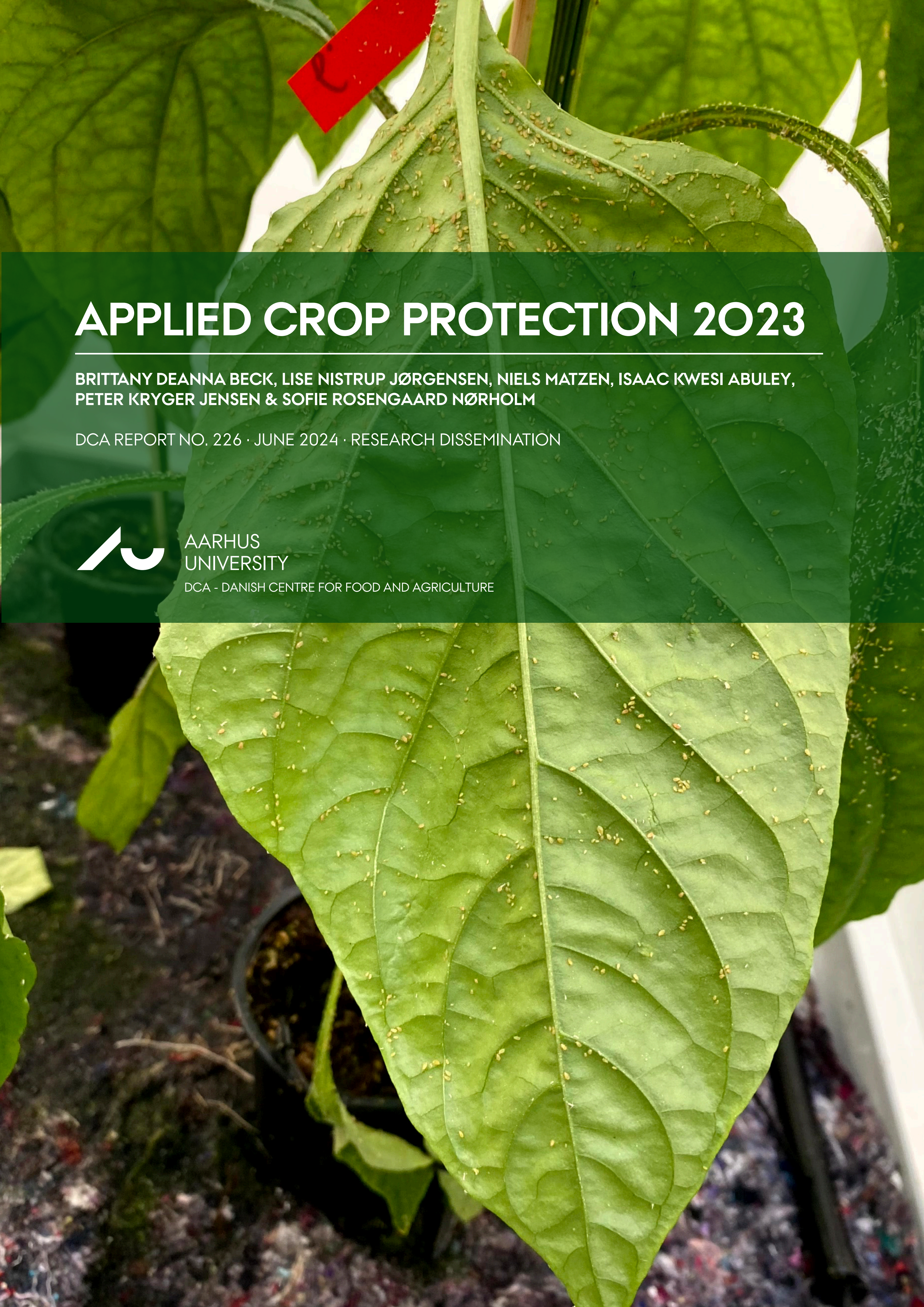

APPLIED CROP PROTECTION 2023

BRITTANY DEANNA BECK, LISE NISTRUP JØRGENSEN, NIELS MATZEN, ISAAC KWESI ABULEY,
PETER KRYGER JENSEN & SOFIE ROSENGAARD NØRHOLM

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Applied Crop Protection 2023

Report from DCA – Danish Centre for Food and Agriculture

AUTHORS:

Brittany Deanna Beck, Lise Nistrup Jørgensen, Niels Matzen, Isaac Kwesi Abuley, Peter Kryger Jensen &
Sofie Rosengaard Nørholm, Department of Agroecology, Aarhus University

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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 and biologicals, 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 up 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, and no part is written or commented on by external partners. 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 Brittany Deanna Beck, Birte Boelt, Peter Hartvig, Peter Kryger Jensen, Lise Nistrup Jørgensen and Mette Sønderskov.

Chapter I: Climate data for the growing season 2022/2023 and specific information on disease attacks in 2023. The information was collected and funded 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 BASF, Bayer Crop Science, KWS, Nordic Seed 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 by BASF and Bayer Crop Science. Certain elements were based on AU's own funding.

Chapter V: Fungicide resistance-related investigations. Testing for fungicide resistance was carried out based on a shared cost covered by projects and the industry. In 2023 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; elements were based on AU's own funding.

Chapter VI: Monitoring population dynamics and assessing fungicide sensitivity of *Phytophthora infestans* in Denmark. Funding has been provided by the Danish GUDP (Green Development and Demonstration Programme) via the ECOSOL project as part of the SusCrop ERA-NET Co-fund, the potato levy board (KAF) and the Danish Environmental Protection Agency's Pesticide Research Programme as part of the Potato-FRAS project.

Chapter VII: Eco-friendly management of late blight in potatoes. Funding for this work was obtained from 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). Specifically, treatments 1, 2, 5, 6, 7 and 8 were funded by KAF, while the remaining treatments as well as modelling works in the study were financed as part of the ECOSOL project.

Chapter VIII: Cultivar resistance against downy mildew (*Peronospora destructor*) in onions**.** This study is part of the INNOVATE-IPM project. Funding has been provided by the Danish Environmental Protection Agency's Pesticide Research Programme under grant number 2021-68771.

Chapter IX: Band spraying in grass seed crops with different herbicide dose rates in the crop band and in the inter-row area. The investigation was financed by the Danish Seed Levy Fund (Frøafgiftsfonden).

Chapter X: Desiccation of potatoes with sodium chloride. The study was financed by the Danish Agricultural Agency's Green Development and Demonstration Programme (GUDP).

Chapter XI: List of chemicals.

Contents

I Climate data for the growing season 2022/2023

Sofie Rosengaard Nørholm & Brittany Deanna Beck

Climate

This section evaluates the overall weather conditions in Denmark during the growing season. A separate section describes the weather conditions recorded at the weather station at AU Flakkebjerg where most of the Aarhus University trials were located (September 2022-August 2023).

The Danish 2022 autumn had 207.5 mm precipitation, a 12% decrease in comparison with the 10-year average from 2011-2020 across the country. The autumn weather was one of the warmest since 1874 when the first measurements began. The average Danish autumn temperature was 10.8°C, which was 1.3°C higher than the average temperature for the period of 1991-2020. October and November also had higher than average temperatures.

With 244.7 mm the 2022/2023 winter had a 31% higher precipitation level than the 30-year average (1991-2020). Most of the precipitation was in January with 124.5 mm, making it the wettest January since 1874. The winter of 2022/2023 had 34.4 days with frost and 7.2 days with snow cover. The average temperature for the country was 3.0°C, which was 0.7°C higher than the 10-year average (2011-2020).

The spring in Denmark 2023 had 136.9 mm precipitation, a 4% increase to the 30-year average (1991-2020). May was very dry with only 14.1 mm of precipitation, which was much lower than the 30-year average (1991-2020) of 47.3 mm. The average spring temperature of 7.3°C was within the normal range (1991-2020).

In the summer of 2023, June was very dry and warm, while July and August were very wet. The precipitation was the highest in July since 1874 in Denmark (140.8 mm). The summer precipitation was 269.8 mm, which was 27% above normal (1991-2020). The average summer temperature was 16.1°C across the country. June was very warm with an average temperature of 16.4°C, which was 1.9°C higher than the normal temperature (1991-2020).

With 163.8 mm the precipitation in autumn 2022 at AU Flakkebjerg was average to 2011-2022. September was a wet month with 68% more precipitation than normal. The temperature in the autumn at AU Flakkebjerg was 10.9°C in line with the average temperature.

During the winter at AU Flakkebjerg, there was an 8% increase of precipitation compared with the average (2011-2022), reaching 165.4 mm. January was exceptional with an 81% increase to the normal AU Flakkebjerg average. The 2022/2023 average winter temperature was 2.9°C, which was only 0.5°C higher than the average temperature (2011-2022). December was 2.2°C colder than the average December temperature (2011-2022).

The average spring temperature was 7.6°C at AU Flakkebjerg, which was near the average spring temperature at AU Flakkebjerg (2011-2022). The precipitation in the spring was 97.6 mm, which was 39.3 mm less than the national average precipitation in the spring. May was very dry, and only 12.7 mm rain was recorded at AU Flakkebjerg.

During the summer at AU Flakkebjerg, the precipitation was 239.9 mm, which was 57% more than the average (2011-2022). The temperature was exactly average at 16.8°C, but the June temperature was 1.2°C higher than the average (2011-2022).

Overall, the very dry months of May and June did influence the diseases where *Septoria* appeared very late in the season.

The overall weather data from AU Flakkebjerg are shown in Figures 1-3. The drought conditions across Denmark for the six main months are shown in Figure 4.

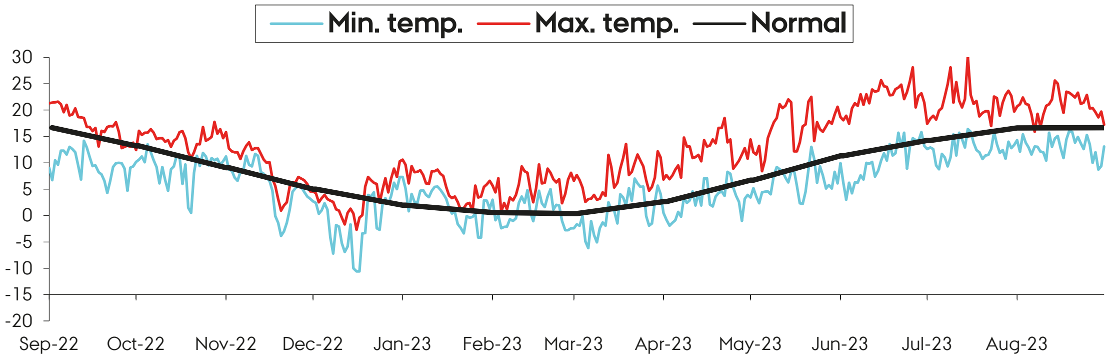


Figure 1. Climate data graph from AU Flakkebjerg for the growing season September 2022-August 2023. The temperature is in °C.

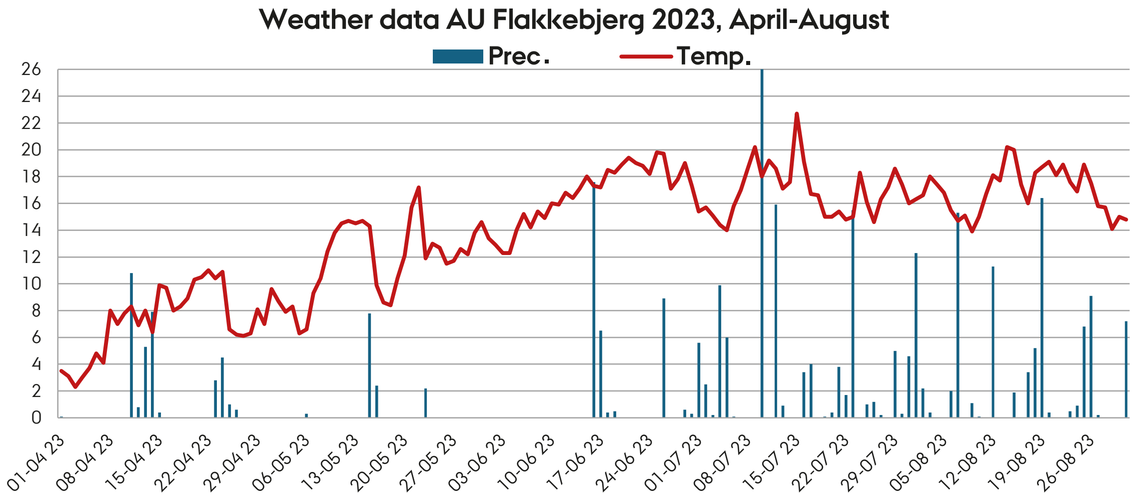


Figure 2. Climate data graph from AU Flakkebjerg for spring and summer 2023. The temperature is in °C and the precipitation is in mm.

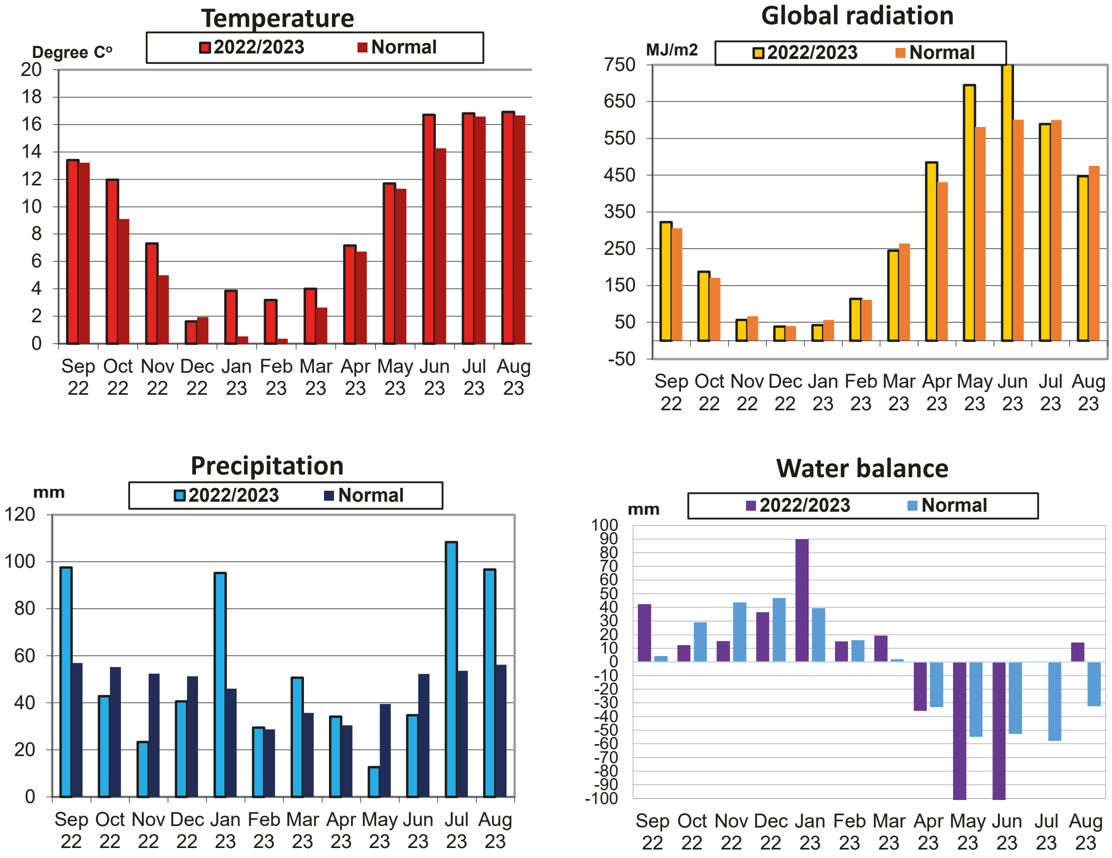
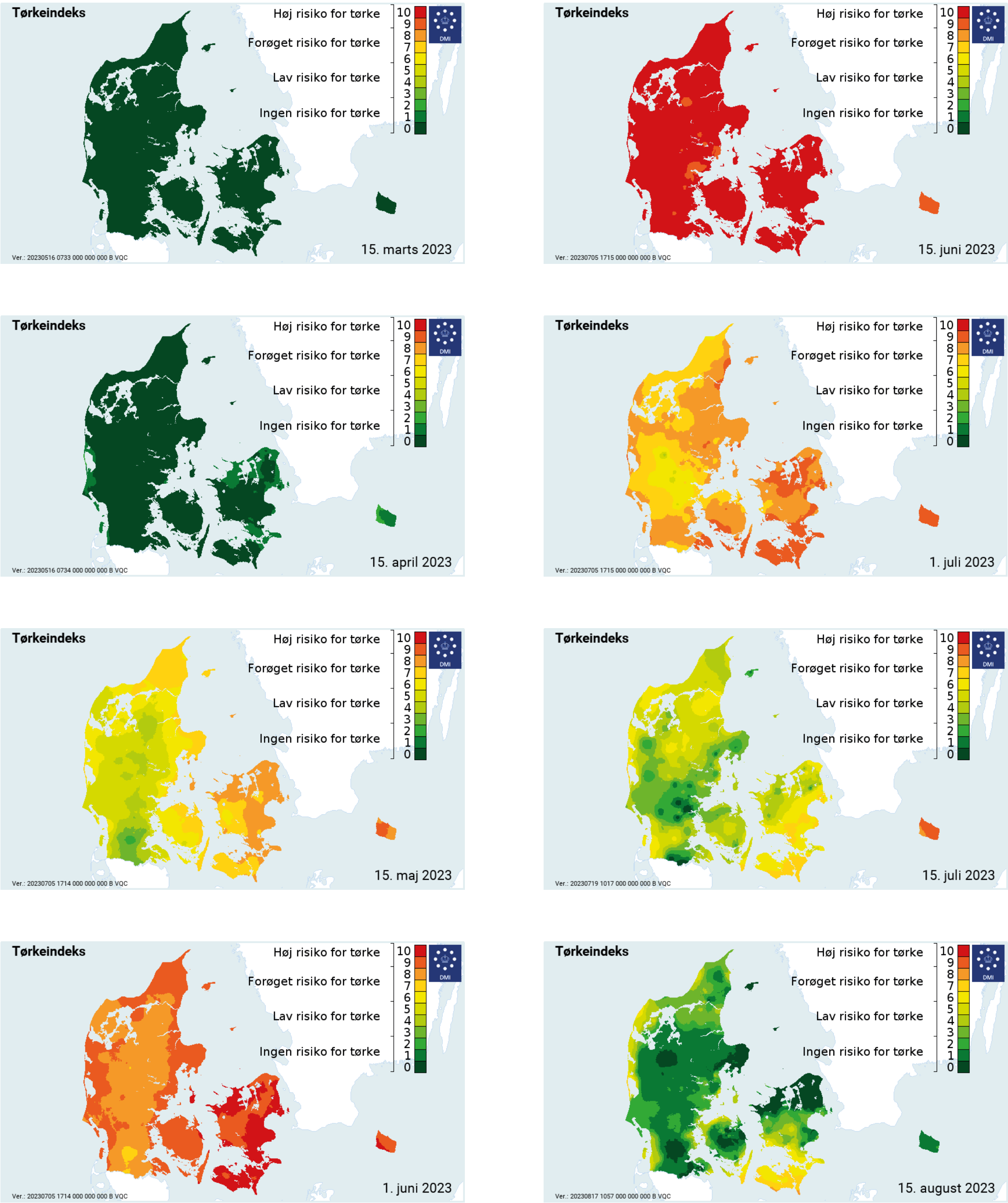


Figure 3. Climate data from AU Flakkebjerg for the growing season September 2022–August 2023. The temperature is in °C, the global radiation is measured in MJ/m^2, the precipitation is in mm, and the water balance is the difference between precipitation and potential evaporation.



Drought index 2023 (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 March-August 2023. Danish Meteorological Institute (DMI).

1. Disease attacks in 2023

Brittany Deanna Beck, Sofie Rosengaard Nørholm, Sidsel Stein Kirkegaard, Isaac Kwesi Abuley & Lise Nistrup Jørgensen

This chapter describes the occurrence of diseases present in the fungicide trials in 2023. This knowledge is important in determining if 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*). The Jyndevad trial station in Jutland has the perfect conditions to stimulate powdery mildew attack on cereals because of the sandy soils. The moderate to severe infestation rate in 2023 made it possible to rate the efficacy of the products.

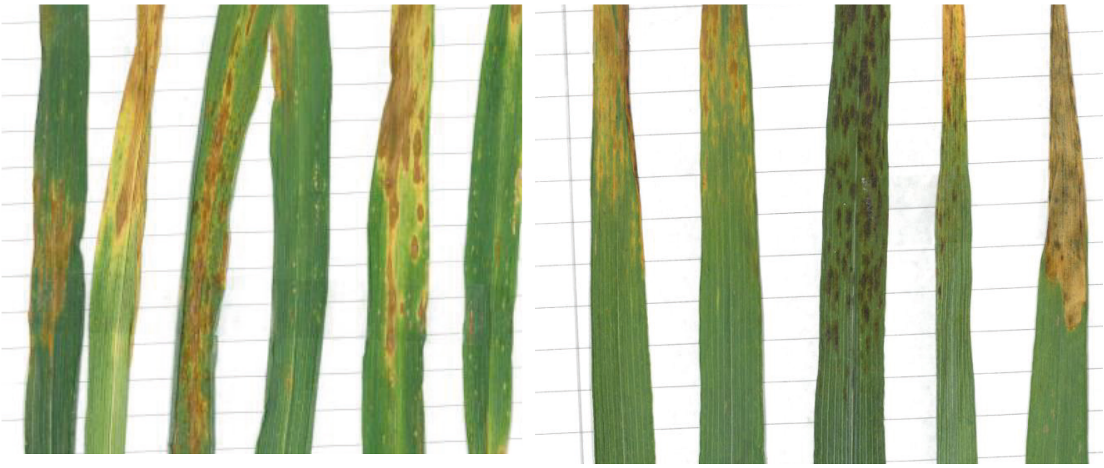
As early as mid-May the cultivar Torp had a severe mildew infection on leaves 3 and 4, which developed an attack of 55% (leaf 3) and 60% (leaf 4) in the untreated plots at growth stage (GS) 45. Later in the season in June, the very dry weather stopped the mildew development, leading to mildew reaching only 6% (leaf 1) and 21% (leaf 2) at GS 73. Information from a SEGES trial reported similar disease development with 20% disease on leaf 2 and 6.5% on leaf 1 at GS 54. Only a minor and insignificant attack from powdery mildew was recorded at AU Flakkebjerg in 2023.

Septoria tritici blotch (*Zymoseptoria tritici*). The weather conditions in April, May and June were low humidity and rainfall. The weather led 2023 to be a year with very low levels of Septoria tritici blotch. At AU Flakkebjerg the following susceptible cultivars Cleveland, Hereford and Rembrandt are grown to help increase disease development. Despite the little rain and three times of irrigation of the fields, there was not sufficient moisture to increase the *Septoria* disease pressure in the critical period.

At the beginning of July, a couple of days of rain helped *Septoria* to develop and led the level of *Septoria* attack to be 30% on leaf 2 and 5% on leaf 1. The late development of *Septoria* did not have any impact on the yield levels. There were sufficient data in some trials to discuss the efficacy of the products, but no conclusions could be made about the impact on yield or grain quality.

Across the country the *Septoria* levels stayed very low, and it was generally difficult to rank the efficacy of the tested fungicides or cultivar susceptibility. In many cases necrotic spots on wheat leaves were mistaken for Septoria tritici blotch. The necrotic symptoms were caused by stress and physiological spots. QPCR testing of many leaf samples collected across Denmark also showed very low levels of occurrence of *Septoria*.

Brown rust (*Puccinia triticina*). No or only minor attacks of brown rust were recorded in trials at AU Flakkebjerg in 2023. The attack levels were also very low – below 5% - in the rest of Denmark.



Many confusing symptoms of *Septoria*-like spots were seen during the season. Very few were verified as Septoria tritici blotch, Septoria nodorum blotch or tan spot. The symptoms were caused by physiological spots (leaves obtained from Susanne Sindberg, TystofteFonden, and collected in Tølløse).

Yellow rust (*Puccinia striiformis*). In the AU Flakkebjerg fields, a susceptible wheat cultivar is chosen to help ensure the spread of yellow rust, and the crop is inoculated with yellow rust in April by using spreader plants. The highly susceptible cultivar Benchmark was grown, although it is no longer sold in Denmark. Despite dry conditions during the growing season, the humidity during nights was sufficient to support the development of a significant and yield-reducing attack of yellow rust.

The conditions led to moderate to severe infection levels in May and June. The severe disease pressure gave good opportunities to test the efficacy of different fungicides. The attack increased to approx. 21% on the flag leaf and 51% on leaf 2 at GS 73. The high level of attack of yellow rust in 2023 reduced yields in Benchmark by 1.5 to 3 tonnes/ha. In trials without inoculation the yellow rust levels were low, and in the rest of Denmark the infection level did not even reach 5%.

Tan spot (*Drechslera tritici-repentis*). To cause tan spot infection, a minimal tillage field at AU Flakkebjerg is simulated by pre-infecting a susceptible cultivar (Kvium) with tan spot-infected straw. In the spring, tan spot had a decent infection in Kvium, even with a dry season and varied water supplies. The disease developed to a moderate level later in the season, still allowing for significant differences between treatments. The late disease pressure had as a result that the treatments did not impact the yield levels or grain quality parameters. The assessments of tan spot at GS 75 showed a disease level of approx. 15% on the flag leaf and 29% on leaf 2. In Denmark in general, only late and very low infection levels of tan spot were seen in 2023.

Fusarium head blight (*Fusarium* spp.). To ensure attack in trials at AU Flakkebjerg, we inoculated wheat crops with *Fusarium* spores. When the crop is flowering, inoculation and irrigation are an effective method to ensure an attack. In the different trials two methods of inoculation are used. The first method is to infect grain which is placed on the soil, the other method is inoculation with a spore solution during flowering. The trials were irrigated three times, but only a low to moderate attack level of *Fusarium* was established, depending on the cultivar. In the cultivars Cleveland and Rembrandt low to moderate attack levels developed, and there were significant differences between treated and untreated plots in the various trials. In the cultivar Hereford, only a very slight attack developed, and no clear differences could be recorded. A severe attack of Fusarium head blight developed in the cultivar trials which ranked cultivar susceptibility. These trials are inoculated either by placing infected grain on the ground at flag leaf emergence or by applying spore inoculation during flowering. These trials are irrigated daily and develop severe attacks and high levels of mycotoxin content.

Triticale and rye

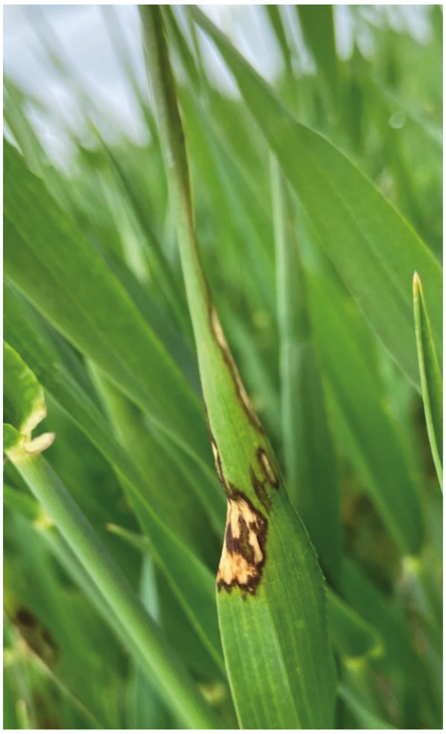
Yellow rust (*Puccinia striiformis*). Triticale trials at AU Flakkebjerg were naturally infected with yellow rust. In most years triticale is severely infected, and 2023 was no exception. Due to the mild weather in May, yellow rust had an optimal development, and by the beginning of June the attack increased. The yellow rust levels for the 2023 season were very similar to 2022. At GS 71, at the end of June, levels increased to 12.5% on leaf 1 and 38% on leaf 2. At GS 75 the attack on the ear of the untreated control was 26%. The disease level was moderate, providing opportunities for ranking the performances of the fungicides. There was a good yield response between treated and untreated plots, up to an increase of 1.2 tonnes/ha.

***Rhynchosporium* (*Rhynchosporium commune*).** In rye trials, a minor attack of *Rhynchosporium* developed during May and at the beginning of June. The low disease level led to fewer opportunities for distinguishing the efficacy of the products. By mid-June, at GS 71, the attack of *Rhynchosporium* in rye increased to only 5.3% on leaf 2, a significantly lower disease pressure than in the previous year.

Winter barley

Powdery mildew (*Blumeria graminis*). Recordings carried out by advisors in the national monitoring system organised by SEGES showed that the level of mildew attack was very low in 2023. AU Flakkebjerg also had similar levels; this prevented the efficacy of the products from being ranked.

***Rhynchosporium* (*Rhynchosporium commune*).** In 2023 *Rynchosporium* was the most dominant disease in winter barley, but the levels of infection still did not become severe due to dry weather during the elongation of the crop. The infection provided minimal opportunities for ranking the performance of the products. The average attack of *Rynchosporium* reached a level of 12% on leaf 2 at GS 75 and 22% on leaf 3 at GS 75. The disease attack had no impact on the yield levels or the grain quality parameters. Across Denmark, SEGES recorded the disease pressure as reaching 40%.



A significant attack on *Rhynchosporium* was recorded in winter barley.

Severe powdery mildew assessed from Jyndevad plots.

Brown rust (*Puccinia hordei*). Brown rust was also present in 2023, and almost all cultivars showed symptoms of rust. At the AU Flakkebjerg field trials, only a slight infection of brown rust developed in Bordeaux and Valerie, giving minor opportunities for ranking the efficacy of the different fungicides in 2023. The average attack of brown rust in this year's trial at AU Flakkebjerg reached a level of 12% on leaf 2 at GS 73 and 15% on leaf 3 at GS 69.

In Denmark SEGES recorded the brown rust attack as being moderate to severe, and it was more than 50% in some parts of Denmark.

Spring barley

Net blotch (*Drechslera teres*). In general recordings carried out by the advisors in the national monitoring system organised by SEGES, net blotch was widespread in Denmark in the cultivar RGT Planet. Even so, the attack level of net blotch across Denmark recorded by SEGES was the lowest in six years.

In field trials at AU Flakkebjerg, the attack of net blotch was moderate to severe due to the highly susceptible cultivars 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 14% on leaf 2 at GS 75-80.

Brown rust (*Puccinia hordei*). At AU Flakkebjerg brown rust developed to a variable extent in all cultivars. The brown rust infection developed from the middle of June, which provided plenty of time for development. The disease developed sufficiently to allow an evaluation of the efficacy of the fungicides. The attack at AU Flakkebjerg reached an average of 10% at GS 70-75 on leaf 2. The brown rust levels were similar to the levels in Denmark recorded by SEGES in other years, reaching 30% infection.

Ramularia leaf spot (*Ramularia collo-cygni*). *Ramularia* had a moderate infection level in 2023 and was already present in some trials at AU Flakkebjerg at GS 73. The attack level of *Ramularia* stayed low to moderate and reached an average level of 6% on leaf 2 at GS 77-79. SEGES recorded that the overall infection level of *Ramularia* in Denmark was very low.

In 2023 several trials were carried out testing biostimulants in winter wheat. One element of the testing included of the ability of biostimulants to collect nitrogen from the air. The aim being to minimise or replace part of the use of nitrogen fertilisers.

Inoculation of rye cultivars with ergot spores during flowering carried out around sunset to ensure sufficient humidity for infection.

Yield increases in fungicide trials in cereals.

Grain production fell by 25% in 2023 and ended up at 7.1 million tonnes. That is 23% lower than the normal harvest of 9.3 million tonnes and the lowest grain production since the drought year 2018. Normal harvest means the average of 2013-2022. Drought during part of the growing period produced low average yields, and a declining grain area contributed further to the fall in the harvest result (Source: Danmarks Statistik).

In winter wheat trials at AU Flakkebjerg, yields varied between 80 dt/ha and 120 dt/ha with an average of more than 100 dt/ha. Yield increases in winter wheat from fungicide usage were on average 2.0 dt/ha based on national trials, which is very low compared with previous years (Figure 5, Table 1). The low yield responses were linked to the very dry growing season, which led to only *minor disease pressure. 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. Increases from standard fungicide treatments in spring barely were 6 dt/ha and in winter barley 5.8 dt/ha, which was a little below normal (Table 1).

Table 1. Yield increases (dt/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 show 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)
2023	2.0 (SEGES)	6.0 (8 SEGES + 15 AU)	5.8 (7 SEGES + 10 AU)

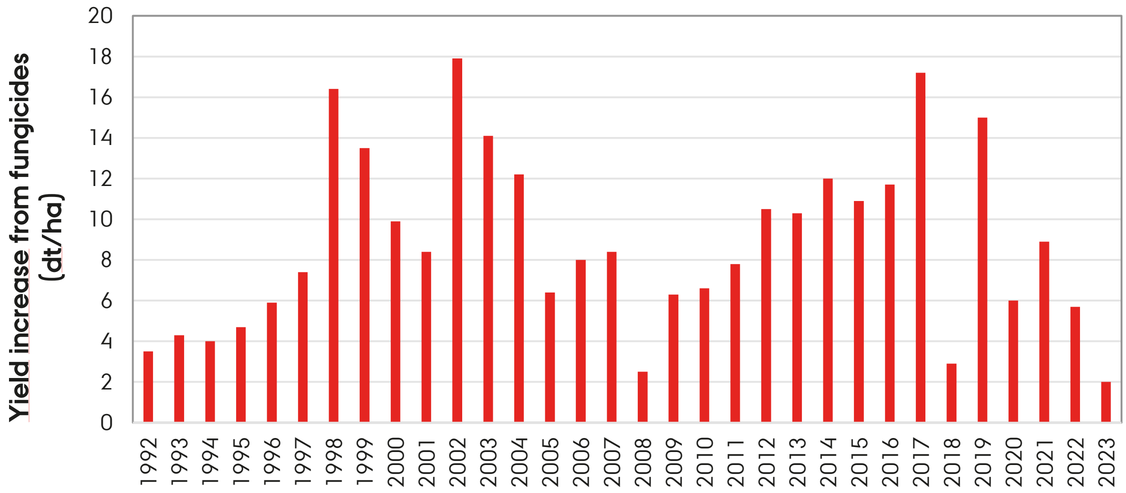


Figure 5. Variation in national average yield responses to fungicides since 1992. Because of dry conditions the year 2023 gave the lowest response seen during this long period.

II Disease control in wheat

Brittany Deanna Beck, Niels Matzen, Hans-Peter Madsen, Sidsel Stein Kirkegaard, Christian Appel Schjeldahl Nielsen, Sofie Rosengaard Nørholm, Anders Almskou-Dahlgaard, Alexander Meyer & Lise Nistrup Jørgensen

Introduction

In this chapter, the 2023 fungicide field trials in wheat are described in brief, and results are summarised. Trial plans that cover several years may have graphs or tables from previous years included to summarise the whole project. The trials are testing new fungicides as well as timings and dose rates of products, and the main results on the major diseases are presented. The trial results are sometimes used as a part of the Biological Assessment Dossier, which companies must prepare to get authorisation for new products or for re-evaluations of old products. Another aim of the trials is solving questions related to optimising the use of fungicides in common control situations for specific diseases. The chapter shows data in tables and figures, and comments and concluding remarks are given on the trials. Most data summarised in this chapter are funded by the companies ADAMA, BASF, Bayer Crop Science, Corteva Agriscience, Syngenta and UPL, who pay to have their products tested. Data are also presented from the activity organised under the umbrella of EuroWheat financed by BASF. EuroWheat is organised by Aarhus University (AU) in collaboration with different organisations who run trials in other countries. All the data from the project are analysed by AU, who 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. The majority of the trials are carried out on fields at AU Flakkebjerg. Some of the 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 placed in fields with 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 150 or 200 l per ha.

Disease assessments in the trials are done 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. When a net yield is calculated, it is converted to dt/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 were extracted from the database at SEGES. The grain price used is DKK 165 per dt wheat and DKK 160 per dt barley.

EuroWheat - comparing effects of SDHIs and azoles

This trial is part of the EuroWheat activity in which 10 trials were carried out across different European countries. The focus of the trials was to investigate the efficacy of SDHIs (succinate dehydrogenase inhibitors) in regions with different climates and levels of resistance. One trial was conducted at AU Flakkebjerg in the cultivar Hereford and was treated at GS 37-39 to protect the flag leaf (22 May). The trial developed a moderate *Septoria* pressure in the AU Flakkebjerg fields as shown in Table 1. The Danish trials showed a high level of control from most of the products including both solo SDHI and solo mefentrifluconazole. The product Proline EC 250 gave only low to moderate control similarly to previous years (Table 1). In the project overall mutation in the *Septoria* populations was assessed, and the results can be found in the chapter on resistance (Chapter V). In Denmark most treatments gave a slight yield increase, and only a few of the increases were significantly different to the untreated plots.

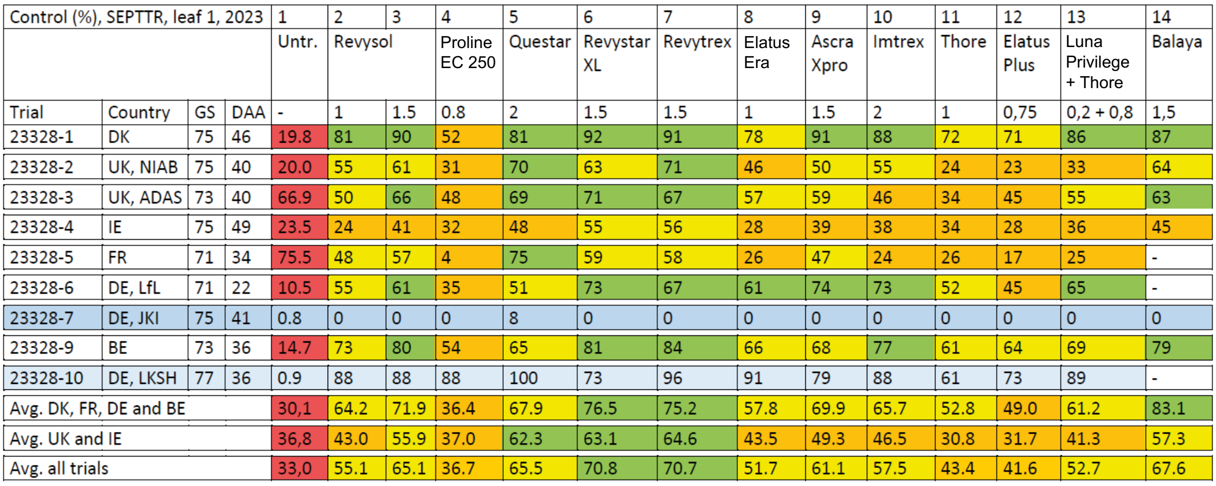
Table 1. Effect of applications on control of *Septoria* in wheat, using SDHIs, azoles and co-formulations of the two groups. Treatments were applied at GS 37-39. GLA: Green Leaf Area. One trial (23328). EuroWheat.

