swedish samples (Table 7).

Data from the last 14 years' monitoring are shown in Table 8. So far, the high level of F129L has not impacted the control from Comet Pro (pyraclostrobin). Amistar has been seen to be more influenced by F129L than Comet Pro.

SDHI mutations were also investigated by BASF. Significant levels of several mutations were found in some of the samples – particularly C-S135R and C-H134R were found which are known to impact EC_{50} values and efficacy most (Rehfus et al., 2016). EC_{50} assessed in the laboratory based on 209 Swedish isolates from 2022 and tested by AU Flakkebjerg showed a major shift and variation in sensitivity reflecting the occurrence of mutations in the population (Figure 9). Additionally, the sensitivity of the isolates to prothioconazole-desthio was also tested, and the results showed that the isolates remain sensitive at the same level as in 2018 (Figure 10).

Table 7. Mutation frequencies in leaf samples with net blotch (*Pyrenophora teres*). The SDHI mutation was detected from samples collected from Denmark and Sweden during 2022 and analysed using qPCR by BASF. Samples were also tested for B-H277Y, D-D124N/E and D-E178K, which were not found at any of the locations.

Location	F129L	C-H134R	C-S135R	C-G79R	C-N75S	D-H134R	D-D145G	D-E178K
Dybbøl/Sønderborg	99%	0%	81%	0%	0%	0%	0%	0%
Aalborg	100%	0%	66%	0%	0%	0%	0%	0%
Rønnede	97%	0%	0%	0%	0%	17%	0%	0%
Årslev/Aabenraa	100%	0%	0%	0%	0%	0%	0%	0%
Ringsted	99%	0%	74%	0%	0%	0%	0%	0%
Gørding	20%	26%	0%	0%	0%	0%	62%	0%
Sorø	98%	0%	68%	0%	25%	0%	0%	0%
Vojens	31%	0%	0%	0%	0%	0%	0%	0%
Slagelse	0%	0%	0%	0%	0%	0%	0%	0%
Sundbyholm	91%	0%	81%	0%	0%	0%	0%	0%
Håle Täng, Grästorp	49%	0%	0%	0%	0%	0%	0%	0%
Stora Mellösa	90%	0%	87%	0%	0%	0%	0%	0%
Lund,	84%	0%	33%	0%	0%	0%	0%	0%
Sandbygård, Borrby	45%	0%	56%	0%	0%	0%	0%	0%
Tierp, Uppsala	80%	46%	0%	17%	0%	16%	0%	0%

Table 8. Summing up results from the strobilurin resistance investigation; F129L incidence in the net blotch fungus (*Pyrenophora teres*) in Denmark.

Year	No. of samples	No. without F129L	No. with 1-20%	No. with >20-61%	No. with >60%	% samples with F129L
2008	20	9	5	3	3	55
2009	44	18	7	13	6	59
2010	16	5	3	7	1	69
2011	34	13	4	12	5	62
2012	19	14	1	2	2	24
2013	25	17	2	4	2	32
2014	20	13	2	3	2	35
2015	8	3	0	3	0	38
2016	20	9	3	8	0	55
2017	10	2	4	2	2	80
2019	12	1	5	3	3	92
2020	9	0	2	2	5	100
2021	2	0	0	2	0	100
2022	9	1	1	1	6	88

Fungicide resistance of *Pyrenophora teres* in Denmark and Sweden

The development of fungicide resistance in Danish and Swedish *P. teres* populations is monitored each year in a similar way as previously described for *Z. tritici.*

Thus, the sensitivity to prothioconazole, which was tested in the form of the metabolites prothioconazole-desthio (PTH-D) and fluxapyroxad (FLX), was analysed for 97 isolates from 10 Danish locations and 209 isolates from 21 Swedish locations in 2022 (Tables 9 and 11). The disease pressure of net blotch was generally moderate.

The *P. teres* isolates were transferred into Milli-Q water, and the spore suspensions were then homogenised and adjusted to a spore concentration of 4 x 10^3 spores/ml. The sensitivity testing was then carried out on microtitre plates with technical duplicates for each isolate. The isolates REF1803 and REF1804 were used as references. The active ingredients prothioconazole-desthio and fluxapyroxad were dissolved in 80% ethanol. These fungicide stock solutions were mixed with 2 x Yeast Bacto peptone Glycerol solution (YBG). The YBG fungicide solutions were added to the microtitre plates with the final concentrations of (mg/l): 5.0, 1.0, 0.2, 0.04, 0.008, 0.0016, 0.00032 and 0 (prothioconazole-desthio) and 10.0, 2.0, 0.4, 0.08, 0.016, 0.0032, 0.00064 and 0 (fluxapyroxad). A total of 50 µl spore solution and 50 µl YBG fungicide solution was added to the 96-deep well microtitre plates. The plates were then wrapped in tinfoil and incubated at 22°C for 5 days in a dark room. The plates were analysed using an ELISA reader at 405 nm. The fungicide sensitivity was found by determining the fungicide concentration, which inhibited *Z. tritici* growth by 50% (EC_{50}). This value was determined by a non-linear regression using Graphpad Prism (Version 9.5.0 (730), November 9, 2022).

The results presented here are a continuation of resistance monitoring for prothioconazole-desthio, which was carried out from 2016 to 2019 and in 2022, and fluxapyroxad, which was carried out in 2018, 2019 and 2022 in Denmark, while investigations in Sweden were carried out for prothioconazole-desthio in 2016, 2018 and 2022 and for fluxapyroxad in 2018 and 2022.

Results – Denmark

The average EC_{50} value for prothioconazole-desthio was 0.1 ppm in Denmark in 2022, which is comparable to the sensitivity measured in previous years, 2019 (avg. 0.1 ppm) and 2018 (avg. 0.09 ppm) (Table 10; Figure 9). The results indicate that the sensitivity of Danish *P. teres* populations has shifted slightly since 2018, but that it remains sensitive to prothioconazole-desthio.

A considerable drop in fluxapyroxad sensitivity of Danish *P. teres* was seen in 2022. The average EC_{50} value was 1.13 ppm in 2022, while EC_{50} values of 0.04 and 0.19 ppm were seen in 2018 and 2019, respectively (Table 10). Furthermore, the distribution of the EC_{50} values suggests that the population has split into two sub-populations with different sensitivity profiles (Figure 10).

In summary, the sensitivity of *P. teres* did not shift substantially towards prothioconazole-desthio in Denmark in 2022, while a considerable shift was seen in fluxapyroxad sensitivity.

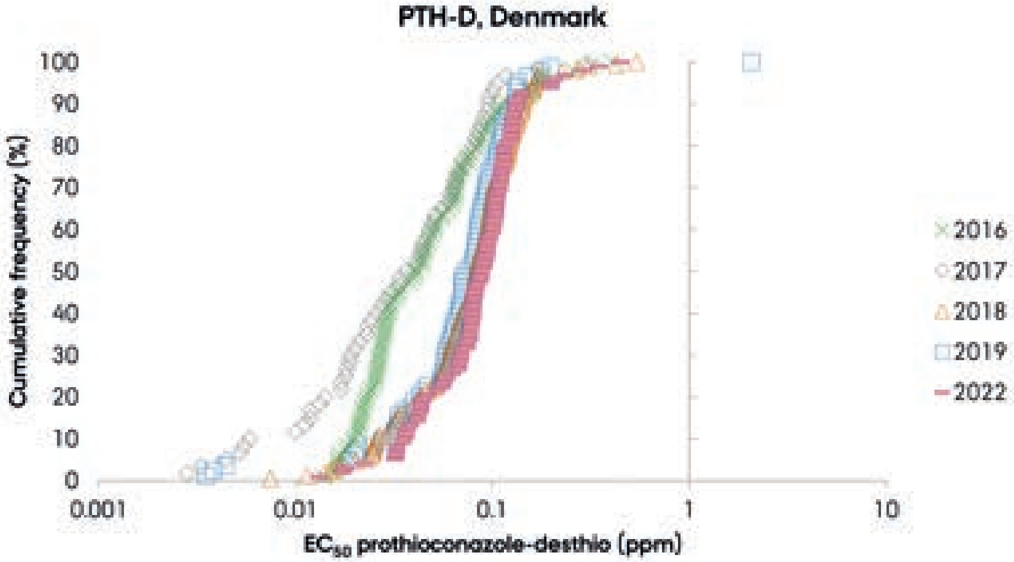


Figure 9. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Danish *P. teres* populations from 2016-2019 and 2022. Each data point represents one isolate.

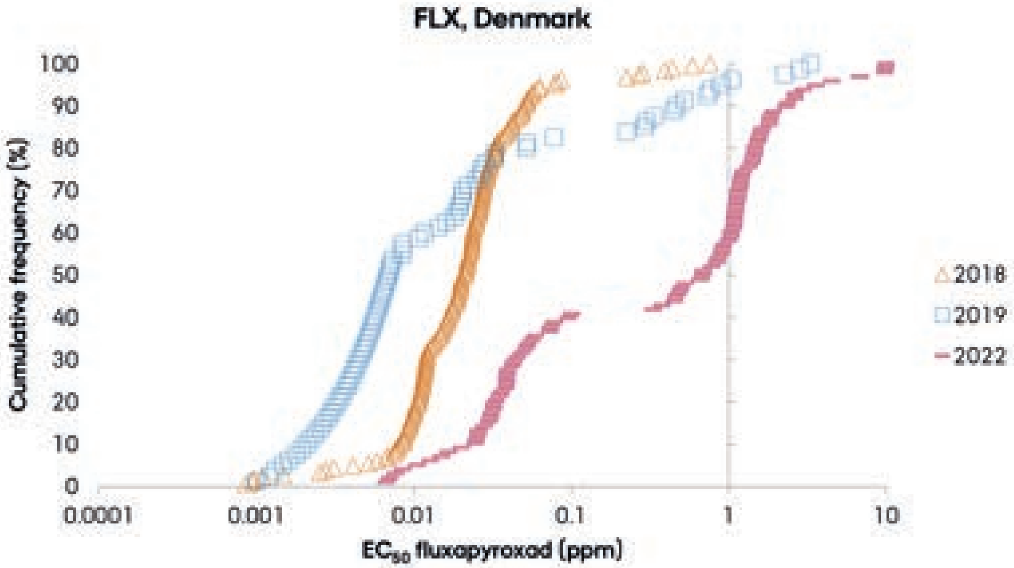


Figure 10. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Danish *P. teres* populations from 2018, 2019 and 2022. Each data point represents one isolate.

Table 9. Mean EC_{50} values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for 97 *P. teres* isolates from 10 Danish locations in 2022.

Location		EC_{50} (ppm)				Number of isolates
		PTH-D	Range	FLX	Range	
22-PT-DK-15	Gørding	0.09	0.04-0.23	1.10	0.00-7.33	10
22-PT-DK-12	Harlev	0.13	0.08-0.35	0.04	0.00-7.33	10
22-PT-DK-06	Hobro	0.09	0.07-0.11	0.94	0.00-7.33	10
22-PT-DK-03	Kolding	0.07	0.01-0.45	0.31	0.00-7.33	10
22-PT-DK-10	Ringsted	0.13	0.08-0.29	0.46	0.00-7.33	10
22-PT-DK-08	Rønde	0.11	0.08-0.14	1.13	0.00-7.33	10
22-PT-DK-05	Sorø	0.09	0.05-0.13	1.69	0.00-7.33	10
22-PT-DK-01	Sønderborg	0.07	0.03-0.20	3.08	0.00-7.33	10
22-PT-DK-18	Vojens	0.11	0.07-0.21	0.56	0.00-7.33	10
22-PT-DK-11	Viborg	0.05	0.04-0.07	1.09	0.00-7.33	7

Table 10. Summary of mean EC_{50} (ppm) values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad assessed for *P. teres* in Denmark. The total numbers of isolates tested are given in brackets.

Year	Prothio-desthio	Fluxapyroxad
2016	0.06 (97)	-
2017	0.05 (60)	-
2018	0.09 (175)	0.04 (184)
2019	0.10 (84)	0.19 (80)
2022	0.10 (97)	1.13 (97)
Average	0.08	0.37

Results - Sweden

For prothioconazole-desthio, the average EC_{50} value of in Sweden was at the same level in 2022 as in 2016-2018 (avg. 0.06 pmm) (Tables 11 and 12; Figure 11). The sensitivity of the Swedish *P. teres* populations was also at the same level as that of the Danish populations (Tables 10 and 12).

Similarly as for the Danish *P. teres* populations, a considerable shift has taken place in the sensitivity of the Swedish *P. teres* populations to fluxapyroxad. This is seen in the average EC_{50} value for fluxapyroxad, which has increased from 0.03 ppm in 2018 to 0.71 2022 (Table 12). Furthermore, the data indicate that the Swedish *P. teres* populations have divided into two sub-populations with different sensitivity profiles (Figure 12), which was similarly seen in Denmark (Figure 10).

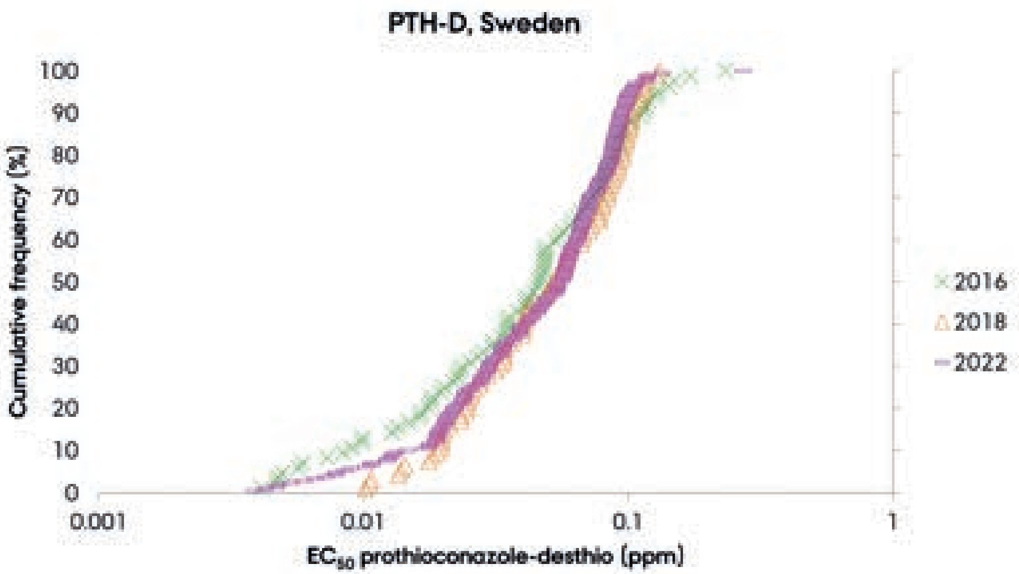


Figure 11. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Swedish *Pyrenophora teres* populations from 2016, 2018 and 2022. Each data point represents one isolate.

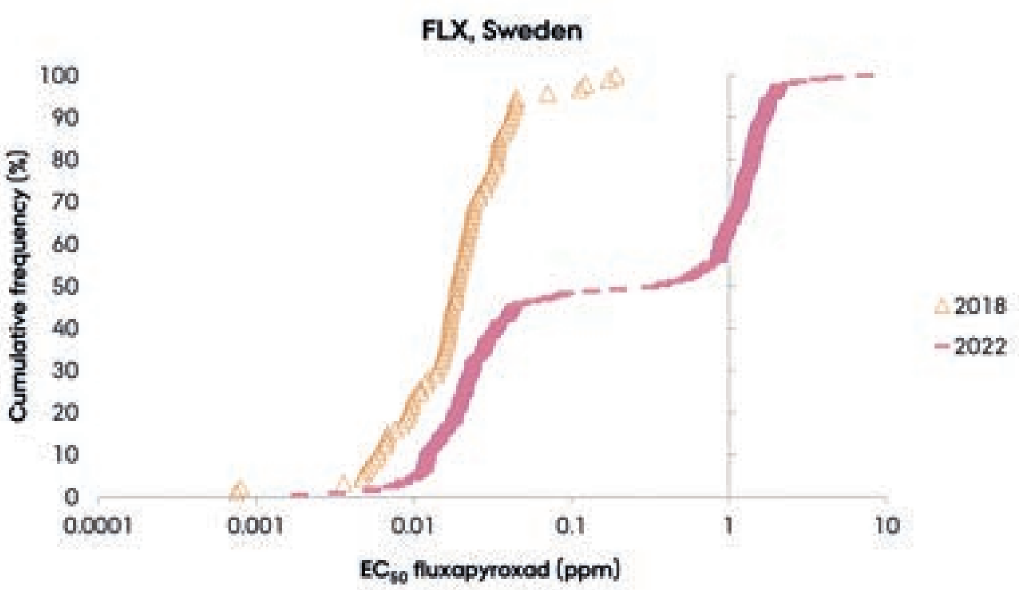


Figure 12. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Swedish *Pyrenophora teres* populations from 2018 and 2022. Each data point represents one isolate.

Table 11. Mean EC_{50} values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for 209 *P. teres* isolates from 21 Swedish locations in 2022.

Location		EC_{50} (ppm)				Number of isolates
		PTH-D	Range	FLX	Range	
22-PT-SW-01	Christinelunds gård, Kalmar	0.05	0.00-0.10	0.40	0.01-1.17	10
22-PT-SW-02	Kastlösa, Kalmar	0.04	0.02-0.09	0.03	0.02-0.06	9
22-PT-SW-03	Fågelsta	0.06	0.03-0.10	0.78	0.02-1.28	10
22-PT-SW-04	Sundbyholm	0.07	0.01-0.10	0.73	0.01-1.46	10
22-PT-SW-05	Äsköping	0.06	0.04-0.06	1.06	0.67-1.76	10
22-PT-SW-06	St. Mellby, Alingsås	0.05	0.02-0.09	0.96	0.02-1.64	10
22-PT-SW-07	Håle Täng, Grästorp	0.05	0.02-0.09	0.25	0.01-1.79	10
22-PT-SW-08	Bolstad, Mellerud	0.04	0.01-0.09	0.70	0.01-1.49	10
22-PT-SW-09	Skofteby, Lidköping	0.04	0.01-0.09	0.37	0.01-1.74	10
22-PT-SW-10	Grimskullen, Falköping	0.04	0.01-0.10	0.49	0.01-2.03	10
22-PT-SW-11	Stora Mellösa	0.07	0.05-0.10	2.05	1.39-4.72	10
22-PT-SW-12	Uppsala	0.04	0.00-0.12	0.95	0.01-3.71	10
22-PT-SW-13	Lund	0.06	0.02-0.09	0.63	0.01-1.65	10
22-PT-SW-14	Sandbygård, Borrby	0.11	0.07-0.27	1.10	0.02-2.10	10
22-PT-SW-15	Halmstad	0.07	0.03-0.10	2.04	0.86-7.33	10
22-PT-SW-17	Örbyhus	0.03	0.01-0.07	0.02	0.01-0.03	10
22-PT-SW-18	Tierp, Uppsala	0.05	0.02-0.09	0.90	0.37-1.53	10
22-PT-SW-19	Sundsvall	0.01	0.00-0.03	0.01	0.00-0.03	10
22-PT-SW-20	Tierp, Uppsala	0.09	0.03-0.13	1.21	0.53-2.01	10
22-PT-SW-21	Ingeberga, Västerås	0.04	0.02-0.09	0.04	0.01-0.13	10
22-PT-SW-22	Uppsala, Tuby	0.08	0.02-0.11	0.15	0.01-1.38	10

Table 12. Summary of mean EC_{50} (ppm) values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad assessed for *P. teres* in Sweden. The total numbers of isolates tested are given in brackets.

Year	Prothio-desthio	Fluxapyroxad
2016	0.06 (84)	-
2018	0.06 (93)	0.03 (93)
2022	0.05 (209)	0.71 (209)
Average	0.06	0.50

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VI Integrating biological control agents and plant resistance inducers into IPM strategies to control potato early blight and late blight

Isaac Kwesi Abuley & Jens Grønbech Hansen

Introduction

Late blight (*Phytophthora infestans*) (Abuley and Hansen, 2021) and early blight (*Alternaria solani*) (Abuley et al., 2019) are important diseases in potatoes, which cause significant yield losses. The control of these diseases in conventional potato production is often through the weekly application of prophylactic fungicides during the growing season, which results in excessive usage of fungicides. Potatoes are currently the most heavily sprayed crop in Denmark, with an average treatment frequency index of 16.2. About 70% of the pesticide usage in potatoes is for controlling fungal pathogens (TFI = 11-12), especially late blight (Miljøstyrelsen, 2021). This massive usage of fungicide is unsustainable for social, economic and environmental reasons. In the light of the EU's Farm to Fork Strategy to reduce pesticide use in conventional potatoes as well as the EU strategy on phasing out copper in organic potato production, there is an increasing interest in finding and adopting environmentally benign alternatives for control of diseases like late and early blight. Biological control agents (BCA) and plant resistance inducers (PRI) are environmentally benign alternatives to fungicides. In this study, we ascertained the efficacy of BCA and PRI alone or in combination with fungicides to control early and late blight.

Early blight trials

Experimental set-up and treatments

The early blight trials in 2022 were carried out at AU Flakkebjerg in the starch and late-maturing potato cultivar Kuras. The experiment was conducted using a randomised complete block design with four replicates (plot size: 7 m x 3.75 m). Each plot consisted of five rows, with 75 cm row spacing. Seed tubers were planted at 33 cm spacing on 28 April 2022. To ensure that early blight was the dominant disease in the potatoes, late blight was controlled by the application of 0.5 l/ha Ranman Top (applied as Ranman Top, 160 g/l cyazofamid) at 7-day intervals. The treatment description and timing of applications are shown in Table 1. The timing of BCAs/PRIs and fungicides was based on the hypothesis that BCAs/PRIs are most effective when applied during a low-risk period. Serenade ASO (*Bacillus amyloliquefaciens*) and FytoSol (COS-OGA) were used as the BCA and PRI, respectively. A low-risk period was defined based on the modified TOMCAST and physiological age of the potato crop (P-days) (Abuley and Nielsen, 2017). Based on the total leaf wetness duration (LWD) per day and the average humidity during the leaf wetness period, the TOMCAST model assigns a daily severity value (DSV) ranging from 0 (no risk) to 4 (high risk). The DSVs are summed up until a predetermined threshold (e.g. 20) is reached before fungicides are recommended. The physiological age is the thermal age of the potato plant. The crop is divided into three phases (resistant, moderately susceptible and susceptible) according to their P-days (Abuley and Nielsen, 2017). A low-risk period is defined as one in which the TOMCAST DSV < 20 and the crop is moderately susceptible (based on the Physiological days model (Abuley and Nielsen, 2017)). The IPM strategies in Table 1 were chosen after a simulation study, which considered several possibilities of integrating BCAs/PRIs into IPM strategies as part of the ECOSOL project.

Inoculation and disease assessment

Barley kernels (110 g per plot) infested with a mixture of five different isolates of *A. solani* were used to inoculate the plots on 15 June. The *A. solani* isolates originated from Danish potato fields. The inoculum preparation was done according to the method described by Abuley et al. (2018). Early blight severity was assessed visually as the percentage of leaf area covered (severity, %) with early blight lesions per plot. The disease assessment was done starting from first symptoms and continued at 7-day intervals until three weeks before harvest. Tubers were harvested from the three middle rows with a tractor-mounted harvester, and the starch content of the tubers was assessed using the underwater-weight starch assessment method (Nissen, 1955).

Data preparation and analysis

Based on the weekly disease assessments, the area under the disease progress curve (AUDPC) was calculated (Shaner and Finney, 1977). The AUDPC data were fitted to a linear model with the "lm" function in the stats R package (R Core Team, 2022). The assumptions of normality were tested graphically (i.e. the QQ-normal plots) and with the Shapiro-Wilk test ($\alpha = 0.05$). The assumption of homogeneity of variance was tested graphically by plotting the residuals against the fitted values as well as the Bartletts test ($\alpha = 0.05$). The effect of treatment was subsequently determined via a Fisher's test (i.e. F-test) using the "anova" function in the stats R package (R Core Team, 2022). Subsequently, a Tukey HSD test was done to discriminate the differences between the treatments ($\alpha = 0.05$).

Table 1. Application of fungicides, biological control agent and plant resistance inducer according to different treatments.

Date	15-07	22-07	29-07	05-08	12-08	19-08	26-08	02-09	09-09	TFI*	Reduction (%)
Treatment	Low-risk period				High-risk period						
Untreated[a]											
Standard[b]	Na		Na		Pro		Na		Pro	5	-
Serenade ASO[c]	Se	Se	Se	Se	Se	Se	Se	Se	Se	0	100
FytoSol[d]	Fyt	Fyt	Fyt	Fyt	Fyt	Fyt	Fyt	Fyt	Fyt	0	100
IPM1[e]	Se	Se	Se	Se	Pro	Se	Na	Se	Pro	2.25	55
IPM2[e]	Fyt	Fyt	Fyt	Fyt	Pro	Fyt	Na	Fyt	Pro	2.25	55
IPM3[f]	Se	Se	Se	Se	Se + Pro	Se	Se + Na	Se	Se + Pro	2.25	55
IPM4[f]	Fyt	Fyt	Fyt	Fyt	Fyt + Pro	Fyt	Fyt + Na	Fyt	Fyt + Pro	2.25	55

[a]No fungicide was applied to control early blight in this treatment.
[b]Standard treatment alternating between 0.4 l/ha Narita (Na) (250 g/l difenoconazole) and 0.45 l/ha Propulse SE 250 (Pro) (125 g/l prothioconazole + 125 g/l fluopyram) at 14-day intervals.
[c]Stand-alone application of 2 l/ha Serenade ASO (Se) (*Bacillus amyloliquefaciens*) at 7-day intervals.
[d]Stand-alone application of 4 l/ha FytoSol (Fyt) (COS-OGA) at 7-day intervals.
[e]Integrated pest management strategy (IPM), in which 2 l/ha Serenade ASO (IPM1) or 4 l/ha FytoSol (IPM2) was sprayed in low-risk periods and 75% fungicide (either 0.34 l/ha Propulse SE 250 or 0.3 l/ha Narita) was sprayed in high-risk periods.
[f]Integrated pest management strategy (IPM), in which 2 l/ha Serenade ASO (IPM3) or 4 l/ha FytoSol (IPM4) was sprayed in low-risk periods and a mixture of 75% fungicide (either 0.34 l/ha Propulse SE 250 or 0.3 l/ha Narita) and 2 l/ha Serenade ASO (IPM3) or 4 l/ha FytoSol (IPM4) was sprayed in high-risk periods.
*Treatment frequency index (TFI). 0.6 l/ha Narita corresponds to 1 TFI, and 0.8 l/ha Propulse SE 250 corresponds to 1 TFI. Serenade ASO and FytoSol have a TFI of zero.

Results

The first symptoms of early blight were found on 18 July, but the subsequent development of the disease was slow until mid-August, after which the disease began to increase rapidly. At the end of the growing season, the disease severity reached 100% (Figure 1).

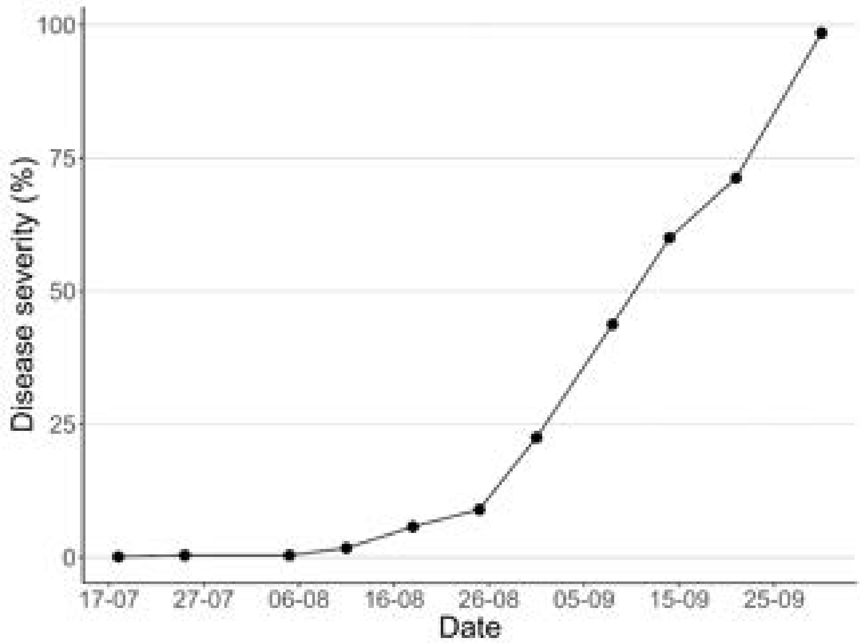

Figure 1. The development of early blight in the untreated plot, 2022 (cultivar: Kuras).

Comparison of AUDPC in the treatments

Treatment had a significant effect on AUDPC (p = 0.0005). Figure 2 shows the AUDPC of the different treatments. The untreated control had the highest AUDPC, while the standard treatment had the lowest AUDPC. The difference between these two treatments was significant (Figure 2). The application of BCA/PRIs either alone or in combination with fungicides reduced early blight attack compared to the untreated control. However, except for IPM2 and IPM4, the differences between the untreated control and the other treatments (i.e. IPM1, IPM3, Serenade ASO and FytoSol) were not significant. The solo applications of BCA or PRI were identical and always inferior to the treatments in which BCA/PRI were used in combination with fungicides. While no differences were seen between the IPM strategies, the IPM2 and IPM4 were the best as they were similar to the standard treatment for AUDPC (Figure 2).

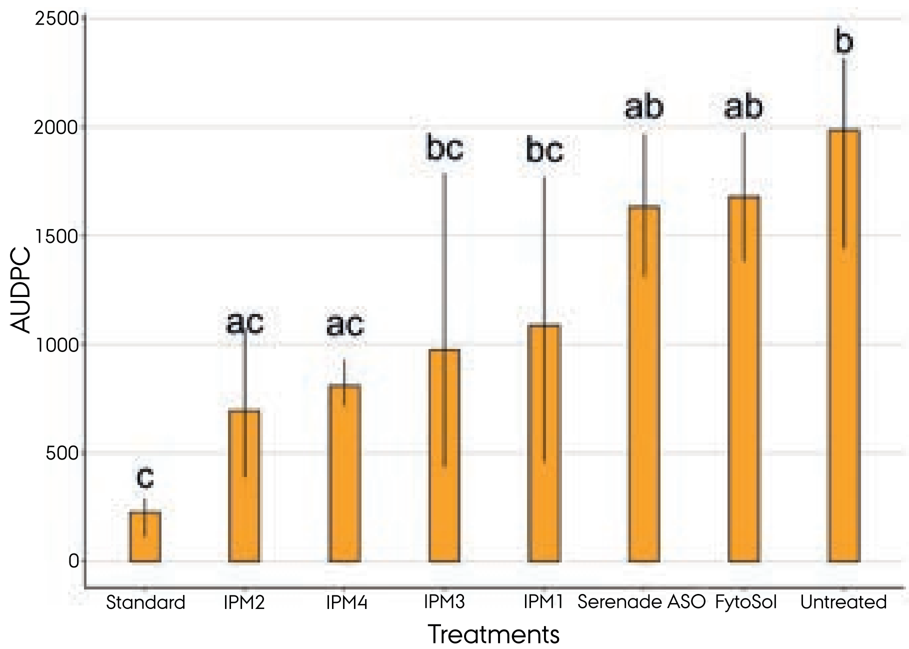

Figure 2. Area under the disease progress curve (AUDPC) of the treatments for early blight. The vertical black line on each bar is the bootstrapped confidence interval (95%). Different letters represent significant differences between treatments. See Table 1 for treatment description.

Comparison of starch yield in the treatments

Treatment had a significant effect on starch yield ($p < 0.0001$). The treatments ranked as follows for starch yield: IPM3 > IPM2 > IPM4 > Standard > IPM1 > Serenade ASO > FytoSol > Untreated (Figure 3). Except for the stand-alone FytoSol and Serenade ASO treatments, the untreated control was significantly different from the other treatments (Figure 3). Moreover, except for the IPM1 treatment, the starch yield was markedly lower in the stand-alone FytoSol and Serenade ASO treatments than in the other IPM and standard treatments (Figure 3). However, no significant differences were observed between the IPM strategies and the standard treatment for starch yield (Figure 3).