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase, dt/ha
GS 37-39 Dose		GS 69 Leaf 2	GS 69 Leaf 3	GS 75 Leaf 1	GS 75 Leaf 2	GS 75 Leaf 2	
1. Untreated		0.4	6.5	19.8	55.0	48.8	108.6
2. Revysol	1.0	0.0	2.0	3.8	10.3	67.5	8.3
3. Revysol	1.5	0.0	1.1	2.0	5.8	74.5	4.6
4. Proline EC 250	0.8	0.3	5.0	9.5	30.0	55.0	0.7
5. Questar	2.0	0.0	1.4	3.8	11.5	68.8	5.5
6. Revystar XL	1.5	0.0	0.6	1.5	5.5	73.8	10.2
7. Revytrex	1.5	0.0	1.8	1.8	5.0	65.0	6.8
8. Elatus Era	1.0	0.0	1.5	4.3	15.5	72.5	9.1
9. Ascra Xpro	1.5	0.0	1.5	1.8	6.5	61.3	11.0
10. Imtrex	2.0	0.0	1.4	2.3	7.3	56.3	7.5
11. Thore	1.0	0.1	3.3	5.5	17.5	70.0	3.8
12. Elatus Plus	0.75	0.1	3.5	5.8	20.5	65.0	6.0
13. Luna Privilege + Thore	0.2 + 0.8	0.0	1.8	2.8	7.8	63.3	7.4
14. Balaya	1.5	0.0	0.8	2.5	7.3	73.8	11.1
LSD_{95}		0.2	1.6	2.8	7.6	18.6	7.5

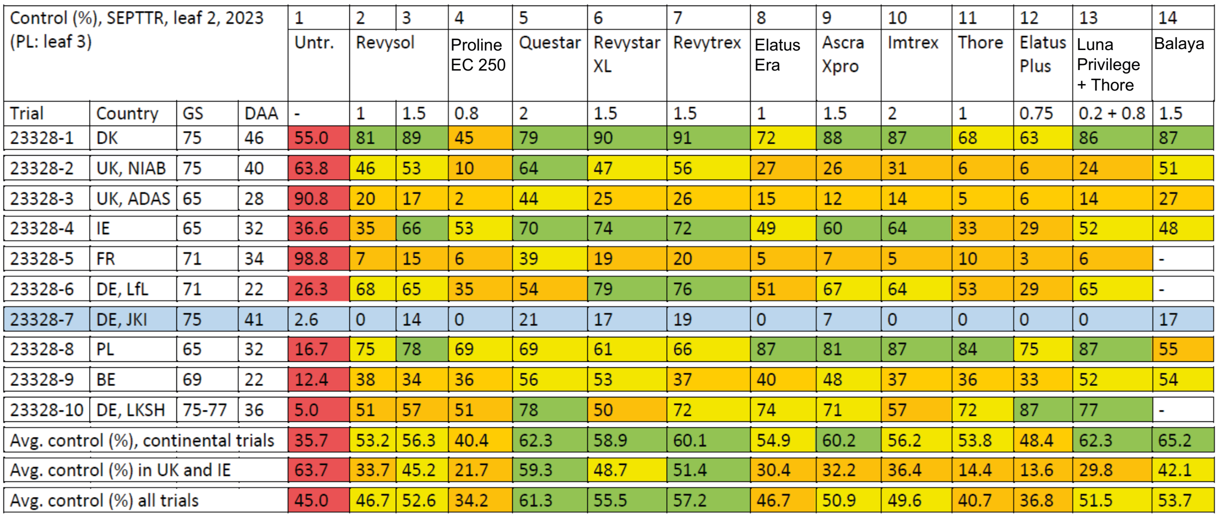
The other countries conducted trials similar to the Danish trial, and the efficacy of the different chemicals depended greatly on the location of the experiment. The results of the 10 trials (Denmark, the UK, Ireland, France, Germany, Poland and Belgium) are shown for the different fungicides in Table 2 assessed on the flag leaf and 2nd leaf. In the different countries a moderate to severe development of *Septoria* was seen, except at two German locations (JKI and LKSH) where the attack stayed at a very low level. Overall, the efficacy of the co-formulations Revytrex and Revystar XL performed best for control of *Septoria*.

A clear distinction in the performances of SDHIs was seen between the obtained effect in mainland Europe (Figure 1) compared to lower efficacy found in the United Kingdom and Ireland (Figure 2). The product Proline EC 250 had lower efficacy in both regions as a result of widespread resistance to prothioconazole. The product Questar (fenpicoxamid) overall had the best efficacy of all the products with only 1 active ingredient. In all trials Revysol (mefentrifluconazole) performed similar to or better than SDHIs and was the second best solo active ingredient shown in Table 2.

Table 2. % control of SEPTTR at GS 71-77, DAA 22-49, on the flag leaf and the 2nd leaf in 2023. 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. Product dosages are presented in l/ha.



Control (%), SEPTTR, leaf 1, 2023				1	2	3	4	5	6	7	8	9	10	11	12	13	14
				Untr.	Revysol		Proline EC 250	Questar	Revystar XL	Revytrex	Elatus Era	Ascra Xpro	Imtrex	Thore	Elatus Plus	Luna Privilege + Thore	Balaya
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	1,5
23328-1	DK	75	46	19.8	81	90	52	81	92	91	78	91	88	72	71	86	87
23328-2	UK, NIAB	75	40	20.0	55	61	31	70	63	71	46	50	55	24	23	33	64
23328-3	UK, ADAS	73	40	66.9	50	66	48	69	71	67	57	59	46	34	45	55	63
23328-4	IE	75	49	23.5	24	41	32	48	55	56	28	39	38	34	28	36	45
23328-5	FR	71	34	75.5	48	57	4	75	59	58	26	47	24	26	17	25	-
23328-6	DE, LfL	71	22	10.5	55	61	35	51	73	67	61	74	73	52	45	65	-
23328-7	DE, JKI	75	41	0.8	0	0	0	8	0	0	0	0	0	0	0	0	0
23328-9	BE	73	36	14.7	73	80	54	65	81	84	66	68	77	61	64	69	79
23328-10	DE, LKSH	77	36	0.9	88	88	88	100	73	96	91	79	88	61	73	89	-
Avg. DK, FR, DE and BE				30,1	64.2	71.9	36.4	67.9	76.5	75.2	57.8	69.9	65.7	52.8	49.0	61.2	83.1
Avg. UK and IE				36,8	43.0	55.9	37.0	62.3	63.1	64.6	43.5	49.3	46.5	30.8	31.7	41.3	57.3
Avg. all trials				33,0	55.1	65.1	36.7	65.5	70.8	70.7	51.7	61.1	57.5	43.4	41.6	52.7	67.6



Control (%), SEPTTR, leaf 2, 2023 (PL: leaf 3)				1	2	3	4	5	6	7	8	9	10	11	12	13	14
				Untr.	Revysol		Proline EC 250	Questar	Revystar XL	Revytrex	Elatus Era	Ascra Xpro	Imtrex	Thore	Elatus Plus	Luna Privilege + Thore	Balaya
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	1.5
23328-1	DK	75	46	55.0	81	89	45	79	90	91	72	88	87	68	63	86	87
23328-2	UK, NIAB	75	40	63.8	46	53	10	64	47	56	27	26	31	6	6	24	51
23328-3	UK, ADAS	65	28	90.8	20	17	2	44	25	26	15	12	14	5	6	14	27
23328-4	IE	65	32	36.6	35	66	53	70	74	72	49	60	64	33	29	52	48
23328-5	FR	71	34	98.8	7	15	6	39	19	20	5	7	5	10	3	6	-
23328-6	DE, LfL	71	22	26.3	68	65	35	54	79	76	51	67	64	53	29	65	-
23328-7	DE, JKI	75	41	2.6	0	14	0	21	17	19	0	7	0	0	0	0	17
23328-8	PL	65	32	16.7	75	78	69	69	61	66	87	81	87	84	75	87	55
23328-9	BE	69	22	12.4	38	34	36	56	53	37	40	48	37	36	33	52	54
23328-10	DE, LKSH	75-77	36	5.0	51	57	51	78	50	72	74	71	57	72	87	77	-
Avg. control (%), continental trials				35.7	53.2	56.3	40.4	62.3	58.9	60.1	54.9	60.2	56.2	53.8	48.4	62.3	65.2
Avg. control (%) in UK and IE				63.7	33.7	45.2	21.7	59.3	48.7	51.4	30.4	32.2	36.4	14.4	13.6	29.8	42.1
Avg. control (%) all trials				45.0	46.7	52.6	34.2	61.3	55.5	57.2	46.7	50.9	49.6	40.7	36.8	51.5	53.7

The co-formulations Revytrex and Revystar XL performed in line with Questar. Yield increases from treatments were generally low to moderate and in most cases not significantly different from the untreated plots.

Overall, the pattern of yield increases mostly fit that of the control effects, with some of the highest increases provided by Revystar XL (12.1 dt/ha) and Revytrex (10.4 dt/ha) overall.

Yellow rust developed a moderate attack in two trials (Belgium and Germany, JKI). The products Questar, Thore and Luna Privilege + Thore had a lower efficacy on yellow rust and powdery mildew.

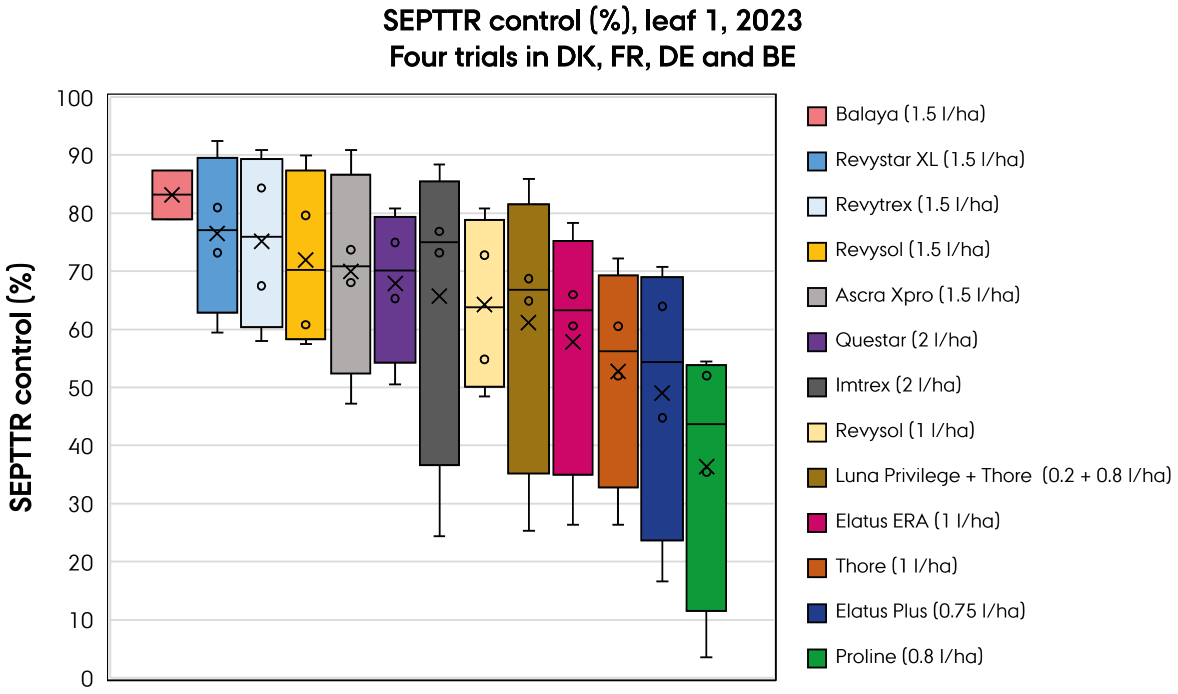


Figure 1. Control of SEPTTR on flag leaves. Four trials in DK, FR, DE and BE. Assessments were carried out at GS 71-75, 22-46 DAA.

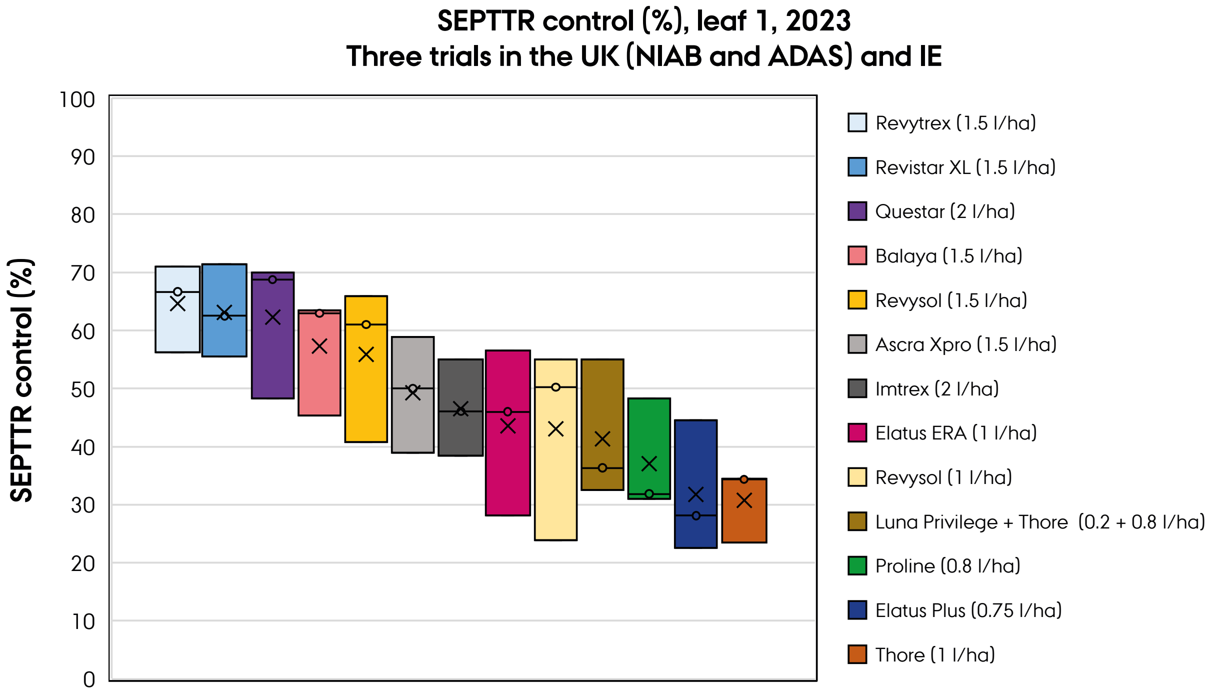


Figure 2. Control of SEPTTR on flag leaves. Three trials in the UK (NIAB and ADAS) and IE. Assessments were carried out at GS 65-75, 28-40 DAA.

Comparison of available ear treatments (23325)

These trials were conducted to test the efficacy of different fungicides at different dose rates when applied at heading (GS 39-40). This trial plan is a replication from previous years with only minor adjustments (Table 3). Three trials were conducted; two located at AU Flakkebjerg in the cultivars Hereford and Cleveland and one located at Velas in the cultivar Hereford. A cover spray was applied in most treatments at GS 32, using Proline EC 250 (0.2 l/ha). The trial tested dose responses of Univoq and Balaya in comparison with older solutions (Table 3). The product Propulse SE 250 was the only product tested at full dose; Balaya and Univoq were tested up to 83-90% of the full rate. In Chapter XI the list of chemicals can be found with the normal dose rates of the products.

Septoria developed a low to moderate level of attack in the trials on both the flag leaf and leaf 2. The control level was between 37% and 81% on leaf 2, and all treatments had significant control (Figure 3). Only slight differences were seen between the control from the treatments on leaf 2. There was a clear dose response from both Balaya and Univoq on the control of *Septoria.* The trial that was conducted in the cultivar Cleveland had a higher level of infection than the other trials with a 48% *Septoria* infection in the untreated plots.

Yields were increased from all the treatments by 2.4-5.0 dt/ha. Only half of the treatments resulted in a positive net yield as shown in Table 3. The early treatment at GS 32 did not increase the yields, which can be shown by comparing treatments 9 and 15. A minor positive impact was measured on TGW from most treatments when compared with the untreated plots.

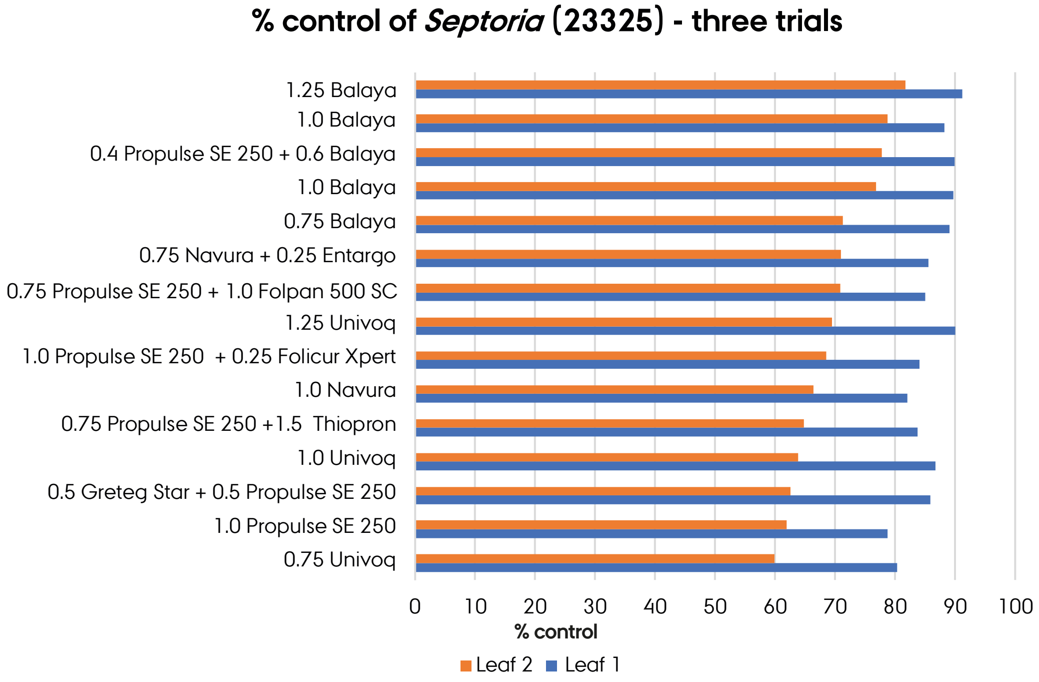


Figure 3. Control of *Septoria* on the two upper leaves. Average of three trials (23325) carried out in 2023. In the untreated plots the attack reached 10% on leaf 1 and 32% on leaf 2 when assessed at GS 75-77.

Table 3. Effect of a T2 application on control of *Septoria*, green leaf area (GLA) and yield responses in wheat when treatments were applied at GS 39-40. Three trials (23325).

Treatments, l/ha			% *Septoria*		Yield & yield increase, dt/ha	Net yield, dt/ha	TGW, g
GS 31-32	GS 39-40	% of full rate	GS 75-77 Leaf 2	GS 75-77 Leaf 1			
1. Proline EC 250 0.2	Propulse SE 250 1.0	100%	12.2	2.1	3.5	-1.0	50.3
2. Proline EC 250 0.2	Propulse SE 250 1.0 + Folicur Xpert 0.25	125%	10.1	1.6	5.1	0.5	50.5
3. Proline EC 250 0.2	Propulse SE 250 0.75 + Thiopron 1.5	125%	11.3	1.6	3.7	-0.6	50.7
4. Proline EC 250 0.2	Propulse SE 250 0.75 + Folpan 500 SC 1.0	150%	9.3	1.5	3.4	-0.2	50.4
5. Proline EC 250 0.2	Univoq 0.75	50-54%	12.8	2.0	4.2	-0.2	50.8
6. Proline EC 250 0.2	Univoq 1.0	66-72%	11.6	1.3	3.4	-1.8	50.3
7. Proline EC 250 0.2	Univoq 1.25	82-90%	9.8	1.0	2.4	-1.3	50.9
8. Proline EC 250 0.2	Balaya 0.75	50%	9.2	1.1	3.4	-1.0	51.1
9. Proline EC 250 0.2	Balaya 1.0	66%	6.8	1.2	5.5	0.4	50.5
10. Proline EC 250 0.2	Balaya 1.25	83-90%	5.9	0.9	2.6	1.6	50.7
11. Proline EC 250 0.2	Navura 1.0	66%	10.8	1.8	4.6	-	50.3
12. Proline EC 250 0.2	Navura + Entargo 0.75 + 0.25	100%	9.3	1.5	5.2	-	50.5
13. Proline EC 250 0.2	Propulse SE 250 0.4 + Balaya 0.6	80%	7.1	1.0	4.3	0.6	50.1
14. Proline EC 250 0.2	Greteg Star 0.5 + Propulse SE 250 0.5	100%	12.0	1.4	4.6	1.2	50.1
15. Untreated	Balaya 1.0	66%	7.4	1.1	3.4	3.4	50.6
16. Untreated	Untreated		32.3	10.0	113.8	-	49.4
No. of trials			3	3	3	3	3
LSD_{95}			2.4		3.5		

Control strategies using two treatments in winter wheat for control of *Septoria* (23326)

The trial plan was conducted in three trials in two different cultivars (Hereford and Benchmark) at AU Flakkebjerg and one trial in Benchmark at Velas. This plan tested the efficacy of products against both *Septoria* and yellow rust. T1 was a cover spray of 0.2 l/ha of Proline EC 250 at GS 32, T2 at GS 37-39 and T3 at GS 61-65. Results are shown in Table 4.

The two trials in Benchmark developed a significant attack of yellow rust. Most treatments provided effective rust control (Figure 4). However, the treatments with the lower rates were slightly inferior to other treatments (treatment 11 with T2 having Univoq and Folpan 500 SC). *Septoria* had a moderate to severe attack on the flag leaf; all treatments gave significant control (60-90%) shown in Table 4. The trial at Velas had multiple diseases with a significant pressure where the diseases were undistinguishable at the later growth stages.

The GLA differed significantly between the untreated and treated plots. The untreated plots had a 30-47% lower GLA than the treatments. All treatments significantly increased the yields by 8.1 to 12 dt/ha. The higher yield responses were harvested in Benchmark, which had a moderate to severe attack of yellow rust. In these trials a good correlation was seen between GLA and yield increases (R2 = 0.73-0.82) (Figure 5). In the trial which only had a moderate attack of *Septoria*, the correlation was lower (R2 = 0.37). There was a clear and significant improvement of TGW for all treatments.

Table 4. Effect of a split ear applications on control of *Septoria* and yellow rust, thousand grain weight (TGW) and yield responses in wheat. Three trials (23326). All treatments including untreated plots were treated with 0.2 l/ha Proline EC 250 at GS 32.

Treatments, l/ha		% *Septoria*			% yellow rust	Yield & yield increase, dt/ha	Net yield, dt/ha	TGW, g
GS 37-39	GS 61-65	GS 71-73 Leaf 1	GS 71-73 Leaf 2	GS 77 Leaf 1	GS 65 Leaf 2			
1. Untreated	Untreated	10.9	22.0	21.2	31.1	94.7	-	43.9
2. Propulse SE 250 0.75	Prosaro EC 250 0.5	1.2	3.3	11.1	4.3	11.4	9.8	47.8
3. Balaya 0.75	Greteg Star 0.35 + Propulse SE 250 0.35	1.1	0.6	3.2	2.2	12.8	11.0	47.2
4. Univoq 0.75	Greteg Star 0.35 + Propulse SE 250 0.35	2.3	3.8	3.0	6.8	12.0	10.1	47.6
5. Univoq 0.75	Propulse SE 250 0.75 + Folicur Xpert 0.25	1.2	2.1	1.8	3.0	12.9	10.7	48.2
6. Balaya 0.3 + Propulse SE 250 0.3	Propulse SE 250 0.75 + Folicur Xpert 0.25	1.5	1.8	2.9	4.5	11.9	9.9	48.0
7. Balaya 0.75	Propulse SE 250 0.75 + Folicur Xpert 0.25	0.6	0.3	1.7	2.6	10.5	8.3	47.5
8. Balaya 0.75	Proline EC 250 0.4 + Entargo 0.25	1.8	0.9	6.1	1.2	10.1	8.1	47.3
9. Balaya 0.75	Juventus 90 0.4 + Entargo 0.25	1.2	1.0	5.9	2.3	9.9	8.0	47.1
10. Balaya 0.75	Propulse SE 250 0.25 + Pictor Active 0.25 + Agropol 0.2	1.5	0.9	2.4	1.8	11.0	9.2	47.5
11. Balaya 0.5 + Folpan 500 SC 1.0	Univoq 0.5 + Folpan 500 SC 1.0	3.8	3.8	3.8	11.4	8.1	-	45.6
No. of trials		3	3	2	2	3	3	3
LSD_{95}				9.0		4.2		2.3

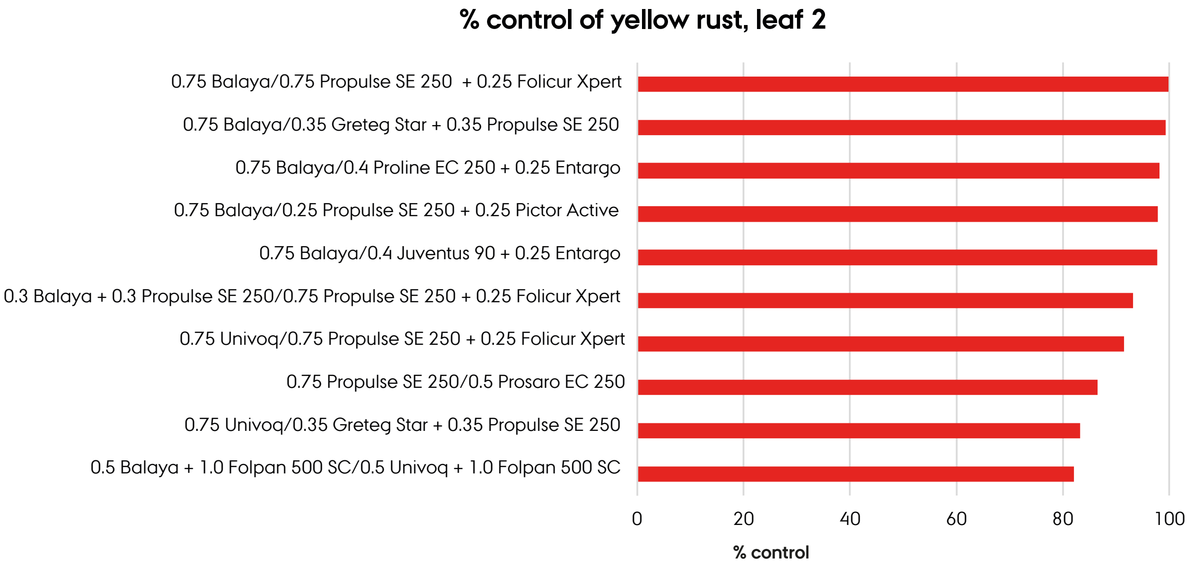


Figure 4. Control of yellow rust on leaf 2. Average of two trials (23326) carried out in Benchmark. In the untreated plots the attack reached 30% on leaf 2.

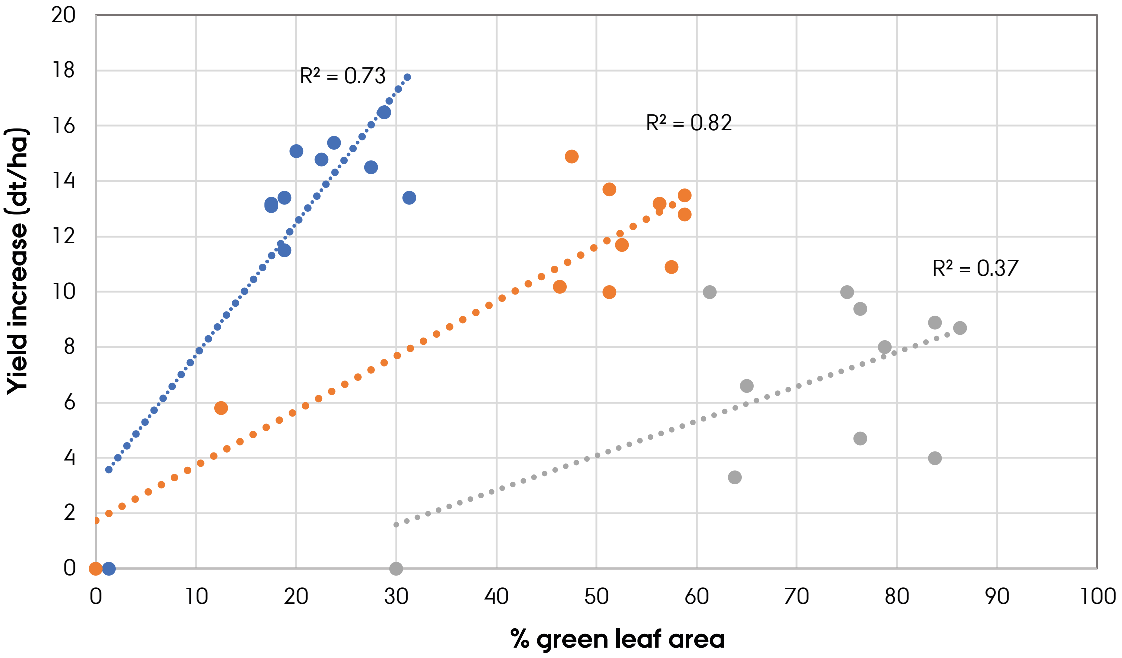


Figure 5. Correlations between green leaf area and harvested yield increases in the three trials from 23326. The best correlations were recorded in the trials with yellow rust. From left to right the order is 23326-1, 23326-2 and 23326-3.

Control strategies using new T1 solutions for control of *Septoria* in winter wheat (23324)

Three trials were carried out to test new T1 solutions at GS 31-32. A T2 cover spray of Balaya 0.5 l/ha or Propulse SE 250 0.5 l/ha + Folicur Xpert 0.25 l/ha was applied at GS 40-51. The trials were conducted at two locations in three different cultivars; at AU Flakkebjerg the trials were in Benchmark and Rembrandt, and the trial located at Velas was in the cultivar Hereford. *Septoria* developed late in the season but had a moderate attack on the flag leaf between the trials, the average attack being 34.5% (GS 77) as shown in Table 5. Overall, the *Septoria* control from the treatments was very similar, although a slightly inferior control was seen when Propulse SE 250 + Folicur Xpert was applied at T2 compared with Balaya (Figure 6). All treatments significantly reduced the disease pressure. However, there was no significant difference in control between treatments. Yellow rust developed in the Benchmark trial, in which all treatments gave good control despite a severe level of attack (Photo p. 26). The timing of the treatment was good in relation to yellow rust development, so even the very reduced rates gave efficient control (Figure 7). The treatments led to a significant yield increase between 4.5 and 8.6 dt/ha, but there were no yield differences between treatments (Table 5).

Table 5. Effects on *Septoria* and yellow rust, yield responses and thousand grain weight (TGW), following application of T1 and T2 timings with different fungicide combinations in wheat (23324).

Treatments, l/ha		% *Septoria*			% rust	Yield & yield increase, dt/ha	Net yield, dt/ha	TGW, g
GS 31-32	GS 40-51	GS 73 Leaf 3	GS 73 Leaf 2	GS 77 Leaf 1	GS 65 Leaf 2			
1. Untreated		9.4	8.5	34.4	42.5	107.0	-	46.7
2. Proline EC 250 0.27 + Serenade ASO 1.0	Propulse SE 250 0.5 + Folicur Xpert 0.25	3.6	1.2	4.7	1.6	6.2	2.2	49.4
3. Proline EC 250 0.27 + Thiopron 1.5	Propulse SE 250 0.5 + Folicur Xpert 0.25	2.8	1.5	4.2	1.8	7.0	2.4	48.4
4. Proline EC 250 0.27	Balaya 0.5	3.6	1.9	3.1	3.5	8.6	5.6	48.8
5. Proline EC 250 0.27 + Thiopron 1.5	Balaya 0.5	2.3	1.9	3.6	2.8	4.5	0.1	48.4
6. Pictor Active 0.33 + Agropol 0.2	Balaya 0.5	3.0	2.0	4.5	2.5	7.9	4.6	48.5
7. Comet Pro 0.42	Balaya 0.5	3.3	2.0	4.1	3.3	5.7	2.4	48.7
8. Proline EC 250 0.2 + Comet Pro 0.25	Balaya 0.5	3.4	1.1	2.7	2.3	6.8	1.5	49.1
9. Juventus 90 0.2 + Pictor Active 0.2 + Agropol 0.2	Balaya 0.5	2.7	1.9	3.6	1.5	8.3	2.5	49.3
10. Proline EC 250 0.3 + Comet Pro 0.5	Balaya 0.5	4.3	1.7	4.2	2.6	7.9	3.5	48.7
11. Propulse SE 250 0.33	Balaya 0.5	2.0	1.7	3.1	2.8	7.7	4.5	48.4
12. Plexeo 90 0.15 + Amistar 0.15	Balaya 0.5	5.1	1.4	3.5	2.5	7.4	-	48.4
13. Untreated	Balaya 0.5	4.2	3.7	2.5	3.8	7.4	5.5	48.7
No. of trials		2	3	3	1	3	3	3
LSD_{95}		1.9	0.9	2.2		4.2		

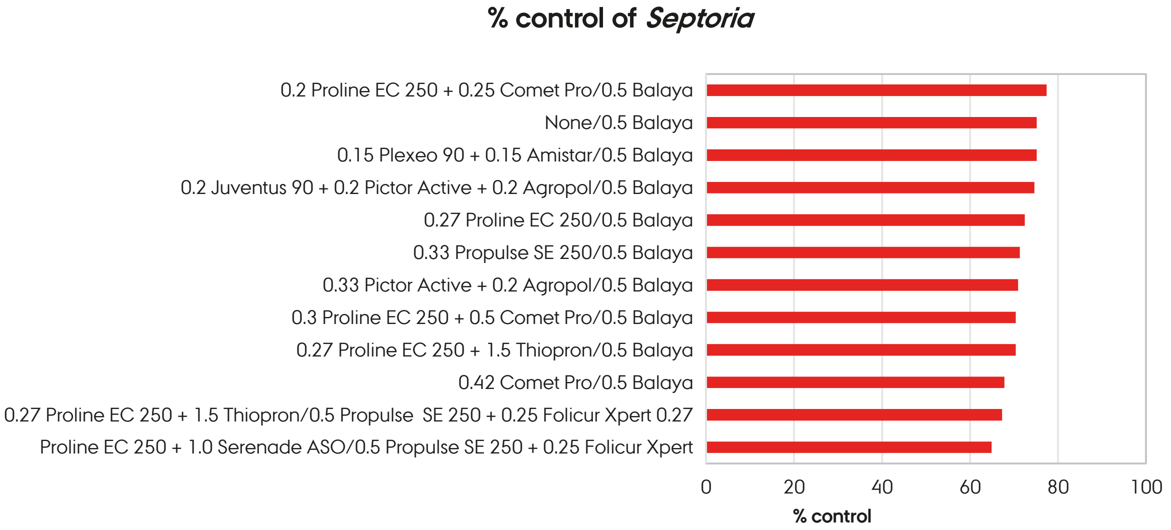


Figure 6. Control of *Septoria*. Average of assessments on leaf 1 in trial 23324-3 and leaf 2 in trial 23324-2.

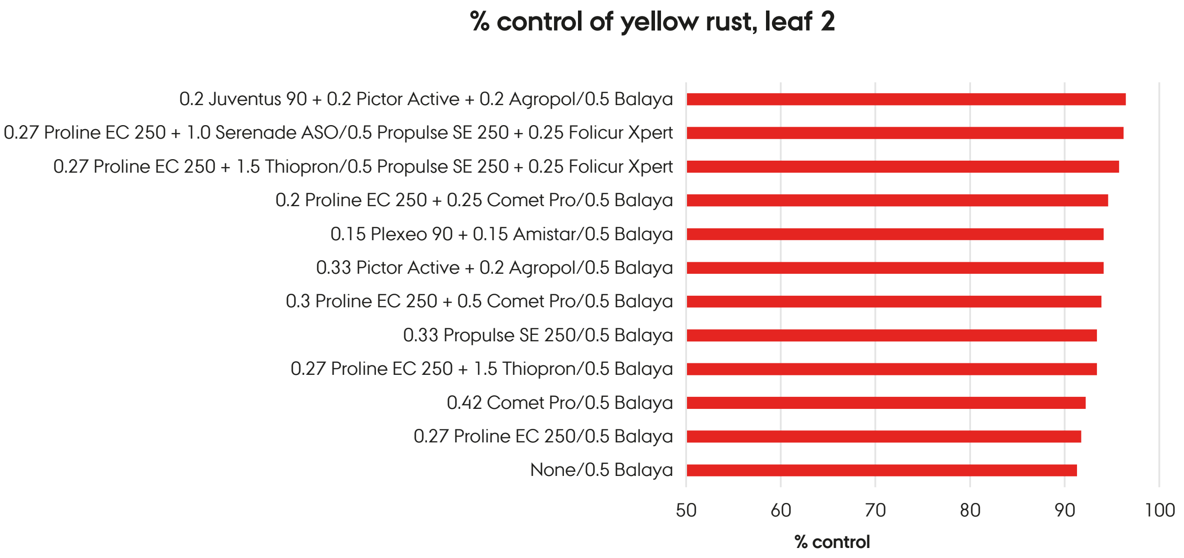


Figure 7. Control of yellow rust on leaf 2 (23324) carried out in Benchmark. In the untreated plots the attack reached 42% on leaf 2.

Disease development in the field trials. Photo taken by drone.

Testing of alternative chemistry and biological control agents (BCA)

There is an increase in the need for alternative low-risk solutions to the standard chemicals and it is becoming a priority for both the government and companies. In this protocol different alternative substances were tested, from different chemistries and biologicals. Two different sulphur treatments were tested (Vertipin and Thiopron) which are currently not authorised for use as crop protection products. The product Polyversum = *Pythium oligandrum* has fungi as the active ingredient. Serenade ASO has a bacterium strain, *Bacillus amyloliquefaciens* QST 713, as its active ingredient. Charge is a biostimulant that is based on the ingredient chitosan. Bion 50 WG (benzothidazole) is known to induce systematic acquired resistance (SAR). Iodus uses seaweed plant extracts and has laminarin as its active ingredient; this is also known to induce the natural resistance of the plant. Revytur was also included and is a mixture of the azole mefentrifluconazole and sulphur. The different alternative compounds were compared to a traditional reference of a chemical pesticide listed in Table 6 as treatments 2 and 3.

Table 6. Effects of treatments at GS 32 and GS 39-45 on control of *Septoria*, green leaf area (GLA), yield responses, net yield and thousand grain weight (TGW). Two trials in 2023 in Hereford and Kvium (23322-1 and 23322-2).

Treatments, l/ha		% *Septoria*			% GLA	Yield & yield increase, dt/ha	Net yield, dt/ha	TGW, g
GS 32	GS 39-45	GS 73-75 Leaf 1	GS 73-75 Leaf 2	GS 77 Leaf 1	GS 77 Leaf 1			
1. Untreated		1.6	5.7	23.8	59.4	108.2	-	49.3
2. Propulse SE 250 0.5	Balaya 0.75	0.2	1.0	5.8	76.3	8.4	4.1	49.3
3. Proline EC 250 0.4	Proline EC 250 0.4	0.6	2.3	15.4	66.3	4.3	1.1	48.7
4. Thiopron 3.0	Thiopron 3.0	0.4	1.5	12.1	75.9	2.2	-3.8	49.0
5. Phosphonate (DSPF016) 3.0	Revytur 2.0	0.1	0.6	6.0	80.0	10.4	-	48.3
6. Serenade ASO 2.0 + Silwet Gold 0.1%	Serenade ASO 2.0 + Silwet Gold 0.1%	0.9	3.6	17.7	63.2	3.2	-0.7	48.3
7. Charge 3.0 + Sorrento 0.1	Thiopron 3.0	0.3	0.9	13.4	65.0	0.8	-	47.8
8. Phosphonate (DSPF016) 3.0 + Thiopron 3.0	Phosphonate (DSPF016) 3.0 + Thiopron 3.0	0.2	1.0	11.5	72.3	5.6	-	48.8
9. Iodus 1.0	Iodus 1.0	0.7	3.4	17.9	64.4	7.6	-	48.2
10. Iodus 1.0 + Thiopron 3.0	Iodus 1.0 + Thiopron 3.0	0.5	1.7	12.2	66.9	7.4	-	49.3
11. Polyversum 0.1	Polyversum 0.1	0.7	3.1	13.5	59.4	7.9	-	47.4
12. Vertipin 3.5	Vertipin 3.5	0.4	1.1	9.9	74.4	6.6	-	49.0
13. Bion 50 WG 0.06	Phosphonate (DSPF016) 3.0 + Thiopron 3.0	0.6	2.1	11.8	70.7	8.7	-	48.5
14. Folpan 500 SC 1.5	Folpan 500 SC 1.5	0.5	1.3	9.9	66.3	7.6	3.8	47.8
15. Folpan 500 SC 1.5 + Thiopron 3.0	Folpan 500 SC 1.5 + Thiopron 3.0	0.2	0.7	0.8	77.3	6.6	-2.2	48.1
No. of trials		2	2	2	2	2	2	2
LSD$_{95}$						5.5		

This protocol was conducted in Hereford and Kvium at AU Flakkebjerg. In the trials two treatments were applied at GS 32 and at GS 39-45. All products had some level of control. When Thiopron was added to Iodus and Folpan 500 SC, there was a 20-30% increase in control, but the addition of Thiopron had no effect on the yield. It is noticeable that various alternative solutions perform better or in line with Proline EC 250. It is also noticeable that the mixture of Folpan 500 SC + Vertipin performs in line with the chemical reference Revytur (Figure 8).

In line with other trials from this season, treatments gave only small yield increase, and only some treatments gave a significant yield increase compared with the untreated plots. The treatments with Proline EC 250, Thiopron solo, Serenade ASO + Silwet Gold and Charge + Sorrento gave only 0.8-4.3 dt/ha increase in yield, which was not a significant yield increase compared with the untreated plots (treatments 3, 4, 6 and 7). The other treatments gave yield increases from 5.6 dt/ha to 10.4 dt/ha.

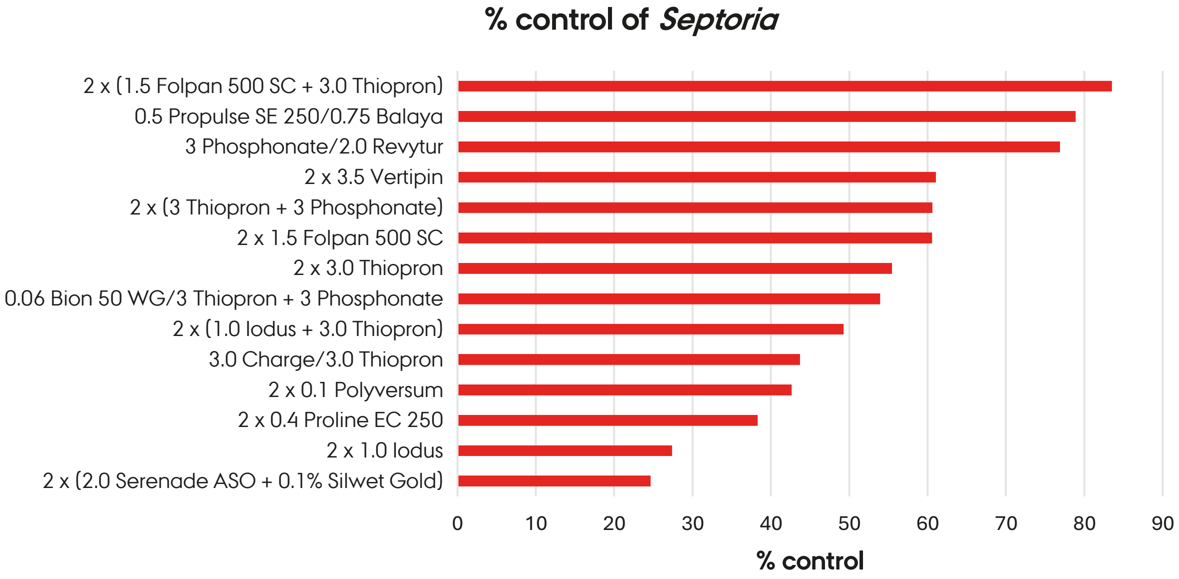


Figure 8. Control of *Septoria* in two wheat trials (23322), using two applications at GS 32 and GS 39-45. 26% attack in average of two trials.

Baltic T1 and T2 solutions for control of *Septoria*

Five different trial plans were used to test different T1 at GS 32-33 and T2 at GS 40-51 against *Septoria*, using treatments which are authorised in the Baltic region and also in several other countries in Europe. The only products approved for use in Denmark are Balaya and Flexity.

The trial (23317) with different T1 and T2 combinations was carried out in the cultivar Cleveland (Table 7). *Septoria* infection reached only a minor level of 5% at GS 65-69 and a moderate level at GS 77-83 with leaf 2 developing 10% and leaf 1 18.8% infection. The weather conditions were not optimal for the development of *Septoria*, but the field was irrigated four times which to some extent helped in the development of the disease. There was no significant difference between the different treatments on leaf 1. When leaf 2 was measured, Delaro Forte/Elatus Era had 20-40% lower efficacy than the other products. There was no significant difference between yields or grain quality between treatments or between the untreated and treated plots. There was no correlation between the GLA and yield data (correlation = -.02) as the control treatments did not prolong the lifespan of the leaves enough to increase the yields.

Table 7. Effects of treatments at GS 32-33 and GS 40-51 on control of *Septoria*, green leaf area (GLA), yield responses, thousand grain weight (TGW) (23317-1).

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase, dt/ha	TGW, g
GS 32-33	GS 40-51	GS 65-69 Leaf 4	GS 71 Leaf 3	GS 73 Leaf 1	GS 73 Leaf 2	GS 77-83 Leaf 1		
1. Untreated		3.0	4.8	2.5	10.3	44.3	79.1	45.8
2. Revystar XL 0.4 + Priaxor 0.4	Revytrex 1.0	0.2	0.3	0.2	0.7	67.5	-0.6	44.8
3. Revystar XL 0.4 + Priaxor 0.4	Univoq 1.0	0.1	0.3	0.2	3.3	73.8	-0.9	46.6
4. Revystar XL 0.4 + Priaxor 0.4	Univoq 1.2	0.1	0.3	0.2	1.3	62.5	-2.4	45.4
5. Balaya 0.5 + Flexity 0.25	Revystar XL 0.4 + Priaxor 0.4	0.1	0.1	0.1	1.2	80.0	-2.7	46.0
6. Input Triple 0.75	Ascra Xpro 1.0	0.6	0.9	0.4	1.8	81.3	-3	45.0
7. Balaya 0.5 + Flexity 0.25	Revytrex 1.0	0.1	0.3	0.0	0.7	78.8	-2.5	46.6
8. Univoq 1.0	Revystar XL 0.5 + Priaxor 0.5	0.1	0.1	0.1	0.6	85.0	0.3	47.2
9. Delaro Forte 1.3	Elatus Era 0.8	1.8	2.5	0.7	5.8	62.5	-2.7	46.2
LSD$_{95}$		0.7	1.6	0.9	2.2	16.8	0.6	2.5

Trial plan 23318 also looked at T1 and T2 treatments for the Baltic regions in the cultivar Hereford (Table 8). Later in the season this trial developed a moderate to high level of *Septoria* infections. The crop was irrigated three times in May-June to help *Septoria* develop. On leaf 2 there was a lower efficacy from the treatments with Elatus Era, Questar + Elatus Plus and Univoq, which gave 71-78% control. This was significantly lower than the other products, which gave above 90% control. There were no differences between the untreated plots and treatments or between treatments in yield and grain quality.

In trial 23332 the aim was to test different solutions at the T1 spray in the cultivar Hereford, using products which are available in the Baltic countries (Table 9). Following a T1 spray all treatments were sprayed with Balaya 0.75 l/ha at T2. The plots with T1 and T2 sprays had better control than the treatment with only a T2. The disease pressure was very low and developed predominantly after T2, and the T1 application only increased the efficacy slightly. T2 was the controlling timing, not the T1 application. None of the T1 treatments improved yields significantly as a result of the low disease pressure.

Table 8. Effects of treatments at GS 32-33 and at GS 40-51 of control of *Septoria*, green leaf area (GLA), yield responses, thousand grain weight (TGW). The trial was carried out in 2023 in the cultivar Hereford (23318-1).

Treatments, l/ha		% *Septoria*					% GLA	Yield & yield increase, dt/ha	TGW, g
GS 32-33	GS 40-51	GS 65 Leaf 4	GS 73 Leaf 3	GS 73 Leaf 2	GS 75 Leaf 1	GS 75 Leaf 2	GS 77 Leaf 1		
1. Untreated		6.5	7.0	1.5	15.0	40.0	60.0	108.5	48.8
2. Balaya 0.5 + Flexity 0.25	Elatus Era 0.8	1.5	2.0	0.2	1.3	11.3	82.5	0.4	49.2
3. Balaya 0.5 + Flexity 0.25	Revytrex 1.0	3.0	2.0	0.5	0.1	2.8	90.0	-0.2	50.2
4. Balaya 0.5 + Flexity 0.25	Revystar XL 0.5 + Priaxor 0.5	1.0	1.6	0.2	0.3	2.8	82.5	4.7	51.3
5. Balaya 0.5 + Flexity 0.25	Ascra Xpro 1.0	0.8	2.0	0.2	0.3	3.0	83.8	2.1	50.1
6. Balaya 0.5 + Flexity 0.25	Univoq 1.2	3.0	2.3	0.3	1.0	10.0	76.3	2.2	49.9
7. Univoq 0.75	Revystar XL 0.5 + Priaxor 0.5	0.8	1.3	0.1	0.2	2.8	82.5	1.2	50.3
8. Balaya 0.5 + Flexity 0.25	Questar 1.2 + Elatus Plus 0.4	1.0	1.3	0.1	1.8	8.8	77.5	2.2	49.3
LSD$_{95}$		1.0	1.0	0.4	2.2	2.8	10.6	0.8	1.9

Table 9. Effects of treatments at GS 32-33 and a cover spray with Balaya at GS 45-51 on control of *Septoria*, green leaf area (GLA), yield responses, net yield and thousand grain weight (TGW). The trial was carried out in the cultivar Hereford (23332-1).

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase, dt/ha	Net yield, dt/ha	TGW, g
GS 32-33	GS 45-51	GS 69 Leaf 4-5	GS 71 Leaf 4	GS 77 Leaf 2	GS 77 Leaf 1	GS 78 Leaf 1			
1. Untreated	Balaya 0.75	4.0	5.8	1.8	0.2	63.0	117.2	-	48.2
2. Pecari 0.4 + Amistar 0.4	Balaya 0.75	1.5	3.5	0.6	0.1	75.0	-2.6	-	50.6
3. Input Triple 0.75	Balaya 0.75	1.5	3.0	0.4	0.1	73.0	-1.9	-	49.7
4. Univoq 1.0	Balaya 0.75	0.2	1.1	0.3	0.1	74.0	-3.7	-9.8	50.7
5. Priaxor 0.4 + Innox 0.4	Balaya 0.75	0.4	1.8	0.4	0.1	75.0	-1.6	-	48.8
6. Daxur 0.75 + Flexity 0.25	Balaya 0.75	0.3	2.1	0.4	0.1	78.0	1.6	-	50.5
7. Revyflex 0.75	Balaya 0.75	0.4	1.4	0.3	0.1	73.0	-0.2	-	49.9
8. Balaya 0.5 + Flexity 0.25	Balaya 0.75	0.5	2.3	0.4	0.1	75.0	-5.9	-11.4	48.8
9. Revystar XL 0.4 + Priaxor 0.4	Balaya 0.75	0.2	1.4	0.3	0.1	75.0	-5.6	-	50.4
LSD$_{95}$		0.7	1.1	0.3	0.0	6.6	7.4	-	2.5

Trial 23333 tested the effect of different solutions at T2 in the cultivar KWS Cleveland. In this trial the T1 was a cover spray of Balaya 0.5 l/ha. As in the other trials *Septoria* did not develop a moderate infection until the later growth stages (GS 77). The products gave 67-97% control of *Septoria* on leaf 2 (GS 75). The different treatments all gave significant control of the disease (Table 10). The treatment with Elatus Era 0.75 l/ha resulted in the least control. The different treatments caused a minor yield increase of 5.6-7.9 dt/ha compared to the untreated plots.

The last trial (23334) tested solutions on upper leaves (T1 application). The trial was conducted at AU Flakkebjerg in the cultivar Hereford. The different products gave significant control in the range of 71-91% control on leaf 2 (Table 11). All treatments led to yield increases although insignificant, and TGW was not impacted significantly.

Table 10. Effects of a cover spray with Balaya at GS 32-33 and treatments at GS 45-51 to control *Septoria*, green leaf area (GLA), yield responses, net yield and thousand grain weight (TGW). The trial was carried out in 2023 in KWS Cleveland (23333-1).

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase, dt/ha	Net yield, dt/ha	TGW, g
GS 32-33	GS 45-51	GS 69 Leaf 4	GS 71 Leaf 3	GS 75 Leaf 1	GS 75 Leaf 2	GS 77 Leaf 1			
1. Balaya 0.5	Untreated	1.8	2.5	5.0	21.7	30.0	116.0	-	45.6
2. Balaya 0.5	Elatus Era 0.75	0.8	1.0	0.4	7.0	42.5	5.7	-	46.7
3. Balaya 0.5	Ascra Xpro 1.0	0.5	0.8	0.1	0.9	47.5	6.5	-	46.9
4. Balaya 0.5	Univoq 1.2	0.5	0.9	0.5	4.0	45.0	7.9	2.0	46.7
5. Balaya 0.5	Balaya 1.0	0.5	0.9	0.0	0.5	67.5	5.2	-0.1	45.6
6. Balaya 0.5	Priaxor 0.5 + Innox 0.5	0.5	0.9	0.4	3.5	41.3	7.5	-	47.2
7. Balaya 0.5	Revystar XL 0.5 + Priaxor 0.5	0.5	0.5	0.1	0.9	62.5	5.6	-	46.2
8. Balaya 0.5	Revytrex 1.0	0.5	0.5	0.1	0.6	67.5	6.7	-	45.5
LSD$_{95}$		0.3	0.3	0.3	3.1	22.0	6.7	-	1.9

Table 11. Effects of treatments at GS 32 and 39-45 to control *Septoria*, green leaf area (GLA), yield responses and thousand grain weight (TGW). The trial was carried out in 2023 in Hereford (23334-1).

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase, dt/ha	TGW, g
GS 32	GS 39-45	GS 61 Leaf 4	GS 72 Leaf 3	GS 73 Leaf 1	GS 73 Leaf 2	GS 78 Leaf 1		
1. Untreated	Untreated	5.8	6.3	2.5	18.8	27.5	115.5	48.5
2. Pecari 0.4 + Amistar 0.4	Elatus Era 0.75	0.8	1.9	0.2	5.3	42.5	4.4	48.7
3. Input Triple 0.75	Ascra Xpro 1.0	0.4	0.4	0.2	3.3	50.0	5.8	49.8
4. Priaxor 0.4 + Innox 0.4	Balaya 1.0	0.2	0.5	0.1	1.6	47.5	3.2	49.3
5. Revyflex	Revytrex 1.0	0.4	0.7	0.1	3.0	45.0	2.7	49.3
6. Priaxor 0.4 + Innox 0.4	Revytrex 1.0	0.3	0.8	0.1	4.3	42.5	5.8	48.5
7. Revystar XL 0.4 + Priaxor 0.4	Univoq 1.2	0.1	0.5	0.2	3.8	52.5	7.9	49.5
8. Revystar XL 0.4 + Priaxor 0.4	Revytrex 1.0	0.1	0.6	0.1	3.8	47.5	4.4	49.6
LSD_{95}		0.8	1.3	0.4	2.2	10.3	5.9	1.8

Testing azoles against *Septoria*

In line with previous years, a line of azoles was tested for control of *Septoria*, using two applications with half rates. Treatments were applied at GS 33 and GS 45-51. This year only the trial carried out at AU Flakkebjerg gave usable *Septoria* data. The data from the trials are given in Table 12.

The change across seasons is given in Figure 9. It can be seen that the reduced efficacy from the old azoles has stabilised at a similar control level since 2016, which also matches a major shift in sensitivity assessed in the lab (Chapter V). Only Revysol performs significantly better than the old azoles. Also, the mixture of mefentrifluconazole + prothioconazole (Navura = BAS 754 00F) performs in line with or slightly inferior to the solo mefentrifluconazole.

The historical data from this protocol shown in Figures 10-12 also visualise the major differences between the performances of old azoles and Revysol, showing a clear difference with respect to control of *Septoria* from assessed green leaf area and yield increases and reflecting the better performance from Revysol.

Table 12. Average *Septoria* attack and yield responses from treatments in winter wheat. One trial in 2023 (23329).

Treatments, l/ha		% *Septoria*			% GLA	Yield & yield increase, dt/ha
GS 32-33	GS 51-55	GS 69 Leaf 3	GS 73-75 Leaf 2	GS 77 Leaf 1	GS 83 Leaf 1	
1. Proline EC 250 0.4	Proline EC 250 0.4	10.5	15.5	27.5	20	2.1
2. Juventus 90 0.5	Juventus 90 0.5	4.5	23.1	26.3	20	2.8
3. Folicur EW 250 0.5	Folicur EW 250 0.5	4.0	13.0	25.0	15	0
4. Proline EC 250 0.4	MCW 406-S 0.25	4.5	16.3	20.0	20	-1.1
5. Prosaro EC 250 0.5	Prosaro EC 250 0.5	4.5	25	28.8	20	7.9
6. Revysol 0.75	Revysol 0.75	1.3	3.5	4.0	51	5.2
7. Navura 0.75	Navura 0.75	2.0	15	7.5	48	6.3
8. Comet Pro 0.625	Comet Pro 0.625	5.5	20.0	38.8	12	3.8
9. Untreated		20	28,8	41.3	11	112.8
No. of trials		1	1	1	1	1
LSD_{95}					10.0	6.3

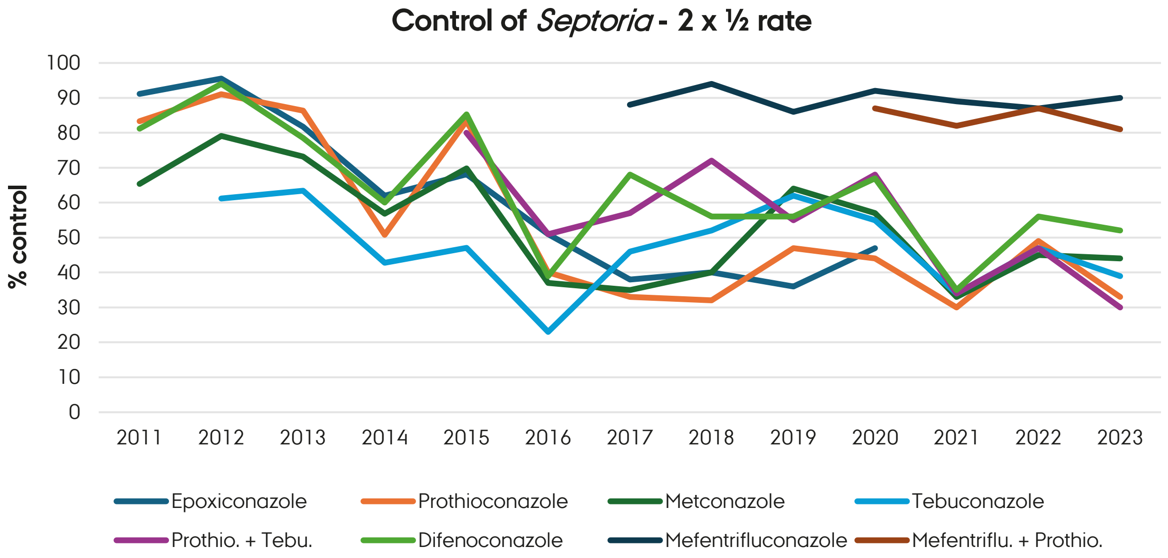


Figure 9. Per cent control of *Septoria*, using two x ½ rates of different azoles. Average of two applications at GS 32-33 and GS 51-55. Development of efficacy across years (2011-2023).

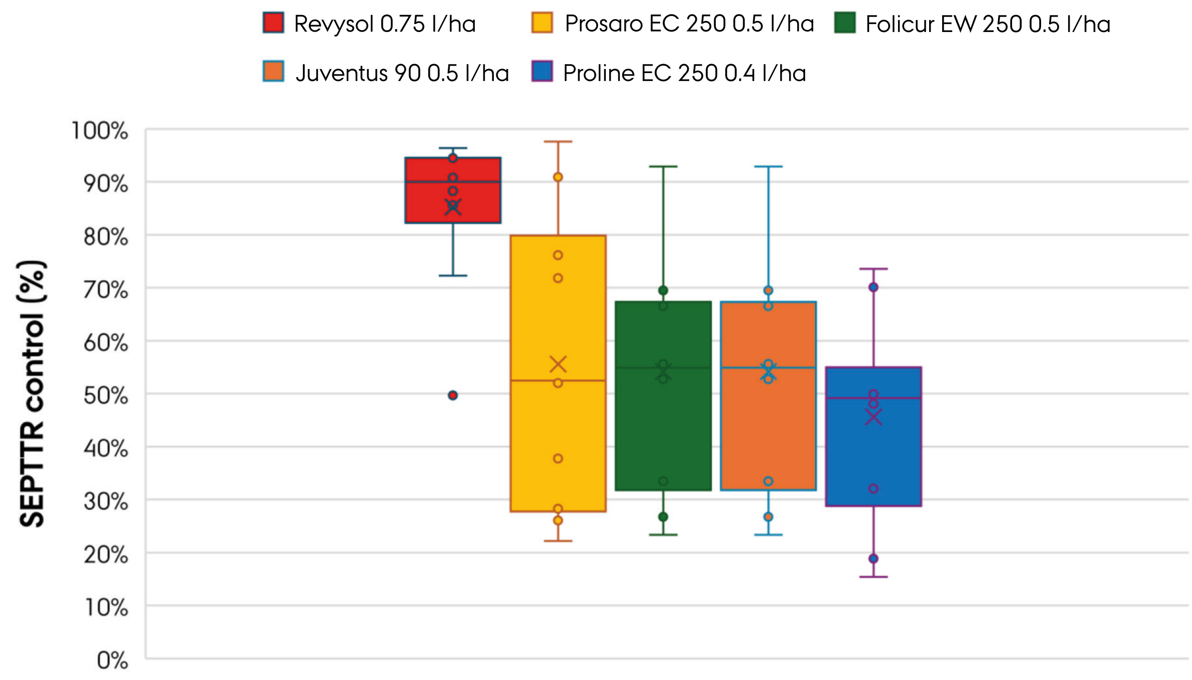


Figure 10. Average control of *Septoria* on leaves 1 and 2 assessed at GS 71-77 from using two treatments with ½ rates of different azole products applied at GS 33 and GS 45-51. Trial data from six seasons (2018-2023).

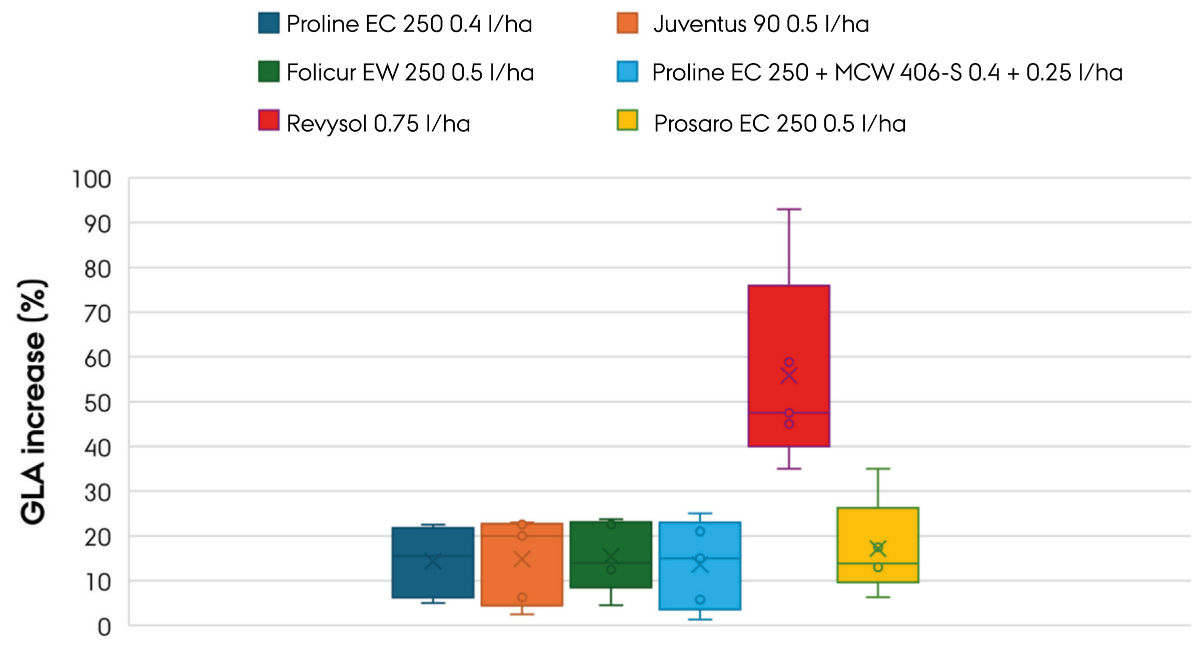


Figure 11. Average green leaf area on flag leaves at GS 77-81 from using two treatments with ½ rates of different azole products at GS 33 and GS 45-51. Trial data 2019- 2021.

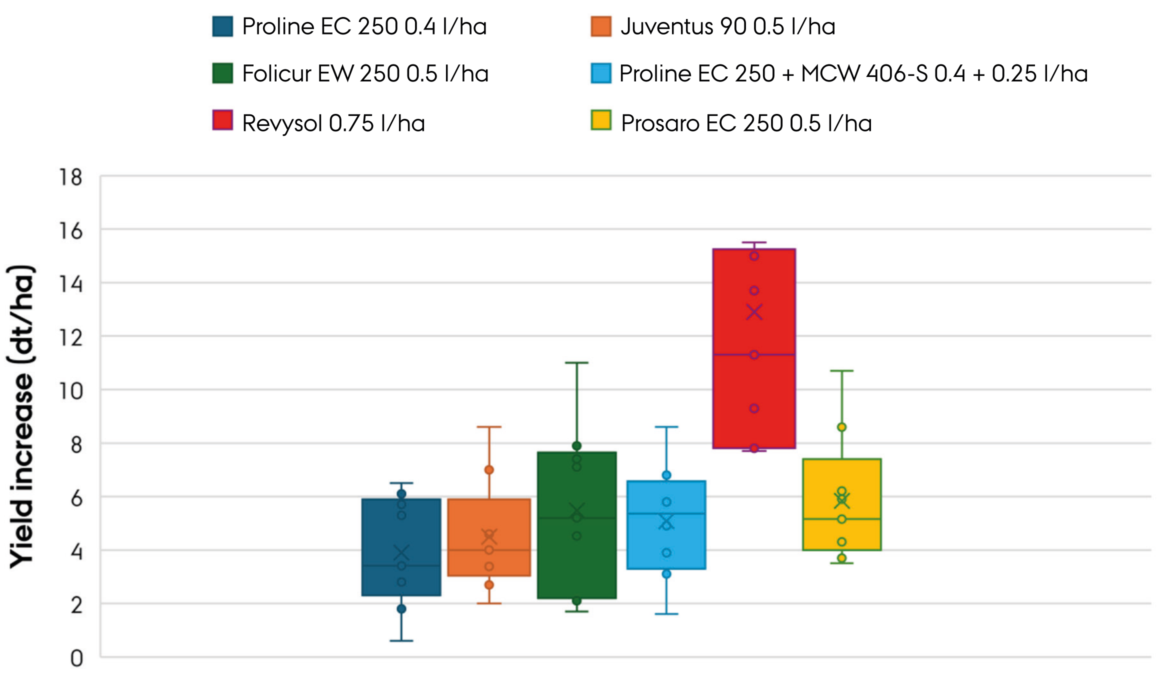


Figure 12. Yield increases (dt/ha) from using two treatments with ½ rates of different azole products at GS 33 and GS 45-51. Trial data 2018- 2022.

Testing different T1 treatments against powdery mildew

This trial tested different fungicides at T1 and a cover spray of Balaya (0.5 l/ha) at T2 on powdery mildew (Table 13). This trial was carried out in the cultivar Torp at Jyndevad Experimental Station because the soil is sandy, which helps the powdery mildew establish itself. In this trial different levels of Talius 200 EC dosages were tested at full rate (0.25 l/ha) and reduced rates.

Powdery mildew developed a significant attack on both leaves 2 and 3 and a moderate attack on the flag leaf. All the treatments helped control the powdery mildew (Figure 13). Treatments sprayed with only the T2 had 10-20% control, and treatments with both T1 and T2 had 23-61% control (untreated 6.5% infection). On leaf 2 the T2 alone gave 0-10% control, and the treatments with both T1 and T2 sprays gave 31-73% control. There is a clear dosage effect from Talius 200 EC with the two lower doses having inferior control. Talius 200 EC at the dosage of 0.25 l/ha had the best lasting control in the trial. Talius 200 EC gave control which was superior to both Proline EC 250 and Flexity.

Yields increases were between 8 dt/ha and 15 dt/ha for all the treatments. The treatments with just the Balaya cover spray did not differ significantly in yield compared with the treatments which also had a T1 spray.

Table 13. Effects of treatments at GS 32 and GS 45-51 on control of powdery mildew, yield responses, net yield, thousand grain weight (TGW). One trial in 2023 in Torp (23308-1). Several treatments are not included due to confidentiality.

Treatments, l/ha		% powdery mildew					Yield & yield increase, dt/ha	Net yield, dt/ha	TGW, g
GS 32	GS 45-51	GS 43-45 Leaf 3	GS 43-45 Leaf 2	GS 59 Leaf 2	GS 71 Leaf 1	GS 71 Leaf 2			
1. Talius 200 EC 0.15	Balaya 0.5	20.0	1.8	2.3	4.0	20.0	11.9	9.0	39.9
2. Talius 200 EC 0.2	Balaya 0.5	18.8	2.0	1.5	2.5	12.5	11.9	8.8	40.9
3. Talius 200 EC 0.25	Balaya 0.5	13.8	0.8	1.0	2.8	10.0	10.9	7.5	39.9
5. Proline EC 250 0.65	Balaya 0.5	33.8	3.5	4.0	3.8	14.5	15.0	10.8	39.9
7. Flexity 0.5	Balaya 0.5	35.0	4.5	4.0	5.0	16.3	13.1	8.9	40.5
8. Untreated	Balaya 0.5	55.0	7.8	8.5	5.3	21.3	10.0	8.1	40.8
9. Untreated		46.3	6.0	18.8	6.5	20.0	65.0	-	37.5
LSD_{95}		9.2	1.9	1.8	1.7	6.4	0.5	-	2.1

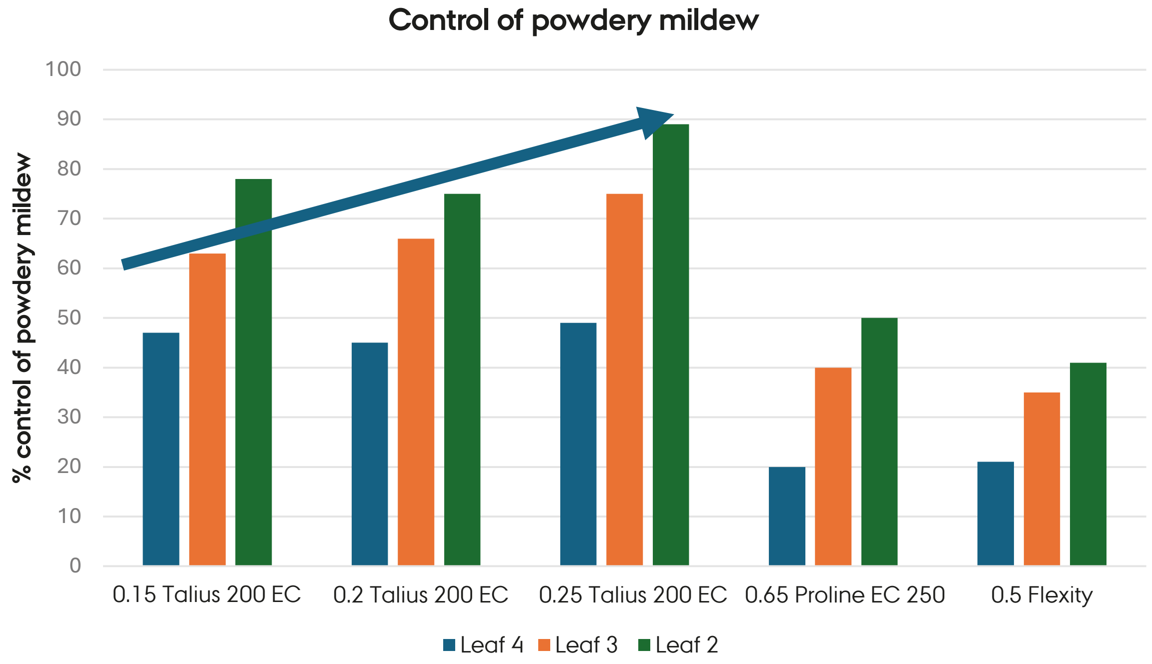


Figure 13. Control of powdery mildew on specific leaf layers. Talius 200 EC has a good persistence and shows a long-lasting effect on leaf 2.

Control of powdery mildew. Untreated plants to the left and 0.25 Talius 200 EC to the right. Photo taken 19 DAA at GS 31-32.

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 2023 was attacked by significant infections of tan spot and almost no *Septoria*. The trial was assessed at four timings (GS 32, 71, 75, 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 (NOS 514218.07, Creator, Informer and Pondus) had a significantly lower level of attack than most of the other cultivars. Figure 14 shows the result for attack of % tan spot, ranking the cultivars according to susceptibility. Creator, Pondus and Informer also showed a better level of control in previous seasons.

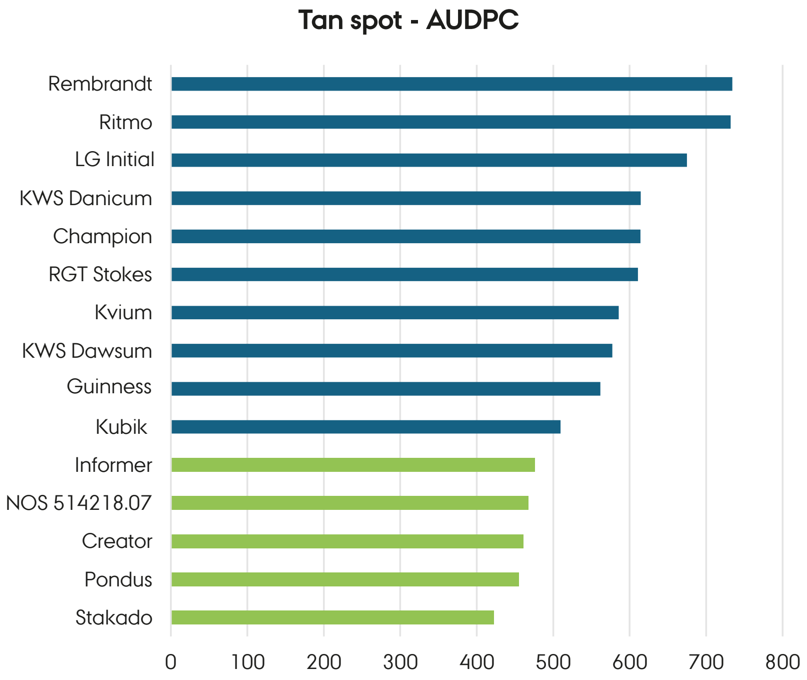


Figure 14. Infection of tan spot in different winter wheat cultivars. Based on four assessments on the upper leaves (23302-1), calculating AUDPC (Area Under Disease Pressure Curve). LSD95 = 93.