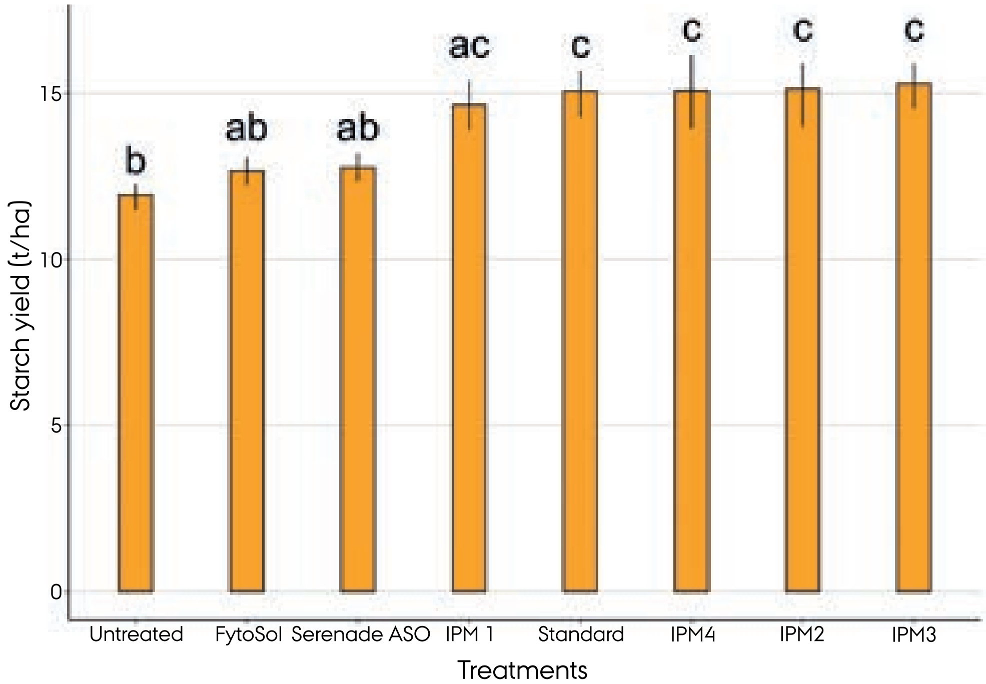

Figure 3. Starch yield of the treatments. The vertical black line on each bar is the bootstrapped confidence interval (95%). Different letters represent significant differences between treatments. See Table 1 for treatment description.

Concluding remarks

The present study indicates some effects of BCAs and PRIs on early blight, albeit insignificant compared to an untreated control. However, when integrated with fungicide application, a significant disease reduction was achieved, while reducing the total fungicide usage. Indeed, a reduction of 55% in fungicide usage (Table 1) compared to the standard fungicide treatment was achieved. This reduction jeopardised neither yield nor disease control. In many instances the yields in the IPM strategies were higher, albeit not significantly, than the yield of the standard treatment. While the IPM strategies were similar for their disease reduction and starch yield, it is noteworthy that the IPM1 strategy (i.e. application of Serenade ASO in low-risk and fungicide in high-risk periods) was the least effective strategy in terms of disease reduction and starch yield. The present study focused on just the efficacy and the yield returns but did not consider the overall net returns for each treatment. Indeed, when such a net return analysis is considered, a different conclusion is likely as BCAs and PRIs are generally more expensive than traditional fungicides.

Late blight trials

The experimental design for the early blight trials was also used for the late blight trials. However, the late blight trials involved two cultivars with varying susceptibility to late blight (Nofy [resistant] and Kuras [susceptible]). The potatoes were protected from early blight attack by spraying either 0.4 l/ha Narita (applied as Narita, 250 g/l difenoconazole) or 0.45 l/ha Propulse SE 250 (125 g/l prothioconazole + 125 g/l fluopyram) at 14-day intervals. The treatment application scheme is shown in Table 2. Polyversum

(*Pythium oligandrum*) and ChiProPlant (chitosan hydrochloride) were used as the BCA and PRI, respectively. As in the early blight trials, only BCA/PRI were applied in IPM2 and IPM4 during low-risk periods. A sub-model for timing BCAs and PRIs was developed in the BlightManager decision support system (DSS) for this purpose. We defined a low-risk period as a period with an infection pressure (IP) of less than 10 during times when late blight is not present in the field. The inclusion of the presence of late blight in the field was made because results from previous field studies conducted at AU Flakkebjerg suggested that the inoculum pressure (i.e. number of sporangia) is critical for the efficacy of BCAs and PRIs. BCAs and PRIs are mostly outcompeted by the pathogen under high inoculum pressures but have a better effect under low inoculum pressures. We also performed simulation studies to select the most promising IPM strategies. Artificial inoculations were done in the spreader rows (cultivar: Folva) on 30 June 2022 with 1000 sporangia/ml of *Phytophthora infestans*. The isolates used for the inoculation were a mix of isolates collected from commercial potato fields at the end of the 2021 season. Late blight disease development was assessed every week as the percentage area of late blight symptoms per plot (severity, %). AUDPC and starch yield were assessed and analysed as described in the early blight section.

Table 2. Application of fungicides, biological control agent and plant resistance inducer according to different treatments in the late blight trials.

Date	29-06	06-07	13-07	20-07	27-07	03-08	10-08	17-08	24-08	31-08	07-09	14-09	TFI*	Reduction (%)
Treatment	Low-risk period			High-risk period										
Untreated[a]														
Standard[b]	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	12	-
Polyversum[c]	Pol	Pol	Pol	Pol	Pol	Pol	Pol	Pol	Pol	Pol	Pol	Pol	0	100
ChiProPlant[d]	Chi	Chi	Chi	Chi	Chi	Chi	Chi	Chi	Chi	Chi	Chi	Chi	0	100
IPM1[e]	Pol	Pol	Pol	RT	RT	RT	RT	RT	RT	RT	RT	RT	6.75	44
IPM2[e]	Chi	Chi	Chi	RT	RT	RT	RT	RT	RT	RT	RT	RT	6.75	44
IPM3[f]	Pol	Pol	Pol	Pol+RT	Pol+RT	Pol+RT	Pol+RT	Pol+RT	Pol+RT	Pol+RT	Pol+RT	Pol+RT	6.75	44
IPM4[f]	Chi	Chi	Chi	Chi+RT	Chi+RT	Chi+RT	Chi+RT	Chi+RT	Chi+RT	Chi+RT	Chi+RT	Chi+RT	6.75	44

[a]No fungicide was applied to control early blight in this treatment.
[b]Standard treatment, in which 0.5 l/ha Ranman Top (RT) (applied as Ranman Top, 160 g/l cyazofamid) at 7-day intervals.
[c]Stand-alone application of 200 g/ha Polyversum (Pol) (*Pythium oligandrum*) at 7-day intervals.
[d]Stand-alone application of 300 g/ha ChiProPlant (Chi) (chitosan hydrochloride) at 7-day intervals.
[e]Integrated pest management strategy (IPM), in which 200 g/l Polyversum (IPM1) or 300 g/l ChiProPlant (IPM2) was sprayed in low-risk periods and 75% fungicide (0.375 l/ha Ranman Top) in high-risk periods.
[f]Integrated pest management strategy (IPM), in which 200 g/l Polyversum (IPM3) or 300 g/l ChiProPlant (IPM4) was sprayed in low-risk periods and a mixture of 75% fungicide (0.375 l/ha Ranman Top) and 200 g/l Polyversum (IPM3) or 300 g/l ChiProPlant (IPM4) was sprayed in high-risk periods.
*Treatment frequency index (TFI). 0.5 l/ha RT corresponds to 1 TFI. Polyversum and ChiProPlant have a TFI of zero.

Results

Disease development in Kuras and Nofy

Late blight occurred in the untreated Kuras and Nofy. However, the first symptoms of late blight were observed earlier in Kuras than in Nofy (Figure 4). Generally, the severity of late blight was higher in Kuras than in Nofy at most assessment dates (Figure 4).

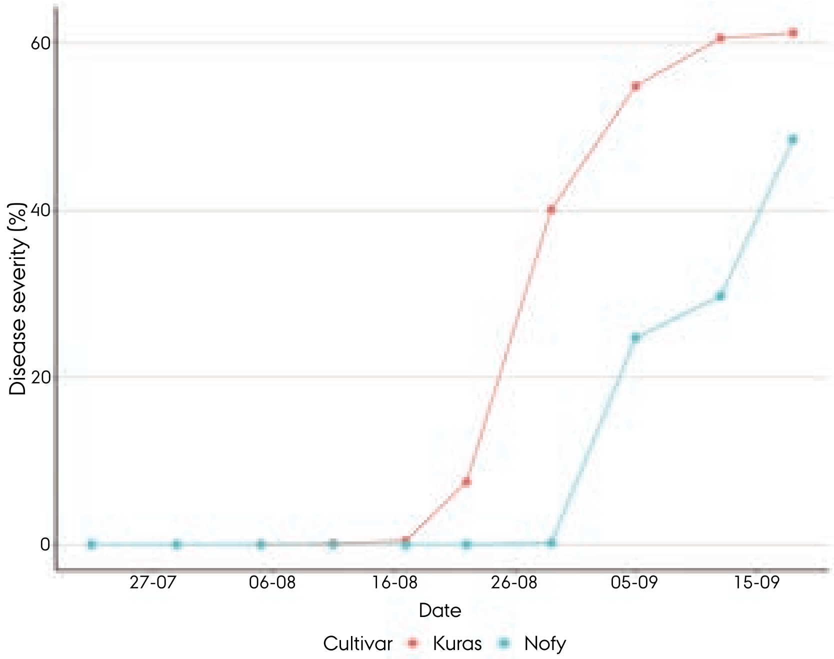

Figure 4. Late blight development in the untreated plots of Kuras and Nofy, AU Flakkebjerg, 2022.

Comparison of AUDPC in the treatment

The effect of the treatments was strong in both cultivars ($p < 0.0001$). However, because of the strong effect of cultivar, we did a separate comparison for each cultivar. Figure 5 shows the AUDPC of the treatments in Kuras and Nofy. In Kuras, the untreated control had the highest AUDPC, followed by Polyversum and ChiProPlant as stand-alone treatments (Figure 5).

However, the differences between these treatments were not significant. In Nofy, however, the ChiProPlant and Polyversum treatments had the highest AUDPC, which differed significantly from the untreated control (Figure 5). In both cultivars, the IPM and standard treatments significantly reduced the severity of late blight compared to the solo BCA/PRI and the untreated control (Figure 5). Moreover, the differences between the IPM and standard treatments in both cultivars were not significant. However, in Kuras all IPM strategies had lower AUDPCs than the standard treatment, in which Ranman Top was applied every week.

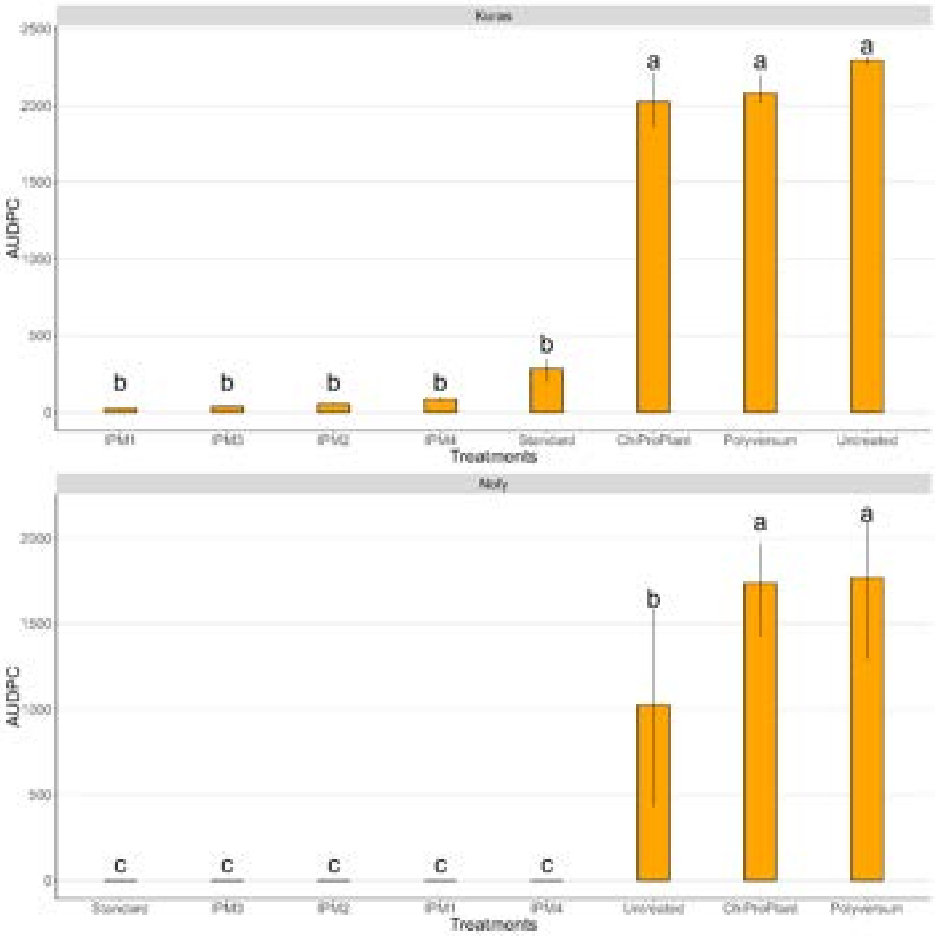

Figure 5. Bar chart showing the area under the disease progress curve (AUDPC) of the treatments for Kuras and Nofy. The vertical black line on each bar is the bootstrapped confidence interval (95%). The letters on each bar indicate the significance of the treatment compared to the other treatments for AUDPC. Bars associated with the same letters are not statistically different and vice versa. See Table 2 for treatment description.

Comparisons of the starch yield in the treatments

Starch yield was also significantly affected by treatment ($p < 0.001$) in both cultivars. In both cultivars, the untreated control had the lowest starch yield, whereas IPM2 and Polyversum as a stand-alone treatment had the highest yield in Kuras and Nofy, respectively. In Nofy, the yield from the untreated control was significantly different from all other treatments, whereas in Kuras the untreated control was significantly different from all treatments, except for ChiProPlant and Polyversum as stand-alone treatments (Figure 6). Again, in Kuras, no significant differences were observed between the standard and the solo treatments of ChiProPlant and Polyversum, even though the yield in the standard treatment was higher than in the Polyversum and ChiProPlant treatments. All IPM strategies recorded a significantly higher yield than the solo treatments of either Polyversum or ChiProPlant, but not the standard treatment.

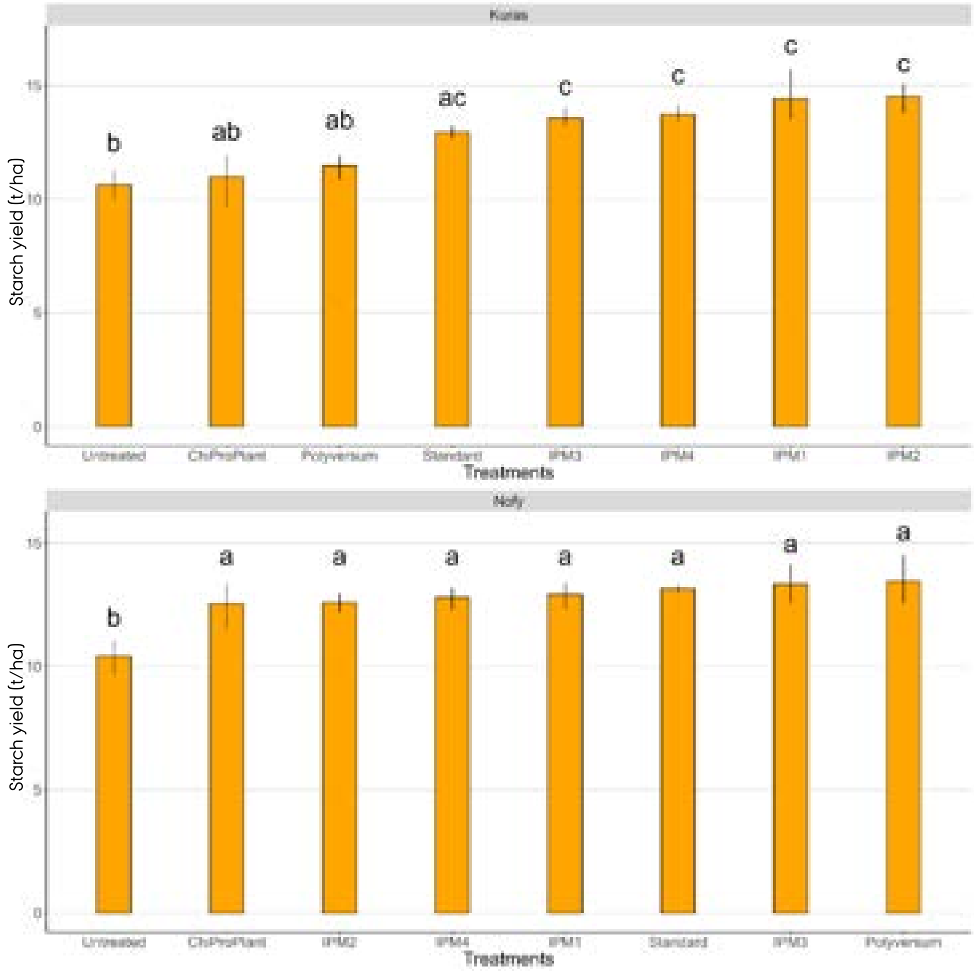

Figure 6. Bar chart showing the starch yield of the treatments for Kuras and Nofy. The vertical black line on each bar is the bootstrapped confidence interval (95%). The letters on each bar indicate the significance of the treatment compared to the other treatments for AUDPC. Bars associated with the same letters are not statistically different and vice versa. See Table 2 for treatment description.

Concluding remarks

This study highlights the effect of BCAs and PRIs alone and in combination with reduced dosages of traditional fungicides. The effect of the BCAs/PRIs was dependent on cultivar, with Kuras showing a better effect than Nofy with the applied BCA/PRI. However, when integrated with fungicides, our results showed the possibility of significantly suppressing late blight attack with few fungicides without any yield penalty. We saved 44% in the IPM strategies and 100% in the stand-alone BCA/PRI treatments. In fact, our results showed higher yield returns, albeit not statistically significant, for tested IPM strategies compared to the standard treatment. The observation that the standard treatment, in which Ranman Top was applied every week, had a slightly higher disease level than the other IPM strategies in Kuras is noteworthy. This observation could possibly be caused by adaptation of the *P. infestans* population to a fungicide, which was applied repeatedly. This suggests that an IPM strategy which either applies fungicides in alternation with BCAs/PRIs or as a mixture depending on the risk of late blight development may be a promising strategy to mitigate the development of fungicides resistance. The absence of a similar trend in Nofy might be explained by the relatively high resistance level in Nofy, which might have reduced the inoculum pressure and thus the possibility for selecting mutants that are adapted to the repeated fungicide application.

Acknowledgements

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VII *Urocystis agropyri* – a new disease discovered in *Poa pratensis* in Denmark

Lise Nistrup Jørgensen & Thies Marten Heick

Herbage grasses for seed production is typically established undersown in for instance spring barley, and seeds are harvested in the following one to three growing seasons. In summer 2022, a field with a history of intense production of *Poa pratensis* with the cultivar Ballin was seen to have reduced and stunted growth. The symptoms were widespread in the third-year crop but also seen in the second-year crop. The symptoms were particularly apparent following a period with dry climate conditions. A closer investigation of the plant samples from the field showed that the plants were attacked by the bunt disease *Urocystis agropyri.*

The leaves of the crop had stripes with dark spores, which under the microscope were verified as *Urocystis agropyri.* The spores are reddish brown, smoothly rounded, and they tend to be in clumps of 5-6 with sterile cells around them. The clumped spores are often referred to as "spore balls" and measure about 20-50 microns. Large quantities of *U. agropyri* spores look like brown or black dust.

Apart from traditional diagnostics using microscopy, the samples were also tested based on DNA and using specific primers for identification. Following extraction of DNA, the partial sequences of internal transcribed spacer (ITS) were compared with readings in a database. The clear amplicons of 503 and 548 bp were obtained with the two sets of designed primers (UA-17F/UA-519R and UA-15F/UA-562R) from the genomic DNA and compared with 50 geographic distinct isolates of *U. agroyri.* This investigation made it possible to verify that the infections were caused by *U. agropyri.*

Plants with attack of *Urocystis agropyri.*
Photo: Charlotte H. Knudsen.

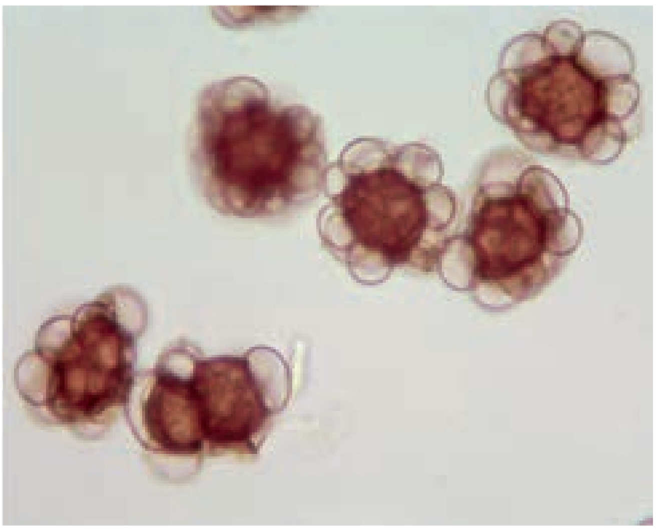

Photo of clumped spores from *Urocystis agropyri.* The photo is from the APS Compendium of turf grass diseases (R. W. Smiley).

This disease has not previously been recognised as a plant pathogen under Danish conditions. However, in literature it is described that *U. agropyri* is found in most countries in Europe and worldwide (CABI). The plant pathogen can infect a range of grasses and is frequently identified as the causal organism of flag smut on wheat, but there is debate still as to whether the different grasses are attacked by the same organism or whether different strains might be present (Fisher and Holton, 1943).

In literature, the following description of *U. agropyri* can be found: "The disease belongs to the 'seedling-infecting' group of smut fungi. Infection occurs before seedling emergence from the soil. Teliospores germinate to produce sporidia that fuse to form infection hyphae that infect young coleoptiles of hosts" (Takahashi and Iwata, 1964). Temperatures between 10°C and 20°C and moist soil favour the infection of wheat and grasses (Purdy, 1965). After infection, the fungus grows both inter- and intra-cellularly until it begins to sporulate. Initially, the leaf blades and then the leaf sheath and all the other above-ground plant parts are attacked. The sori containing the spore balls first appear as white streaks on the leaf at 6-10 weeks after planting and later change colour through grey to black. Infected plants may fail to produce seeds or have malformed inflorescences due to the pathogen's growth and sporulation.

Spores from infected leaves may be transported for long distances with seed, straw or on farm machinery (Line, 1998). The smut spores can survive for four years in the soil and for up to ten years under conditions of optimal seed storage (Neergaard, 1977).

From other countries it has been stated that early detection of symptoms is very difficult to verify in grass crops. The disease often first becomes apparent several years after the first infections have taken place. *U. agropyri* will most likely not become recognised in turf grass until after 3-4 years' cropping. Smut infection will weaken the plants and make them more susceptible to high temperatures and drought stress.

In summary, the finding of *U. agropyri* in Denmark indicates that it is important to ensure a wide cropping interval (3-4 years) between perennial grass seed crops to reduce the risk of a build-up of inoculum.

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VIII Cercospora leaf spot – a recent disease in sugar beet; fungicide resistance and variation in strains

Thies Marten Heick, Lisa Schulz, Tine Thach, Annemarie Fejer Justesen & Lise Nistrup Jørgensen
(part of text is taken from Lisa Schulz' master's thesis)

Cercospora leaf spot (CLS) in sugar beet is caused by the fungal pathogen *Cercospora beticola* and is the most destructive foliar disease of sugar beet worldwide (Skaracis et al., 2010). It can cause grave damage to the leaf canopy and thereby reduce the yield and quality of sugar beet.

In general, the severity of an infection with *C. beticola* depends greatly on environmental conditions as well as the resistance level of the cultivars used and agricultural practices (e.g. crop rotation and chemical treatments). Sugar yield losses have been reported to be up to 50% and more (Rossi et al., 2000b).

In Denmark, outbreaks of CLS have still been scarce and mostly local, primarily due to the current, less favourable climate conditions. However, the disease severity has increased in recent years, and it is anticipated that CLS will become a challenge in Northern climate regions in the years to come (Hansen, 2022).

Cercospora beticola primarily infects species of the genus *Beta* but can also cause symptoms on other species of the *Chenopodiaceae* family (like *Spinacea* and *Amaranthus*) (Weiland and Koch, 2004). Even though *C. beticola* is known to be a heterothallic fungus and occurs as one of two mating types (MAT1-1-1 or MAT1-2-1), there is no current knowledge of a sexual stage of *C. beticola* (Rangel et al., 2020). Nevertheless, *C. beticola* populations are generally characterised by high genetic diversity. It has therefore been suggested that hyphal anastomosis or different mating types within populations (MAT1-1-1 and MAT1-2-1) contribute to the sexual recombination within *C. beticola* populations. (Rangel et al., 2020).

Between the growing seasons *C. beticola* is known to overwinter in form of pseudostromata (persistent hyphal structures) on infected plant debris (Weiland and Koch, 2004). These structures have in the past been regarded as the main source of primary inoculum. More recent population studies have, however, reviewed the role of clonally reproduced primary inoculum as the source of infection (Groenewald et al., 2008) and stressed the potential role of imported inocula via plant material, agricultural equipment (Knight et al., 2018, 2019) as well as windborne conidia or stromata from other host plants (Khan et al., 2008; Knight et al., 2020). A study by Spanner et al. (2022) has recently confirmed the presence of viable *C. beticola* structures in sugar beet seed lots (in the pericarb of the fruit) and suggested the spreading of the pathogen, including strains carrying fungicide resistance via the trading of seeds. The life cycle of *C. beticola* is shown in Figure 1.

Life cycle and infection biology

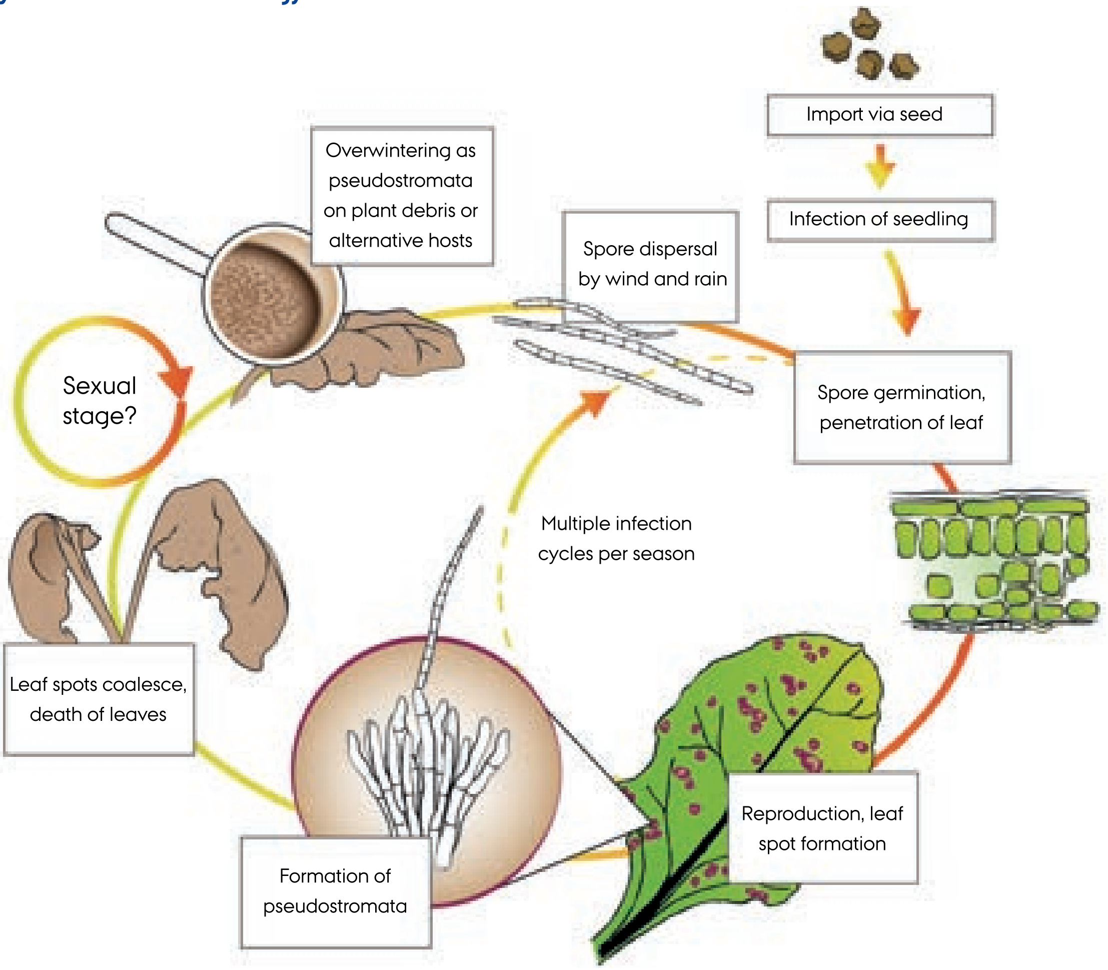

Figure 1. Life and disease cycle of *Cercospora beticola* on sugar beet (adapted from Rangel et al., 2020).

When conidia have formed, they are released and/or carried by wind or dispersed by water splashes to the sugar beet plants. Once landed on the host, they germinate and penetrate the leaves through its stomata and develop hyphae which grow intercellularly inside the parenchymatous leaf tissue (Rangel et al., 2020).

The appearance of the first symptoms depends on climatic conditions but can be typically expected 5 to 21 days after infection (Khan et al., 2009). Most *Cercospora* species are necrotrophs. The fungi produce phytotoxins and hydrolytic enzymes to kill cells in advance of mycelial growth (Weiland and Koch, 2004). This causes the formation of typically reddish-brown coloured leaf spots with a centre of grey-brown necrotic tissue (Figure 2). The lesions range between 0.5 mm and 6 mm in diameter. New pseudostromata develop and become visible as characteristic dark speckles within the grey centre of the leaf spots. They serve to identify *C. beticola* together with conidiophore structures and the long, thin septate conidia (from 2.5 µm to 4 µm wide and from 50 µm to 200 µm long) (Figure 3) (Weiland and Koch, 2004). The pseudostromata give rise to several following generations of asexually produced spores. The fungus is known to induce abundant sporulation about three days after the infected tissue dies (Rossi et al., 2000a).

Figure 2. Sugar beet leaf showing mild symptoms of *C. beticola*. (Photo taken on 10 March 2022). Photo: Lisa Schulz.

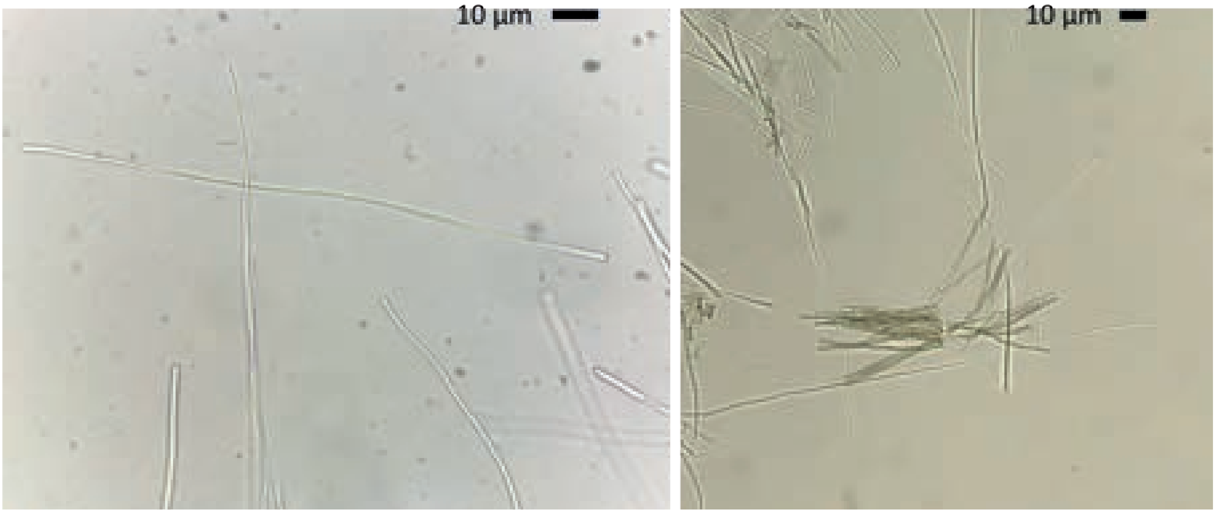

Figure 3. Micrographs of conidiospores (left) and conidiophores (right) of *C. beticola.* (Photos: Lisa Schulz).