Control of Fusarium head blight

In six trials different fungicides against *Fusarium* were tested and evaluated for their efficacy.

The trials were carried out using artificial inoculation with spores during flowering. Typically, the trials were inoculated once or twice following the spraying. The results from the reference treatments are shown in Table 14. The disease pressure in the trials was low to moderate. The control of Fusarium head blight (FHB) using Prosaro EC 250 or Proline EC 250 gave on average 45% control, while benefits in yields were non-significant.

Table 14. Control of Fusarium head blight and yield responses from six specific trials, which were inoculated with a spore mixtures of *F. culmorum* and *F. graminearum*.

	% Fusarium head blight							Yield, dt/ha
	23314-1	23314-2	23314-3	23321-1	23335-1	23336-1	Average of six trials	Average of six trials
Untreated	11.0	17.0	24.0	43.0	21	21.0	19.6	110.0
Prosaro EC 250 0.75-1.0/Proline EC 250 0.8	0.0	7.0	17.0	26.5	6	8.0	10.8	112.1

Ranking susceptibility to Fusarium head blight (FHB) in winter wheat in 2021

In line with previous years the Department of Agroecology, Aarhus University, AU 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, 15 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) (25 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, 12 and 14 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 15. As seen in Figure 16, the cultivars Rembrandt, Champion, RGT Stokes, Kvium and Kubik had the most severe attacks. Least attack was seen in KWS Danicum. The cultivar Ritmo were used as the susceptible reference cultivar and Sheriff and Skalmeje as the most resistant references. Data from the two trials correlated quite well as can be seen in Figure 15.

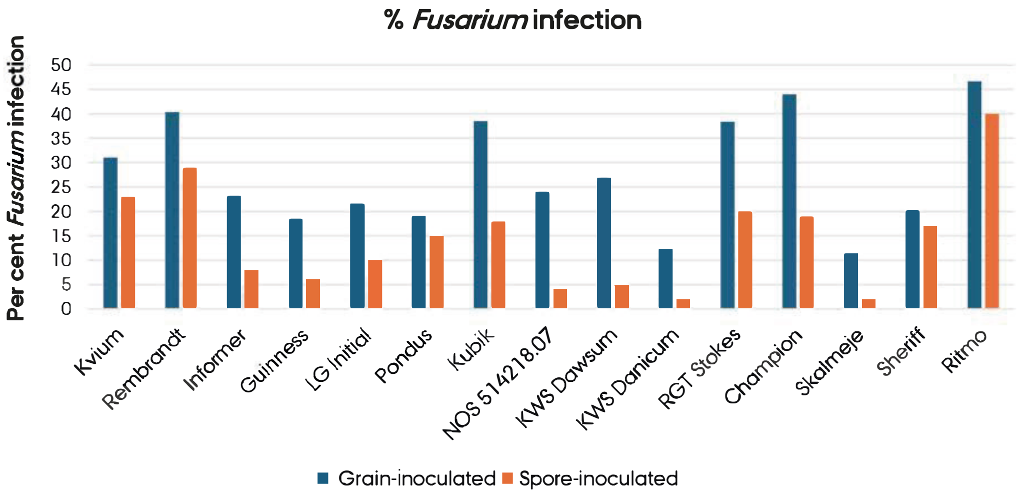


Figure 15. Per cent attack of Fusarium head blight in different cultivars tested in two wheat trials infected by different methods.

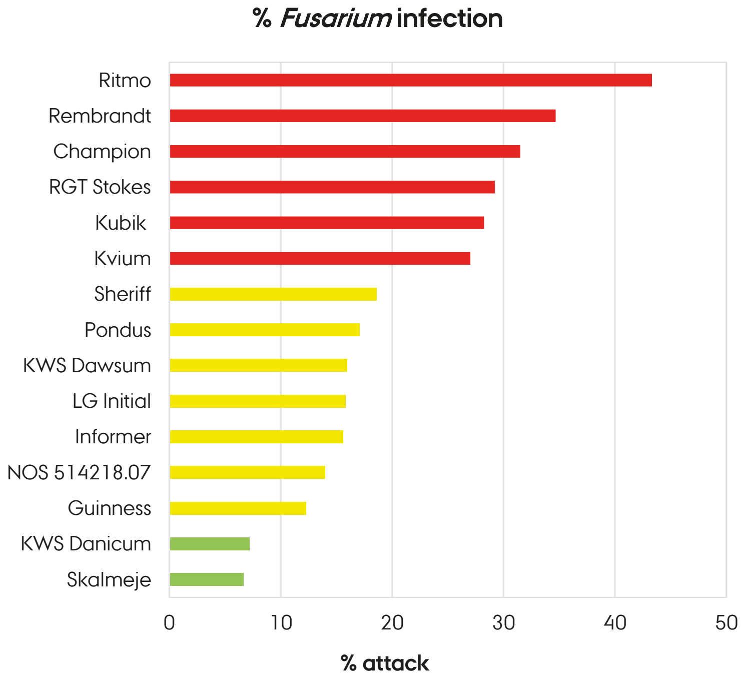


Figure 16. Percentage of ears in different cultivars attacked by Fusarium head blight in July 2022. Average of both trials.

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 as *F. graminearum* and *F. culmorum* do not produce these toxins. All cultivars had DON levels much higher than the maximum acceptable limit of 1250 ppb. A relatively good correlation was found between *Fusarium* infections and DON content (R^2=0.57) (Figure 17). The content of ZEA was unusually high and correlated less well with the infection level scored in the trials (R^2 = 0.22) (Figure 18).

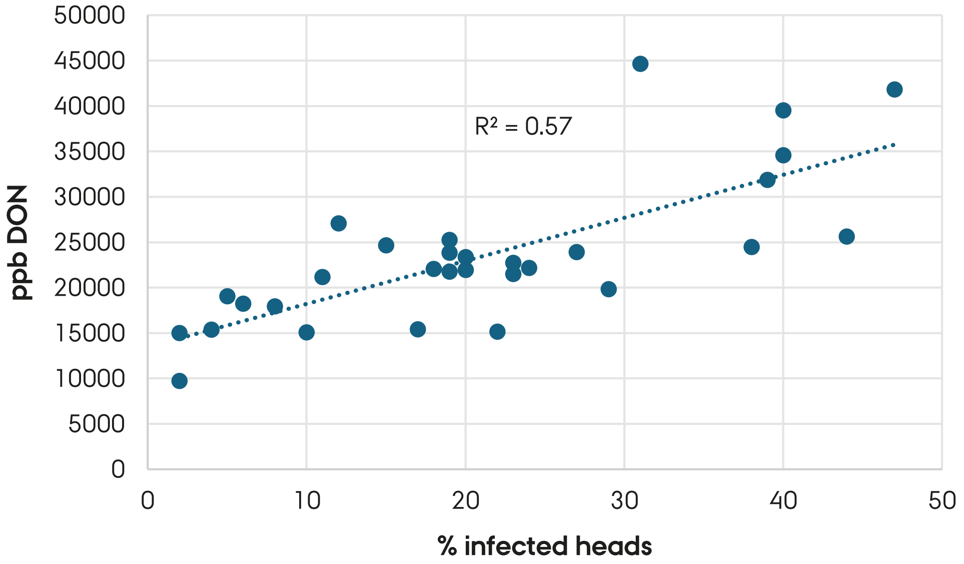


Figure 17. Correlation between % *Fusarium* attack and the deoxynivalenol (DON) content measured as ppb from the two trials in 2023.

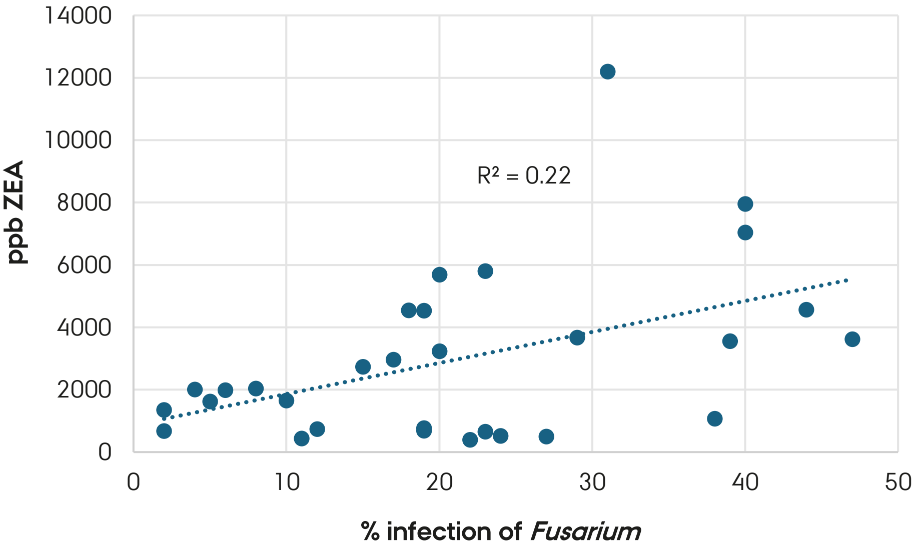


Figure 18. Correlation between % *Fusarium* attack and the zearalenone (ZEA) content measured as ppb from the two trials in 2023.

III Disease control in barley, rye and triticale

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

In this chapter the field trials are following the same experimental protocol as stated in Chapter II: Disease control in wheat. The first part will discuss barley trials, and the second part will discuss rye and triticale trials.

Control of diseases using alternative solutions in barley

In two trials alternative solutions were tested in winter and spring barley, respectively, to test their control against multiple diseases. This was conducted in the spring barley cultivar Skyway and the winter barley cultivar Valerie. The different alternatives are listed in Tables 1 and 2. Two different sulphur treatments were tested (Vertipin and Thiopron), which are currently not authorised for use as crop protection products in Denmark. Serenade ASO controls by using the active ingredient of a bacterium strain, *Bacillus amyloliquefaciens* QST 713. Charge is a biostimulant that is based on the ingredient chitosan. Bion 50 WG (benzothidazole) is known to induce systematic acquired resistance (SAR). Iodus is based on seaweed extracts and has the active ingredient of laminarin, which is known to also induce the natural resistance of the plants. As part of a GUDP project two new biologicals were also included: V1P and TF2. The different alternative compounds were compared to a traditional reference of a chemical pesticide listed below as treatments 2 and 3.

In spring barley there was a low infection rate of net blotch (*Pyrenophora teres*), Ramularia leaf spot (*Ramularia collo-cygni*) and brown rust (*Puccinia hordei*), shown in Table 1. The treatment where Bion 50 WG was used at T1 and Proline EC 250 at T2 had control similar to the treatment using Proline EC 250 at T1 and T2 against all three diseases. Only the products with prothioconazole (treatments 2, 3 and 12) had significant control of net blotch. The prothioconazole treatments and the treatments with Thiopron and Iodus + Thiopron had significant control of *Ramularia*. Rust was significantly controlled by all prothioconazole treatments and the treatments with phosphonate, Vertipin as well as Iodus with Thiopron.

In the spring barley trial, a significant yield increase was recorded from most treatments. The reference treatments yielded superiorly to most of the alternative substances. Several of the alternative substances did, however, increase yields significantly. The least effective response was seen from the treatment at T1 of Bion 50 WG and T2 of Proline EC 250, which might be a result of some phytotoxic responses previously described from the use of Bion 50 WG in barley. V1P proved to have some effect on rust control while this was less so for TF2. However, for control of net blotch TF2 was superior to VP1.

In winter barley there was low to moderate infections of *Rhynchosporium* (*Rhynchosporium commune*) and brown rust (Table 2). All the products including the references only gave 20% control of *Rhynchosporium*, while the control of rust was more pronounced, and the best solutions reached 97% efficacy. Similar to the spring barley trial, the treatment in which Bion 50 WG was used at T1 and Proline EC 250 at T2 had control of rust similar to the treatment using Proline EC 250. The rust was controlled by products with prothioconazole, phosphonate, Iodus solo and V1P.

In the winter barley trial, no significant yield increase was measured from any treatments. Not even the reference treatments increased yields, which is a result of relatively low infections and dry cropping conditions.

Table 1. Disease attack, thousand grain weight (TGW) and yield responses, using alternative products compared to traditional fungicides applied twice at GS 31-32 and GS 51-55 in spring barley. One trial (23382).

Treatments, l/ha		% *Ramularia*	% net blotch	% rust		TGW, g	Yield & yield increase, dt/ha	Net yield, dt/ha
GS 31-32 / 51-55	Dose	GS 77 Leaf 2	GS 73 Leaf 3	GS 73 Leaf 3	GS 77 Leaf 2			
1. Untreated		6.3	10.5	4.8	6.8	48.6	68.4	-
2. Propulse SE 250	0.5	1.3	0.3	0.1	0.7	49.3	9.8	6.3
3. Proline EC 250	0.4	3.0	2.0	0.2	0.2	48.8	8.4	5.1
4. Thiopron	3.0	1.8	7.5	2.1	3.3	49.3	5.3	-0.8
5. Phosphonate	3.0	3.0	4.8	1.6	2.5	48.3	6.0	-
6. Serenade ASO + Silwet Gold	2.0 + 0.1	4.3	5.3	0.9	3.8	52.3	5.6	1.6
7. Charge + Sorrento	3.0 + 0.1	4.8	7.5	2.8	4.3	51.2	4.3	-
8. Phosphonate + Thiopron	3.0 + 3.0	4.5	5.5	1.1	2.1	48.3	4.4	-
9. Iodus	1.0	3.3	7.5	2.3	4.8	49.5	5.3	-
10. Iodus + Thiopron	1.0 + 3.0	1.5	7.5	1.7	2.3	47.5	3.9	-
11. Vertipin	3.5	3.5	8.5	1.1	2.3	47.3	5.2	-
12. Bion 50 WG / Proline EC 250	0.06 + 0.4	2.1	1.8	0.3	0.4	50.2	0.3	-
13. V1P	4.0	4.8	10.5	1.4	4.1	47.6	1.5	-
14. TF2	4.0	3.0	5.3	3.0	5.8	50.7	4.3	-
LSD_{95}		2.4	4.3	1.4	2.6	3.7	4.9	-

Net blotch was commonly seen in the trials using cultivars Chapeau and RGT Planet.

Table 2. Disease attack, thousand grain weight (TGW) and yield responses, using alternative products compared to traditional fungicides applied twice at GS 31-32 and GS 51-55 in winter barley. One trial (23371).

Treatments, l/ha		% *Rhynchosporium*	% rust			TGW, g	Yield & yield increase, dt/ha	Net yield, dt/ha
GS 31-32 / 51-55	Dose	GS 69 Leaf 3	GS 73 Leaf 2	GS 73 Leaf 1	GS 75 Leaf 2			
1. Untreated		15.0	2.0	2.0	12.0	49.4	74.3	-
2. Propulse SE 250	0.5	12.0	0.1	0.0	2.0	48.5	1.5	-2.0
3. Proline EC 250	0.4	12.0	0.1	0.0	0.5	51.0	-1.5	-4.8
4. Thiopron	3.0	15.0	1.8	0.4	6.3	47.9	-10.3	-16.4
5. Phosphonate	3.0	13.5	2.0	0.6	5.3	48.7	2.1	-
6. Serenade ASO + Silwet Gold	2.0 + 0.1	13.5	2.0	0.5	8.0	49.9	-4.8	-8.8
7. Charge + Sorrento	3.0 + 0.1	14.3	2.0	0.6	6.5	47.8	-10.8	-
8. Phosphonate + Thiopron	3.0 + 3.0	12.0	2.0	0.5	4.5	50.8	-1.0	-
9. Iodus	1.0	14.3	1.8	0.4	3.5	49.0	-5.5	-
10. Iodus + Thiopron	1.0 + 3.0	12.0	2.0	0.5	7.5	51.5	5.3	-
11. Vertipin	3.5	12.0	1.5	0.4	6.3	51.6	1.7	-
12. Bion 50 WG / Proline EC 250	0.06 + 0.4	12.0	0.5	0.0	1.0	49.7	1.5	-
13. V1P	4.0	12.0	2.0	0.5	5.0	48.9	-2.1	-
14. TF2	4.0	12.0	2.0	0.5	9.0	49.9	-5.5	-
LSD_{95}		1.3	0.4	0.1	4.0	3.5	NS	-

Comparison of market-related solutions in spring and winter barley

Two identical protocols were carried out in both winter and spring barley at AU Flakkebjerg. The trial plan was to test different fungicide solutions typically using half of the approved rates. The trial was to investigate the performances on all the relevant leaf diseases in barley with this plan and to compare the efficacy of the products in 2023.

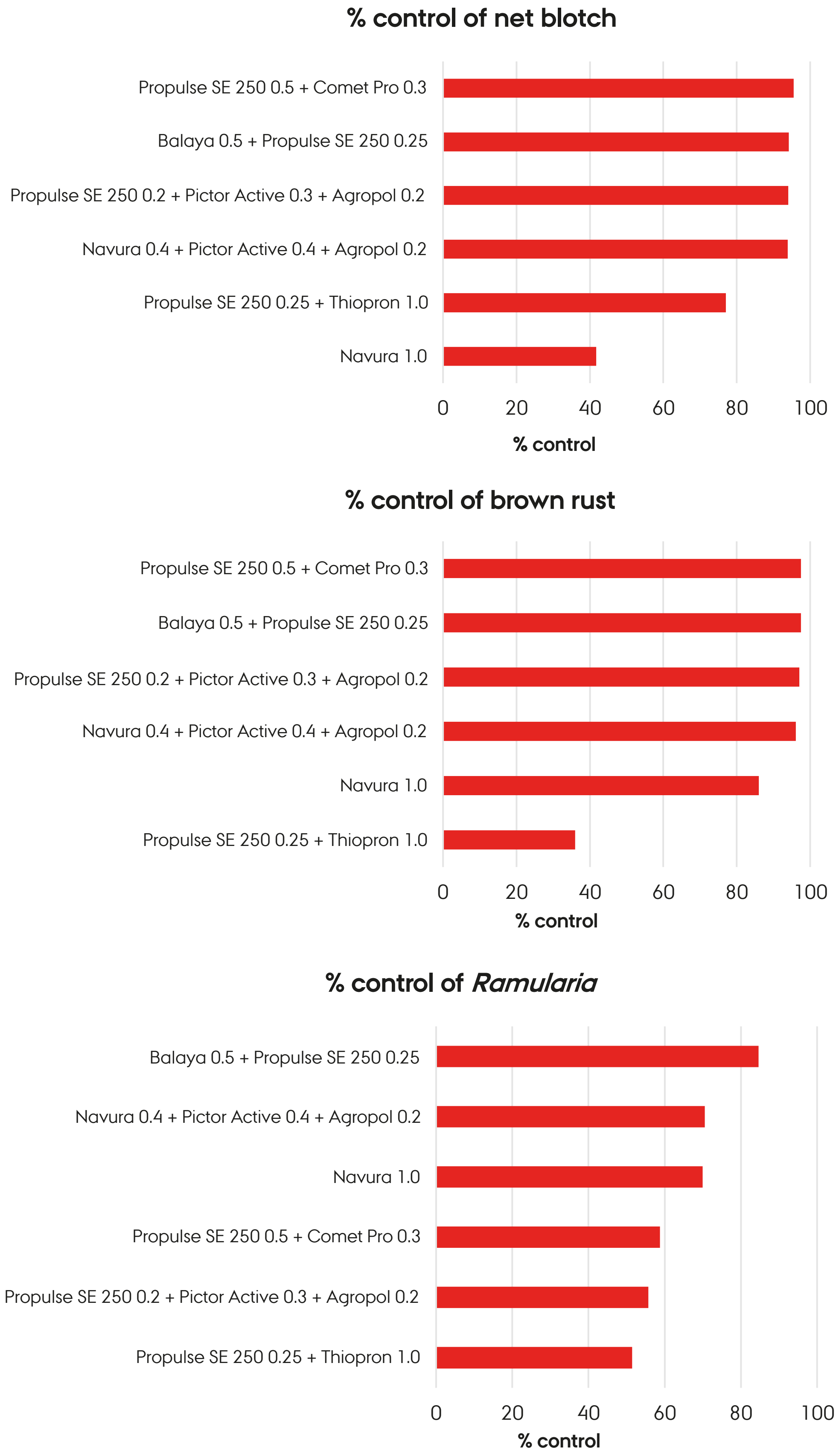
Results from the three spring barley trials are shown in Table 3. The spring barley trials were carried out in the cultivars Chapeau, Skyway and RGT Planet. All these trials developed moderate to severe attacks of net blotch (*Pyrenophora teres*), Ramularia leaf spot (*Ramularia collo-cygni*) and brown rust (*Puccinia hordei*). As shown in Table 3, most of the tested solutions provided very similar and good control of the diseases. The effect on net blotch, Ramularia leaf spot and brown rust is also shown in Figure 1. Yield levels were relatively low, but even so responses from fungicides were significant although no significant differences were seen between the different treatments (Table 3).

Navura is a new product tested in barley. The product consists of a mixture of mefentrifluconazole and prothioconazole. The product showed a relatively weak effect on net blotch where other combinations clearly outperformed the product. Products which include pyraclostobin and also SDHIs are generally more effective on this disease. This was very clear when testing the mixture Navura + Pictor Active, which gave control in line with the best solutions. Propulse SE 250 mixed with Comet Pro did also outperform the mixture of Propulse SE 250 mixed with Thiopron. This was most pronounced against brown rust against which neither Propulse SE 250 nor Thiopron is very effective.

Table 3. Disease attack, green leaf area (GLA), thousand grain weight (TGW) and yield responses, using different fungicides applied at half rates at GS 37 in spring barley. Three trials 2023 (23384).

Treatments, l/ha		% net blotch	% *Ramularia*	% brown rust	% GLA	TGW, g	Yield & yield increase, dt/ha	Net increase, dt/ha
GS 37	Dose	GS 77 Leaf 2-3 / Leaf 2	GS 77 Leaf 2-3 / Leaf 2	GS 77 Leaf 2-3 / Leaf 2	GS 83 Leaf 2			
1. Propulse SE 250 + Comet Pro	0.5 + 0.3	1.1	3.3	0.6	5.1	57.1	5.2	2.7
2. Propulse SE 250 + Thiopron	0.25 + 1.0	5.6	3.9	14.7	6.9	56.9	2.0	0.0
3. Balaya + Propulse SE 250	0.5 + 0.25	1.4	1.2	0.6	13.3	56.0	6.2	3.5
4. Navura	1.0	14.2	2.4	3.2	9.7	56.1	5.3	-
5. Propulse SE 250 + Pictor Active + Agropol	0.2 + 0.3 + 0.2	1.5	3.6	0.7	11.6	56.8	5.6	3.8
6. Navura + Pictor Active + Agropol	0.4 + 0.4 + 0.2	1.5	2.4	0.9	10.5	56.3	5.8	-
7. Untreated		24.3	8.1	22.9	3.1	55.4	55.7	-
No. of trials		3	3	3	3	3	3	3
LSD_{95}		2.4	0.9	2.3	8.6	1.2	2.8	-

Ramularia leaf blotch in barley.



% control of net blotch

% control of brown rust

% control of *Ramularia*

Figure 1. Per cent control of net blotch, brown rust and *Ramularia* (three trials) in spring barley. Leaves were assessed at GS 77. Attack in untreated plots was 24% net blotch, 22.9% brown rust and 8% *Rhynchosporium*.

The three trials were carried out in winter barley in the cultivars Neptun, Valerie and Bordeaux. In the winter barley trials a low to moderate level of *Rhynchosporium* and brown rust developed as shown in Table 4. Treatment 2 using the mixture of Propulse SE 250 and Thiopron had a significantly lower control of both diseases with only 25% control of *Ramularia* and 32% of brown rust. There was no significant difference in yield or grain quality between the untreated and treated plots. This could be a result of the winter barley trials being impacted by drought conditions, even though the yield levels were still good.

Overall, the widely used solution Propulse SE 250 + Comet Pro again proved to be a very robust solution against all major diseases in barley. Similarly, the mixture of Propulse SE 250 + Pictor Active showed good results and so did the mixture of Propulse SE 250 + Balaya. The combination of Propulse SE 250 + Thiopron did not prove great for control of rust diseases, which is also known from the literature. Navura as a solo product has a low efficacy against net blotch, but when combined with other products it can provide effective control of all relevant leaf diseases in barley.

Table 4. Disease control, using different fungicides applied at half rates at GS 37 in winter barley. Three trials 2023 (23370).

Treatments, l/ha		% *Rhynchosporium*			% rust	Yield & yield increase, dt/ha	Net yield, dt/ha
GS 37	Dose	GS 61 Leaf 2	GS 71 Leaf 2	GS 71 Leaf 3	GS 71 Leaf 2-3		
1. Propulse SE 250 + Comet Pro	0.5 + 0.3	1.2	1.5	11.9	0.7	0.7	-1.8
2. Propulse SE 250 + Thiopron	0.25 + 1.0	2.4	2.9	16.9	4.8	2.1	0.1
3. Balaya + Propulse SE 250	0.5 + 0.25	1.3	1.5	12.1	0.6	-1.3	-3.9
4. Navura	1.0	1.5	1.3	11.3	0.8	2.7	-
5. Propulse SE 250 + Pictor Active + Agropol	0.2 + 0.3 + 0.2	1.2	1.5	12.9	1.0	1.7	-0.1
6. Navura + Pictor Active + Agropol	0.4 + 0.4 + 0.2	1.6	1.9	13.7	0.7	5.3	-
7. Untreated		3.1	5.1	22.5	7.1	93.7	-
No. of trials		2	3	3	2	3	3
LSD_{95}						NS	

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

Ramularia leaf spot is becoming a concern in barley because of its adapted resistance to several groups of fungicides in multiple regions across Western Europe, causing the future control strategies to be under pressure. The pathogen has been found to be extremely diverse, and these diversities are found in multiple regions of Europe which leads this to be a challenging disease to control.

Ramularia leaf spot has developed resistance to strobilurins (QoIs). This group of actives used to have a good efficacy against RLS. 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 frequency 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 and 2022, the trials in 2023 tested several different combinations of fungicides applied at GS 45-51. In the *Ramularia* trials 0.5 l/ha Comet Pro was applied during elongation to keep down attacks of rust and other leaf blotch diseases.

The trial was part of the Eurobarley project, in which a similar trial plan was carried out in four other countries. In 2023, in the Danish trial there was only a low to moderate level of attack of Ramularia leaf spot, which still resulted in sufficient infection to evaluate the efficacy of the different products (Table 5). In Denmark, only Proline EC 250 stood out from the treatments, having a lower level of control with 69% from the full dose.

Table 5. Attack of Ramularia leaf spot and yield responses, using different fungicides applied at GS 45-51 in spring barley (23386). Danish trial as part of the Eurobarley project.

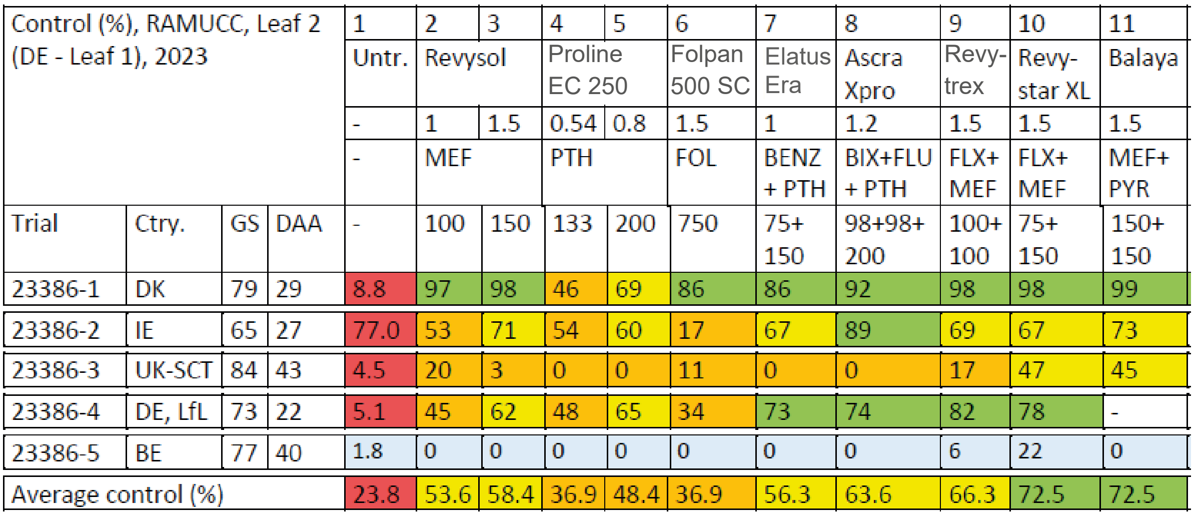
Treatments, l/ha		% net blotch	% net blotch	% *Ramularia*		TGW, g	Yield & yield increase, dt/ha	Net increase, dt/ha
GS 45-51	Dose	GS 73 Leaf 4	GS 77 Leaf 2	GS 77 Leaf 2	GS 81 Leaf 2			
1. Untreated		9.5	1.3	5.8	8.8	54.0	66.5	-
2. Revysol	1.0	1.9	0.2	0.5	0.3	54.5	-4.5	-
3. Revysol	1.5	3.0	0.2	0.8	0.2	54.1	6.3	-
4. Proline EC 250	0.54	4.0	0.4	3.0	4.7	53.7	0.7	-1.4
5. Proline EC 250	0.8	3.0	0.7	2.5	2.8	52.6	-0.7	-3.5
6. Folpan 500 SC	1.5	5.0	0.4	1.3	1.3	52.6	0.8	-0.7
7. Elatus Era	1.0	3.0	0.2	0.6	1.3	53.6	-5.1	-
8. Ascra Xpro	1.2	2.0	0.1	0.5	0.7	53.7	1.4	-
9. Revytrex	1.5	2.8	0.1	0.3	0.2	54.0	-1.6	-
10. Revystar XL	1.5	1.8	0.1	0.2	0.2	53.8	0.7	-
11. Balaya/Revycare	1.5	3.0	0.1	0.3	0.3	54.1	2.4	-2.6
12. BAS 768 00F	4.0	5.8	0.3	1.0	0.2	53.0	-1.0	-
13. BAS 831 00F	2.25	0.2	0.1	0.3	0.2	53.0	-3.7	-
14. Navura	1.5	4.0	0.4	0.9	0.7	53.5	0.9	-
LSD_{95}		1.3	0.3	1.1	0.9	2.2	7.8	-

The trial from Ireland had a severe infection and all other countries had a moderate infection. This provided good efficacy data for *Ramularia* (Table 6). In Ireland the product Ascra Xpro was the only product that out-performed with a high level of control of 89%. Overall, the collective of the trials had the most efficacy from Revystar XL and Balaya (73% control), while Folpan 500 SC and Proline EC 250 only gave 37%-48% control.

The trial in Belgium had a significant attack of rust (83%), while the trial in Scotland had 13% attack (Table 6). In both trials all treatments gave 81-100% control, except for Folpan 500 SC, which gave an insufficient control of 2-17%.

All trials except for the Danish trial saw yield increases from the treatments. The yield increase of Revysol and Proline EC 250 both showed the increase in dose increased in the yields. The treatment with Balaya led to the best yield increases across the four trials, while Folpan 500 SC showed the lowest yield increases. The other products did not follow similar patterns in the different countries.

Table 6. Control of Ramularia leaf spot using different fungicides applied at GS 45-51 in barley in five different trials across Europe (23386). Data in the column "Untr." show per cent attack with an average attack of 23.8% across the trials.



Control (%), RAMUCC, Leaf 2 (DE - Leaf 1), 2023				1	2	3	4	5	6	7	8	9	10	11
				Untr.	Revysol		Proline EC 250		Folpan 500 SC	Elatus Era	Ascra Xpro	Revy-trex	Revy-star XL	Balaya
				-	1	1.5	0.54	0.8	1.5	1	1.2	1.5	1.5	1.5
				-	MEF		PTH		FOL	BENZ + PTH	BIX+FLU + PTH	FLX+ MEF	FLX+ MEF	MEF+ PYR
Trial	Ctry.	GS	DAA	-	100	150	133	200	750	75+ 150	98+98+ 200	100+ 100	75+ 150	150+ 150
23386-1	DK	79	29	8.8	97	98	46	69	86	86	92	98	98	99
23386-2	IE	65	27	77.0	53	71	54	60	17	67	89	69	67	73
23386-3	UK-SCT	84	43	4.5	20	3	0	0	11	0	0	17	47	45
23386-4	DE, LfL	73	22	5.1	45	62	48	65	34	73	74	82	78	-
23386-5	BE	77	40	1.8	0	0	0	0	0	0	0	6	22	0
Average control (%)				23.8	53.6	58.4	36.9	48.4	36.9	56.3	63.6	66.3	72.5	72.5

Results from fungicide trials in rye and triticale

Two trials were carried out in 2023 – one in winter rye and one in triticale, testing different commonly used fungicides (23364).

The attack of yellow rust in the triticale cultivar Neogen began at the beginning of June and was driven by natural infection. The attack also spread to the ears, but that was late in the season. Generally, the attack level of rust was quite low, compared to previous years. The five different treatments showed a good control, but there were only significant differences in comparison with the untreated plots.

The yield responses were good and significant and varied between 11.3 dt/ha and 19.5 dt/ha (Table 7). The different solutions gave very comparable levels of rust control and yield responses.

Table 7. Attack of diseases in triticale, green leaf area (GLA) and yield responses, using different fungicides applied at GS 32-33 and GS 51-55 (23364-1).

Treatments, l/ha		% yellow rust			% GLA	TGW, g	Yield & yield increase, dt/ha	Net increase, dt/ha
GS 32-33 & 51-55	Dose	GS 65 Leaf 3	GS 71 Leaf 2	GS 75 Ear	GS 75 Leaf 2			
1. Propulse SE 250 + Comet Pro	2 x (0.35 + 0.2)	5.0	5.8	5.0	65.0	46.9	17.0	12.9
2. Propulse SE 250 + Comet Pro	1 x (0.35 + 0.2)	8.5	5.0	4.3	66.3	47.4	16.4	14.4
3. Propulse SE 250 + Thioprон	2 x (0.35 + 1.0)	5.5	5.0	4.5	67.5	48.0	19.5	14.6
4. Proline EC 250 + Comet Pro	2 x (0.2 + 0.375)	5.5	5.0	2.8	68.8	47.3	11.3	7.0
5. Comet Pro	2 x 0.6	6.3	5.0	2.0	73.8	49.6	16.3	12.1
6. Untreated		20.0	23.8	15.0	30.0	46.0	75.0	-
LSD_{95}		3.8	4.8	4.2	7.1	5.7	8.3	-

The rye trial (23364-2) only developed a minor attack of *Rhynchosporium*. Data from the trial are shown in Table 8.

The five different treatments provided a significant and very similar control of *Rhynchosporium* in comparison with the untreated plots: only 5% infection. The yields increased minorly and provided negative net yields from low infection rates.

Table 8. Attack of *Rhynchosporium* in rye, green leaf area (GLA) and yield responses, using different fungicides applied at GS 32 and GS 51-55 (23364-2).

Treatments, l/ha		% *Rhynchosporium*		% GLA	TGW, g	Yield & yield increase, dt/ha	Net increase, dt/ha
GS 32 & 51-55	Dose	GS 59 Leaf 3	GS 71 Leaf 2	GS 83 Leaf 2			
1. Propulse SE 250 + Comet Pro	2 x (0.35 + 0.2)	1.5	2.8	36.3	34.8	2.1	-2.0
2. Propulse SE 250 + Comet Pro	1 x (0.35 + 0.2)	3.3	3.0	24.5	34.2	0.8	-1.2
3. Propulse SE 250 + Thiopron	2 x (0.35 + 1.0)	1.5	3.0	25.0	33.7	1.5	-3.4
4. Proline EC 250 + Comet Pro	2 x (0.2 + 0.375)	3.0	2.8	42.5	33.1	0.1	-4.2
5. Comet Pro	2 x (0.6)	2.3	3.5	32.5	33.6	0.2	-4.0
6. Untreated		4.3	5.3	19.3	34.2	50.0	-
LSD_{95}		1.7	1.2	15.3	1.8	0.3	-

Ranking of cultivar susceptibility to ergot

In a project partly financed by the breeders, the Department of Agroecology, Aarhus University, Flakkebjerg investigated the susceptibility to ergot among the winter rye cultivars most commonly grown in Denmark. The investigation was financed by KWS and Nordic Seed.

In this year's trials, 12 cultivars, sown in 1-m^2 plots were tested in two replicates with buffer zones of triticale between all plots (23303). The trial was inoculated three times on 31 May and on 2 and 5 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. Figure 2 provides a ranking of the tested cultivars.

A major variation in the level of infections was seen in the trial. Helltop and Stannos, which in previous years have showed a high level of ergots, were less infected in 2023. In line with previous seasons, DHEK073 was the most resistant cultivar and is known to have specific resistant genes. Also, KWS Jethro and KWS Igor showed a good reduction in attack. Cultivars from KWS which are based on PollenPlus Systems showed a variable level of attack. In Figure 3 data are summarised from four seasons and show that KWS Jethro and KWS Receptor got least attack, while KWS Tayo and KWS Berado had a slightly higher level of attacked heads.

The ears from the trial were harvested and threshed. A grain sample of 200 g per cultivar was analysed for ergot content. These data, however, did not show any differences between cultivars most likely as a result of ergots dropping off already in the field, which leads to unreliable results.