One of the typically many sporulation cycles takes about 12 days, depending on how favourable weather conditions are. Optimal conditions are temperatures between 25°C and 35°C during the day and around 16°C at night and a very high relative humidity (RH) (between 90% and 95%) (Forsyth et al., 1963). Spore production is favoured by temperatures between 15°C and 23°C, but spores do not form at temperatures under 10°C or above 38°C (Pool and McKay, 1916). Conidia germination is highest at RH close to 100% and a temperature of 25°C (Khan et al., 2009).

In an advanced stage of infection, typically late in the season, the plant re-stimulates vegetative growth to compensate loss of foliage. This happens at the cost of sugars stored in the root. The consequence of this can be the loss of root weight, sucrose content as well as inferior juice quality, all of which will contribute to an overall lower sugar yield (Rossi et al., 2000b).

Control of *Cercospora beticola* using fungicides

In many sugar beet cultivations, fungicide applications are the primary tool to control CLS disease. A variety of fungicides are registered and can be used by growers in various parts of the world for the control of the fungus (Skaracis et al., 2010). The main active ingredients used against *C. beticola* belong to the strobilurins (QoI; FRAC group 3) and the demethylase inhibitors (DMI; FRAC group 11).

The high reliance on fungicides has given rise to fungicide-resistant *C. beticola* strains in several regions (Nikou et al., 2009; Kumar et al., 2021; Muellender et al., 2021), rendering the disease challenging to manage.

Fungicide resistance to QoI in *C. beticola* has been well described in the literature and associated with the G143A amino acid alteration in the *cytb* gene (Bolton et al., 2013). In two recent studies, Muellender and colleagues (2021) and Spanner and colleagues (2021) found evidence for the association of target-site resistance in the *cyp51* gene with reduced DMI sensitivity in European *C. beticola* populations. Traditionally, fungicide use in Denmark has been relatively restricted, also in sugar beet crops. Recent findings also confirmed that *C. beticola* is a seedborne disease, and fungicide resistance was found in seed lots destined for European farmers (Spanner et al., 2022). Therefore, the Danish *C. beticola* population might already be adapted to fungicides despite the rare occurrence of CLS and relatively lower fungicide exposure in Denmark (Heick et al., 2020).

The presented study set out to give a status of fungicide sensitivity and to screen for fungicide target-site resistance in Danish *C. beticola* isolates to determine the potential risk of fungicide resistance in the light of increasing disease severity in Denmark.

Testing for fungicide resistance

In-vitro sensitivity (EC_{50} values) of Danish *C. beticola* samples from 2021 (n = 33; three sites) was tested towards fungicides of the DMI (prothioconazole-desthio, difenoconazole), QoI (azoxystrobin) and SDHI (boscalid, fluopyram, fluxapyroxad) classes (FRAC group 7) using a microtitre assay. The isolates were produced as described by Secor et al. (2010). All isolates were resistant to azoxystrobin with EC_{50} values > 10 mg/l. The sensitivity levels towards DMIs were in line with the results of Muellender et al. (2021), indicating a similar DMI adaption in Danish *C. beticola* isolates as seen in other European countries (Table 1). SDHI fungicides were insensitive (EC_{50} > 10 mg/l) against *C. beticola*, which confirms previous findings in other *Cercospora* species (Sautua et al., 2020).

The samples from 2021 and an additional 41 samples collected in 2020 (from eleven sites) were analysed for the presence of amino acid alteration G143A, using qPCR (Bolton et al., 2013). G143A was found in 70% of the samples from 2020 and in all samples from 2021.

Further, the *cyp51* gene of samples from 2021 was amplified with a PCR and sequenced to find amino acid alterations associated with DMI insensitivity. Seven different CYP51 haplotypes were identified; the most frequent was harbouring L144F in combination with I309T and a synonymous mutation at amino acid position 170. An alteration at position 294, which led to an alteration from lysine to arginine (K294R), was found in three samples. K294R has not been previously described, and its impact on DMI sensitivity needs to be validated. Sequences of the *cyp51* gene obtained in this study were uploaded to the Nucleotide BLAST database for genome sequencing under the accession numbers: ON324109 - ON324115.

The results presented herein are the first report of QoI-resistant and DMI-adapted *C. beticola* isolated from Denmark. Furthermore, the ineffectiveness of SDHI fungicides against *C. beticola* was shown. Therefore, it is advocated that the management of *C. beticola* exploits the possibilities of fungicide resistance strategies such as applying lower doses, mixing active ingredients and alternating fungicides with different modes of action. Furthermore, a sustainable IPM approach should include agronomic practices such as crop rotation, the sowing of tolerant cultivars and the application of non-chemical biopesticides.

Genetic diversity of *Cercospora beticola* in Denmark

There is a broad base of scientific literature on the genetic structure and diversity as well as the population dynamics of *C. beticola* in other parts of the world. Tools used in these studies include microsatellite markers (also known as Simple Sequence Repeats, SSR), randomly amplified polymorphic DNA (RAPD), amplified fragment length polymorphisms (AFLP) and single nucleotide polymorphisms (SNPs) (Groenewald et al., 2007; Turgay et al., 2010; Vaghefi et al., 2017a).

C. beticola populations are described to have an overall high genetic and genotypic diversity (at allele, gene and genotype level). Other studies have aimed to quantify genetic homogeneity and differentiation between *C. beticola* populations to analyse whether and at which spatial scale gene flow is happening (Groenewald et al., 2008; Vaghefi et al., 2017a; Knight et al., 2019). Overall populations of the fungus are characterised by low intercontinental differentiation as well as high levels of gene flow (Groenewald et al., 2008; Knight et al., 2019; Rangel et al., 2020).

The genetic diversity of *C. beticola* in Denmark has not previously been investigated due to rare occurrences. It is relevant now to study the diversity of the Danish population of *C. beticola*, particularly in the light of increasing observations of CLS in Danish sugar beet fields and the recent *in vitro* detection of fungicide resistance. This study was initiated based on funding from Sukkerroeafgiftsfonden in 2021 and 2022 (projects: "Cercospora-bladplet – en risiko for dansk sukkerproduktion" and "Cercospora-bladplet – en risiko for dansk sukkerproduktion, del II"). The objective was to implement the method of SSR genotyping of *C. beticola* to be able to study genetic diversity and population structure in the Danish population of *C. beticola* in the future.

Table 1. EC_{50} (mg/l) values for prothioconazole-desthio (PTZ-desthio), difenoconazole (Dif), azoxystrobin (Azo), fluopyram (Flu), fluxapyroxad (Flux) and boscalid (Bos) and amino acid alterations found in the *cytb* and *cyp51* region of the *C. beticola* isolates used in this study.

Isolate	EC_{50} PTZ-desthio (mg/l)	EC_{50} Dif (mg/l)	EC_{50} Azo (mg/l)	EC_{50} Flu (mg/l)	EC_{50} Flux (mg/l)	EC_{50} Bos (mg/l)	Amino acid alteration found in *cytb*	Amino acid alteration found in *cyp51*
Wildtype strain	0.01	0.01	0.01	>10	>30	>30		
QoI-resistant strain	0.3196	0.18	>30	>10	>30	>30	G143A	
21-CB-DK-01-01	0.02	0.54	>30	>10	>30	>30	G143A	L144F
21-CB-DK-01-02	0.01	0.12	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-03	0.02	0.35	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-04	0.01	0.57	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-05	0.01	0.32	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-06	0,03	0.35	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-07	0.01	0.98	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-08	0.02	0.12	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-09	0.01	0.09	>30	>10	>30	>30	G143A	L144F + I309T, E170
21-CB-DK-01-10	0.02	0.49	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-11	0.00	0.07	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-01-12	0.04	0.18	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-02-01	0.32	4.22	>30	>10	>30	>30	G143A	L144F + I309T, E170
21-CB-DK-02-02	0.00	0.25	>30	>10	>30	>30	G143A	L144F, H306R
21-CB-DK-02-03	0.00	0.47	>30	>10			G143A	L144F, H306R
21-CB-DK-02-04	0.27	1.31	>30	>10	>30	>30	G143A	L144F + I309T, E170
21-CB-DK-02-05	0.01	0.29	>30	>10			G143A	L144F, H306R
21-CB-DK-02-06	0.01	0.19	>30	>10			G143A	Y464S
21-CB-DK-02-07	0.06	0.58	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-02-08	0.30	2.23	>30	>10	>30	>30	G143A	L144F + I309T, E170
21-CB-DK-02-09	0.01	0.12	>30	>10			G143A	L144F, K294R, H306R
21-CB-DK-02-10	0.02	0.24	>30	>10			G143A	L144F, K294R, H306R
21-CB-DK-02-11	0.02	0.11	>30	>10			G143A	L144F, H306R
21-CB-DK-03-01	0.04	0.72	>30	>10	>30	>30	G143A	L144F + I309T, E170
21-CB-DK-03-02	0.03	0.52	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-03-03	0.01	0.36	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-03-04	0.01	0.30	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-03-05	0.01	0.51	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-03-06	0.04	0.09	>30	>10	>30	>30	G143A	L144F + I309T, E170
21-CB-DK-03-07	0.01	0.02	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-03-08	0.11	0.18	>30	>10	>30	>30	G143A	L144F + I309T, E170, K294R
21-CB-DK-03-10	0.07	0.27	>30	>10			G143A	L144F + I309T, E170
21-CB-DK-03-11	0.12	0.03	>30	>10	>30	>30	G143A	L144F, E170
Mean	0.05	0.52	>30	>10	>30	>30		

Thirteen SSR markers previously developed for *C. beticola* by Groenewald et al. (2007) and Vaghefi et al. (2017b) were applied. In total, 114 Danish *C. beticola* isolates from diseased sugar beet leaves sampled at different sites in 2020-2022 were successfully SSR genotyped. Initial results showed the presence of a minimum of 37 Multi Locus Genotypes (MLG) in the Danish population of *C. beticola* across the three sampled years. In some field sites, only one MLG was detected, whereas other field sites contained multiple MLGs. The initial results indicate a high diversity to be further investigated. Future studies will include comparison of the genotypes identified in Denmark with genotypes identified in other countries to determine the level of differentiation among populations and possible gene flow to infer on the possible source of Cercospora leaf spot in Denmark.

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IX Effect of pH-adjusting adjuvants on the performance of two glyphosate formulations

Per Kudsk & Mette Sønderskov

Recently, a number of pH-adjusting adjuvants have been marketed in Denmark. Some of the adjuvants are primarily promoted for the use with glyphosate products, whereas others are recommended for a wider range of pesticides. The claims of the distributors of a better performance of the pesticides in mixtures with these adjuvants are only supported by testimonies from farmers and not by data. This study provides data for some of the available adjuvants in combination with two glyphosate products.

A pH-adjusting adjuvant could potentially promote performance in two ways. Firstly, a lower pH of the spray carrier could have an effect on the uptake and performance of a pesticide, although a change in pH may also speed up the degradation of the active ingredient in the spray tank. A second effect is related to the ability of strong acids like sulphuric and phosphoric acid to form insoluble complexes with calcium and magnesium and thus overcome the detrimental effect of hard water with several pesticides, notably glyphosate.

Methods

The objective of this study was to assess the effect of one concentration of three pH-adjusting adjuvants (Bio pH Control, Fosmagnit and NovaBalance) on the performance of the two most used glyphosate products (Roundup PowerMax (720 g glyphosate/kg) and Glyphomax HL (480 g glyphosate/l) in Denmark and provide some evidence on the mode of action of the adjuvants. The composition of Bio pH Control has not been disclosed, while the main active component of Fosmagnit and NovaBalance is phosphoric acid. Furthermore, the effect of two sources of water hardness (8 dH° and 17 dH°) was tested.

As a first step, the pH of solutions with different concentrations of the two glyphosate products alone and in tank mixture with the three pH-adjusting adjuvants in the two water sources was measured. pH was measured at two concentrations of the glyphosate products, the maximum recommended dose and 10% of this dose, reflecting the dose range used in the following efficacy experiments. The efficacy was studied in outdoor pot trials on two weed species, the grass species *Lolium perenne* (perennial ryegrass) and the broadleaved weed species *Viola arvensis* (field pansy). The plants were grown in 1-litre pots in a growth medium containing all necessary nutrients and treated with a dose range of glyphosate. The herbicides were applied in water with different hardness (8 dH° and 17 dH° where 1 dH° equals 10 mg CaO/l), which is representative for the variation observed in most of the agricultural area of Denmark. ED_{50} doses were estimated using a three-parameter log-logistic model. Following the first series of efficacy experiments, a second series of experiments looking into the causes of the observed effects of one of the pH-adjusting adjuvants (Bio pH Control) was conducted. In these experiments, the effect of the adjuvant was compared to ammonium sulphate and an acetic acid/sodium acetate buffer. The pH of the spray solutions was also measured in these experiments. Each experiment was replicated, and the results of the second experiment are shown below. No significant differences were observed between the two replications, but variability in the second experiment was generally lower due to a better distribution of the glyphosate doses along the dose response curve.

Results

The pH of the water used in the study was 7.6 and 7.3 for the soft and hard water, respectively. Addition of both glyphosate products alone reduced pH significantly, and more in the soft than the hard water (Table 1). In most cases, the inclusion of the pH-adjusting adjuvants further decreased pH.

Table 1. pH values of the spray mixtures applied in the first experiment at two doses of each glyphosate product.

	Soft water (8 dH°, pH 7.6)		Hard water (17 dH°, pH 7.3)	
	0.13%/1.33% Roundup PowerMax	0.15%/1.5% Glyphomax HL	0.13%/1.33% Roundup PowerMax	0.15%/1.5% Glyphomax HL
No adjuvant	4.80/3.89	4.90/4.44	5.75/4.42	6.12/5.04
0.2% Bio pH Control	2.40/2.99	2.36/3.33	2.86/3.50	3.12/4.25
0.3% Fosmagnit	2.78/3.19	2.82/3.45	5.18/4.26	5.29/4.69
0.1% NovaBalance	3.10/3.48	3.48/4.50	5.40/4.28	5.62/4.70

The plants treated with Roundup PowerMax are shown in Figures 1 and 2. The photos were taken shortly before harvest. The plants were more affected when the spray solutions were applied in soft water and there were differences between the four treatments with adjuvants. This was also reflected in the estimated ED_{50} doses (Figures 3 and 4).

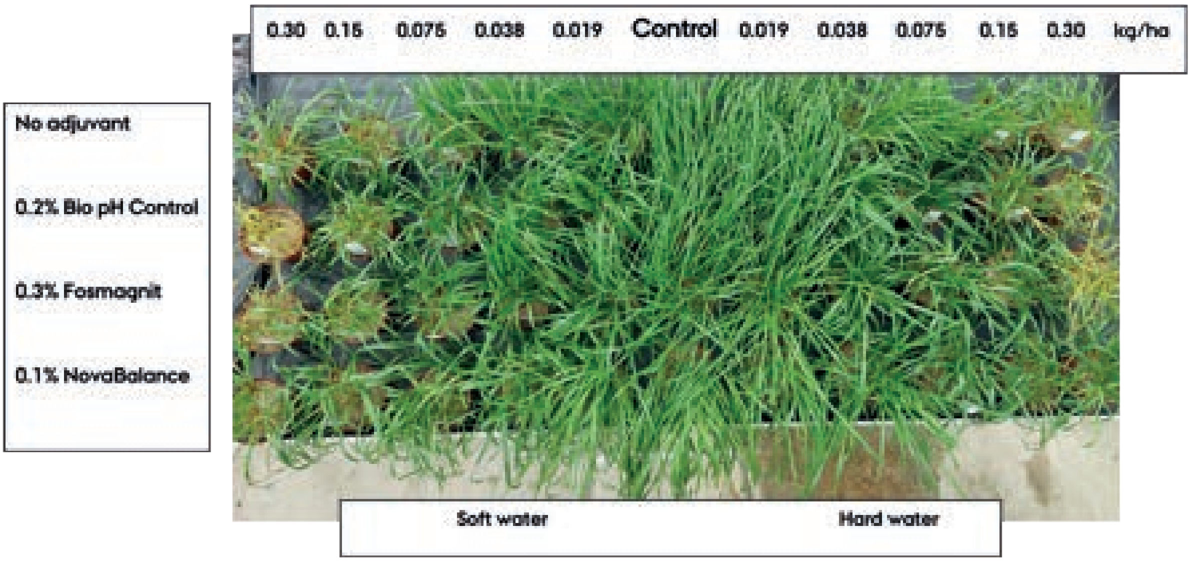

Figure 1. Photo of *L. perenne* plants treated with Roundup PowerMax prior to harvest (experiment 1).