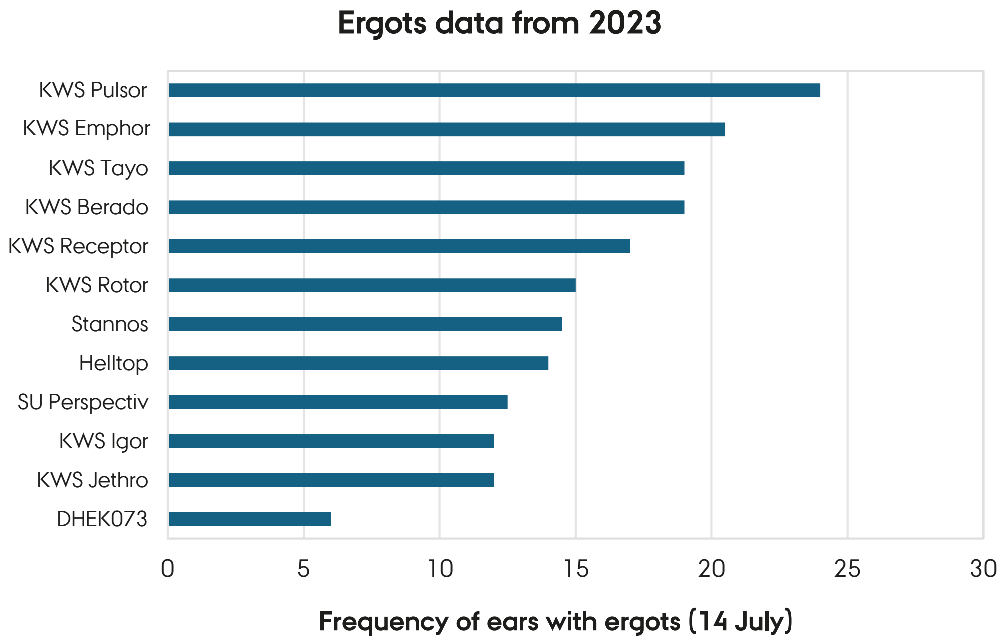


Figure 2. Number of ergots per 100 ears heads of rye inoculated with ergot during flowering (23303). LSD_{95}=8.5.

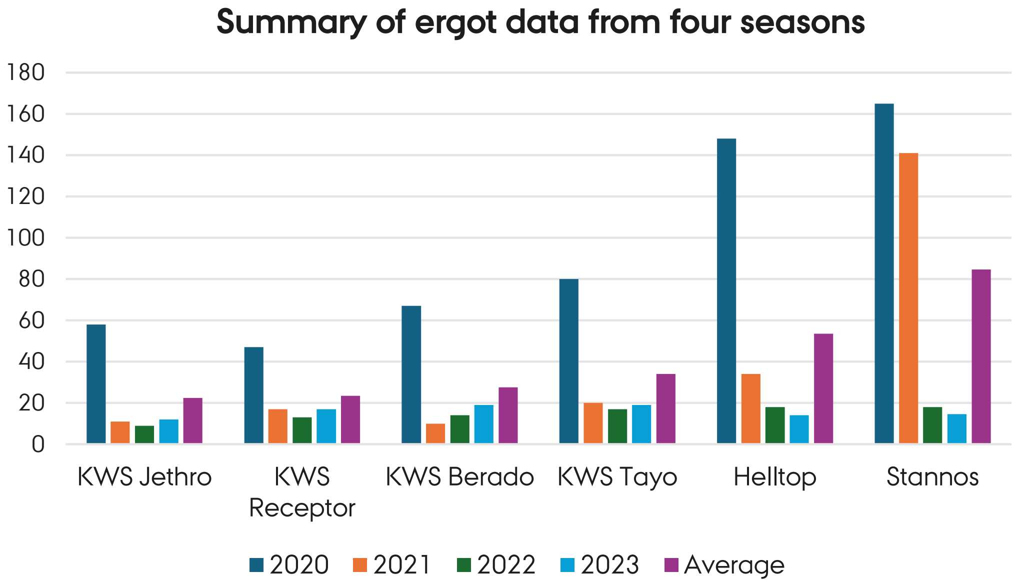


Figure 3. Summary of data from four seasons with main included rye cultivars tested for susceptibility to ergot.

IV Control strategies in different cereal cultivars

Brittany Deanna Beck, Niels Matzen, Hans-Peter Madsen, Sidsel Stein Kirkegaard, Anders Almskou-Dahlgaard, Sofie Rosengaard Nørholm & Lise Nistrup Jørgensen

Data from six wheat cultivars

Eight different control strategies were compared in six different wheat cultivars. The cultivars reflect some of the most commonly grown cultivars in Denmark. The cultivar mixture included three quite resistant cultivars which have different levels of resistance against yellow rust, mildew and *Septoria* (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 based on rain, humidity and the resistance of a cultivar. The trials were placed at two locations – one at AU Flakkebjerg and one near Horsens at Velas. At AU Flakkebjerg there was also a treatment based on only treating the crop when the qPCR method showed signs of *Septoria* DNA. The following strategies were tested:

1. Untreated
2. 0.75 l/ha Balaya (GS 37-39)
3. 0.75 l/ha Univoq (GS 37-39)
4. 0.75 l/ha Balaya / 0.75 l/ha Univoq (GS 37-39 / GS 55-61)
5. 3.0 l/ha Thiopron / 3.0 l/ha Thiopron (GS 37-39 / GS 55-61)
6. 0.3 l/ha Balaya + 3.0 l/ha Thiopron / 0.3 l/ha Univoq + 3.0 l/ha Thiopron (GS 37-39 / GS 55-61)
7. Treatments according to qPCR; only relevant for AU Flakkebjerg
8. Treatments according to Crop Protection Online

The trials initially only developed low to moderate levels of *Septoria* attack. Only the cultivar Rembrandt showed attack earlier in the season. All treatments reduced disease attack adequately. Only one treatment was applied based on qPCR; that was in the cultivar Rembrandt. DNA assessments later showed good reduction of *Septoria* DNA in line with reference treatments, indicating good timing from the qPCR.

Rembrandt is registered as a susceptible cultivar to *Septoria* and was treated following the CPO of four days with precipitation (Treatment 8). An application was made at GS 39 on 26 May, applying 0.6 l/ha Balaya. At both AU Flakkebjerg and Velas, the other cultivars did not have enough rain to reach the threshold to make fungicide application necessary.

Control from different treatments is shown in Figure 1. Yield levels were generally moderate to high and increases following fungicide applications were low to moderate (Figures 2 and 3; Table 1). Only Rembrandt increased yields significantly in the range of 8-12 dt/ha. In the cultivar mixture none of the treatments gave a positive net yield return.

The measurements from the qPCR are shown in Figure 4. A clear difference between cultivars and treatments were seen from the measurements. The qPCR model reduced the level of DNA in line with the treatments according to CPO.

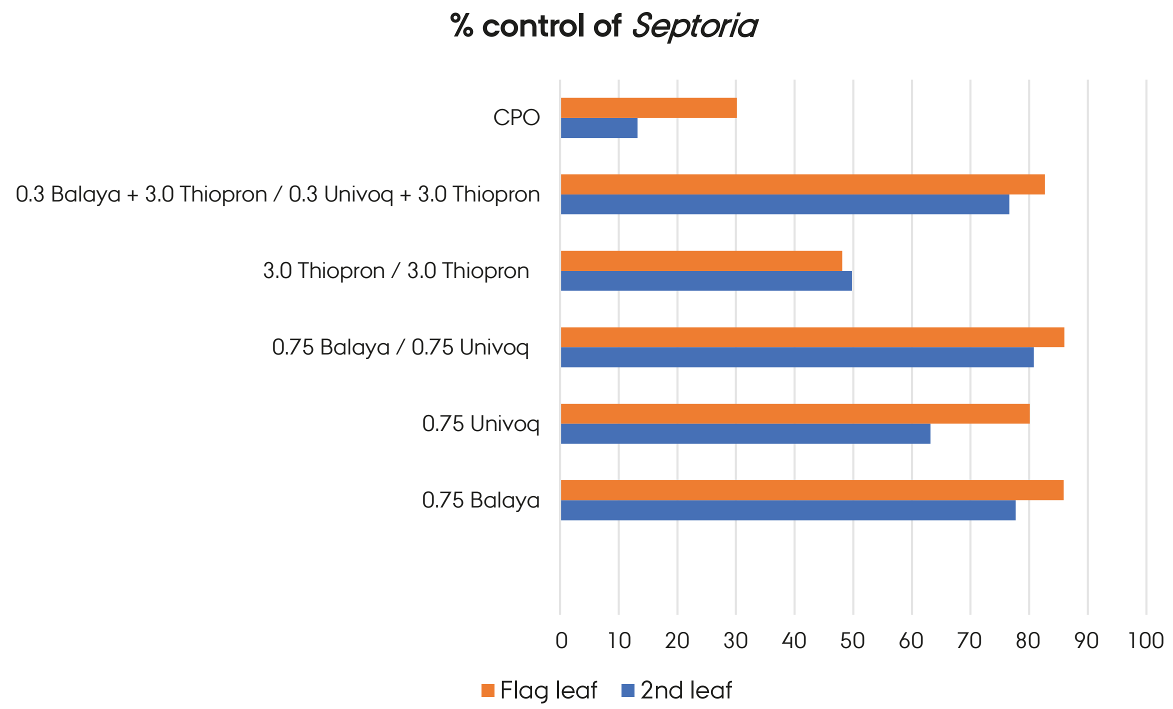


Figure 1. Attack of *Septoria* assessed on the flag leaf and the second leaf at GS 75. All treatments reduced the attack. The level of attack varied very much between the cultivars.

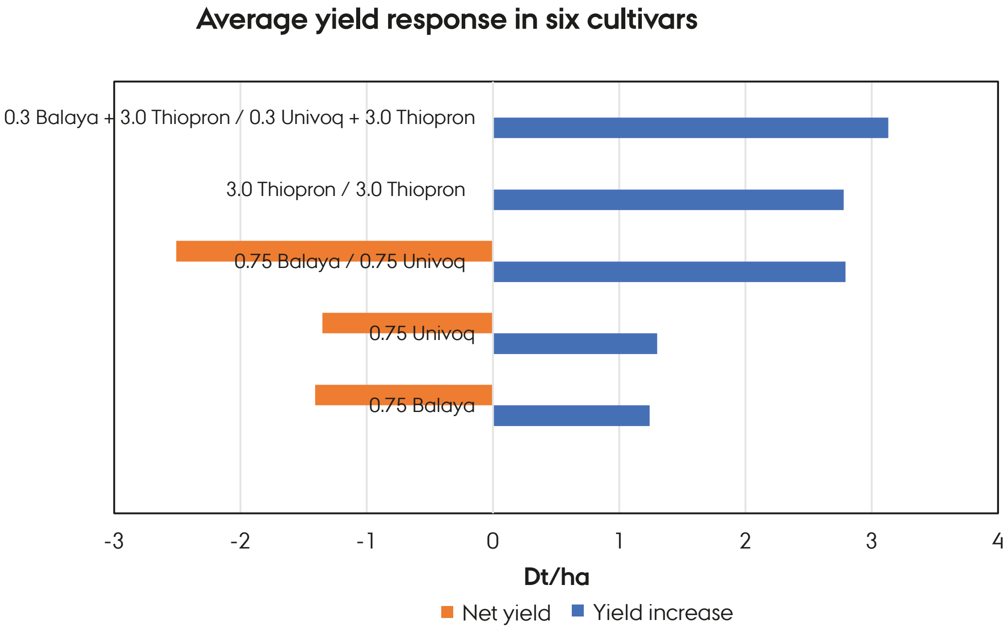


Figure 2. Yield increases and net yields following treatments with different treatments in six different cultivars. Average of two trials. (Thiopron is not an approved pesticide in Denmark so there is no net value).

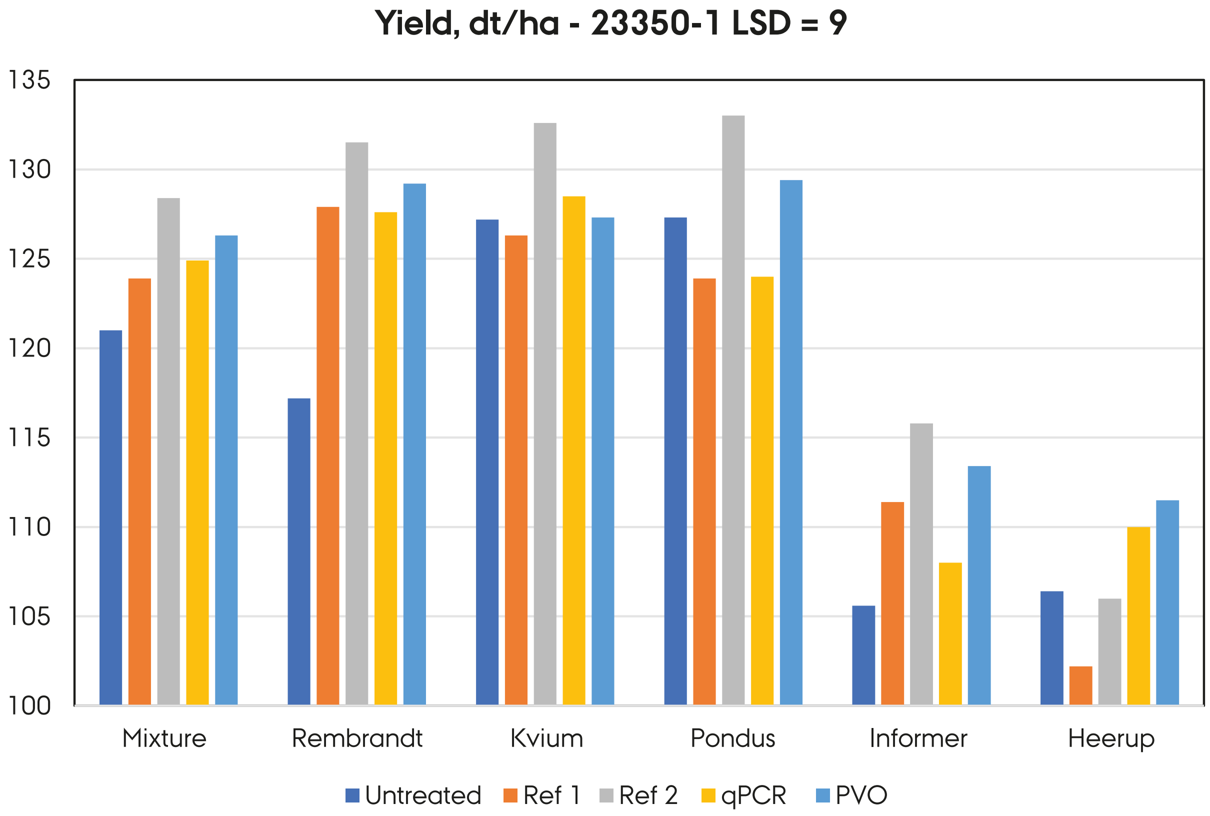


Figure 3. Gross yield in the AU Flakkebjerg trial (23350-1) comparing four of the eight tested solutions. Reference 1 is Balaya (treatment 2) and Reference 2 is Balaya and Univoq (treatment 4). The cultivar mixture includes Kvium, Pondus and Informer.

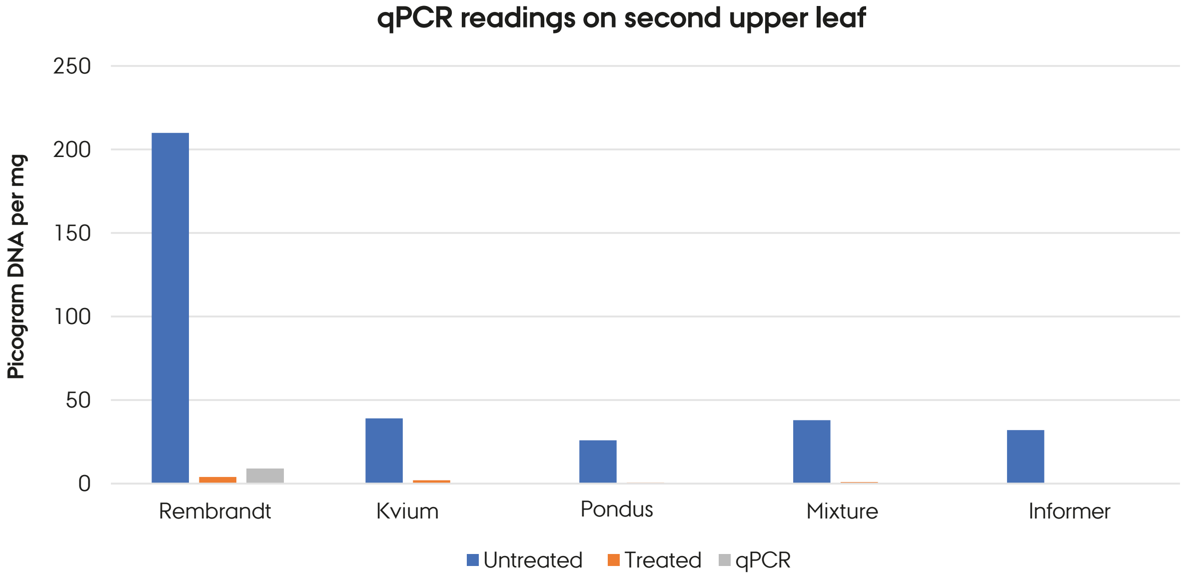


Figure 4. Results from qPCR testing measured in picogram DNA per mg, based on leaf samples in the trial with different cultivars and treatments. Treated = two treatments with fungicides. qPCR only released treatments in Rembrandt. Treatments accordingly reduced the DNA content of *Zymoseptoria tritici* to be in line with the standard treatments. The cultivar mixture includes Kvium, Pondus and Informer.

Table 1. % *Septoria*, 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 eight different fungicide treatments (23350). The cultivar mixture includes Kvium, Pondus and Informer. (Continues on the next page).

Cultivars	% *Septoria*, leaf 1, GS 75								% *Septoria*, leaf 2, GS 75							
	Untr.	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron	qPCR	CPO	Untr.	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron	qPCR	CPO
Cultivar mixture	0.9	0.1	0.2	0.0	0.6	0.1	0.7	1.1	8.8	1.8	4.2	1.9	4.2	2.2	5.0	8.5
Rembrandt	24.0	12.7	14.4	6.8	17.2	10.1	21.7	8.2	32.2	11.2	12.2	5.1	15.5	4.9	10.7	13.0
Kvium	1.2	0.2	0.1	0.2	0.4	0.1	1.7	1.2	7.4	0.9	1.2	0.7	2.3	1.3	6.7	7.4
Pondus	0.8	0.1	0.1	0.1	0.1	0.1	1.0	0.7	5.2	1.4	1.1	0.6	1.7	1.3	5.7	4.4
Informer	0.6	0.1	0.2	0.1	0.4	0.2	0.5	0.6	8.8	0.8	3.6	1.0	6.7	1.9	5.0	8.8
Heerup	4.5	1.1	1.8	1.8	2.7	1.6	5.3	4.9	18.4	5.3	10.8	8.5	12.0	6.8	8.3	18.4
Average	5.3	2.4	2.8	1.5	3.6	2.0	5.2	2.8	13.5	3.6	5.5	3.0	7.1	3.1	6.9	10.1
No. of trials	2						1	2	2						1	2

Cultivars	% *Septoria*, leaf 1, GS 79							
	Untr.	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron	qPCR	CPO
Cultivar mixture	10.0	2.3	2.7	2.7	2.7	3.7	10.0	10.0
Rembrandt	46.7	26.7	26,7	18.3	31.7	20.0	40.0	40.0
Kvium	20.0	13.3	5.7	2.3	4.3	6.7	10.0	16.7
Pondus	10.0	4.3	3.0	1.7	4.3	3.0	6.7	8.3
Informer	13.3	4.3	5.0	2.3	3.6	3.6	13.3	13.3
Heerup	29.1	9.1	9.1	8.3	16.6	16.6	25.0	25.0
Average	21.5	10.0	8.7	5.9	10.5	8.9	17.5	18.9
No. of trials	1							

Table 1. % *Septoria*, 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 eight different fungicide treatments (23350). The cultivar mixture includes Kvium, Pondus and Informer. (Continued).

Cultivars	% green leaf area, leaf 1, GS 79-83								% green leaf area, leaf 2, GS 79-83							
	Untr.	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron	qPCR	CPO	Untr.	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron	qPCR	CPO
Cultivar mixture	64.2	78.3	72.5	72.5	75.8	76.7	63.3	70.0	38.5	52.6	55.1	56.8	58.5	61.0	35.2	35.2
Rembrandt	37.5	47.5	49.2	58.4	41.7	56.7	36.7	33.3	32.6	30.1	38.5	59.3	24.8	43.9	20.3	15.3
Kvium	63.4	70.8	70.0	75.0	72.5	71.7	60.0	56.7	45.0	54.2	52.5	63.4	60.0	60.8	43.3	43.3
Pondus	68.4	76.7	72.5	79.2	71.7	73.4	56.7	56.7	58.5	65.2	65.2	67.5	57.5	55.0	30.0	30.0
Informer	69.2	78.4	73.4	80.9	80.6	82.3	56.7	60.0	33.4	45.9	38.4	50.9	45.8	48.3	15.0	16.7
Heerup	54.0	64.0	60.6	60.9	58.1	56.5	40.0	40.0	32.4	49.1	40.8	37.5	36.6	42.4	15.0	15.0
Average	59.5	69.3	66.4	71.2	66.7	69.6	52.2	52.8	40.1	49.5	48.4	55.9	47.2	51.9	26.5	25.9
No. of trials	2						1	1	2						1	1

Cultivars	TGW (g)							
	Untr.	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron	qPCR	CPO
Cultivar mixture	53.9	55.7	53.6	55.5	54.6	54.4	52.8	54.7
Rembrandt	51.0	52.1	51.8	52.9	53.1	53.0	52.4	52.3
Kvium	53.9	53.5	53.1	54.0	53.1	55.1	54.4	56.8
Pondus	53.7	53.9	53.6	54.7	54.1	54.3	51.4	52.2
Informer	56.0	57.4	56.5	57.0	55.7	55.8	53.6	55.5
Heerup	49.7	49.9	49.8	50.0	49.5	49.8	47.7	53.2
Average	53.0	53.8	53.1	54.0	53.4	53.7	52.1	54.1
No. of trials	2						1	1

Table 1. % *Septoria*, 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 eight different fungicide treatments (23350). The cultivar mixture includes Kvium, Pondus and Informer. (Continued).

Cultivars	Yield & yield increase, dt/ha								Net increase, dt/ha				
	Untr.	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron	qPCR	CPO	0.75 Balaya	0.75 Univoq	0.75 Balaya / 0.75 Univoq	3.0 Thiopron / 3.0 Thiopron	0.3 Balaya + 3.0 Thiopron / 0.3 Univoq + 3.0 Thiopron
Cultivar mixture	112.5	1.7	3.0	0.9	5.9	5.2	3.9	5.2	-1.0	0.4	-4.4	0.0	- 2.5
Rembrandt	110.1	4.6	9.7	5.3	5.8	5.6	10.4	12.0	2.0	7.1	0.0	-0.1	-2.1
Kvium	121.6	-3.0	-4.7	5.5	4.5	-0.7	1.4	0.1	-5.7	-7.4	0.2	-1.4	-8.4
Pondus	124.2	-1.9	4.7	1.7	2.1	3.9	-3.4	2.1	4.6	2.1	-3.6	-3.8	-3.8
Informer	106.0	3.0	-0.3	3.0	4.0	2.7	2.4	7.8	0.4	-3.0	-2.3	-1.9	-5.0
Heerup	106.4	3.1	-4.5	0.4	-5.6	2.1	3.6	5.1	0.5	-7.2	-4.9	-11.5	-5.6
Average	113.5	1.3	1.3	2.8	2.8	3.1	3.1	5.4	0.1	-1.3	-2.5	-3.1	4.6
No. of trials	2								2				

Untr. = Untreated; 0.75 l/ha Balaya, GS 37-39 (costs = 2.65 dt/ha); 0.75 l/ha Univoq, GS 37-39 (costs = 2.65 dt/ha); 0.75 l/ha Balaya, GS 37-39 / 0.75 l/ha Univoq, GS 55-61 (costs = 5.3 dt/ha); 3.0 l/ha Thiopron, GS 37-39 / 3.0 l/ha Thiopron, GS 55-61 (costs = 5.9 dt/ha); 0.3 l/ha Balaya + 3.0 l/ha Thiopron, GS 37-39 / 0.3 l/ha Univoq + 3.0 l/ha Thiopron, GS 55-61 (costs = 7.68 dt/ha); CPO = Crop Protection Online.

Control strategies in winter wheat cultivars – impact on *Fusarium*

In the 2023 growing season, AU Flakkebjerg for the first time conducted experiments in which they investigated the disease-reducing effects of cultivar mixtures on Fusarium head blight in wheat. The experiment was carried out as part of a project financed by the Danish Environmental Protection Agency and the EU. The trial was laid out as a split-plot trial with cultivars as the first factor and control measures as the second.

In the experiment, grains infected with *Fusarium culmorum* and *Fusarium graminearum* were laid out on 25 May at GS 39. In total, irrigation was applied three times in the experiment (23 May: 14 mm, 30 May: 21 mm and 15 June: 15 mm) to ensure that *Fusarium* had good conditions in which to develop. Three solo cultivars were included in the experiment: Rembrandt, Informer and Sheriff, chosen as representatives of susceptible, medium susceptible and moderately resistant cultivars, respectively. In addition, a mixture of the three cultivars was also included with the aim to investigate if mixtures can reduce the risk of disease development. The experiment also included the testing of different control solutions which included both a chemical solution and two solutions with biological agents. Spraying was done twice in the experiment at GS 37-39 and GS 61-65. Mycotoxin was measured from ground grain samples, using HPLC-MS. The level of *Septoria* was overall low to moderate as a result of the dry season; however, a clear difference was still seen between the susceptibility of the included cultivars in which Rembrandt clearly stood out as most susceptible.

The results show that there was a reduction in both Fusarium head blight and the amount of mycotoxin measured as deoxynivalenol (DON) in the mixture compared with the average of the individual cultivars. Data are shown from untreated plots (Table 2) as well as across all treatments (Table 3). As can be seen, the cultivar mixture also contributed to a reduction in *Septoria*, and a small yield benefit was also recorded.

As expected, the treatments applied for control of Fusarium head blight and Septoria tritici blotch gave a clear reduction, using the standard chemical reference, but also a reduction from the biosolutions was seen (Table 4). Both reduced *Septoria* significantly while only 2 biosolutions reduced *Fusarium* significantly, which also was reflected in a slightly lower level of mycotoxins. A tendency to higher yields from the chemical references was recorded; however, the differences were not significantly improved.

Table 2. Data from untreated plots with three solo cultivars and the mixture of the three. Trial 23353-1. Different letters indicate significant differences. The cultivar mixture includes Sheriff, Rembrandt and Informer.

Cultivars	**Number of *Fusarium*-infected ears per 2 x 1 m row**		**DON, ppb**	**% *Septoria***		**Yield, dt/ha**
Date/Leaf number	**2 July**	**7 July**		**Leaf 2**	**Flag leaf**	
Cultivar mixture	1.7	4.7	944	7.0	3.0	102.5 a
Sheriff	3.5	2.7	1122	2.3	1.3	94.0 b
Rembrandt	7.7	10.0	1392	16.7	8.7	101.0 ab
Informer	0.7	7.7	1273	2.7	0.7	96.5 ab
Average of solo cultivars	*4.0*	*6.8*	*1309*	*7.2*	*3.6*	*97.2*
% benefit with mixture	57%	30%	25%	3%	17%	5%

Table 3. Data showing impact of cultivars on Fusarium head blight and Septoria tritici blotch from across all treatments in the trial. Different letters indicate significant differences. The cultivar mixture includes Sheriff, Rembrandt and Informer.

Cultivars	Number of *Fusarium*-infected ears per 2 x 1 m row		DON, ppb	% *Septoria*		Yield, dt/ha
Date/Leaf number	**3 July**	**7 July**		**Leaf 2**	**Flag leaf**	
Cultivar mixture	1.2 b	3.6 ab	1002	3.9 b	1.8 b	101.2 a
Sheriff	2.4 a	2.5 b	833	1.3 b	0.8 c	99.1 a
Rembrandt	5.6 b	6.9 ab	1200	10.1 a	4.8 a	105.4 a
Informer	0.4 b	4.1 b	1141	1.5 b	0.3 c	96.9 a
Average of solo cultivars	*2.7*	*4.5*	*1058*	*4.3*	*2.0*	*100.5*
% benefits from the mixtures	55%	20%	5%	9%	10%	1%

Table 4. Data showing impact on Fusarium head blight and Septoria tritici blotch from different control treatments, from across all cultivars in the trial. Different letters indicate significant differences.

Treatments applied at GS 37 and 62-65	Number of *Fusarium*-infected ears per 2 x 1 m row		DON, ppb	% *Septoria*		Yield and yield increase, dt/ha
Date/Leaf number	**2 July**	**7 July**		**Leaf 2**	**Flag leaf**	
Untreated		6.3a	1194	7.2a	3.4a	98.7
0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert		2.7b	849	2.4b	1.0b	5.0
3.0 Thiopron / 0.3 Lalstop G46 WG		4.3ab	1181	3.4b	1.6b	0.9
2 x biosolution		3.8b	952	3.8b	1.8b	1.9
LSD_{95}		2.0		2.0	0.9	5.6

Fusarium head blight in winter wheat.

Control strategies in different winter barley cultivars

In one trial with winter barley cultivars, five different control strategies including a control and a decision support system for crop protection were tested. The treatments given below were tested in one trial at AU Flakkebjerg.

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

The cultivars Neptun, Bordeaux, Valerie and a mixture of the three developed moderate attacks of *Rhynchosporium*, but none of the treatments gave a high level of control as an attack was already present when treatments were applied (Table 5). All four cultivars were treated with a mixture of 0.38 l/ha Propulse SE 250 + 0.35 l/ha Comet Pro based on the attack of *Rhynchosporium* and precipitation. Only a minor attack of brown rust was seen in the trial, and no significant control was seen. All treatments had only a slight impact on the green leaf area as a result of a very dry and hot spell of weather. Yield levels were moderate and a major variation in yield increases was measured, mainly as a result of variation in senescence following drought, and therefore yields did not differ significantly.

Table 5. Control of diseases in winter barley and yield response. The cultivar mixture includes Valerie, Neptun and Bordeaux. (Continues on the next page).

Cultivars	% *Rhynchosporium*, leaf 3, GS 69					% *Rhynchosporium*, leaf 2, GS 75				
	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Cultivar mixture	21.7	20.0	16.7	20.0	18.3	12.7	8.3	6.7	6.7	7.3
Valerie	16.7	11.7	13.3	11.7	13.3	7.3	1.7	3.0	2.8	3.0
Neptun	23.3	18.3	20.0	21.7	20.0	21.7	15.0	16.7	10.0	10.0
Bordeaux	23.3	20.0	18.3	23.3	13.3	11.7	10.0	9.3	11.7	7.0
Average	21.3	17.5	17.1	19.2	16.2	13.4	8.8	8.9	7.8	6.8
LSD_{95}	3.6					7.2				

Cultivars	% GLA, leaf 2, GS 83				
	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Cultivar mixture	50.0	56.7	70.0	63.3	55.0
Valerie	58.3	56.7	71.7	71.7	80.0
Neptun	46.7	61.7	53.3	63.3	56.7
Bordeaux	50.0	41.7	58.3	60.0	60.0
Average	51.3	54.2	63.3	64.6	62.9
LSD_{95}	NS				

Table 5. Control of diseases in winter barley and yield response. The cultivar mixture includes Valerie, Neptun and Bordeaux. (Continued).

Cultivars	Yield & yield increase, dt/ha					Net increase, dt/ha			
	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Cultivar mixture	64.3	3.0	23.7	11.5	12.4	0.5	21.9	8.3	10.2
Valerie	56.1	2.3	15.0	21.0	26.2	-0.2	13.2	17.8	24.0
Neptun	67.2	2.3	3.1	12.6	5.7	-0.2	1.3	9.4	3.5
Bordeaux	55.1	2.3	11.5	15.6	20.8	-0.2	9.7	12.4	18.6
Average	60.7	2.5	13.3	15.2	16.3	0.0	11.5	12.0	14.1
LSD$_{95}$	NS								

Untr. = Untreated; 0.5 l/ha Pictor Active + 0.25 l/ha Proline EC 250, GS 37-39 (costs = 2.5 dt/ha); 0.25 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 37-39 (costs = 1.8 dt/ha); 0.25 l/ha Pictor Active, GS 32 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 51 (costs = 3.2 dt/ha); CPO = Crop Protection Online (costs 2.2 dt/ha).

Rhynchosporium in winter barley (Neptun).

Control of strategies in different spring barley cultivars

In four spring barley cultivars, five different control strategies including control and Crop Protection Online (CPO) were tested. Three cultivars were used as solo cultivars together with 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. 0.5 l/ha Pictor Active + 0.25 l/ha Proline EC 250 (GS 37-39)
3. 0.25 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro (GS 37-39)
4. 0.25 l/ha Pictor Active / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro (GS 32 / GS 51)
5. Treatments according to Crop Protection Online

The trial developed only a moderate attack of net blotch. There was no significant difference between the treatments but in most cases a difference between untreated and treated plots.

A moderate attack of *Ramularia* came late in the season and provided a good difference both to the untreated plots and between the treatments.

CPO recommended no spray in all cultivars and therefore these plots stayed untreated through the season.

Skyway and the cultivar mix provided the highest yield levels, but in general the yield levels were low and the grain quality not very good due to the wet weather at harvest and a lot of green side shoots in the field (Table 6).

Table 6. 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. CPO = Crop Protection Online (23352-1). The cultivar mixture includes Skyway, KWS Irina and RGT Planet. (Continues on the next page).

Cultivars	% net blotch, leaf 2, GS 79					% *Ramularia*, leaf 2, GS 79				
	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Cultivar mixture	5.7	1.8	1.2	1.0	8.3	5.0	2.7	3.3	2.0	6.7
Skyway	4.3	1.5	1.0	0.5	4.7	5.7	2.0	2.7	1.0	5.7
KWS Irina	2.0	1.3	1.0	0.9	2.8	8.0	4.0	5.3	2.7	8.3
RGT Planet	10.3	1.7	1.5	1.0	6.3	5.0	1.7	3.7	0.8	5.0
Average	5.6	1.6	1.2	0.9	5.5	5.9	2.6	3.8	1.6	6.4
LSD_{95}	4.6					2.9				

Table 6. 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. CPO = Crop Protection Online (23352-1). The cultivar mixture includes Skyway, KWS Irina and RGT Planet. (Continued).

Cultivars	% GLA leaf 2, GS 83					TGW, g/1000				
	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Cultivar mixture	16.7	68.3	61.7	75.0	11.0	54.9	57.4	57.8	56.3	56.5
Skyway	26.7	78.3	61.7	88.3	20.0	55.9	55.5	56.7	57.2	54.8
KWS Irina	41.7	81.7	68.3	85.0	35.0	52.3	53.7	54.9	56.6	55.3
RGT Planet	16.7	66.7	56.7	73.3	21.0	55.6	56.7	56.1	57.3	55.4
LSD_{95}	23.7					1.8				
Average	25.5	73.8	62.1	80.4	21.8	54.7	55.8	56.4	56.9	55.5

Cultivars	Yield & yield increase, dt/ha					Net increase, dt/ha			
	Untr.	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	0.5 Pictor Active + 0.25 Proline EC 250	0.25 Propulse SE 250 + 0.3 Comet Pro	0.25 Pictor Active / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Cultivar mixture	58.8	3.2	4.4	6.7	-1.5	0.7	2.6	3.5	-1.5
Skyway	54.9	4.3	8.6	11.6	4.5	1.8	6.8	8.4	4.5
KWS Irina	49.3	9.7	7.3	8.9	3.4	7.2	5.5	5.7	3.4
RGT Planet	57.1	5.6	11.6	9.0	-2.2	3.1	9.8	5.8	-2.2
LSD_{95}	10.1								
Average	55.0	5.7	8.0	9.1	1.1	3.2	6.2	5.8	1.1

Untr. = Untreated; 0.5 l/ha Pictor Active + 0.25 l/ha Proline EC 250, GS 37-39 (costs = 2.5 dt/ha); 0.25 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 37-39 (costs = 1.8 dt/ha); 0.25 l/ha Pictor Active, GS 32 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 51 (costs = 3.2 dt/ha); CPO = Crop Protection Online.

V Fungicide resistance-related investigations

Niels Matzen, Brittany Deanna Beck, Birgitte Boyer Frederiksen & Lise Nistrup Jørgensen

Fungicide resistance of *Zymoseptoria tritici* in Denmark and Sweden

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 (GS) 73-77 and forwarded for analysis at AU Flakkebjerg. The sensitivity to prothioconazole, which was tested in the form of the metabolites prothioconazole-desthio (PTH-D) and fluxapyroxad (FLX), was analysed for 131 isolates from 21 Danish samples and 149 isolates from 19 Swedish samples in 2023 (Tables 1 and 3). The disease pressure of Septoria tritici blotch was generally very low in 2023. The aim was to collect 10 isolates from each location, which was not always possible.

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 sensitive 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 = ppm): 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 (Heick et al., 2023).

Danish results with resistance to *Zymoseptoria tritici*

The severity of Septoria tritici blotch in Denmark was low to moderate in 2023. This made it difficult to find leaves with good symptoms of Septoria tritici blotch. Twenty-five samples were collected from different sites and fields, but it was only possible to isolate spores from 21 sites. In several cases, only a few isolates were collected as *Septoria* infections were limited.

For prothioconazole-desthio, the average EC_{50} value in Denmark for 2023 was 0.44 ppm, indicating a comparable sensitivity compared with previous years, 2022 (avg. 0.30 ppm), 2021 (avg. 0.32 ppm) and 2020 (avg. 0.44 ppm) (Figure 1; Table 2). The resistance factor was on average 44 in 2023, which is at the higher end compared with previous years' findings with a range between 30 and 44. The sensitivity varied widely among sites, with resistance factors ranging from 8 to 102 (Table 1). These findings suggest that, overall, the sensitivity of the Danish *Z. tritici* population has shifted but also stabilised at a reduced sensitivity level. At some sites, such as the two sites at Aabenraa and Hadsund, the resistance level must be regarded as critical.

Table 1. Mean EC$_{50}$ values and resistance factors (RF) for prothioconazole-desthio (PTH-D) and fluxapyroxad (FLX) for 131 *Z. tritici* isolates from 21 Danish samples collected across Denmark in 2023.

Isolate		EC$_{50}$ (ppm)						Number of isolates
		PTH-D	RF	Range	FLX	RF	Range	
23-ZT-DK-01	Flakkebjerg	0.09	9	0.02 - 0.37	0.17	1	0.04 - 0.87	10
23-ZT-DK-02	Rudkøbing	0.36	36	0.05 - 1.47	0.94	6	0.03 - 3.00	18
23-ZT-DK-03	Flakkebjerg	0.20	20	0.11 - 0.32	0.51	3	0.04 - 1.09	5
23-ZT-DK-04	Horsens	0.25	25	0.07 - 0.58	0.49	3	0.11 - 0.89	6
23-ZT-DK-05	Horsens	0.20	20	0.06 - 0.62	0.47	3	0.01 - 1.79	6
23-ZT-DK-06	Flakkebjerg	0.08	8	0.02 - 0.15	0.13	1	0.11 - 0.17	4
23-ZT-DK-07	Flakkebjerg, Snekkerup	0.42	42	0.42 - 0.42	0.22	1	0.22 - 0.22	1
23-ZT-DK-09	Årslev, Aabenraa	0.98	98	0.04 - 3.31	0.25	2	0.01 - 1.00	7
23-ZT-DK-10	Aabenraa	1.02	102	0.09 - 3.87	0.28	2	0.00 - 0.88	10
23-ZT-DK-11	Roslev	0.08	8	0.01 - 0.15	0.57	4	0.37 - 0.78	2
23-ZT-DK-14	Skamby	0.73	73	0.02 - 2.87	0.53	4	0.02 - 2.00	6
23-ZT-DK-15	Odense	0.81	81	0.08 - 2.16	0.60	4	0.54 - 0.65	3
23-ZT-DK-16	Hadsund	0.93	93	0.93 - 0.93	1.80	12	1.80 - 1.80	1
23-ZT-DK-17	Tølløse	0.30	30	0.05 - 0.60	1.04	7	0.14 - 1.84	4
23-ZT-DK-21	Tølløse	0.38	38	0.08 - 0.69	1.20	8	0.33 - 2.07	2
23-ZT-DK-24	Flakkebjerg	0.36	36	0.02 - 1.03	0.42	3	0.03 - 2.16	10
23-ZT-DK-25	Horsens	0.31	31	0.03 - 0.97	0.76	5	0.05 - 2.81	8
23-ZT-DK-26	Horsens	0.61	61	0.07 - 1.65	0.83	6	0.07 - 2.18	8
23-ZT-DK-27	Vojens	0.37	37	0.08 - 1.51	0.93	6	0.01 - 2.75	9
23-ZT-DK-28	Vojens	0.45	45	0.03 - 1.93	0.59	4	0.03 - 2.37	10
23-ZT-DK-29	Gørding	0.09	9	0.09 - 0.09	0.05	0	0.05 - 0.05	1

Similarly, a decreased sensitivity to fluxapyroxad in terms of increased EC$_{50}$ was seen for Danish *Z. tritici* in 2023 (avg. 0.60 ppm) compared with the results of 2022 (avg. 0.46 ppm) and 2021 (avg. 0.44 ppm) (Figure 2; Table 2). Despite the observed progressively decreased sensitivity since 2018, the resistance factor is still generally at a low level, indicating that *Z. tritici* is still sensitive to fluxapyroxad.

In summary, the sensitivity of Danish *Z. tritici* population towards the two active ingredients did shift a little but, overall, not substantially in 2023.

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)	3
2022	0.30 (176)	30	0.46 (176)	3
2023	0.44 (131)	44	0.60 (131)	4
Ref. IPO323	0.01	-	0.15	-

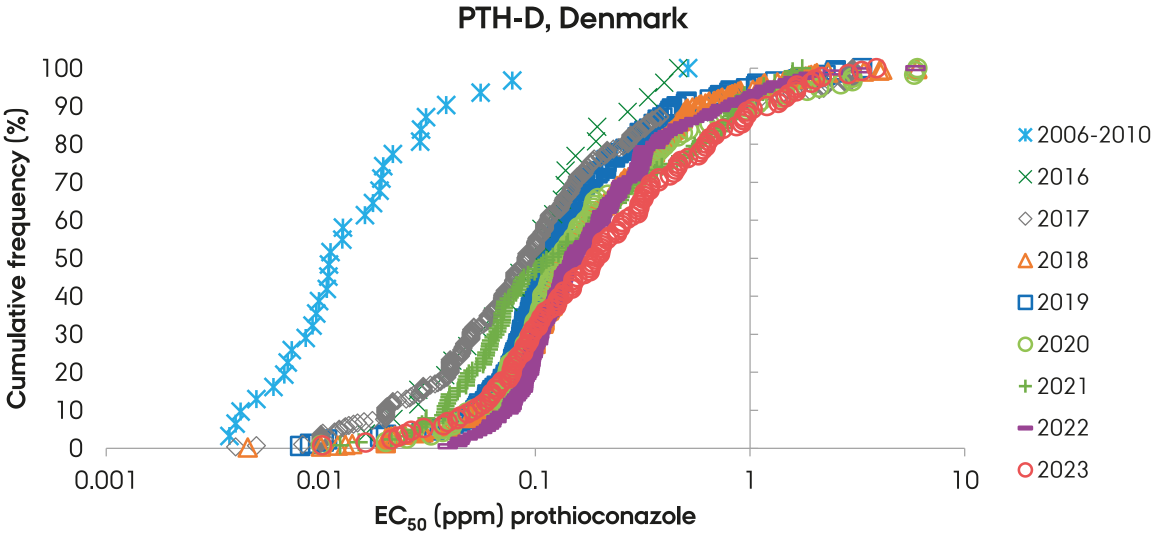


Figure 1. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Danish *Z. tritici* populations from 2016 to 2023. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

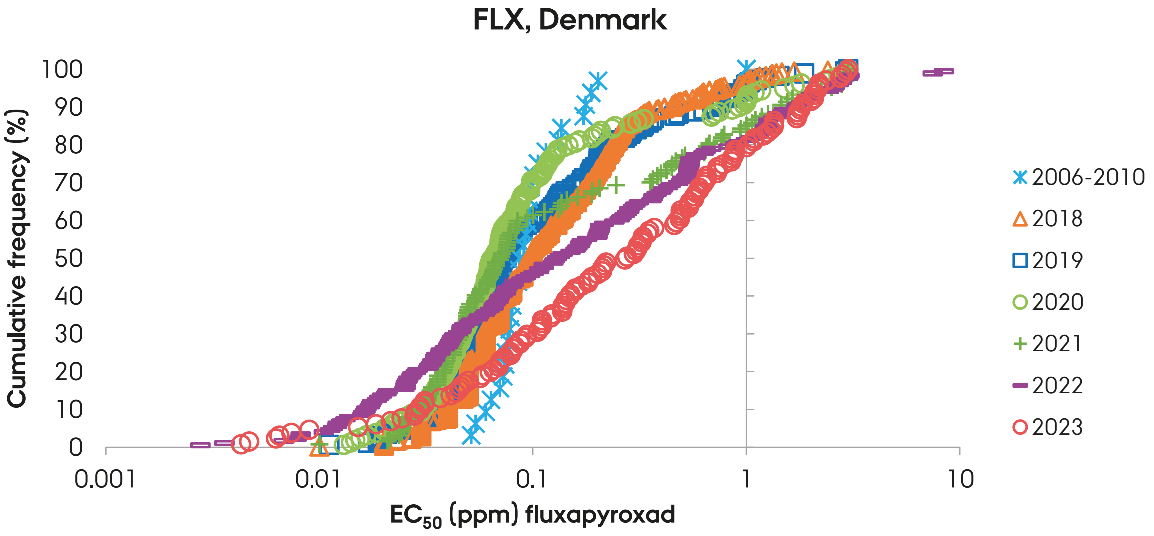


Figure 2. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Danish *Z. tritici* populations from 2018 to 2023. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

Results - Sweden

The severity of Septoria tritici blotch in Sweden was also only low to moderate in 2023. This made it difficult to find leaves with good symptoms of Septoria tritici blotch. Samples were collected from 22 sites, but it was only possible to isolate spores from 19 sites.

The average EC_{50} value was 0.30 ppm for prothioconazole-desthio in Sweden in 2023, which is higher than 2020-22, but comparable to previous years' findings (Figure 3; Table 4). In 2020-22 it has been in the range of 0.11-0.15 ppm. Therefore, this year's results were more in line with 2018 (0.35 ppm), which also was a very dry season (Table 4). It has previously been discussed that seasons with dry weather and low disease pressure increase the risk of shifting compared with more normal weather seasons. 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 30 in 2023 for the Swedish populations compared to 44 for the Danish populations also illustrates this. Resistance factors varied from 3 to 91 in Sweden in 2023 (Table 3).

For fluxapyroxad, the average EC_{50} value in Sweden for 2023 was 0.48 ppm, which is also higher compared to the findings of previous years, in which the range was between 0.09 ppm and 0.22 ppm (Figure 4; Table 4). Despite this increase, the resistance factor remains low compared with the resistance factor for prothioconazole. As in the previous years, the Danish *Z. tritici* populations have been less sensitive to fluxapyroxad compared with the Swedish populations on average, with resistance factors of 1-3 in Sweden compared with 3-5 in Denmark in 2021-2023.

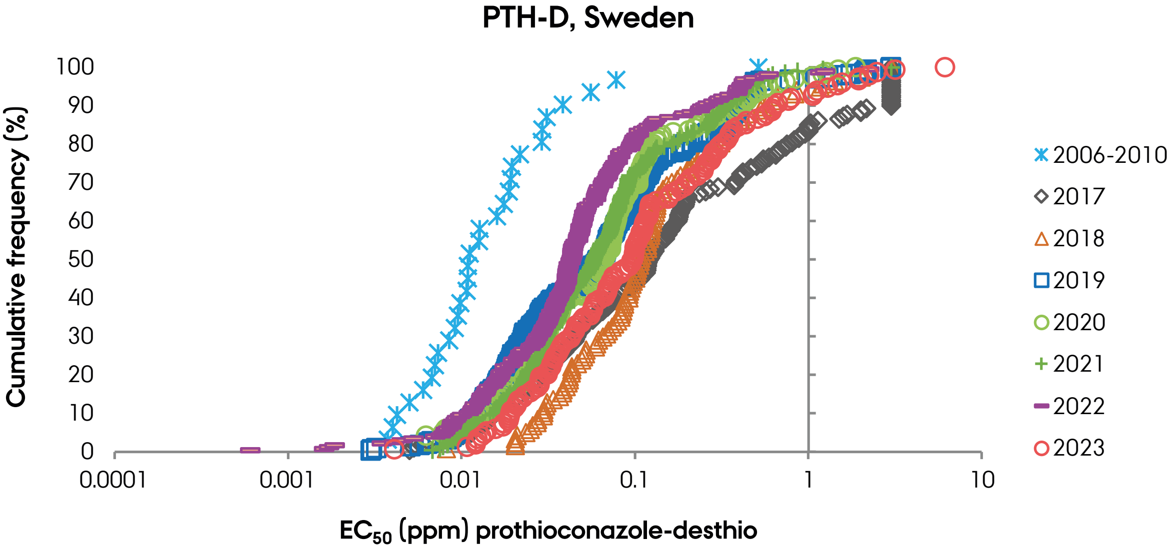


Figure 3. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Swedish *Z. tritici* populations from 2017 to 2023. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

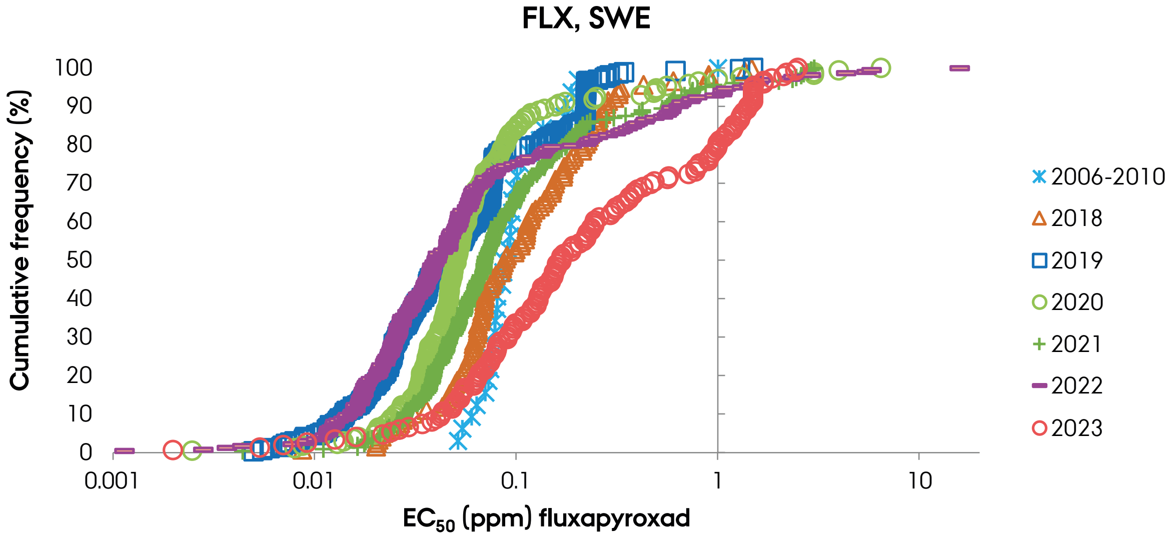


Figure 4. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Swedish *Z. tritici* populations from 2018 to 2022. Isolates from 2006 to 2010 are shown for comparison. Each data point represents one isolate.

Table 3. Mean EC$_{50}$ values and resistance factors (RF) for prothioconazole-desthio (PTH-D) and fluxapyroxad (FLX) for 149 *Z. tritici* isolates from 19 Swedish locations in 2023.

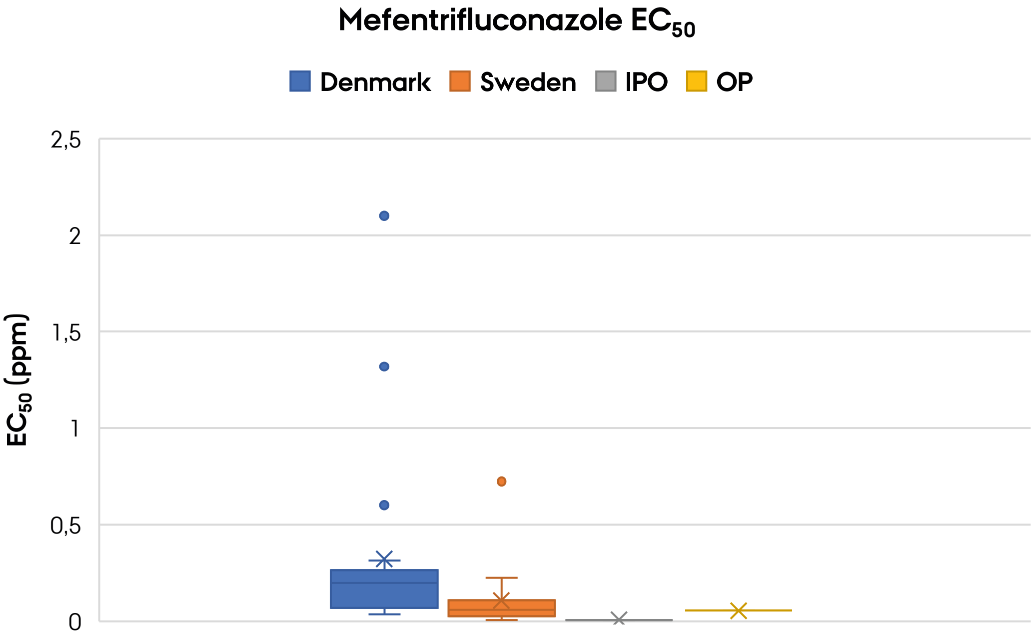
Isolate		EC$_{50}$ (ppm)						Number of isolates
		PTH-D	RF	Range	FLX	RF	Range	
23-ZT-SW-01	Everöd, Kiristianstad	0.20	20	0.03 - 0.58	0.65	4	0.09 - 2.12	10
23-ZT-SW-04	Emtunga, Vara	0.39	39	0.02 - 1.47	0.35	2	0.01 - 1.50	9
23-ZT-SW-05	St Mellby, Alingsås	0.11	11	0.03 - 0.27	0.18	1	0.00 - 0.92	8
23-ZT-SW-06	Quantenburg, Bolstad	0.10	10	0.02 - 0.26	0.43	3	0.04 - 1.69	7
23-ZT-SW-07	Sörbyn, Brålanda	0.91	91	0.02 - 6.10	0.36	2	0.01 - 0.82	7
23-ZT-SW-08	Ravelgården, Järpås	0.28	28	0.01 - 1.12	0.34	2	0.06 - 1.40	10
23-ZT-SW-09	Håberg, Grästorp	0.14	14	0.02 - 0.44	0.39	3	0.01 - 1.50	10
23-ZT-SW-10	Torestorp, Skövde	0.79	79	0.01 - 3.18	0.14	1	0.02 - 0.24	10
23-ZT-SW-11	Fröslunda, Lidköping	0.09	9	0.01 - 0.35	0.21	1	0.03 - 0.77	10
23-ZT-SW-12	Skofteby, Lidköping	0.19	19	0.03 - 0.77	0.39	3	0.03 - 1.69	6
23-ZT-SW-13	Nolebo, Lundsbrunn	0.06	6	0.00 - 0.25	0.84	6	0.05 - 1.50	9
23-ZT-SW-14	Grönhagen, Vinköl	0.21	21	0.03 - 0.56	1.04	7	0.06 - 2.50	5
23-ZT-SW-15	Jordbruksverket, Skara	0.27	27	0.07 - 0.79	0.78	5	0.08 - 2.42	5
23-ZT-SW-16	Svingbolsta, Östervåla	0.03	3	0.01 - 0.06	0.24	2	0.04 - 1.02	10
23-ZT-SW-17	Kattarp	0.09	9	0.03 - 0.28	0.59	4	0.13 - 1.50	6
23-ZT-SW-18	Kävlinge	0.70	70	0.05 - 2.25	0.74	5	0.07 - 1.50	10
23-ZT-SW-19	Egonsborg-Trelleborg	0.38	38	0.04 - 1.29	0.93	6	0.01 - 1.86	4
23-ZT-SW-20	Eriksfölt-Löderup	0.33	33	0.05 - 1.06	0.70	5	0.08 - 1.46	5
23-ZT-SW-21	Hviderup	0.45	45	0.07 - 1.56	0.54	4	0.05 - 2.20	8

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
2023	0.30 (149)	30	0.48 (149)	3
Ref. IPO323	0.01	-	0.15	-

Testing of sensitivity to other azoles

One isolate was picked from each site in Denmark and Sweden and tested for sensitivity to another two azoles, which are commonly used in the countries. These data are shown in Figure 5 and Table 5 and show a steady level of resistance to these two actives.



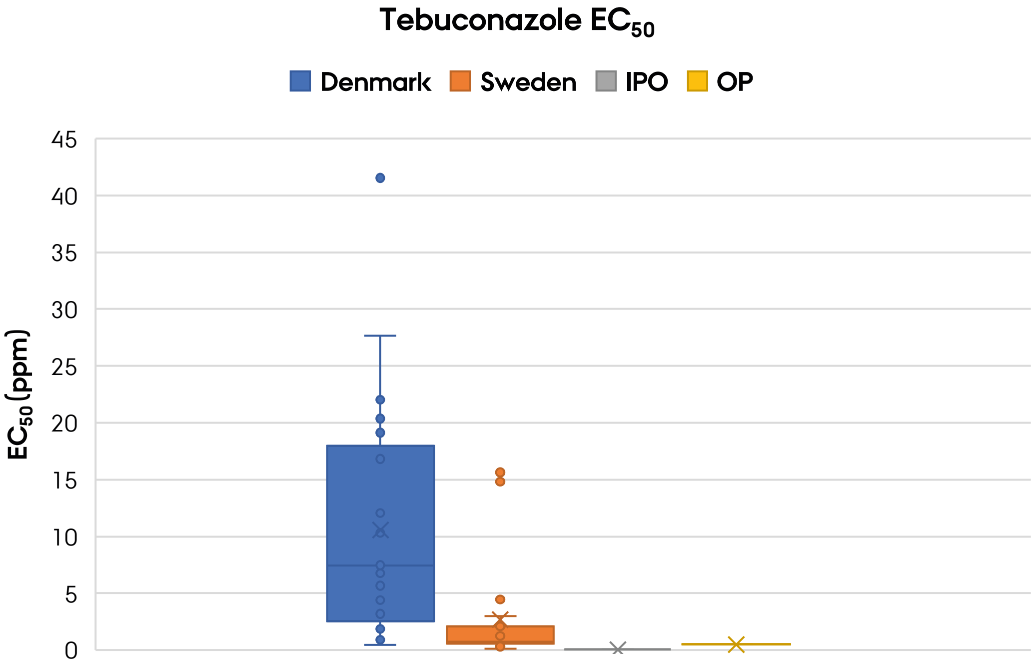


Figure 5. Sensitivity of *Zymoseptoria tritici* to the two azoles tebuconazole and mefentrifluconazole in 21 Danish and 19 Swedish isolates, using one isolate per site. The testing is compared with the two sensitive references IPO323 and OP15.

Table 5. Sensitivity of *Z. tritici* to two azoles based on a testing out of a subset of isolates from the general testing in 2023. Data from 2023 are compared with data from 2021 and 2022.

Location	Year	EC_{50}			Number of isolates
		Fluopyram	Mefentrifluconazole	Tebuconazole	
Denmark	2021	-	0.30	4.92	20
	2022	2.15	0.44	8.57	23
	2023	-	0.32	10.6	21
Sweden	2021	-	0.07	1.54	26
	2022	1.73	0.06	3.01	28
	2023	-	0.11	2.6	19
IPO323	Reference		0.006	0.05	

Mutation detection

From Denmark and Sweden 62 and 57 isolates were randomly taken across all the sampling and tested for four specific mutations, one azole mutation and three SDHI mutations. From each site two to three isolates were tested, using specific primers. Results are shown in Table 6. The frequency of the CYP51 mutation S534T was high in Denmark (58%), while still lower in Sweden (35%). This links nicely with the lower EC50 values in Sweden compared with the Danish EC50 values for the azole prothioconazole. The levels of S524T have increased significantly over the last years. The mutation is well known for impacting the efficacy of prothioconazole significantly.

The three SDHI mutations investigated (sdh-c) show similar frequencies in Denmark and Sweden although again the Danish levels are slightly higher. The mutations are expected to impact the performance of the SDHIs negatively (boscalid, fluxapyroxad, bixafen, fluopyram and solatanol). One site from Denmark in 2022 showed a high level of H152R. This field was sampled again in 2023, but here we did not find any H152R mutations. We did, however, still find low frequency of H152R, indicating that the mutation is present at low levels. In line with findings from previous years – it was also seen in 2023 that most mutations were N86S.

Table 6. Azole and SDHI mutations in specific isolates of *Zymoseptoria tritici* collected during 2023 and analysed, using qPCR as described by Helllin et al., 2020.

	Sweden	Denmark
Tested number of isolates	57	62
CYP51 mutation S524T	20 (35%)	36 (58%)
SDHI mutation T79N	2 (4%)	9 (15%)
SDHI mutation N86S	15 (26%)	20 (32%)
SDHI mutation H152R	0 (0%)	3 (5%)

Leaf samples from untreated plots from eight EuroWheat trials were sampled at GS 75 and checked for both azole and SDHI mutations in the *Zymoseptoria tritici* populations. The samples were picked from Denmark, the UK, France, Germany and Belgium. The analyses for mutation were carried out by BASF, using pyrosequencing and qPCR based on DNA extracted from leaves. Unfortunately, no samples were available from the trials carried out in Ireland and Poland (efficacy data shown in Chapter II). As seen in Table 7, the level of mutations varies quite a lot across Europe, which is in accordance with previous findings (Jørgensen et al., 2021). N86S is the most widespread SDHI mutation followed by T79N. H152R was only detected in trials from the UK and Northern Germany. This mutation was, however, also seen at low levels in Danish samples tested from the national monitoring (Table 7).

With respect to CYP51 mutations which impact the performances of azoles, the level of mutations is very high for several mutations (Table 8). Particularly the S524T has increased in recent years and is now widespread. The highest levels of S524T are found at the trial sites in the UK and Northern Germany, while the Danish site still represents the lower level.

Table 7. Frequencies of the sdh-b mutations T268I and N225I and the sdh-c mutations T79N, N86S and H152R collected from untreated plots. Analyses were also carried out for the sdh-b mutations H267L/R, I269V and N225T and the sdh-c mutations T79I, W80L/S/T and S83G, but these were not detected. Colours signify the following ranges of mutation frequencies: green: 0%, yellow: 1-20%, orange: 21-40%, red: 41-60%, dark red: 61-100%.

Trial ID	Location	sdh-b		sdh-c		
		T268I	N225I	T79N	N86S	H152R
23328-1	DK	0	0	0	18	0
23328-2	UK, NIAB	0	0	14	56	11
23328-3	UK, ADAS	0	0	22	58	9
23328-4	IE					
23328-5	FR	0	0	13	45	0
23328-6	DE, LfL	0	13	0	27	0
23328-7	DE, JKI	5	0	18	50	6
23328-8	PL					
23328-9	BE	0	0	12	42	0
23328-10	DE, LKSH	0	0	16	47	0

Table 8. Frequencies of CYP51 mutations collected from untreated plots. Colours signify the following ranges of mutation frequencies: green: 0%, yellow: 1-20%, orange: 21-40%, red: 41-60%, dark red: 61-100%.

Trial ID	Location	CYP51						
		D134G	V136A	V136C	S188N	A379G	I381V	S524T
23328-1	DK	23	28	19	69	26	100	31
23328-2	UK, NIAB	41	56	46	60	85	100	96
23328-3	UK, ADAS	34	45	52	63	85	100	95
23328-4	IE							
23328-5	FR	36	44	27	56	31	97	40
23328-6	DE, LfL	66	70	22	23	25	100	30
23328-7	DE, JKI	34	49	30	57	44	100	70
23328-8	PL							
23328-9	BE	28	40	28	61	35	95	52
23328-10	DE, LKSH	45	56	22	51	67	100	95

Fungicide resistance of *Pyrenophora teres* in Denmark and Sweden

The development of fungicide resistance in Danish and Swedish *P. teres* populations have been monitored since 2016 in a similar way as previously described (Heick et al., 2023).

Thus, the sensitivity to prothioconazole, which was tested in the form of the metabolite prothioconazole-desthio (PTH-D) and fluxapyroxad (FLX), was analysed for 141 isolates from 15 Danish samples and 77 isolates from 8 Swedish locations in 2023 (Tables 9 and 11). The disease pressure of net blotch was generally moderate. From a few samples P. teres could not be isolated due to unclear and mixed infections.

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-1. 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-1): 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 has been carried out since 2016 and for fluxapyroxad, which has been carried out since 2018 in Denmark, while investigations in Sweden were carried out for prothioconazole-desthio in 2016, 2018, 2022 and 2023 and for fluxapyroxad in 2018, 2022 and 2023.

Results – Denmark

The average EC$_{50}$ value for prothioconazole-desthio was 0.15 ppm in Denmark in 2023, which is comparable or a slightly decreasing sensitivity compared with previous years (Figure 6; Table 10). The results indicate that the sensitivity of Danish *P. teres* populations to prothioconazole-desthio has shifted since 2018, and that some localities have relative high resistance factors (>20). The most sensitive isolates have disappeared as can be seen in Figure 6.

A considerable drop in fluxapyroxad sensitivity was seen in 2022 and this was similarly seen in 2023. The average EC$_{50}$ value was 1.42 ppm in 2023, while EC$_{50}$ values of 0.04 and 0.19 ppm were seen in 2018 and 2019, respectively (Table 10). The distribution of the EC$_{50}$ values suggests that the population has split up into two sub-populations with different sensitivity profiles (Figure 7). It has not so far been clarified which specific target site mutations has caused the shifting to the SDHI-fungicides.

As farmers in most seasons use a mixture of azoles, SDHIs and strobilurins for control of leaf diseases in barley, it has not been very clear if field failures can be expected as a result of the shifting taking place.

Table 9. Mean EC$_{50}$ values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for 141 *P. teres* isolates from 9 Danish sites in 2023.

Isolate		EC$_{50}$ (ppm)						
		PTH-D	RF	Range	FLX	RF	Range	Number of isolates
23-PT-DK-01	Flakkebjerg	0.08	8	0.01-0.12	0.01	0	0.01-0.02	10
23-PT-DK-02	Skanderborg, SEGES	0.15	15	0.08-0.30	1.57	10	0.26-5.12	10
23-PT-DK-03	Hobro	0.11	11	0.00-0.37	0.01	0	0.00-0.03	9
23-PT-DK-04	Slimminge	0.20	20	0.10-0.48	0.71	5	0.01-1.97	10
23-PT-DK-05	Flakkebjerg	0.11	11	0.02-0.25	0.28	2	0.01-1.92	10
23-PT-DK-10	Bramstrup	0.35	35	0.09-0.62	0.83	6	0.02-3.58	10
23-PT-DK-11	Tølløse	0.16	16	0.08-0.35	1.89	13	0.84-5.00	10
23-PT-DK-12	Foulum	0.16	16	0.08-0.45	3.72	25	0.71-8.00	10
23-PT-DK-13	Foulum	0.18	18	0.08-0.40	2.52	17	1.26-6.00	9
23-PT-DK-14	Abildgård	0.13	13	0.06-0.32	1.57	10	0.38-6.00	10
23-PT-DK-15	Abildgård	0.17	17	0.08-0.51	1.57	10	0.69-2.68	10
23-PT-DK-18	Tystofte	0.13	13	0.12-0.15	2.71	18	1.61-3.85	3
23-PT-DK-19	Tystofte	0.08	8	0.04-0.14	0.95	6	0.53-1.27	10
23-PT-DK-20	Tølløse	0.07	7	0.05-0.09	0.02	0	0.01-0.02	10
23-PT-DK-21	Tølløse	0.09	9	0.05-0.12	3.84	26	1.19-9.02	10

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)
2023	0.15 (141)	1.42 (141)
Average	0.09	0.70

Results - Sweden

For prothioconazole-desthio, the average EC_{50} value of in Sweden was similar or only slightly increased in 2023 compared with 2016-18 (avg. 0.06 pmm) (Figure 8; Table 12). The sensitivity of the Swedish *P. teres* populations (Table 11) was similar or slightly more sensitive compared with the Danish populations (Table 9).

Similarly, as for the Danish *P. teres* populations, a considerable shift has taken place in the sensitivity to fluxapyroxad (Figure 9). This is very pronounced for some of the samples, in which the resistance factor has reached levels higher than 20 (Table 11). The average EC_{50} value for fluxapyroxad has increased from 0.03 ppm in 2018 to 0.6 2023 (Table 12). As also seen for 2022 data, the 2023 data indicate that the Swedish *P. teres* populations have divided into two sub-populations with different sensitivity profiles (Figure 9), which was similarly seen in Denmark (Figure 7).

In Sweden also a mixture of azoles, SDHIs and strobilurins are typically used for control of leaf diseases in barley. The mixtures make it unclear and difficult to spot a specific drop in the efficacy of individual components.

Table 11. Mean EC_{50} values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for 77 *P. teres* isolates from 8 Swedish locations in 2023.

Isolate		EC_{50} (ppm)						
		PTH-D	RF	Range	FLX	RF	Range	Number of isolates
23-PT-SW-01	Grinskullen, Falköping, Skara	0.17	17	0.07-0.43	4.60	31	0.10-9.19	10
23-PT-SW-02	Stockgården, Källby, Skara	0.21	21	0.08-0.42	1.60	11	0.04-7.34	10
23-PT-SW-03	Flo, Gråstorp, Skara	0.09	9	0.03-0.17	3.66	24	1.17-6.50	10
23-PT-SW-04	Lännäs, Sollefteå, Uppsala	0.04	4	0.01-0.11	0.02	0	0.01-0.03	10
23-PT-SW-05	Åhl gård, Ôrbyhus, Uppsala	0.12	12	0.05-0.36	2.02	13	0.85-4.21	10
23-PT-SW-07	Staby, Örsundsbro	0.06	6	0.00-0.12	0.30	2	0.01-1.65	10
23-PT-SW-08	Stenhalla gård, Lövånger Uppsala	0.02	2	0.01-0.06	0.03	0	0.01-0.07	10
23-PT-SW-10	Öjebyn, Piteåt, Uppsala	0.04	4	0.01-0.12	0.02	0	0.00-0.04	7

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)
2023	0.10 (77)	0.60 (77)
Average	0.06	0.45

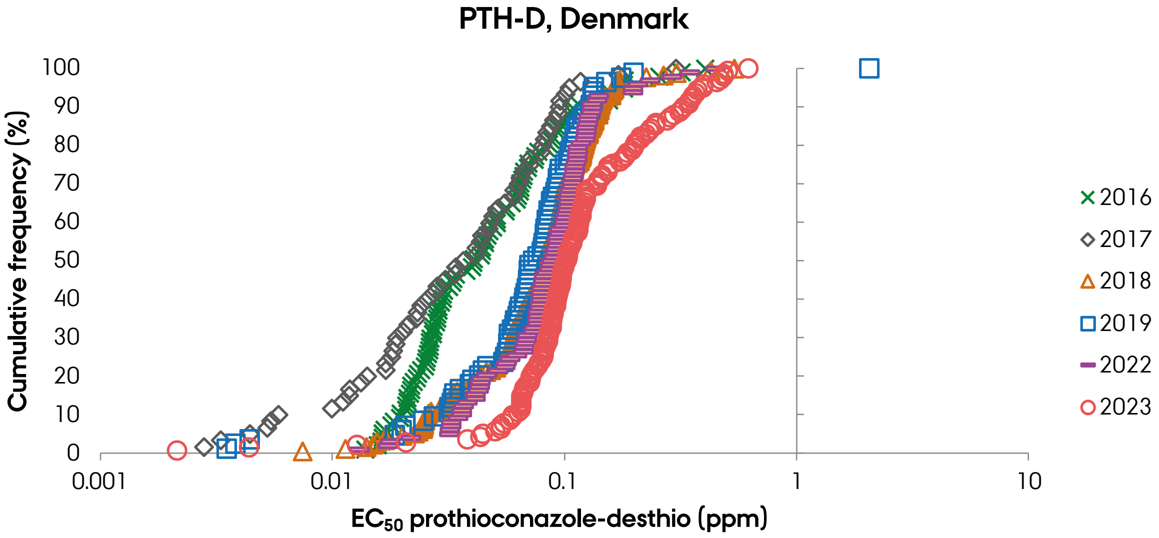


Figure 6. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Danish *P. teres* populations from 2016 to 2019 and 2022-2023. Each data point represents one isolate.

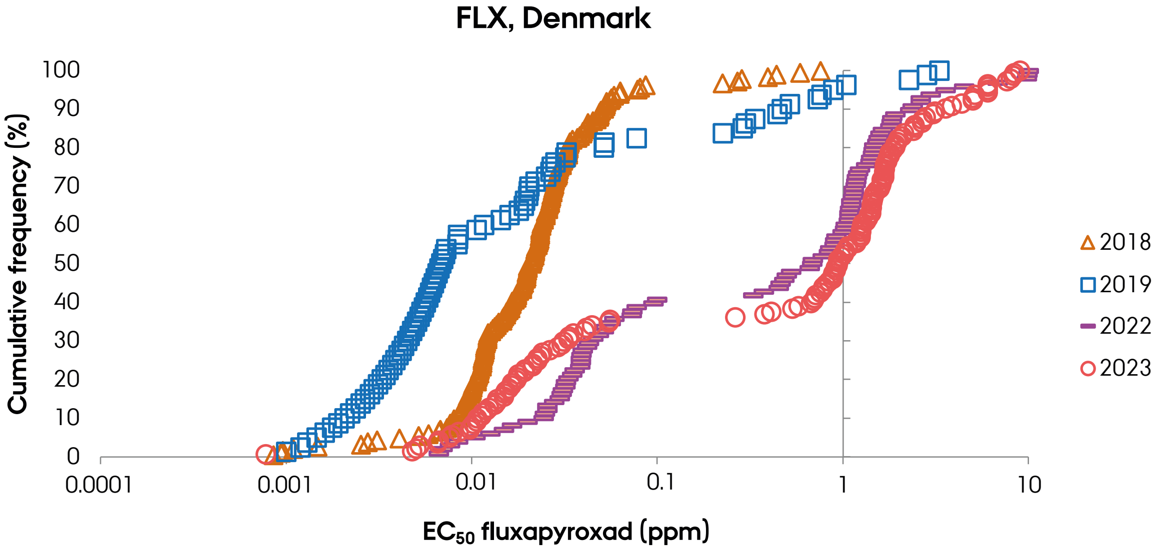


Figure 7. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Danish *P. teres* populations from 2018-2019 and 2022-2023. Each data point represents one isolate.