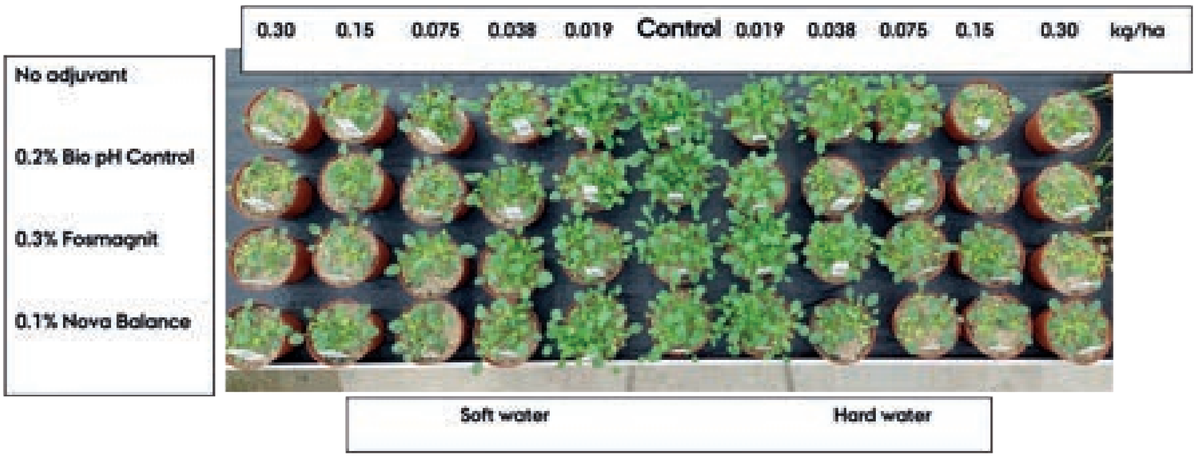

Figure 2. Photo of *V. arvensis* plants treated with Roundup PowerMax prior to harvest (experiment 1).

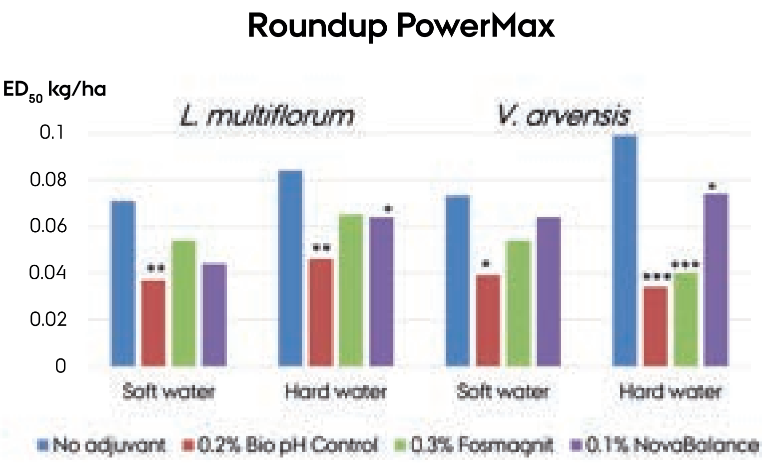

Figure 3. Estimated ED_{50} doses (based on fresh weight data) for Roundup PowerMax applied alone and in mixture with three pH-adjusting adjuvants in soft and hard water. Statistically significant differences compared to no adjuvant are indicated by asterisks (*p < 0.05, **p < 0.01 and ***p < 0.001).

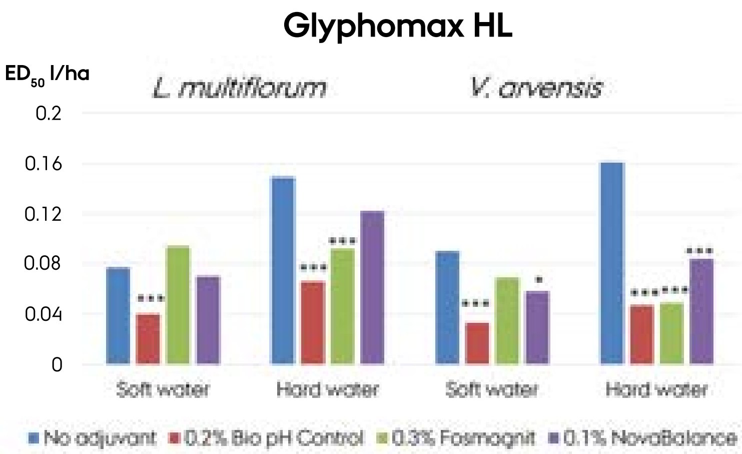

Figure 4. Estimated ED_{50} doses (based on fresh weight data) for Glyphomax HL applied alone and in mixture with three pH-adjusting adjuvants in soft and hard water. Statistically significant differences compared to no adjuvant are indicated by asterisks (*p < 0.05, **p < 0.01 and ***p < 0.001).

The pH measurements from the second series of experiments are shown in Table 2. Plants treated with Roundup PowerMax prior to harvest are shown in Figure 5, and the estimated ED_{50} doses are shown in Figures 6 and 7.

Table 2. pH values of spray mixtures applied in the second experiment at two doses of each glyphosate product.

	Soft water (8 dH°, pH 7.6)		Hard water (17 dH°, pH 7.3)	
	0.13%/1.33% Roundup PowerMax	0.15%/1.5% Glyphomax HL	0.13%/1.33% Roundup PowerMax	0.15%/1.5% Glyphomax HL
No adjuvant	4.94/3.96	5.16/4.77	5.78/4.51	6.30/5.08
0.2% Bio pH Control	2.48/3.16	2.53/3.56	2.79/3.40	3.01/4.00
1% ammonium sulphate	5.26/4.16	5.52/4.88	6.24/4.66	6.65/5.24
0.1M acetic acid buffer	3.39/3.63	3.67/3.70	3.63/3.81	3.94/3.91

Figure 5. Photo of *L. perenne* plants treated with Roundup PowerMax prior to harvest (experiment 2).

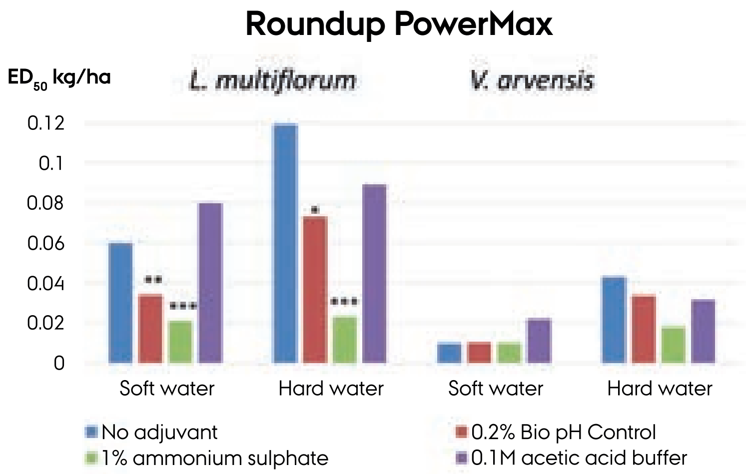

Figure 6. Estimated ED_{50} doses for Roundup PowerMax (based on fresh weight data) applied alone and in mixture with Bio pH Control, ammonium sulphate and an acetic acid/sodium acetate buffer in soft and hard water. Statistically significant differences compared to no adjuvant are indicated by asterisks (*$p < 0.05$, **$p < 0.01$ and ***$p < 0.001$).

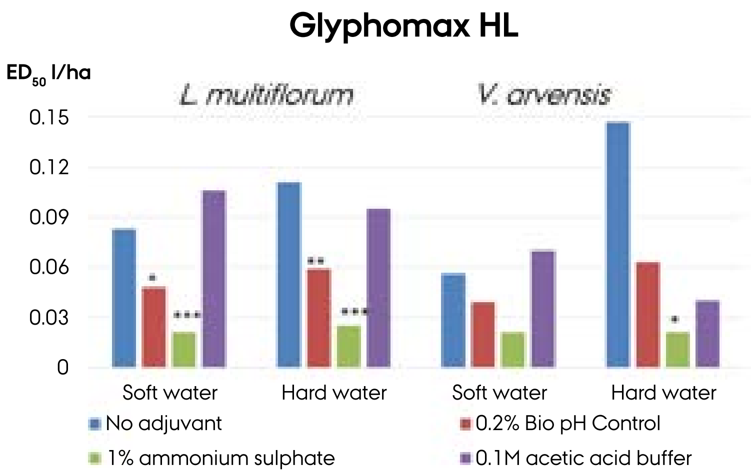

Figure 7. Estimated ED_{50} doses for Glyphomax HL (based on fresh weight data) applied alone and in mixture with Bio pH Control, ammonium sulphate and an acetic acid/sodium acetate buffer in soft and hard water. Statistically significant differences compared to no adjuvant are indicated by asterisks (*$p < 0.05$, **$p < 0.01$ and ***$p < 0.001$).

Discussion

pH measurements

The pH measurements revealed a significant interaction between glyphosate product and concentration, water hardness and the three pH-adjusting adjuvants (Table 1). pH was always lower in soft compared to hard water and Roundup PowerMax always reduced pH more than Glyphomax HL, irrespective of concentration and water source, although the differences between the two glyphosate products often were minor. In soft water, addition of pH-adjusting adjuvants always reduced pH and more so at the low than the high glyphosate concentration. With Fosmagnit and NovaBalance, the pH reductions at the high glyphosate concentration were negligible, whereas Bio pH Control reduced pH by approx. 1 unit. In hard water the differences between the pH-adjusting adjuvants became more apparent. Whereas addition of Bio pH Control also reduced pH at both glyphosate concentrations in hard water, the effects on pH of Fosmagnit and NovaBalance were insignificant. It is noteworthy that the main effect on the pH of the spray solutions came from the glyphosate products and that the pH-adjusting adjuvants primarily contributed to a pH reduction at the low glyphosate concentration.

The results suggest that while the concentration of Bio pH Control was sufficient to reduce pH in soft as well as hard water, this was not the case with the two other adjuvants, which only reduced the pH significantly in soft water. Fosmagnit used as a pH adjuster is recommended at concentrations from 0.3% to 0.5%, while the recommended concentration of NovaBalance depends on water hardness. For water with a hardness between 8 dH° and 18 dH°, the recommended concentration is 0.1% as used in this study. Possibly, a higher dose of Fosmagnit and NovaBalance would have resulted in a larger reduction in pH, but in the present study, it was not possible to test more than one dose of each of the three adjuvants.

The pH measurements of the treatments applied in the second series of experiments confirmed the assumption that addition of 1% ammonium sulphate would have no or only a minor influence on the pH of the spray solution, whereas the use of the acetic acid/sodium acetate buffer would ensure a constant pH value close to that of Bio pH Control, although the latter resulted in a somewhat lower pH value at the low glyphosate concentration. Nonetheless, the three treatments allowed us to examine the cause of any effects of the pH-adjusting adjuvants.

Efficacy

The ED_{50} doses estimated on the basis of the fresh weight data confirmed the observations from the photos in Figures 1 and 2 that the pH-adjusting adjuvants generally improved the performance of the two glyphosate products (Figures 3 and 4). Significant differences were more common in hard than soft water. Among the three adjuvants, Bio pH Control always improved the performance of Roundup PowerMax and Glyphomax HL significantly, while this was inconsistent for Fosmagnit and NovaBalance, observed in three and four of the eight configurations, respectively (2 glyphosate products x 2 water hardness levels x 2 weed species).

It is notable that the adjuvant causing the most significant reduction in the pH of the spray solution is also the adjuvant promoting glyphosate performance mostly. This may suggest a correlation between pH and glyphosate performance. It is known that Fosmagnit and NovaBalance contain phosphoric acid, while the composition of Bio pH Control is undisclosed, except a description that it consists of four components. As Bio pH Control can reduce the pH of a water solution to between 2 and 3, it is highly likely that Bio pH Control also contains a strong acid like phosphoric or sulphuric acid. Both acids are known to overcome hard water antagonism on glyphosate by forming insoluble complexes with the calcium ions in the hard water preventing the formation of glyphosate-Ca salts that are less active than other glyphosate salts (Schönherr and Schreiber, 2004). Another way of overcoming the adverse effect of hard water and calcium ions is the addition of ammonium sulphate (Thelen et al., 1995). In contrast to the pH-adjusting adjuvants, ammonium sulphate only has a negligible effect on the pH of the spray solution.

To be able to distinguish between the effect of pH and overcoming antagonism by calcium ions, a third treatment was introduced, namely applying the glyphosate products in an acetic acid/sodium acetate buffer. The buffer reduces the pH of the spray solution, but as calcium acetate is a very soluble salt, it will not overcome calcium antagonism.

In contrast to the first experiment, Bio pH Control only increased the effect of the two glyphosate products significantly on *L. perenne* (Figures 4 and 5). On *L. perenne*, addition of ammonium sulphate also improved the performance of glyphosate significantly, while using the acetic acid/sodium acetate buffer had no effect on glyphosate performance. Considering that ammonium sulphate did not reduce the pH of the spray solution but rather increased it, the results strongly suggest that the positive effect of Bio pH Control and other pH-adjusting adjuvants on the performance of glyphosate is due to the ability of these adjuvants to inactivate calcium and thus overcome the detrimental effects of hard water, rather than to a reduction in pH of the spray solution. This conclusion is substantiated by the fact that the only significant difference observed on *V. arvensis* was when ammonium sulphate was added to Glyphomax HL applied in hard water.

Conclusions

The study revealed that of the three pH-adjusting adjuvants, Bio pH Control promoted glyphosate activity more than Fosmagnit and NovaBalance in both soft and hard water, but also that the effects, not surprisingly, were more pronounced in hard water. Whether this difference between the adjuvants could be overcome by increasing the concentrations of the adjuvant products will require further studies. The effect of ammonium sulphate was comparable to or better than the effect of Bio pH Control, and farmers applying glyphosate in hard water should consider the costs of ammonium sulphate versus the pH-adjusting adjuvants before deciding on which adjuvant to use. Some of the adjuvant distributors recommend the use of both a pH-adjusting adjuvant and ammonium sulphate, but the benefits of this practice should be better documented considering the superior effect observed in this study of ammonium sulphate alone.

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X Results of crop protection trials in minor crops in 2022

Andrius Hansen Kemezys, Peter Hartvig, Kaspar Ingvordsen & Per Elmegaard Andersen

In 2022, the minor crops group at AU Flakkebjerg (Aarhus University) carried out 75 field and greenhouse trials. The activities of the group are characterised by covering not only a variety of crops, but also all types of pests as well as plant growth regulators. The 2022 trials included 32 trials with weed control in minor crops and 43 trials with control of fungal diseases and insect pests. Based on the variety of crops and pests, many stakeholders are involved in the trials. The trials are financed by various levy funds, the Danish Agricultural Agency's Green Development and Demonstration Programme (GUDP), the Danish Environmental Protection Agency, ØKS Interreg, agrochemical companies and private trial partners. The Swedish minor use project under Lantbrukarnas Riksförbund (LRF) has been a major collaborator for many years.

The available range of chemical crop protection products has decreased substantially, and this development seems especially evident in the minor crops. Denmark is located in the EU's Northern Administrative Zone, where agricultural production is small compared to the EU's Central and Southern zones, hence the market for crop protection products for minor crops is small and of little interest to the agrochemical companies. An authorisation in arable crops is often a prerequisite for a product to be on the market, and without uses in major crops there is a major risk that it will disappear from the market.

Because of this development the minor crop group's activities have become increasingly influenced by the growing interest in alternative products such as microbials and other biopesticides. There is also a great interest in products with an effect on a pest, but which are not classified as crop protection products. This includes products on the list of basic substances, but also fertilisers, plant elicitors, plant enhancers and biostimulants. For weed control, increasing awareness that chemical pesticides cannot handle all weed issues leads to an interest in non-chemical control and integrated weed management in general.