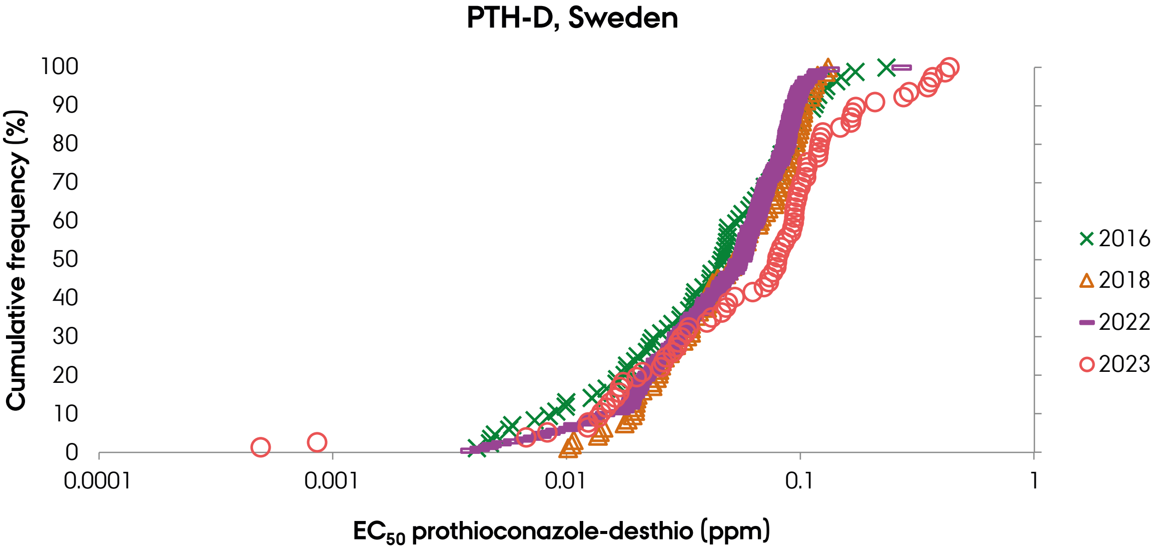


Figure 8. Cumulative frequencies of EC_{50} values (ppm) of prothioconazole-desthio for Swedish *P. teres* populations from 2016 to 2023. Each data point represents one isolate.

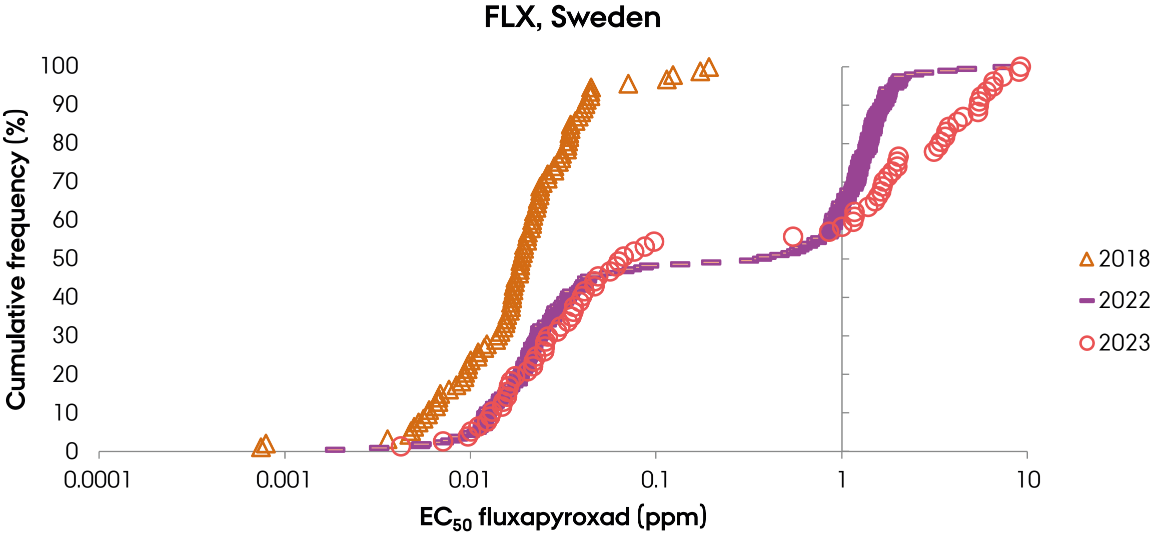


Figure 9. Cumulative frequencies of EC_{50} values (ppm) of fluxapyroxad for Swedish *P. teres* populations from 2018 to 2023. Each data point represents one isolate.

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VI Monitoring population dynamics and assessing fungicide sensitivity of *Phytophthora infestans* in Denmark

Isaac Kwesi Abuley & Jens Grønbech Hansen

Introduction

Phytophthora infestans causes late blight, which is the most devastating disease in potato production in Denmark. Fungicides are key to the management of late blight (Abuley et al., 2023). Potato is the one most sprayed crop in Denmark. *Phytophthora infestans* has a high evolutionary capacity, enabling the pathogen to evolve and overcome control measures such as fungicides. As a part of the EuroBlight network we have monitored the population dynamics as well as evaluated the sensitivity of the Danish *P. infestans* to key fungicides used in late blight management. In this paper, we present the population dynamics of *P. infestans* from 2017 to 2023 and fungicide resistance testing in 2022 and 2023.

The *Phytophthora infestans* population in Denmark

The *P. infestans* population in Denmark was recorded during the years 2017 to 2023 (Figure 1), indicating that the population of *P. infestans* consists of genetically diverse genotypes ("Other") and mainly two clonal lineages, namely EU_41_A2 and EU_43_A1, with varying frequencies over the years. The genotypes of *P. infestans* were determined via simple sequence repeat (SSR) markers at the James Hutton Institute. The *P. infestans* population in Denmark has until 2022 been characterised by genetically diverse *P. infestans* genotypes (i.e. other genotypes), accounting for >50% of the *P. infestans* population in Denmark. The majority of these "other" genotypes are considered to be the result of sexual recombination. The EU_13_A2 *P. infestans* genotype with reduced sensitivity to metalaxyl was found at low frequencies (<1%) in 2017, 2020 and 2023 (Figure 1), whereas the EU_36_A2 was found in one and two fields in 2017 (~2%) and 2019 (~4%), respectively, in the Danish *P. infestans* population. The EU_41_A2 genotype was the dominant clone in Denmark from 2017 to 2020, after which the EU_43_A1 genotype took over as the dominant clone in Denmark from 2021 to 2023 (Figure 1). The EU_43_A1 genotype emerged for the first time in Denmark in 2018, and it has increased gradually to become the dominant *P. infestans* clone in Denmark since 2021. In 2022, the EU_43_A1 became the most dominant *P. infestans* genotype surpassing all genotypes including the "Other" genotypes. This drastic increase in the frequency of the EU_43_A1 was linked to its resistance to one of the active ingredients used in Denmark: mandipropamid (Abuley et al., 2023). In 2023, however, the frequency of EU_43_A1 declined, mainly because of the decreased usage of mandipropamid.

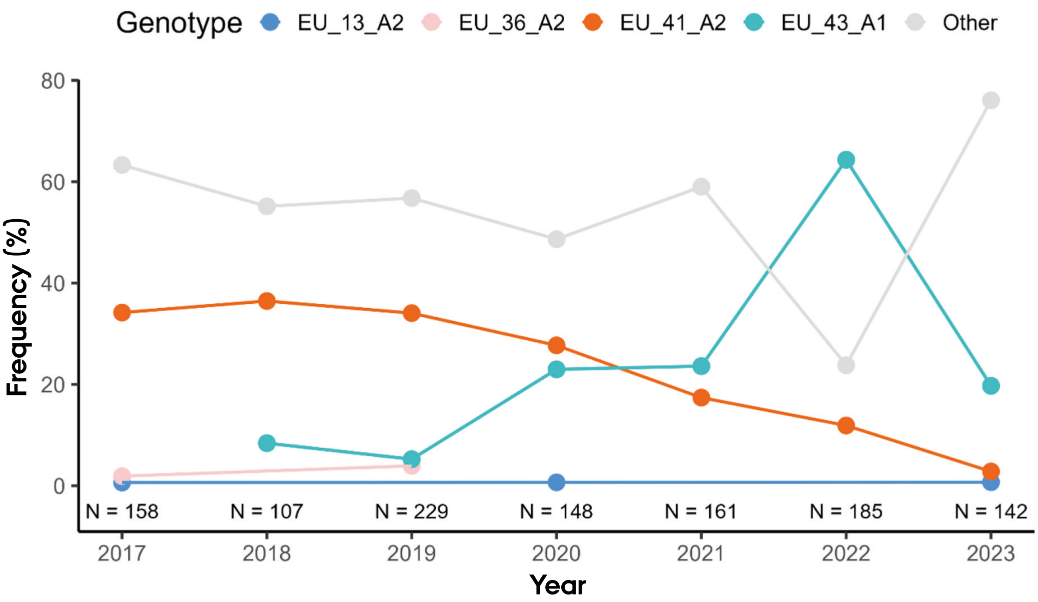

Figure 1. Frequency of *Phytophthora infestans* genotypes across different years in Denmark.

Fungicide resistance monitoring in 2022

In 2022, in response to the widespread report of reduced efficacy of mandipropamid in potato fields in Denmark, we sampled >100 potato leaves infected with late blight from several fields in Denmark. Single spore isolations were done to isolate the associated *P. infestans* from the lesion. Genotype (SSR) analysis was carried out on 72 of the samples to determine their genotype. Of the 72 samples, 63 were EU_43_A1, 5 were EU_41_A2 and 4 were "Other" genotypes. Fungicide sensitivity analysis was done using a floating disc assay, using 25 EU_43_A1 and 5 EU_41_A2 isolates. The results are shown in Figure 2. The EU_43_A1 genotype infected the leaf discs at all tested concentrations, whereas the EU_41_A2 showed a clear dose-response with an EC_{50} value of about 0.5 µg/ml (Figure 2). A further test was done to investigate the sensitivity of the EU_43_A1 genotype to higher concentrations (up to 100 µg /ml) of mandipropamid, and the result is shown in Figure 3. Compared with the other genotypes tested, the EU_43_A1 was able to infect the leaf disc at all tested concentrations, with average disease incidence exceeding 70%. In conclusion, we determined that the EU_43_A1 genotype has a strong resistance to mandipropamid, with an EC_{50} value probably exceeding the highest dose we have tested (100 µg/ml).

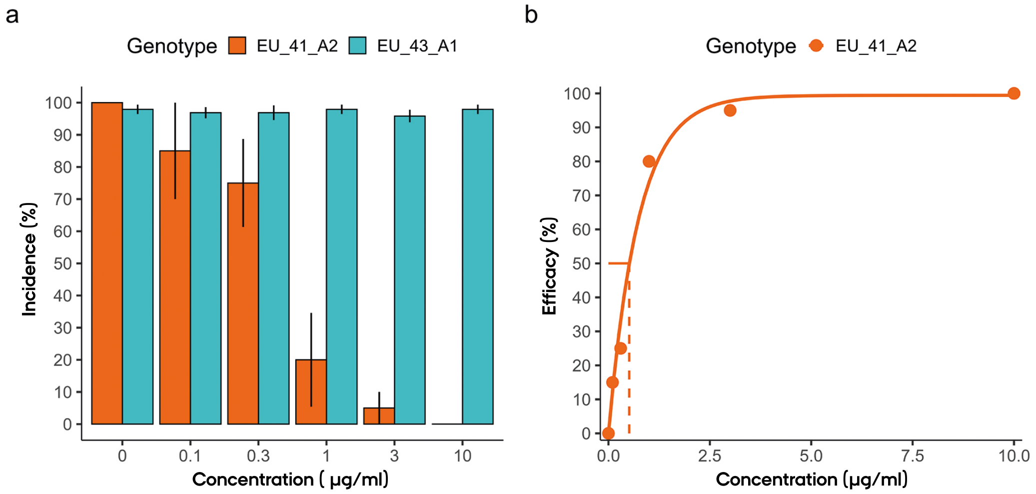

Figure 2. Incidence of late blight (a) and fitted dose–response curves (b) showing the sensitivity of the EU_41_A2 (n = 5) and EU_43_A1(n = 25) genotypes of *Phytophthora infestans* to mandipropamid from the in vitro leaf disc test. The vertical black line associated with each bar in (a) is the bootstrapped confidence interval (95%). The dashed vertical line in (b) indicates the dosage (µg/ml) at which 50% disease control is obtained (EC_{50} value).

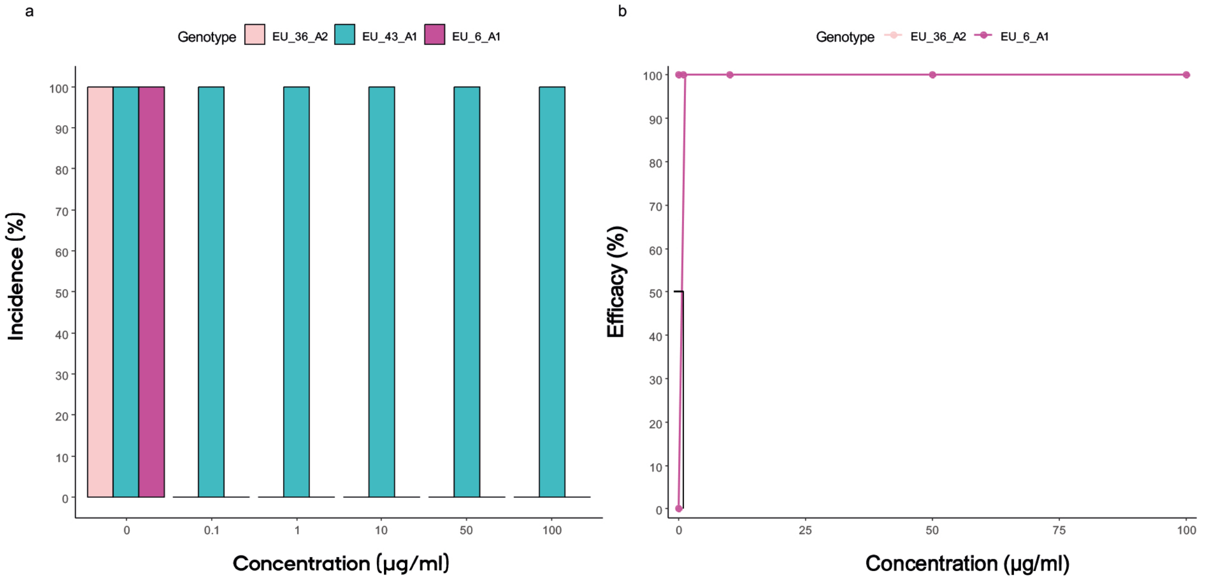

Figure 3. Incidence of late blight (a) and fitted dose–response curves (b) showing the sensitivity of the EU_36_A2 (n = 1), EU_43_A1 (n = 5) and EU_6_A1 (n = 1) genotypes of *Phytophthora infestans* to mandipropamid from the in vitro leaf disc test. The vertical black line in (b) indicates the dosage (µg/ml) at which 50% disease control is obtained (EC_{50} value).

Sensitivity of *Phytophthora infestans* isolates to fluazinam

In early 2023, sensitivity tests were conducted on 5 EU_43_A1, 1 EU_41_A1 and 1 other *P. infestans* genotypes against fluazinam. The aim was to assess the sensitivity of Danish isolates to fluazinam, the primary protectant fungicide for the 2023 growing season, due to reported resistance to mandipropamid. Tests were performed on pea agar with varying fluazinam concentrations (0, 250, 500, 750 and 1000 µg/ml). Results indicated high sensitivity among all Danish isolates to fluazinam, with an EC_{50} value of less than 0.2 µg/ml (Figure 4).

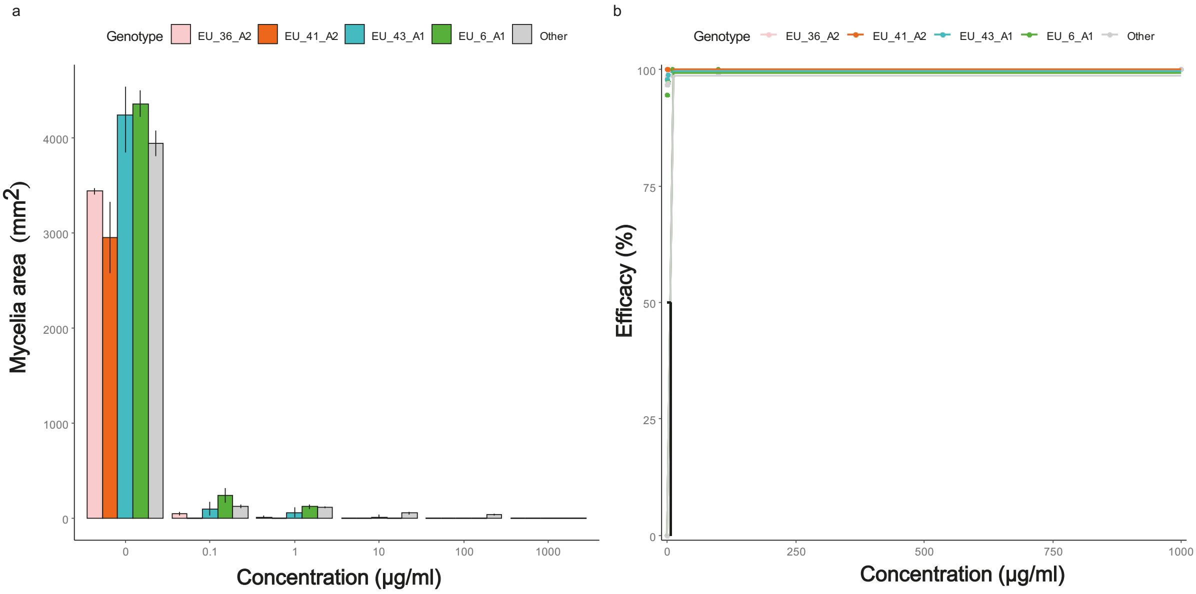

Figure 4. (a) Mycelia growth of various *P. infestans* genotypes at different fluazinam concentrations. (b) Dose-response curve for these genotypes to fluazinam. The vertical black line associated with each bar in (a) is the bootstrapped confidence interval (95%). The vertical black line in (b) indicates the dosage (µg/ml) at which 50% disease control is obtained (EC_{50} value).

Fungicide sensitivity monitoring in 2023

In 2023, over 100 *P. infestans* isolates were sampled in different potato fields in Denmark. Thirty-one of the *P. infestans* isolates collected during the 2023 growing season were tested against the commonly used active ingredients for late blight control: mandipropamid (Revus), fluazinam (Shirlan Ultra), propamocarb (Sporax), cymoxanil (Cymbal WG) and oxathiapiprolin (Zorvec Enicade). The tested isolates were genotyped and found to be EU_43_A1 (n = 4) and "Other" (n = 27) genotypes. The results, which are shown in Figure 5 and Table 1, indicate that most Danish isolates were sensitive to the tested fungicides, with EC_{50} values well below their field rates. However, EU_43_A1 showed resistance against mandipropamid (Figure 5; Table 1).

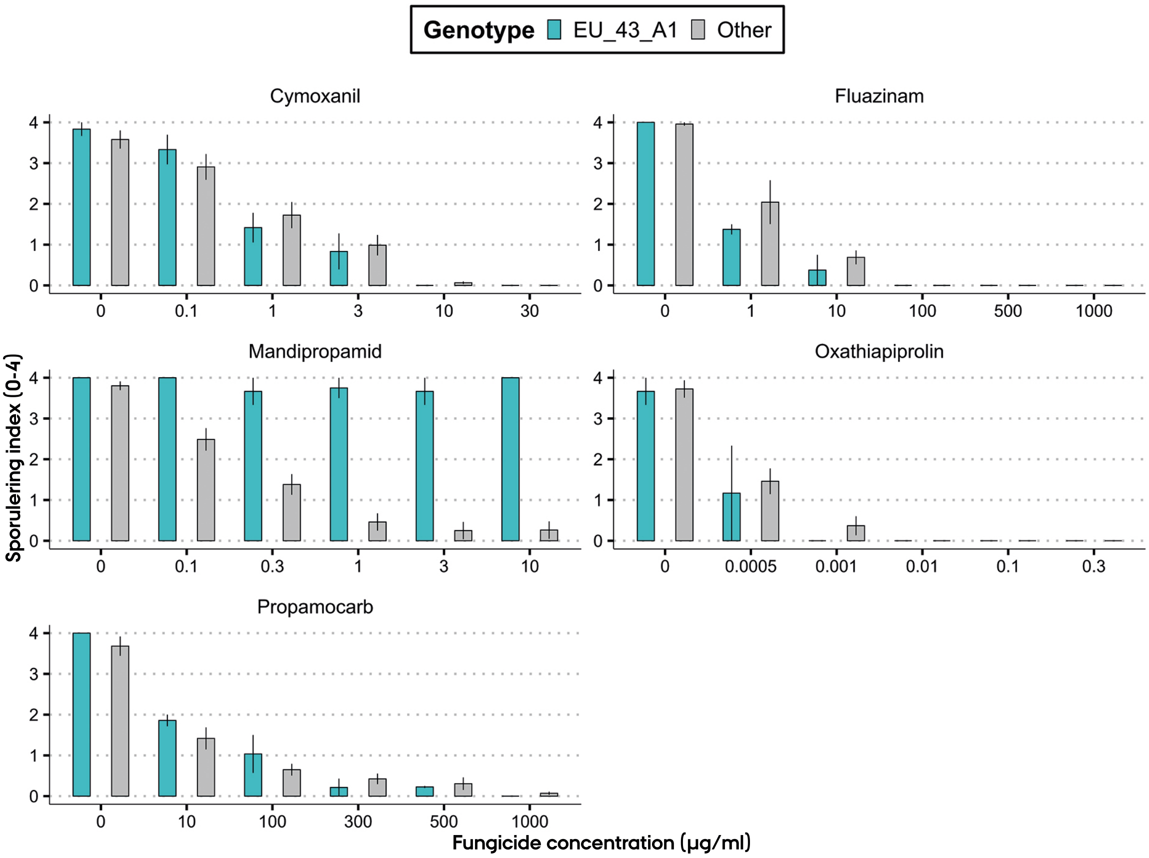

Figure 5. The sensitivity of EU_43_A1 (n = 3) and "Other" *Phytophthora infestans* genotypes to different fungicide active ingredients. Sensitivity was measured by assessing the sporulation index per leaf disc (from 0 = "no sporulation" to 4 = "heavy sporulation"). The vertical black line associated with each bar is the bootstrapped confidence interval (95%).

Table 1. The effective concentration at which 50% late blight control is achieved for different fungicide active ingredients for EU_43_A1 and "Other" *Phytophthora infestans* genotypes.

Active ingredient	Genotype*	Mean EC_{50} of tested isolates (µg/ml)**
Cymoxanil	EU_43_A1	0.59 (0.00013)
	Other	0.91 (0.0007)
Propamocarb	EU_43_A1	9.1 (0.00041)
	Other	6.1 (0.00047)
Fluazinam	EU_43_A1	0.1 (0.0001)
	Other	1 (0.00021)
Mandipropamid	EU_43_A1	>10
	Other	0.165 (0.000071)
Oxathiapiprolin	EU_43_A1	0.000256 (0.00000009)
	Other	0.000287 (0.00000009)

*The number of isolates tested per genotype are 4 (EU_43_A1) and 27 (Other).
**Values in brackets are the standard error of the mean EC_{50} values.

Acknowledgements

We are grateful for the funding from the following funding bodies: (1) the Danish GUDP (Green Development and Demonstration Programme) via the ECOSOL project as part of the SusCrop ERA-NET Co-fund; (2) the potato levy board (KAF); (3) the Danish Environmental Protection Agency's Pesticide Research Programme as part of the Potato-FRAS project.

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VII Eco-friendly management of late blight in potatoes

Isaac Kwesi Abuley & Jens Grønbech Hansen

Introduction

Late blight (*Phytophthora infestans*) is an important disease in potatoes and causes significant yield losses (Abuley and Hansen, 2021a). In conventional potato production, the control of late blight is dependent on excessive fungicide application. This study explores eco-friendly and alternative disease control products, such as biological control agents (BCA) which can be integrated into late blight management with fewer fungicides.

Materials and methods

Experimental design and treatments

The experiment set-up was a randomised complete block design with four replicates (plot size: 7 m x 3.75 m). Each plot consisted of five rows, at 75 cm row spacing. Seed tubers were planted in the rows at 33 cm spacing on 27 April 2023. The trials involved two cultivars with varying susceptibility to late blight (Nofy [resistant] and Kuras [susceptible]). The following treatments were investigated:

The tested treatments include (see Table 1 for details of the fungicide/BCA applications):

1. **Untreated:** No fungicide application to control late blight.
2. **Weekly fungicide treatment (standard treatment):** Here, 0.45 kg/ha Kunshi (375 g/kg fluazinam + 250 g/kg cymoxanil) or 0.4 l/ha Shirlan Ultra (500 g/l fluazinam) was sprayed at weekly intervals. Note that the dosage used here for either fungicide is considered the full dosage.
3. **75% dose of fungicide (IPM-Reference):** Here, 75% of either Kunshi or Shirlan Ultra fungicide was applied only when recommended in the IPM 1-4 strategies. This treatment served as the reference fungicide treatment for the IPM strategies.
4. **Local DSS (BlightManager):** This treatment followed the recommendations of the BlightManager decision support system as described by Abuley and Hansen (2021b). The fungicide used in this treatment was either Shirlan Ultra or Kunshi.
5. **BCA 1** (weekly ChiProPlant): Only ChiProPlant at a rate of 300 g/ha was applied at 7-day intervals. The same ChiProPlant dosage was used in other treatments, so the dosage will not be repeated subsequently.
6. **BCA 2** (weekly Polyversum): Only Polyversum at a rate of 200 g/ha was applied at 7-day intervals. The same Polyversum dosage was used in other treatments, so the dosage will not be repeated subsequently.
7. **IPM 1: strategy 1 with BCA 1 (IPM1-ChiProPlant):** Here, ChiProPlant was applied during low-risk periods, and fungicides (75%) were applied in moderate- to high-risk periods. Low-risk periods were defined as periods by the BlightManager DSS as periods with infection pressure below 10 and late blight has not been found in the field.
8. **IPM 2: strategy 2 with BCA 1 (IPM2-ChiProPlant):** Here, ChiProPlant was applied during low-risk periods, and fungicides (75%) plus ChiProPlant (as a tank mixture) were applied in moderate- to high-risk periods.
9. **IPM 3: strategy 1 with BCA 2 (IPM1-Polyversum):** Here, Polyversum was applied during low-risk periods, and fungicides (75%) were applied in moderate- to high-risk periods.

10. **IPM 4: strategy 2 with BCA 2 (IPM2-Polyversum):** Here, Polyversum was applied during low-risk periods, and fungicides (75%) plus Polyversum (as a tank mixture) were applied in moderate- to high-risk periods.
11. **BCA1 – IPM strategy 1 with the Hutton Criteria (IPM1-ChiProPlant-Hutton):** This follows the same strategy as IPM 1, except that the Hutton Criteria was used to define the risk periods.
12. **BCA1 – IPM strategy 2 with the Hutton Criteria (IPM2-ChiProPlant-Hutton):** This follows the same strategy as IPM 1, except that the Hutton Criteria was used to define the risk periods.

Table 1. Fungicide application per treatment.

Treatment	20 July 2023	27 July 2023	03 August 2023	10 August 2023	16 August 2023	23 August 2023	30 August 2023	6 September 2023
Standard treatment	0.4 l/ha SU	0.4 l/ha SU	0.4 l/ha SU	0.45 kg/ha KU	0.45 kg/ha KU	0.45 kg/ha KU	0.45 kg/ha KU	0.4 l/ha SU
IPM-Reference	-	0.3 l/ha SU	0.3 l/ha SU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.3 l/ha SU
DSS	-	0.2 l/ha SU	0.4 l/ha SU	0.4 l/ha SU	0.34 kg/ha KU	0.45 kg/ha KU	0.45 kg/ha KU	0.4 l/ha SU
Weekly ChiProPlant	300 g/ha CHP	300 g/ha CHP	300 g/ha CHP	300 g/ha CHP	300 g/ha CHP	300 g/ha CHP	300 g/ha CHP	300 g/ha CHP
Weekly Polyversum	200 g/ha POLY	200 g/ha POLY	200 g/ha POLY	200 g/ha POLY	200 g/ha POLY	200 g/ha POLY	200 g/ha POLY	200 g/ha POLY
IPM 1-ChiProPlant	300 g/ha CHP	0.3 l/ha SU	0.3 l/ha SU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.3 l/ha SU
IPM 2-ChiProPlant	300 g/ha CHP	300 g/ha CHP + 0.3 l/ha SU	300 g/ha CHP + 0.3 l/ha SU	300 g/ha CHP + 0.34 kg/ha KU	300 g/ha CHP + 0.34 kg/ha KU	300 g/ha CHP + 0.34 kg/ha KU	300 g/ha CHP+ 0.34 kg/ha KU	300 g/ha CHP + 0.3 l/ha SU
IPM 1-Polyversum	200 g/ha POLY	0.3 l/ha SU	0.3 l/ha SU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.3 l/ha SU
IPM 2-Polyversum	200 g/ha POLY	200 g/ha POLY + 0.3 l/ha SU	200 g/ha POLY + 0.3 l/ha SU	200 g/ha POLY + 200 g/ha CHP	200 g/ha POLY + 0.34 kg/ha KU	200 g/ha POLY + 0.34 kg/ha KU	200 g/ha POLY + 0.34 kg/ha KU	200 g/ha POLY + 0.3 l/ha SU
IPM 1-ChiProPlant-Hutton	300 g/ha CHP	0.3 l/ha SU	0.3 l/ha SU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.34 kg/ha KU	0.3 l/ha SU
IPM 2-ChiProPlant-Hutton	300 g/ha CHP	300 g/ha CHP + 0.3 l/ha SU	300 g/ha CHP + 0.3 l/ha SU	300 g/ha CHP + 0.34 kg/ha KU	300 g/ha CHP + 0.34 kg/ha KU	300 g/ha CHP + 0.34 kg/ha KU	300 g/ha CHP + 0.34 kg/ha KU	300 g/ha CHP + 0.3 l/ha SU

*Product abbreviations: ChiProPlant (CHP), Polyversum (POLY), Shirlan Ultra (SU) and Kunshi (KU).

Inoculation and disease and tuber yield assessments

No artificial inoculations were made in the experiment. However, all neighbouring experiments were inoculated.

Late blight disease development was assessed every week as the percentage area of late blight symptoms per plot (severity, %). The disease assessment data were used to calculate the area under the disease progress curve (AUDPC) to compare the cultivars. Disease progress curves were also made with the disease assessment data to visualise the development of the disease over time. Tubers were harvested from an area of ~16 m^2 from the middle of the plots.

Data analysis

All data analysis was done in the R language for programming and statistical computing (Version 4.3.2) (R Core Team, 2023). Both AUDPC and tuber yield were analysed with the Gaussian linear model, using the "lm" function in R. The treatment effect was determined via F-test, using the ANOVA function in R. A posthoc analysis was done using the "*emmeans*" function in the emmeans package in R (Lenth, 2022). All plots were generated with the *ggplot* package (Version 3.5.0) (Wickham, 2016).

Results

Disease development in Nofy and Kuras

The disease progress curve is shown in Figure 1. The first late blight attack was observed on 27 July in Kuras and on 15 August in Nofy. Generally, there was dry weather in June, but more rain in July and August was conducive to late blight and untreated plots reached 100% infection in both cultivars, albeit earlier in Kuras than in Nofy (Figure 1).

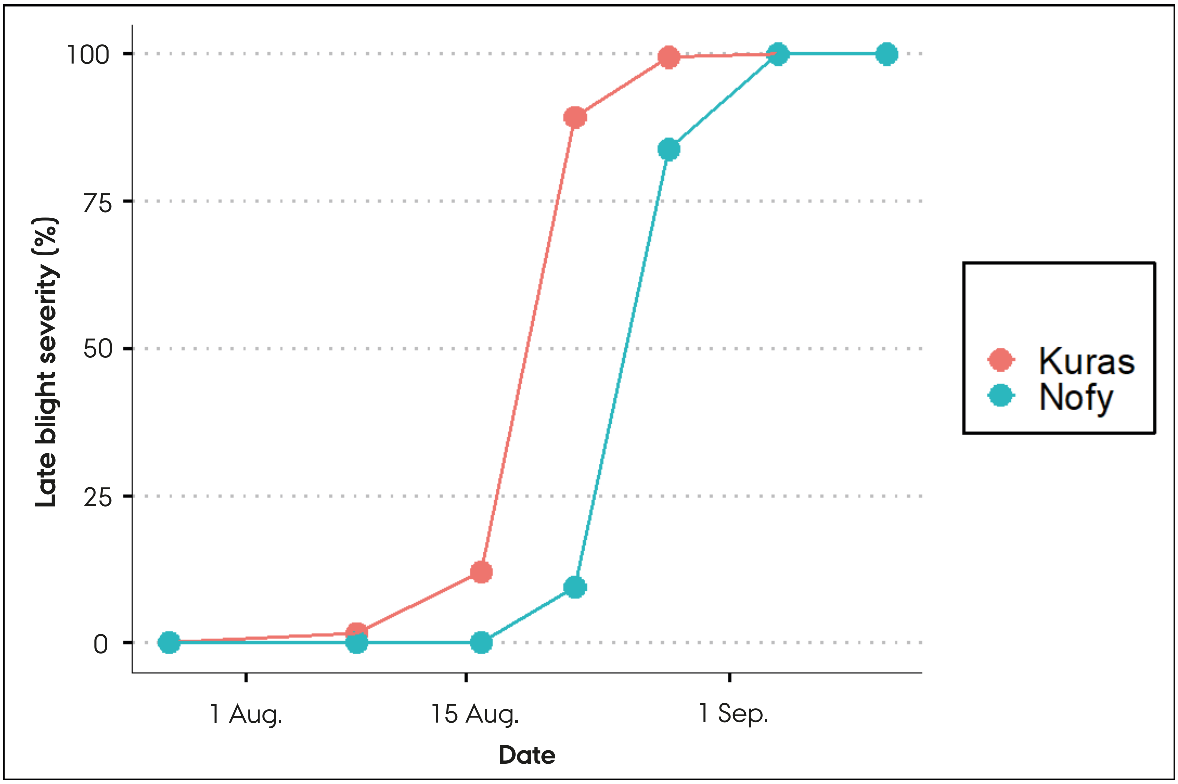

Figure 1. Late blight development in the untreated plots of Kuras and Nofy, AU Flakkebjerg, 2023.

Disease progression in all treatments

Figure 2 shows the disease progression in Kuras and Nofy for all treatments. The results indicate that all treatments including fungicides had lower disease levels at all assessment times. In contrast, late blight developed rapidly on the plots that were either untreated or treated with only BCAs (weekly Polyversum and ChiProPlant) (Figure 2). However, the weekly ChiProPlant treatment had a lower level of late blight than both the untreated and the weekly Polyversum treatment.

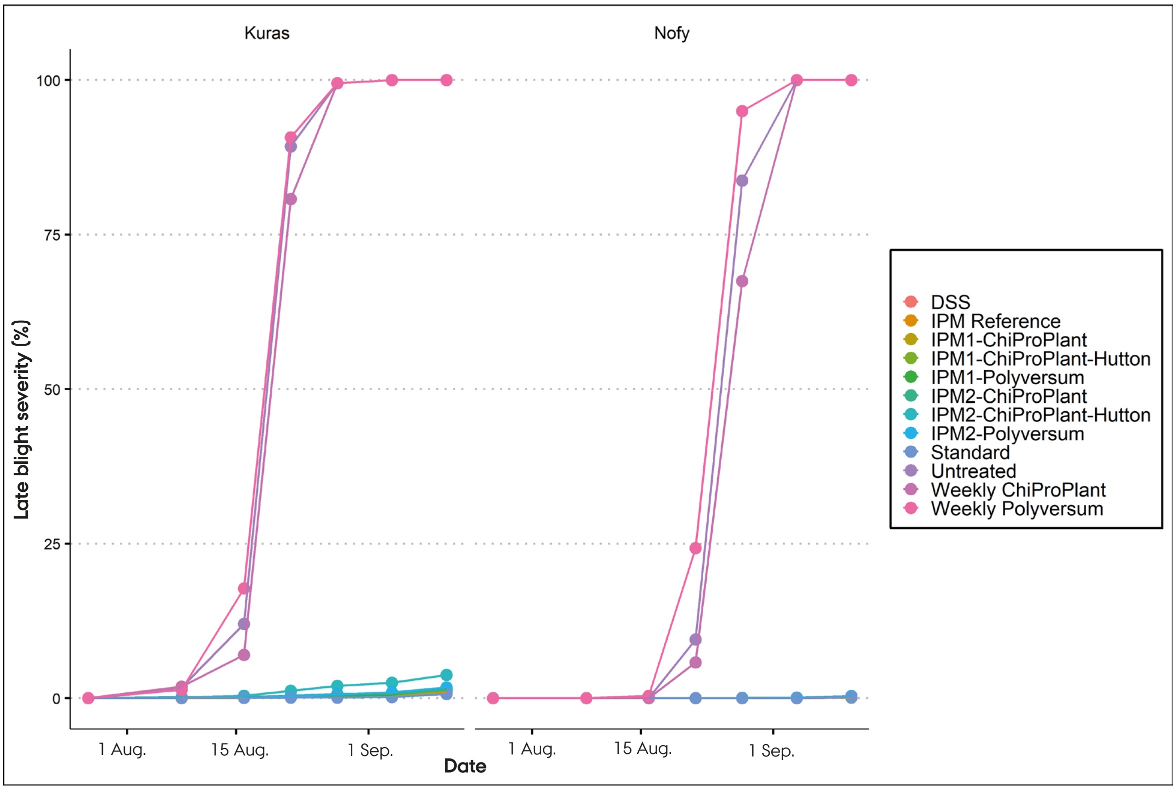

Figure 2. The disease progression in Kuras and Nofy sprayed according to different treatment strategies.

Comparison of AUDPC and tuber yield of the treatments

Treatment had a significant effect (p<0.0001) on AUDPC and tuber yield in both cultivars However, because of the strong effect of cultivar, we did a separate comparison for each cultivar. Table 2 shows the mean AUDPC and tuber yield of the treatments in Kuras and Nofy. For AUDPC, all IPM and fungicide treatments were significantly lower than the stand-alone weekly BCA and untreated treatments in both cultivars (Table 2). Also, the result shows an insignificant difference between the stand-alone weekly BCA and untreated treatments. However, in both Kuras and Nofy, the weekly ChiProPlant treatment had a lower AUDPC compared with the untreated and Polyversum. The levels of disease were always lower in the resistant (Nofy) cultivar compared with the susceptible (Kuras) cultivar for all treatments (Table 2).

The tuber yield also followed a similar trend as observed in the AUDPC, with the untreated plots and weekly BCA treatments recording a significantly lower tuber yield compared with the IPM and fungicide treatments (Table 2). The highest tuber yield was observed in the standard treatment (Nofy) and IPM2-ChiProPlant-Hutton treatment. For Kuras, the difference between the standard and the IPM and other fungicide treatments was not statistically significant (Table 2). For Nofy, the IPM2-ChiProPlant-Hutton treatment was significantly different from the Blight Manager DSS (DSS), IPM1-Polyversum and IPM2-ChiProPlant- Hutton treatments, but not from other fungicide or IPM treatments (Table 2).