However, testing of chemical solutions is still the major activity in the minor crops group, and a summary of the most important activities is presented below.

ØKS Interreg project 'Regional network and collaboration on plant protection in minor crops'

The minor crops group has been actively involved in the Interreg projects since 2020. The project on plant protection in minor crops, which was a collaboration in the Øresund-Kattegat-Skagerak region between Norway, Sweden and Denmark, ended in 2022, and the selected results of the Interreg trials are presented below:

Control of mildew in squash

This trial had as its objective to screen for alternative products for control of powdery mildew. Squash was chosen as a model crop as it is known often to be infested by powdery mildew, but it is expected that the results from this trial can be transferred to other crops (e.g. cucumbers or potted roses) to a certain extent. The highest control of mildew was obtained with the product Kumulus S, while a number of other alternative products showed significant reduction of mildew compared to the untreated control. The development of mildew in the treated plots is presented in Figure 1 below.

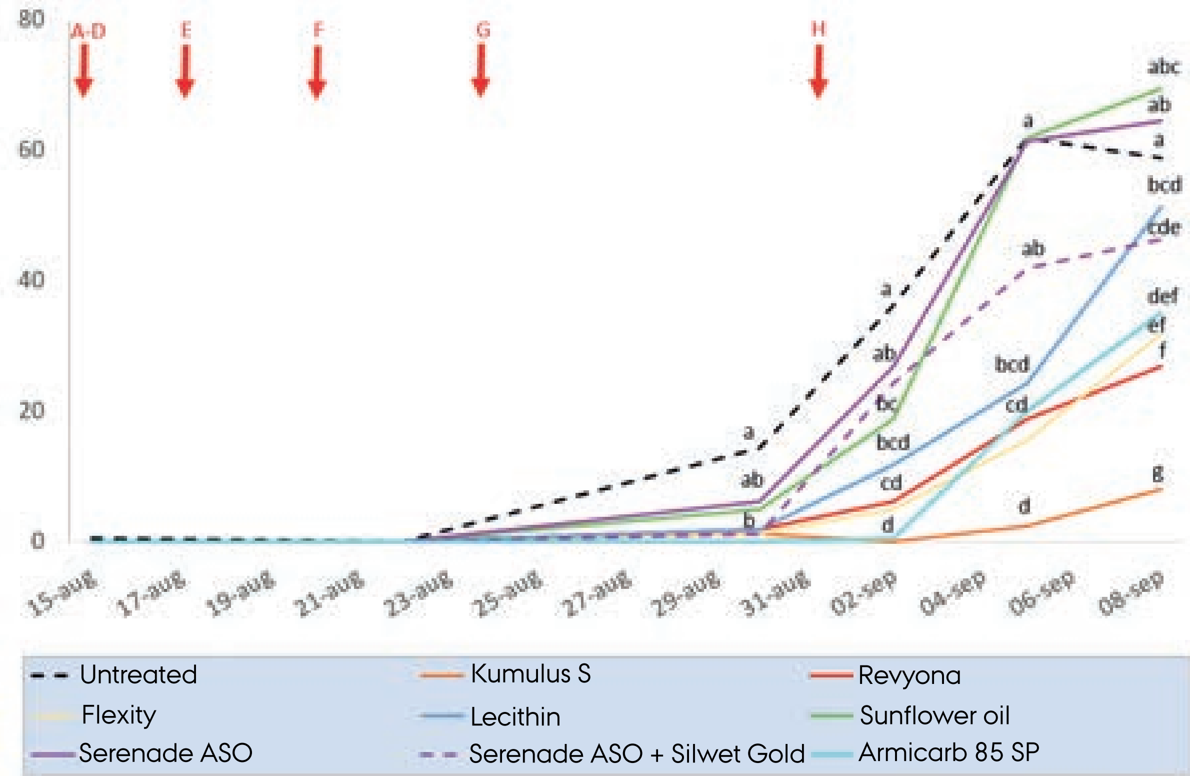


Figure 1. The development of pest severity (%, y axis) of mildew in squash. The chemical products Revyona and Flexity were applied two times, Kumulus S was applied four times, while the remaining alternative products were applied eight times. The arrows above the figure show the application timings at the beginning of the season (A-D, before the graph interval) and the last treatments (E-H, from mid-August to September), respectively.

Control of *Lygus* bugs

As it is difficult to conduct field trials with *Lygus* bugs, the trial to screen for effective products that might be used in the future was carried out in the laboratory. *Lygus* bugs have been identified as an increasing problem in different horticultural crops, including strawberries. The *Lygus* bugs were collected in a field of quinoa, placed on Petri dishes and sprayed directly with the test products. This technique identifies the products that have a rapid mode of action, mainly by the contact with the bugs, but it excludes the products that need to be digested or need longer time to show the efficacy. A number of products were identified to provide rather high efficacy (over 80% five days after treatment): Mospilan SG, Steward 30 WG, Lamdex, Mavrik Vita, Spruzit Neu, Conserve, Requiem Prime, Flipper, Eradicoat Max, rapeseed oil + green soap (used in Norway) and Fibro. The latter five products are alternative products and they are of particular interest. The results of the screening trial are shown in Figure 2.

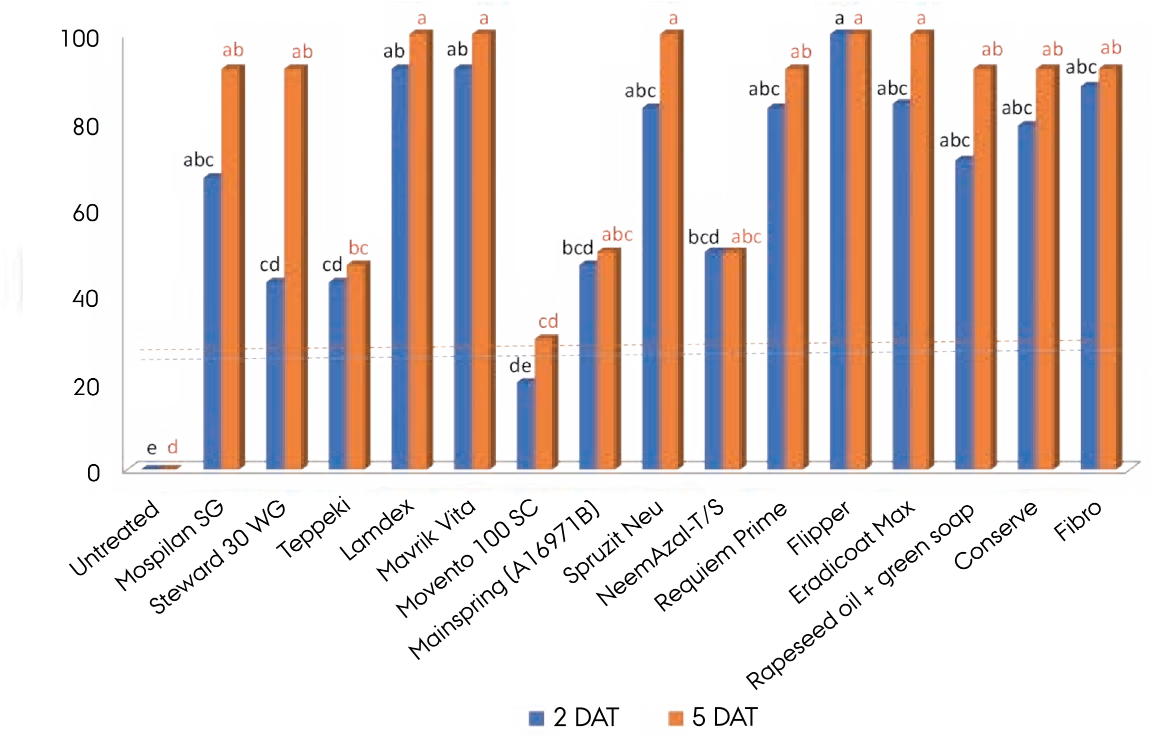


Figure 2. Percentage efficacy of a number of products that were screened for control of *Lygus* bugs. The trial was assessed on adult bugs two and five days after treatment (DAT), respectively.

GUDP project OPTIPOTTE – biopesticides as an alternative to synthetic pesticides in potted plant production

In 2022 a new GUDP project – OPTIPOTTE – was started. The aim of the project is to obtain greater knowledge about the efficacy of biopesticides and optimise their application. The project supports the green transition within the horticultural industry and is in line with the increasing demand for pesticide-free plants. Project OPTIPOTTE contributes to reaching the goal of omitting synthetic pesticides from potted plant production. The project aims to investigate and document results with different alternative products for the control of diseases and pests, which can be used not only in potted plants, but also in other horticultural crops.

A number of biopesticides have been approved and marketed for the control of diseases and pests in greenhouses. There are, among other things, microbiological agents and agents based on naturally occurring substances such as plant extracts. They are becoming increasingly more interesting as they are cheaper to develop than synthetic pesticides. In addition to biopesticides, there are also other solutions that can be used in greenhouses, for example biostimulants and basic substances.

The project includes a number of screening trials in 2022 and 2023 at the research facilities at AU Flakkebjerg, while the results will be implemented and demonstrated by pot plant producers in 2024 and 2025. A number of screening trials were carried out in 2022 in the greenhouses at AU Flakkebjerg, and selected results are presented below.

Aphids in pepper

The green peach aphid (*Myzus persicae*) is one of the most important pests in the greenhouses for all crops. Pepper (*Capsicum annum*) was chosen as a model plant to test the efficacy of a number of alternative products. The trial was carried out with six replicates under controlled conditions with artificial infestation of *M. persicae*.

The applications with the test products were carried out three times in a cabin sprayer on 13, 22 and 30 June, respectively. However, the population of the aphids in the untreated control decreased at the time of application B; therefore Table 1 presents the aphid counts the day before the first application (column 1) and the aphid counts six days after the first application only.

Teppeki was used as a chemical reference, while Flipper, SB Plant Invigorator, Agricolle, Siltac SF and Neudosan Agro are alternative products. SB Plant Invigorator, Agricolle and Siltac SF were also tested in a tank mix with an adjuvant (Silwet Gold). The tank mixes did not improve the efficacy of the single products. Flipper was tested with a water conditioner – Dynex – and in a tank mix with both Dynex and Silwet Gold. No increase in product efficacy was observed when Silwet Gold was added to the tank mix. Teppeki, Flipper, SB Plant Invigorator and Siltac SF provided over 90% efficacy.

Table 1. The efficacy of products for control of green peach aphids (*M. persicae*) in pepper. Results in the table show mean values of aphid counts per pepper leaf that had previously been marked. The observations marked in green show products that provided over 90% efficacy at the assessment six days after the first application.

Pest code					MYZUPE	MYZUPE
Pest scientific name					*Myzys persicae*	*Myzus persicae*
Pest name					Green peach aphid	Green peach aphid
Crop code					CPSAN	CPSAN
Crop name					Bell pepper	Bell pepper
Rating date					13-06-2022	20-06-2022
Part rated					LEAF; C	LEAF; C
Rating type					COUNT	COUNT
Number of subsamples					2	2
Days after first/last applic.					-1; -1	6; 6
Trt.-eval. interval					-1 DA-A	6 DA-A
Trt. no.	**Treatment name**	**Rate**	**Rate unit**	**Appl code**	1	2
1	Untreated control				84.5 a	87.8 ab
2	Teppeki	0.14	% W/V	ABC	104.4 a	0 d
3	Flipper	1	% V/V	ABC	87.8 a	6.8 d
	Dynex	0.15	% V/V	ABC		
4	SB Plant Invigorator	1	% V/V	ABC	61.1 a	1.3 d
5	Agricolle	0.6	% W/V	ABC	66.7 a	49.6 bcd
6	Siltac SF	0.07	% V/V	ABC	84.8 a	7 d
7	Flipper	1	% V/V	ABC	107.2 a	32 cd
	Dynex	0.15	% V/V	ABC		
	Silwet Gold	0.025	% V/V	ABC		
8	SB Plant Invigorator	1	% V/V	ABC	125 a	5.8 d
	Silwet Gold	0.025	% V/V	ABC		
9	Agricolle	0.6	% W/V	ABC	110.5 a	72.8 abc
	Silwet Gold	0.025	% V/V	ABC		
10	Siltac SF	0.07	% V/V	ABC	117 a	51.6 bcd
	Silwet Gold	0.025	% V/V	ABC		
11	Silwet Gold	0.025	% V/V	ABC	134.9 a	104.3 a
12	Neudosan Agro	1.8	% V/V	ABC	92 a	7.3 d
LSD P=.05					46.9	36.69
Standard Deviation					40.53	31.7

Three projects funded by the Danish vegetable and fruit production funds

Strawberry production in tunnels

The project objective was to test alternative products for weed and insect control in strawberry production in tunnels. Two methods were tested – thermal (hot water) for weed control and establishment of physical barriers (insect net) for control of insects in the tunnels. Both methods were tested for efficacy and for any side effects that might be caused by the nature of the treatments, especially the risk of increased humidity or temperature in the production tunnels. The project was targeted at organic strawberry production, but applicable to conventional strawberry production as well.

Two insect net trials were established at two different strawberry producers. Two types of insect nets were tested for covering the strawberry tunnels – fine mesh 0.15 x 0.3 mm and larger mesh 0.27 x 0.79 mm. It was observed that both types of nets were able to reduce the number of thrips at the beginning of the insect attack in the middle of June compared with the non-netted tunnels, but the number of thrips increased later in the trial period (data not shown), and the nets could not keep the larger infestation from the strawberries. The temperature and humidity monitoring showed that the netting of the tunnels caused a temperature increase of approximately 1-3°C, and it caused a reduction of the relative humidity of approximately 1-5%. These side effects are considered moderate and acceptable.

Three hot water treatment trials were established – two of them for efficacy and one trial for monitoring of any increased temperature or humidity. The application was carried out by pouring nearly boiling water of 98-99°C on emerged weeds with commercially available equipment known from weed control on semi-permeable surfaces (e.g. public squares, pavements, etc.).

Hot water treatment in a strawberry trial in Hørve. The applications in this trial were carried out on tractor tracks between the plastic-covered strawberry beds where the weeds are not wanted as they can grow between the berries, thus reducing the strawberry quality either by mechanical damage or by creating a microclimate that enhances development of berry diseases, e.g. *Botrytis.* The first five metres of the track to the right were treated with hot water four times, while the track to the left is the untreated control.

The treatments in the hot water trials were designed for testing two different intensities (operating speeds) of the treatment (normal and 50% reduced intensities) and the different number of applications. The results indicated that the applications must be repeated at least four times during the season, but the application intensity can be reduced in spring treatments when the weeds are small. It is important to carry out a satisfactory weed control prior to the strawberry ripening, so that there are as few weeds as possible prior to harvest.

Left: Very clear weed control six days after first application in April 2022. The plots at the front and again at the back of the photo were untreated controls, while the two plots in between were treated with either normal or 50% reduced intensities with no clear differences – thus suggesting that the intensity in spring can be reduced. – Right: The plot at the front received two applications of hot water, while the plot behind it only received one single application, and the regrowth of the weeds was observed. The last yellowish plot was a reference with the chemical product Reglone (diquat, which is no longer authorised in Denmark).

Thermal weed control in seeded onions

This was another project focusing on thermal solutions for weed control in terms of flame treatment for inter-row treatment in onions. One of the trials in this project focused on three factors: onion size at application, operating height of the burner and burning intensity (operating speed). The selectivity results suggested that the burning intensity and the onion size were the most important parameters in terms of damage to onions, while the burner height did not seem to influence the severity of the damage. The operating height of the burners is interesting because when the burners are lowered, flames will mainly hit inter-row weeds with less risk of damaging onions, while the opposite situation occurs with highly positioned burners flames that have easier access to small intra-row weeds, but also with a higher risk of damaging the onion plants. Regarding burning intensity, it was observed that the higher the intensity, the greater the damage to onions. Importantly, the onion size played an important role in selectivity. The greatest damage was observed to small onions (up to 28% on 24 June), while larger onions were not damaged to the same extent. However, the onions were able to recover, and the damage had decreased at the assessment on 22 July. The yield results (Figure 3, grey bars) did not show any significant difference. The flame treatment seemed to be more suitable for larger onions – BBCH 16 and higher. However, the onions treated at lower growth stages were able to recover, and the yield measurement showed no significant difference in onion yield.

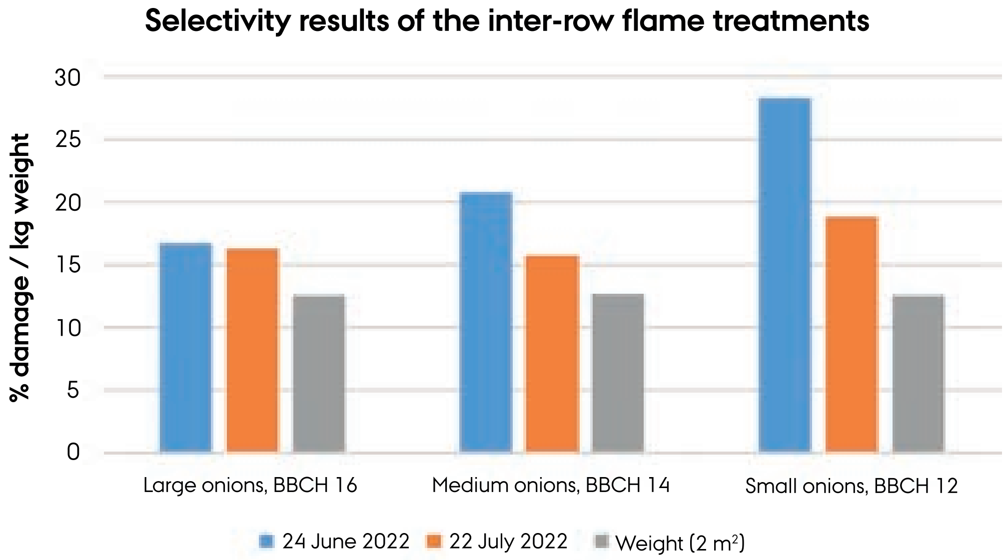


Figure 3. Selectivity results of the inter-row flame treatment in onions. Damage was evaluated two times after treatment (24 June and 22 July) and weight at harvest was measured (weight on 2 m^2).

Inter-row flame treatment in onions.

Enhanced herbicide efficacy by liquid nitrogen fertiliser

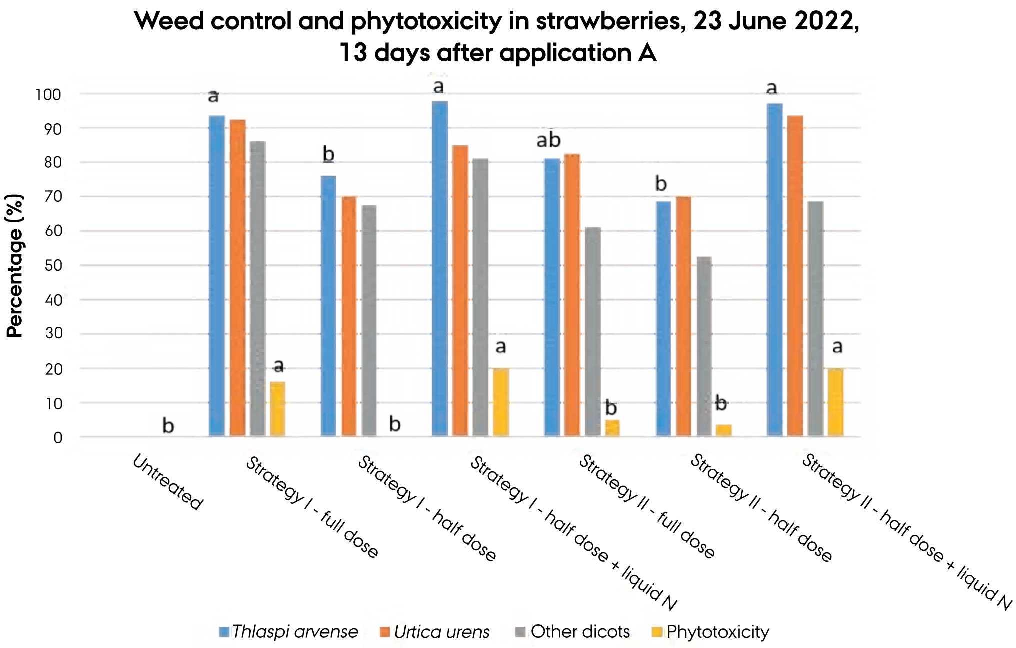
An addition of liquid nitrogen fertiliser (NS 30-2) in a tank mix with herbicides can boost the efficacy of a number of herbicides. The addition of liquid nitrogen fertiliser to a tank mix with reduced herbicide dose rates can possibly be considered as a way of reducing the amount of herbicide used in horticulture. However, there is a risk of burning or scorching the plant foliage with liquid nitrogen fertiliser, and it is very important to investigate the unwanted crop phytotoxicity effects when adding liquid nitrogen fertiliser to a tank mix with herbicides.

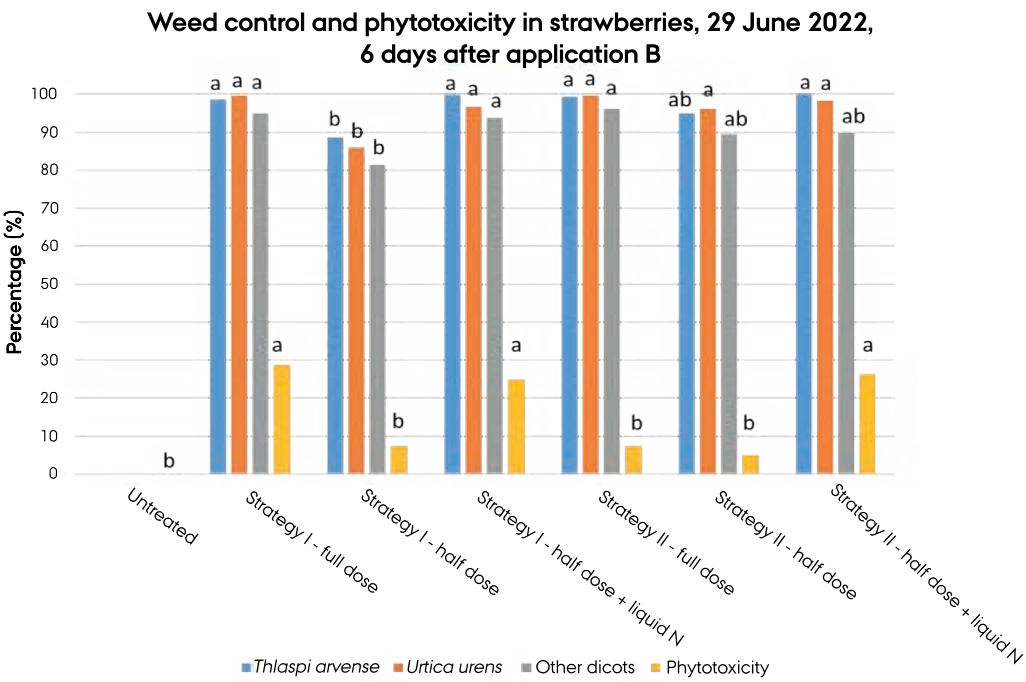
This project was a continuation of a semi-field study conducted in 2021, where a number of different common weeds and horticultural crops – carrots and onions – were grown in pots and tested for the added efficacy by using liquid nitrogen fertiliser and for crop selectivity. The best combinations were chosen, and in 2022 three trials were carried out in three different crops: carrots, onions and newly established strawberries.

Two different herbicide strategies were tested in each of the trials. All three trials had the same trial design, but with different herbicides. – The effect of full dose (field rate), half dose and half dose with addition of liquid nitrogen fertiliser, respectively, was tested for control of weeds and whether they caused any phytotoxicity to carrots, onions and strawberries. Unfortunately, the addition of liquid nitrogen fertiliser did not result in any significant added efficacy in the trials with carrots and onions – partially because the half dose rate was providing satisfactory efficacy to control the weeds in the trials (data not shown). Nevertheless, the strawberry trial showed the very clear pattern that reduced herbicide dose rates could be boosted by the addition of liquid nitrogen fertiliser to a tank mix (Figure 4).

In the strawberry trial, a very clear boost effect was observed from the addition of liquid nitrogen to the reduced dose rate of the herbicide strategies against all weed species (significant differences in many cases). Increased phytotoxicity in the form of scorched strawberry leaf edges was also observed in treatments with liquid nitrogen fertiliser, but the phytotoxic damage can be considered acceptable and was at the same level as herbicide strategy I at full dose. The later assessments showed that the strawberries were able to recover, and no decreased plant vigour could be associated with any of the treatments (data not shown).

At the moment, however, the use of liquid nitrogen fertiliser for enhancing herbicide efficacy, as described in the trials above, is not approved.





Strategy / application	A	B	C
Strategy I (full dose)	Stomp CS + Boxer (1.6 + 1.5 l/ha)	Boxer + Goltix WG (1.5 l/ha + 0.7 kg/ha)	Boxer + Goltix WG (1.5 l/ha + 0.7 kg/ha)
Strategy II (full dose)	Goltix WG (1 kg/ha)	Betanal + Boxer (2 + 2 l/ha)	Betanal + Boxer (2 + 2 l/ha)
Liquid nitrogen fertiliser	40 kgN/ha	20 kgN/ha	20 kg N/ha

Figure 4. Percentage (%) efficacy for treatment of weeds and percentage (%) damage (phytotoxicity) as a result of treatment with herbicides alone or in mixture with liquid nitrogen fertiliser in strawberries just before applications B (top graph) and C (bottom graph), respectively.

XI List of chemicals

Fungicides		
Name	**Active ingredients**	**Gram/l or kg**
Amistar	Azoxystrobin	250
Armicarb 85 SP	Potassium hydrocarbonate	850
Ascra Xpro	Prothioconazole + bixafen + fluopyram	130 + 65 + 65
Aviator Xpro	Prothioconazole + bixafen	150 + 75
Balaya	Mefentrifluconazole + pyraclostrobin	100 + 100
BAS 754 00F	Prothioconazole + mefentrifluconazole + N,N-dimethylcapramid	-
BAS 768 00F	Revysol + sulphur	600 + 25
BAS 831 00F	Xemium + Dev cpd	90 + 90
Bion	Acibenzolar-S-methyl (benzothidiazole)	500
Cayunis	Bixafen + spiroxamine + trifloxystrobin	75 + 150 + 100
Charge	Chitosan	30
ChiProPlant	Chitosanhydrochloride	0.25 - 2
Comet Pro	Pyraclostrobin	200
Curbatur	Prothioconazole	250
Delaro Forte	Prothioconazole + trifloxystrobin	175 + 150
Elatus Era	Azoxystrobin + benzovindiflupyr	30 + 15
Elatus Plus	Benzovindiflupyr	100
Entargo	Boscalid	500
Fandango S	Prothioconazole + fluoxastrobin	100 + 50
Flexity	Metrafenon	300
Folicur EW 250	Tebuconazole	250
Folicur Xpert	Tebuconazole + prothioconazole	160 + 80
Folpan 500 SC	Folpet	500
FytoSol	COS-OGA	12.5
Glacis	Prothioconazole	250
Greteg Star	Azoxystrobin + difenoconazole	125 + 125
Imtrex	Fluxapyroxad	62.5
Input Triple	Spiroxamine + prothioconazole + proquinazid	200 + 160 + 40
Iodus	Laminarin	45
Juventus 90	Metconazole	90
Kayak Era	Prothioconazole + cyprodinil	75 + 225
Kumulus S	Sulphur	800
Lalstop G46	*Clonostachys rosea*	1 x 10^9 CFU/g
Lecithin	Phospholipids	-
Luna Privilege	Fluopyram	500
Madison	Prothioconazole + trifloxystrobin	88 + 175
MCW 406-S	Difenoconazole	250
Narita	Difenoconazole	250

Fungicides		
Name	**Active ingredients**	**Gram/l or kg**
Orius Max	Tebuconazole	200
Pecari	Prothioconazole	300
Phosphonate	Phosphonic acid	504
Pictor Active	Pyraclostrobin + boscalid	250 + 150
Polyversum	*Pythium oligandrum* M1	1000000000 CFU/kg
Priaxor	Pyraclostrobin + fluxapyroxad	150 + 75
Proline EC 250	Prothioconazole	250
Proline Xpert	Tebuconazole + prothioconazole	80 + 160
Propulse SE 250	Fluopyram + prothioconazole	125 + 125
Prosaro EC 250	Prothioconazole + tebuconazole	125 + 125
Prothio 300	Prothioconazole	300
Questar	Fenpicoxamid	100
Ranman Top	Cyazofamid	160
Revycare	Mefentrifluconazole + pyraclostrobin	100 + 100
Revyona	Mefentrifluconazole	75
Revysol	Mefentrifluconazole	100
Revystar XL	Mefentrifluconazole + fluxapyroxad	100 + 50
Revytrex	Mefentrifluconazole + fluxapyroxad	66.7 + 66.7
Serenade ASO	*Bacillus amyloliquefaciens*	7131 x 10^{12} CFU/L
Sunflower oil	Oil	1000
Thiopron 825	Sulphur	825
Thore	Bixafen	125
Univoq	Prothioconazole + fenpicoxamid	100 + 50
Verben	Prothioconazole + proquinazid	200 + 50
Vertipin	Sulphur	700

Herbicides		
Name	**Active ingredients**	**Gram/l or kg**
Betanal	Phenmedipham	160
Boxer	Prosulfocarb	800
Glyphomax HL	Glyphosate	480
Goltix WG	Metamitron	700
Reglone	Diquat	200
Roundup PowerMax	Glyphosate	720
Stomp CS	Pendimehalin	455

Insecticides		
Name	**Active ingredients**	**Gram/l or kg**
Agricolle	Extract from seaweeds	-
Conserve	Spinosad	120
Eradicoat Max	Maltodextrin	476
Fibro	Paraffin oil	797
Flipper	Carboxylic acid potassium salts	480
Lamdex	Lambda-cyhalothrin	20
Mainspring (A16971B)	Cyantraniliprole	400
Mavrik Vita	Tau-fluvalinate	240
Mospilan SG	Acetamiprid	200
Movento 100 SC	Spirotetramat	100

Insecticides		
Name	**Active ingredients**	**Gram /l or kg**
NeemAzal-T/S	Azadirachtin	10
Neudosan Agro	Carboxylic acid potassium salts	515
Rapeseed oil + green soap	Oil and soap	-
Requiem Prime	Terpenoid	152.3
SB Plant Invigorator	Sodium lauryl ether sulphate	10-30
Siltac SF	Polyether-modified silicone	<750
Spruzit Neu	Pyrethrin I and II + oilseed rape oil	4.59 + 825
Steward 30 WG	Indoxacarb	300
Teppeki	Flonicamid	500

Adjuvants		
Name	**Active ingredients**	**Gram /l or kg**
Agropol	Adjuvant	-
Bio ph Control	-	-
Contact	Adjuvant	-
Dynex (water conditioner)	Tetrasodium-ethylendiamintetraacetate	250 - 750
Fosmagnit	Phosphoric acid	-
NovaBalance	Phosphoric acid	-
Silwet Gold	Adjuvant	-
Silwet L 77	Adjuvant	-

About DCA

DCA - Danish Centre for Food and Agriculture is the entrance to research in food and agriculture at Aarhus University (AU).

The Centre comprises AU departments with food and agricultural science activities. These are primarily Department of Agroecology, Department of Animal Science, Department of Food Science, Centre for Quantitative Genetics and Genomics, and parts of Department of Engineering.

DCA has a Centre Unit, which supports and coordinates DCA activities in relation to research based policy support, industrial and sector collaboration, international collaboration, and communication.

Research results from DCA
Research results are published in international scientific journals, and they are available at the university publication database (pure.au.dk).

DCA reports
DCA also publishes a report series, which primarily communicates policy support tasks from DCA to the Ministry of Food and Environment of Denmark. Further publications include reports that communicates knowledge from research activities. The reports may be downloaded free of charge at the DCA website: dca.au.dk.

Newsletters
A Danish and English DCA newsletter communicate knowledge within agricultural and food research, including research results, advice, education, events and other activities. You can register for the free newsletter at dca.au.dk.

SUMMARY

This publication contains results from protection trials which were carried out at the Department of Agroecology within the area of agricultural crops. Most of the results come from field trials, but results from laboratory testing and greenhouse and semi-field trials are Included.

The report contains results that throw light upon:

- Effects of new pesticides
- Results of different control strategies, including how to control specific pests as part of an integrated control strategy involving both cultivars and control thresholds
- Results with pesticide resistance
- Trial results from different cropping systems