Table 2. Mean area under the disease progress curve (AUDPC) and tuber yield of the investigated treatments in Kuras and Nofy. The letters associated with the AUDPC and tuber yield are the significant letters. Values within a column that have the same letters are not significantly different and vice versa.

	Kuras		Nofy	
Treatment	AUDPC	Tuber yield	AUDPC	Tuber yield
DSS	10.71 a	58.69 b	0.5 a	51.08 b
IPM-Reference	6.52 a	59.77 b	1.54 a	55.62 bc
IPM1-ChiProPlant	11.69 a	57.32 b	1.79 a	52.86 bc
IPM1-ChiProPlant-Hutton	14.22 a	57.32 b	1.04 a	52.54 bc
IPM1-Polyversum	14.55 a	57.21 b	2.16 a	51.46 b
IPM2-ChiProPlant	19.79 a	54.73 b	1.67 a	54.36 bc
IPM2-ChiProPlant-Hutton	55.12 a	60.2 b	1.65 a	50.18 b
IPM2-Polyversum	20.13 a	56.83 b	1.86 a	51.98 bc
Standard	5.48 a	54.27 b	0.67 a	57.21 c
Untreated	2333.75 b	41.87 a	1651.62 bc	43.79 a
Weekly ChiProPlant	2249 b	42 a	1523.62 b	42.35 a
Weekly Polyversum	2379.25 b	41.03 a	1815.83 c	41.07 a

Fungicide savings

Fungicide savings varied from 9.37% in the DSS-based treatment to 100% in the stand-alone BCA treatments (Table 3). However, the 100% savings in fungicides in the stand-alone BCA treatments did not result in effective disease control. For the fungicide treatments, the maximum savings were observed to be 34.375% in the IPM-Reference and other IPM treatments (Table 3).

Table 3. This table provides a summary of the fungicide and Biological Control Agent application, treatment frequency and the percentage of fungicide saved relative to the standard treatment.

Treatment	No. of fungicide applications	No. of BCA applications	Treatment frequency index	% fungicide saved
DSS	8	0	7.25	9.375
IPM-Reference	7	0	5.25	34.375
IPM1-ChiProPlant	7	1	5.25	34.375
IPM1-ChiProPlant-Hutton	7	8	5.25	34.375
IPM1-Polyversum	7	1	5.25	34.375
IPM2-ChiProPlant	7	8	5.25	34.375
IPM2-ChiProPlant-Hutton	7	8	5.25	34.375
IPM2-Polyversum	7	8	5.25	34.375
Standard	8	0	8	
Untreated				
Weekly ChiProPlant	0	8	0	100
Weekly Polyversum	0	8	0	100

Concluding remarks

Generally, the results suggest that using the BCA alone does not prove to be an effective strategy for late blight management. However, integrating the BCA with fungicide, either in alternation or as a mixture, proved to be as effective as the standard fungicide treatments. Approximately 9% of fungicide was saved by using the DSS alone. However, when we integrated a BCA, which was timed according to DSS, the fungicide savings increased to about 34%.

The IPM-Reference treatment, which involves spraying fungicide only when the IPM strategies are also sprayed with fungicide, did not differ from the IPM strategies in which both BCA and fungicide were sprayed in terms of disease level and yield. These results suggest that BCA might not be contributing to the disease control observed in the IPM strategies. In other words, the disease control observed in the IPM strategies is most likely due to the use of fungicides alone.

Acknowledgements

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VIII Cultivar resistance against downy mildew (*Peronospora destructor*) in onions

Isaac Kwesi Abuley & Peter Hartvig

Introduction

Downy mildew (*Peronospora destructor*) is a serious disease that causes significant yield losses in onion production in Denmark, particularly when the attacks commence early in the season. Onion plants are intensively sprayed against downy mildew, which is not sustainable. Given the recent demands to reduce pesticide usage in agriculture, there is a pressing need to develop tools that can assist farmers in the correct usage of fungicides. Host resistance is an effective and environmentally friendly tool for managing plant diseases. For onion downy mildew, host resistance is considered one of the key elements for successful disease management that relies less on fungicides. However, systematic classification of the resistance and its subsequent integration into IPM strategies has not been carried out in Denmark. This study focused on assessing the resistance level of onion cultivars to downy mildew.

Materials and methods

Field experiments were carried out at AU Flakkebjerg and at Eggeslevmagle to assess the resistance of different onion cultivars (Table 1) to downy mildew. The experiment at AU Flakkebjerg was artificially inoculated by placing infected onion bulbs between the rows in the middle of July.

The disease level was assessed as the percentage of the leaf area affected by downy mildew per plot. The disease assessment data were used to calculate the relative area under the disease progress curve (rAUDPC) as described by Abuley and Hansen (2022). The rAUDPC data were subjected to analysis of variance (ANOVA). Posthoc analysis was done using the Tukey HSD test in R (R Core Team, 2023).

Table 1. Tested onion cultivars at AU Flakkebjerg and at Eggeslevmagle.

Cultivar	Location
Hystore	AU Flakkebjerg and Eggeslevmagle
Hylander	AU Flakkebjerg and Eggeslevmagle
Hygate	AU Flakkebjerg
Highroad	AU Flakkebjerg and Eggeslevmagle
Redlander	AU Flakkebjerg
Restora	AU Flakkebjerg and Eggeslevmagle
EXP 388	AU Flakkebjerg and Eggeslevmagle
BGS 377	AU Flakkebjerg and Eggeslevmagle
Fasto	AU Flakkebjerg
37-117	AU Flakkebjerg and Eggeslevmagle
Redrover	AU Flakkebjerg and Eggeslevmagle

Results and discussion

A significant disease development was observed at the two experimental sites, which made it possible to distinguish between the cultivars. rAUDPC, which indicates the disease level among the different onion cultivars, is depicted in Figure 1. The statistical analysis showed a significant effect of the cultivar on the rAUDPC ($p<0.001$). The results suggest that the onion cultivars Redlander, Restora, EXP 388 and Hylander exhibit greater resistance to downy mildew. These resistant cultivars are promising for future management of downy mildew.

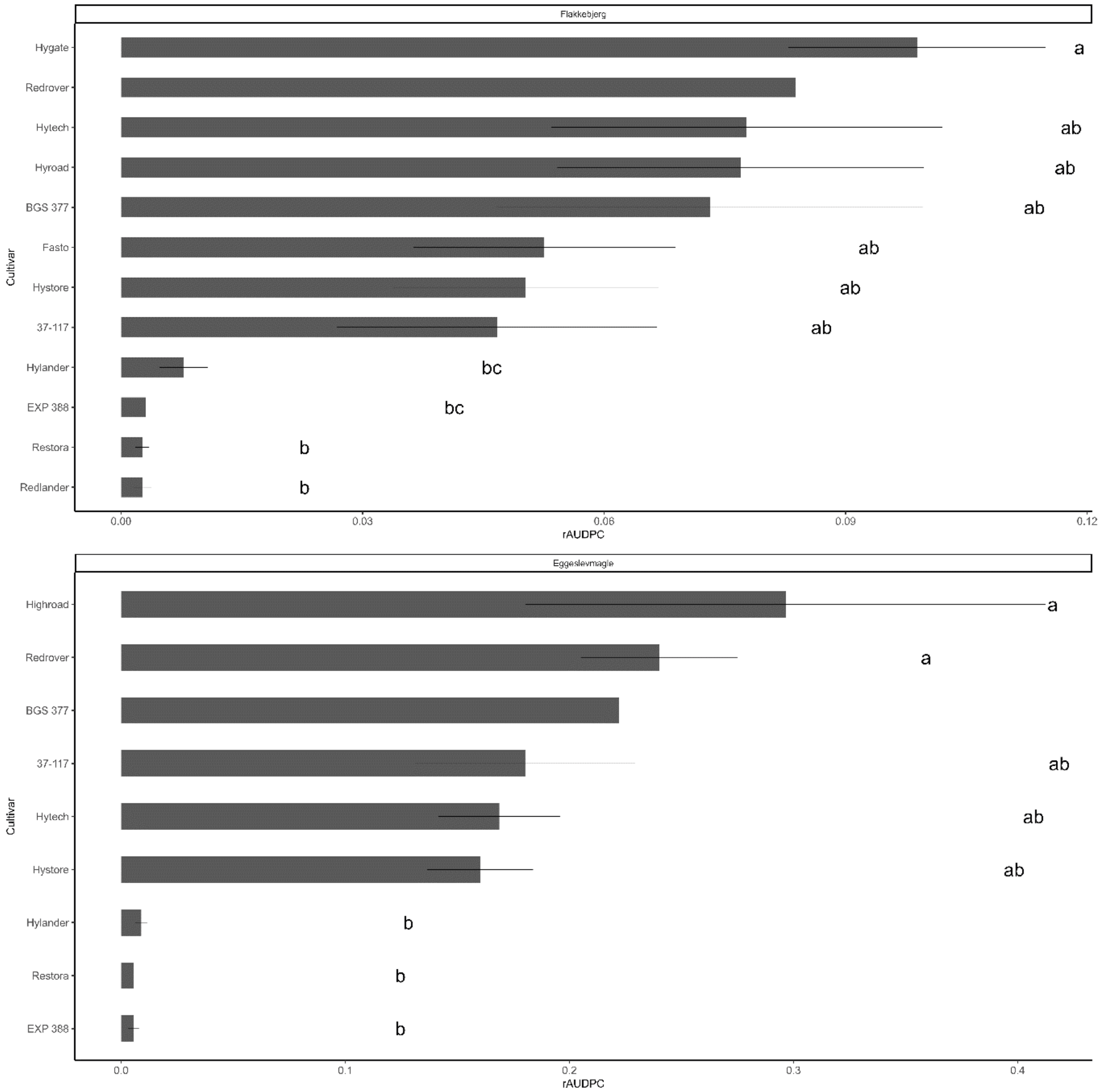

Figure 1. A bar chart showing the mean relative area under the disease course curve (rAUDPC) for downy mildew in different onion cultivars. The horizontal line on each bar is the standard error. The letter(s) on each bar are the letter(s) of significance. Bars that have the same letters are not significantly different and vice versa.

Acknowledgements

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IX Band spraying in grass seed crops with different herbicide dose rates in the crop band and in the inter-row area

Peter Kryger Jensen, Steen Christian Sørensen & Verner Lindberg

Weeds reduce seed yield and quality and can be difficult to control effectively in grass seed crops. Availability of herbicides has gradually declined, and at the same time selectivity issues make control of a number of grass weeds in grass seed crops hazardous or impossible. Grasses for seed production have typically been established undersown broadcast in a cover crop. Broadcast-sown crops give the best crop cover and competitiveness against weeds. However, weed control can only be carried out with selective herbicides and herbicide dose rates. Some grass seed crops can be grown at a larger row spacing without reducing the yield potential. When the grass seed crops are grown at larger row spacing, herbicides can be applied using band spray equipment. The purpose of the present activities was to test crop selectivity and seed yield following band spray application of relevant herbicides applied at the recommended dose rate above the crop band and at an increased dose rate in the inter-row space.

Materials and methods

Field trials were carried out at AU Flakkebjerg (55˚19´N, 11˚24´E) in 2021–2023. Three grass species – perennial ryegrass cv Matilde (*Lolium perenne*), cocksfoot cv Amba (*Dactylis glomerata*) and tall fescue cv Kora (*Festuca arundinaceae*) – were included. All three grasses were established undersown in spring barley cultivated according to normal practice. The grasses were established at a row spacing of 0.36 m. Following harvest of the cover crop, the straw was removed, and cultivation followed normal practice. A double band sprayer was used for the experimental treatments. The band sprayer was equipped with two even spray nozzles: a TeeJet 4001E nozzle centred above the crop band, spraying a 0.12 m wide band, and a TeeJet 6501E nozzle centred above the inter-row space, spraying a 0.24 m wide band. The nozzle centred above the inter-row space was shielded. With a speed of 4.0 km/h the volume rate was 500 l/ha in the crop band and 250 l/ha in the inter-row area. Experimental treatments were applied in September when almost all crop biomass and leaves were in the 0.12 m crop band. Table 1 shows the herbicides tested in the trials.

Table 1. Herbicides tested in the trial series.

Herbicide	Active ingredient	Company
Agil 100 EC	Propaquizafop 100 g/l	Adama
DFF	Diflufenican 500 g/l	Bayer Crop Science
Primera Super	Fenoxaprop-p-ethyl 69 g/l + cloquintocet-mexyl (safener) 33.5 g/l	Bayer Crop Science
Mateno Duo	Aclonifen 500 g/l + diflufenican 100 g/l	Bayer Crop Science
Atlantis OD	Mesosulfuron-methyl 10 g/l + iodosulfuron-methyl 2 g/l + mefenpyr-diethyl (safener) 30 g/l	Bayer Crop Science

Phytotoxicity was evaluated several times in the autumn following the treatment and again in the spring. Seed yield was determined in all trials.

Results and discussion

Perennial ryegrass

Four herbicides were included in the trial series, and they were tested at two dose rates. Herbicides with a regular authorisation or a minor use authorisation were tested at the recommended dose rate above the crop band and at both the recommended and double the recommended dose rate in the inter-row area. Mateno Duo was not authorised for use in grass seed crops when the trial series was initiated but has since got a minor use authorisation at the high dose rate of 0.7 l/ha. The assessments of crop phytotoxicity and seed yield in perennial ryegrass are shown in Tables 2-4. A control of volunteer cereals in the entire trial was carried out in November 2020 in the first year. This treatment damaged the crop and is probably the reason for the generally low yield level in 2021 (Table 2). Despite this, almost no phytotoxicity was observed following any of the treatments during the three years. Nor was any influence of the treatments on the yield seen in any of the three years. Use of double the recommended/authorised dose rate in the inter-row area of the four herbicides therefore seems safe in perennial ryegrass.

Table 2. Phytotoxicity assessments and seed yield in perennial ryegrass 2020/2021 treated with band spraying in September 2020 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 30 Sep. 2020 (%)	Phytotoxicity 28 Oct. 2020 (%)	Phytotoxicity 10 June 2021 (%)	Seed yield (kg/ha)
Agil 100 EC*	0.12	0.24	0	0	0	1071
Agil 100 EC*	0.12	0.12	0	0	0	1104
DFF	0.15	0.3	0	0	0	1139
DFF	0.15	0.15	0	0	0	1023
Primera Super*	0.4	0.8	0	0	0	976
Primera Super*	0.4	0.4	0	0	0	1068
Mateno Duo	0.35	0.7	4	0	0	1129
Mateno Duo	0.35	0.35	3	0	0	1039
LSD (p=0.05)			2	NS	NS	NS

* Surfactant is added.

Table 3. Phytotoxicity assessments and seed yield in perennial ryegrass 2021/2022 treated with band spraying in September 2021 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 27 Sep. 2021 (%)	Phytotoxicity 20 Oct. 2021 (%)	Phytotoxicity 9 June 2022 (%)	Seed yield (kg/ha)
Agil 100 EC*	0.12	0.24	0	0	0	1559
Agil 100 EC*	0.12	0.12	0	0	0	1443
DFF	0.15	0.3	0	0	0	1526
DFF	0.15	0.15	0	0	0	1574
Primera Super*	0.4	0.8	0	0	0	1405
Primera Super*	0.4	0.4	0	0	0	1515
Mateno Duo	0.35	0.7	0	0	0	1465
Mateno Duo	0.35	0.35	0	0	0	1609
LSD (p=0.05)			NS	NS	NS	NS

* Surfactant is added.

Table 4. Phytotoxicity assessments and seed yield in perennial ryegrass 2022/2023 treated with band spraying in September 2022 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 26 Sep. 2022 (%)	Phytotoxicity 25 Oct. 2022 (%)	Phytotoxicity 1 June 2023 (%)	Seed yield (kg/ha)
Agil 100 EC*	0.12	0.24	0	0	0	3366
Agil 100 EC*	0.12	0.12	0	0	0	3214
DFF	0.15	0.3	0	0	0	3424
DFF	0.15	0.15	0	0	0	3549
Primera Super*	0.4	0.8	0	0	0	3258
Primera Super*	0.4	0.4	0	0	0	3357
Mateno Duo	0.35	0.7	0	0	0	3108
Mateno Duo	0.35	0.35	0	0	0	3263
LSD (p=0.05)			NS	NS	NS	NS

* Surfactant is added.

Tall fescue

The same herbicides and dose rates were used in the tall fescue trials (Tables 5-7). No phytotoxicity was found in any of the treatments during the three years' trials, and the seed yield was not influenced by any of the herbicide treatments.

Table 5. Phytotoxicity assessments and seed yield in tall fescue 2020/2021 treated with band spraying in September 2020 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 30 Sep. 2020 (%)	Phytotoxicity 28 Oct. 2020 (%)	Phytotoxicity 10 June 2021 (%)	Seed yield kg/ha)
Agil 100 EC*	0.12	0.24	0	0	0	850
Agil 100 EC*	0.12	0.12	0	0	0	849
DFF	0.15	0.3	0	0	0	927
DFF	0.15	0.15	0	0	0	834
Primera Super*	0.4	0.8	0	0	0	883
Primera Super*	0.4	0.4	0	0	0	909
Mateno Duo	0.35	0.7	0	0	0	895
Mateno Duo	0.35	0.35	0	0	0	841
LSD (p=0.05)			NS	NS	NS	NS

* Surfactant is added.

Table 6. Phytotoxicity assessments and seed yield in tall fescue 2021/2022 treated with band spraying in September 2021 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 27 Sep. 2021 (%)	Phytotoxicity 20 Oct. 2021 (%)	Phytotoxicity 9 June 2022 (%)	Seed yield (kg/ha)
Agil 100 EC*	0.12	0.24	0	0	0	1319
Agil 100 EC*	0.12	0.12	0	0	0	1204
DFF	0.15	0.3	0	0	0	1244
DFF	0.15	0.15	0	0	0	1197
Primera Super*	0.4	0.8	0	0	0	1250
Primera Super*	0.4	0.4	0	0	0	1189
Mateno Duo	0.35	0.7	0	0	0	1337
Mateno Duo	0.35	0.35	0	0	0	1270
LSD (p=0.05)			NS	NS	NS	NS

* Surfactant is added.

Table 7. Phytotoxicity assessments and seed yield in tall fescue 2022/2023 treated with band spraying in September 2022 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 26 Sep. 2022 (%)	Phytotoxicity 25 Oct. 2022 (%)	Phytotoxicity 1 June 2023 (%)	Seed yield (kg/ha)
Agil 100 EC*	0.12	0.24	0	0	0	1422
Agil 100 EC*	0.12	0.12	0	0	0	1051
DFF	0.15	0.3	0	0	0	1193
DFF	0.15	0.15	0	0	0	1131
Primera Super*	0.4	0.8	0	0	0	1218
Primera Super*	0.4	0.4	0	0	0	1063
Mateno Duo	0.35	0.7	0	0	0	1223
Mateno Duo	0.35	0.35	0	0	0	1317
LSD (p=0.05)			NS	NS	NS	NS

* Surfactant is added.

Cocksfoot

In the trial series in cocksfoot, Atlantis OD replaced Agil 100 EC. Atlantis OD does not have an authorisation in cocksfoot. In the first year Atlantis OD was tested at a dose rate of 0.6 l/ha in the crop band and at 0.6 l/ha and 0.9 l/ha in the inter-row area. Severe phytotoxicity was observed both in the autumn and in the spring following both dose rates of Atlantis OD (Table 8). In the spring following the autumn treatment, the crop damage could be registered as a reduction in crop height. There was no significant effect of the various phytotoxicity symptoms on seed yield. Treatment with the other three herbicides gave small temporary phytotoxicity symptoms, and there was no difference in seed yield between the high and the low dose rate in the inter-row area.

However, due to the severe phytotoxicity symptoms following Atlantis OD, the dose rate was reduced to 0.3 l/ha above the crop band in the following two years. The results from the following two years in which the dose rate of Atlantis OD was reduced are shown in Tables 9 and 10. The only phytotoxicity registered was in the 2021/2022 trial with DFF at the low dose rate, and the assessment was "non-significant". The score is due to one single plot and is probably due to some other factors than the herbicide treatment or to an experimental error although this could not be established. There was no significant effect of herbicide dose rate on the seed yield.

Table 8. Phytotoxicity assessments and seed yield in cocksfoot 2020/2021 treated with band spraying in September 2020 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 30 Sep. 2020 (%)	Phytotoxicity 28 Oct. 2020 (%)	Phytotoxicity 10 June 2021 (%)	Seed yield (kg/ha)
Atlantis OD	0.6	0.9	9	26	15	1258
Atlantis OD	0.6	0.6	15	20	11	1252
DFF	0.15	0.3	1	5	0	1318
DFF	0.15	0.15	5	4	0	1315
Primera Super*	0.4	0.8	6	0	0	1214
Primera Super*	0.4	0.4	5	0	0	1219
Mateno Duo	0.35	0.7	0	0	0	1343
Mateno Duo	0.35	0.35	0	0	0	1289
LSD (p=0.05)			8	15	9	NS

* Surfactant is added.

Table 9. Phytotoxicity assessments and seed yield in cocksfoot 2021/2022 treated with band spraying in September 2021 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 27 Sep. 2021 (%)	Phytotoxicity 20 Oct. 2021 (%)	Phytotoxicity 9 June 2022 (%)	Seed yield (kg/ha)
Atlantis OD	0.3	0.6	0	0	0	1393
Atlantis OD	0.3	0.3	0	0	0	1307
DFF	0.15	0.3	0	0	0	1452
DFF	0.15	0.15	4	15	8	1386
Primera Super*	0.4	0.8	0	0	0	1429
Primera Super*	0.4	0.4	0	0	0	1402
Mateno Duo	0.35	0.7	0	0	0	1401
Mateno Duo	0.35	0.35	0	0	0	1427
LSD (p=0.05)			NS	NS	NS	NS

* Surfactant is added.

Table 10. Phytotoxicity assessments and seed yield in cocksfoot 2022/2023 treated with band spraying in September 2022 at growth stage 25-30 (BBCH).

Herbicide	Dose rate above crop band (l/ha)	Dose rate in the inter-row area (l/ha)	Phytotoxicity 26 Sep. 2022 (%)	Phytotoxicity 25 Oct. 2022 (%)	Phytotoxicity 1 June 2023 (%)	Seed yield (kg/ha)
Atlantis OD	0.3	0.6	0	0	0	1642
Atlantis OD	0.3	0.3	0	0	0	1790
DFF	0.15	0.3	0	0	0	1767
DFF	0.15	0.15	0	0	0	1777
Primera Super*	0.4	0.8	0	0	0	1726
Primera Super*	0.4	0.4	0	0	0	1596
Mateno Duo	0.35	0.7	0	0	0	1734
Mateno Duo	0.35	0.35	0	0	0	1730
LSD (p=0.05)			NS	NS	NS	NS

* Surfactant is added.

Atlantis OD at a rate of 0.6 l/ha above the crop row in September 2020 damaged the crop, and a reduced crop height was seen the following spring.

Conclusion

Band application of herbicides is possible when the crop is established at a row spacing of 0.24 m or more. In this project we tested band application in perennial ryegrass, tall fescue and cocksfoot grown at 0.36 m row spacing. Established this way, weeds in the crop band can be controlled with band application using a selective herbicide. In the inter-row space, we tested band application spraying a 0.24 m wide space between the crop rows, and four different herbicides were tested in each crop. Herbicides with an authorisation in the crop were tested at the authorised dose rate and double the authorised dose rate in the inter-row space. Atlantis OD is not authorised in cocksfoot but was tested at a dose rate that was tolerated by the crop in the crop band and at double that dose rate in the inter-row space. Band spraying in the inter-row space was carried out with a shielded band sprayer and therefore very limited foliage was hit during the application. It was therefore not a surprise that purely foliar-acting herbicides such as Primera Super could be used at double the recommended dose rate in the inter-row area without any crop damage. Herbicides with both foliar and soil uptake might be taken up by the roots from the inter-row space. However, the herbicides tested in this project did not result in crop damage or yield reduction in the treatments where the herbicide dose rate was doubled in the inter-row area. The high dose rates must be authorised before use in practice and so must the use of Atlantis OD in cocksfoot.

Acknowledgements

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X Desiccation of potatoes with sodium chloride

Peter Kryger Jensen, Steen Christian Sørensen & Verner Lindberg

Potatoes for purposes such as propagation are desiccated in order to obtain a certain tuber size. Following the ban on desiccants with the active ingredient diquat, effective methods to desiccate the crop are now lacking. In order to find alternative desiccation options, a project focusing on alternative methods and combinations of methods of crop desiccation or non-chemical control of haulm killing was run in 2022-2023. One of the methods studied in the project was the use of sodium chloride applied as a spray. In an English investigation (Stalham, 2020), effective desiccation of potatoes was obtained using a dose rate of 310 kg/ha of NaCl applied as a concentrated brine solution. The purpose of the present activities was to study the influence of different factors on the efficacy of sodium chloride used as a desiccant in potatoes.

Materials and methods

Field trials were carried out at AU Flakkebjerg (55°19´N, 11°24´E) in 2022 and 2023. In 2022 all trials were in the cultivar (cv) Kuras. The crop was grown according to normal practice except for the level of nitrogen fertiliser, which was reduced to 90 kg/ha. In 2022, four trials were carried out studying: 1. desiccation efficacy as a response to decreasing NaCl dose rate, 2. influence of application technique on desiccation with NaCl, 3. influence of additives on desiccation with NaCl and 4. influence of weather conditions on desiccation with NaCl.

Based on the experience from 2022, the nitrogen level was reduced to 30 kg/ha nitrogen in 2023. The activities in 2023 included two experiments, one studying the influence of potato cultivar and the other trial studying the influence of weather conditions following the application.

NaCl was applied as a concentrated brine solution (Saltex, Omex). The NaCl concentration was 26.8%. Application was carried out with a self-propelled plot sprayer. The different application rates were obtained by changing nozzle size and sprayer speed (Table 1) in all experiments except Experiment no. two in 2022 studying application technique.

Table 1. Sprayer settings to apply different application rates of Saltex.

Saltex dose rate (l/ha)	Nozzle	Nozzle output (l/min)	Speed
1120	LD-06	2.4	2.6
560	LD-06	2.4	5.2
280	LD-015	0.6	2.6
140	LD-015	0.6	5.2
70 (+ 70 l/ha water)	LD-015	0.6	5.2

The experiment studying the influence of application techniques used the settings shown in Table 2.

Table 2. Spray techniques used in the spray technical experiment in 2022.

Saltex dose rate (l/ha)	Nozzle	Nozzle output (l/min)	Speed
1120	LD-06	2.4	2.6
1120	MD DUO-06	2.4	2.6
1120	Dropleg with 2 LD-06	2.4	3.5
560	LD-06	2.4	5.2
560	MD DUO-06	2.4	5.2
560	Dropleg with 2 LD-06	2.4	7.0

Application in 2022 in the cultivar Kuras was at growth stage 69 (BBCH).
Desiccation of leaves and stems was evaluated several times in each of the experiments.

Results and discussion

The first experiment in 2022 studied the desiccation following application of five dose rates of Saltex. The desiccation of leaves and stems was very limited in the experiment, even at the highest dose rate. Desiccation of leaves one and two weeks after application is shown in Table 3.

Table 3. Desiccation of potato cv Kuras following application at growth stage 69 with decreasing dose rates of NaCl applied in Saltex. Experiment in 2022.

Dose rate of Saltex (NaCl in brackets) kg/ha	Desiccation of leaves (%) one week after application	Desiccation of leaves (%) two weeks after application
1120 (300)	12.5	16.3
560 (150)	6.0	8.5
280 (75)	0.8	2.5
140 (37.5)	0.3	1.0
75 (18.75)	0.3	1.0
LSD (p=0.05)	2.0	2.0

The desiccation assessments from the experiments in 2022 with application techniques are shown in Table 4, results with additives in Table 5 and results with weather conditions in Table 6. Generally, a very low desiccation effect of leaves was achieved in these experiments. Based on the experience in 2022, it seemed that the application at growth stage 69 was at a too early stage and before the potato crop had started the natural maturing process. Further, the nitrogen level (90 kg/ha) seemed to be too high. Therefore, the nitrogen level was reduced to 30 kg/ha and desiccation was delayed in 2023 until the natural maturing symptoms were visible in the earliest maturing cultivars.

Table 4. Desiccation of potato cv Kuras following application at growth stage 69 with different application techniques and two dose rates of NaCl applied in Saltex. Experiment in 2022.

Technique	Dose rate of Saltex (l/ha)	Desiccation of leaves (%) one week after application	Desiccation of leaves (%) two weeks after application
LD-06	1120	16.3	23.8
MD DUO-06	1120	16.3	23.8
Dropleg with 2 LD-06	1120	8.5	15.0
LD-06	560	6.0	10.5
MD DUO-06	560	5.5	11.3
Dropleg with 2 LD-06	560	8.0	11.3
LSD (p=0.05)		2.7	3.3

Dropleg was used with two LD-06 nozzles angled into the crop rows.

Table 5. Desiccation of potato cv Kuras following application at growth stage 69 with two dose rates of NaCl applied in Saltex with or without additives. Experiment in 2022.

Additive	Dose rate of Saltex (l/ha)	Desiccation of leaves (%) one week after application	Desiccation of leaves (%) two weeks after application
Without additive	1120	17.5	23.8
0.1% Contact (surfactant)	1120	10.0	14.4
0.5% Renol (oil additive)	1120	10.5	15.0
Without additive	560	8.0	9.3
0.1% Contact (surfactant)	560	6.0	8.5
0.5% Renol (oil additive)	560	5.5	7.8
LSD (p=0.05)		3.7	3.3

Table 6. Desiccation of potato cv Kuras following application at growth stage 69 with two dose rates of NaCl applied in Saltex under different weather conditions. Experiment in 2022.

Weather at the application date	Dose rate of Saltex (l/ha)	Desiccation of leaves (%) one week after application	Desiccation of leaves (%) two weeks after application
Cloudy conditions	1120	9.8	16.3
Sunshine	1120	8.0	11.8
Cloudy conditions	560	6.3	9.8
Sunshine	560	5.0	10.0
LSD (p=0.05)		4.7	4.9

Results from the experiment studying desiccation in five potato cultivars are shown in Tables 7–9. Application was carried out on 11 August 2023 when the earliest cultivars – Spunta, Desiree and Stratos – had reached growth stage 91. Desiccation of leaves (Table 7) and stems (Table 8) in these early cultivars was very quick and reached high levels at both Saltex dose rates. The desiccation level of leaves and especially stems on Sava was somewhat lower. The late cultivar – Ydun – was at growth stage 69 at application, and desiccation of both leaves and stems was limited at both Saltex dose rates.

Table 7. Desiccation of potato cultivars sprayed with Saltex on 11 August 2023. Assessment of leaf desiccation (% desiccation).

Cultivar	GS at application	Saltex dose rate (l/ha)	Leaf desiccation (%)			
			14 Aug.	18 Aug.	25 Aug.	6 Sep.
Spunta	91	1120	86	99	100	100
Spunta		560	63	91	96	97
Spunta		Untreated	21	40	59	79
Desiree	91	1120	82	97	99	98
Desiree		560	53	80	84	85
Desiree		Untreated	13	24	33	46
Ydun	69	1120	16	36	50	54
Ydun		560	8	24	33	36
Ydun		Untreated	0	4	6	6
Sava	90	1120	39	81	88	89
Sava		560	17	49	66	71
Sava		Untreated	2	7	15	25
Stratos	91	1120	94	99	100	100
Stratos		560	80	94	98	99
Stratos		Untreated	30	46	61	87
LSD (p=0.05)			18	15	13	12

Table 8. Desiccation of potato cultivars sprayed with Saltex on 11 August 2023. Assessment of stem desiccation (% desiccation)

Cultivar	GS at application	Saltex dose rate (l/ha)	Stem desiccation (%)			
			14 Aug.	18 Aug.	25 Aug.	6 Sep.
Spunta	91	1120	30	65	96	98
Spunta		560	21	53	85	94
Spunta		Untreated	8	19	35	53
Desiree	91	1120	18	41	87	94
Desiree		560	8	28	50	51
Desiree		Untreated	0	1	4	8
Ydun	69	1120	0	1	4	11
Ydun		560	0	0	1	4
Ydun		Untreated	0	0	0	0
Sava	90	1120	0	6	21	41
Sava		560	0	1	13	19
Sava		Untreated	0	0	0	0
Stratos	91	1120	13	29	95	99
Stratos		560	5	20	91	99
Stratos		Untreated	0	3	10	54
LSD (p=0.05)			9	14	18	21

Table 9. Regrowth (%) in potato cultivars sprayed with Saltex on 11 August 2023.

Cultivar	GS at application	Saltex dose rate (l/ha)	Leaf desiccation (%)		
			25 Aug.	6 Sep.	13 Sep.
Spunta	91	1120	1	1	1
Spunta		560	1	4	9
Spunta		Untreated	0	0	0
Desiree	91	1120	6	22	38
Desiree		560	5	55	69
Desiree		Untreated	0	0	0
Ydun	69	1120	18	98	100
Ydun		560	2	13	56
Ydun		Untreated	0	0	0
Sava	90	1120	3	58	76
Sava		560	0	0	5
Sava		Untreated	0	0	0
Stratos	91	1120	1	1	1
Stratos		560	1	1	1
Stratos		Untreated	0	0	0
LSD (p=0.05)			4	19	25

Desiccation of potato cultivars three days after application of 1120 l/ha Saltex.

Figure 1 shows the course of desiccation of leaves and Figure 2 the corresponding course of stem desiccation.

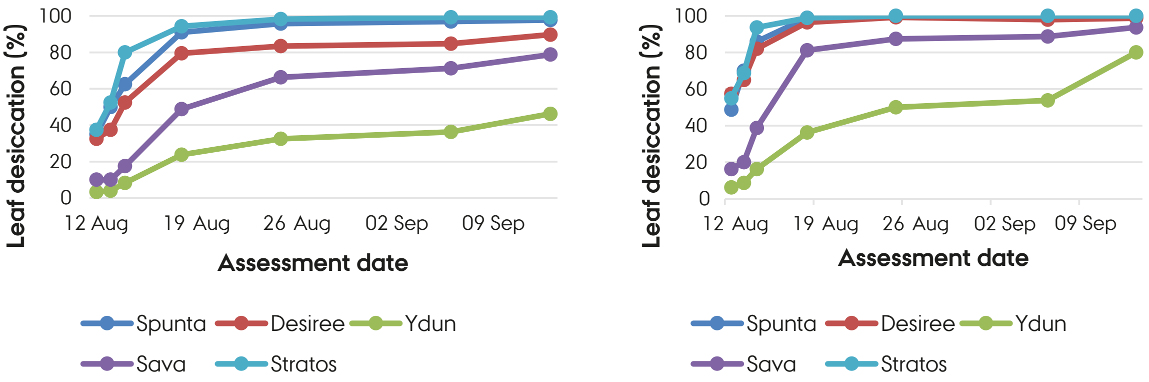

Figure 1. Desiccation of leaves in five potato cultivars following application of Saltex on 11 August 2023. To the left: 560 l/ha Saltex; to the right: 1120 l/ha Saltex.

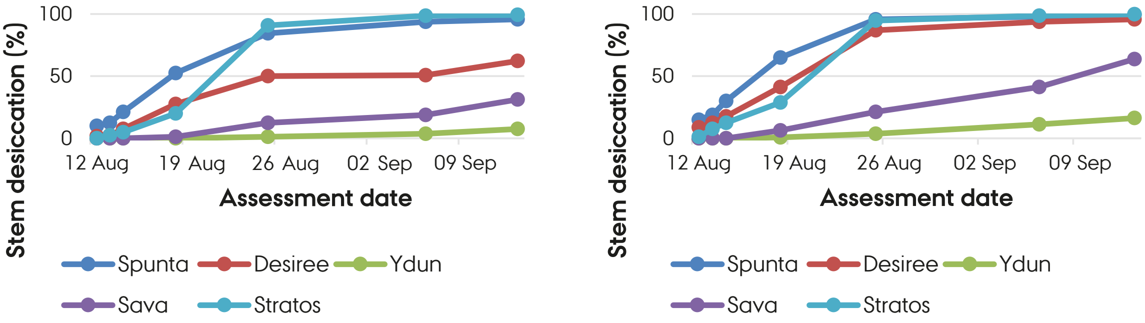

Figure 2. Desiccation of stems in five potato cultivars following application of Saltex on 11 August 2023. To the left: 560 l/ha Saltex; to the right: 1120 l/ha Saltex.

In the second experiment in 2023, the intention was to study the effect of Saltex applied under different weather conditions. The actual applications should be placed relatively close in order to avoid changes in crop development having an influence on the result. The results are shown in Tables 10 and 11. The experiment was carried out in Sava, but the obtained desiccation effect was higher than the desiccation effect on Sava seen in the cultivar experiment (Tables 7 and 8), probably because it was a little more mature. Desiccation effects were generally very high at both Saltex dose rates. Therefore, Saltex dose rates should have been lower in order to study possible interactions with weather conditions at application.

Table 10. Desiccation of potato cv Sava following application at five different timings with two dose rates of NaCl applied in Saltex under different weather conditions in 2023. Leaf desiccation.

Application time	GS at application	Saltex dose rate (l/ha)	Leaf desiccation (%)		
			18 Aug.	25 Aug.	6 Sep.
Untreated			20	35	65
10 Aug., morning	91	1120	98	99	100
10 Aug., afternoon	91	1120	99	100	100
11 Aug., morning	91	1120	96	99	100
11 Aug., afternoon	91	1120	97	99	100
14 Aug., morning	92	1120	60	95	100
10 Aug., morning	91	560	85	91	96
10 Aug., afternoon	91	560	95	98	99
11 Aug., morning	91	560	91	98	99
11 Aug., afternoon	91	560	88	97	99
14 Aug., morning	92	560	40	90	100
LSD (p=0.05)			5	4	3

Table 11. Desiccation of potato cv Sava following application at five different timings with two dose rates of NaCl applied in Saltex under different weather conditions in 2023. Stem desiccation.

Application time	GS at application	Saltex dose rate (l/ha)	Stem desiccation (%)		
			18 Aug.	25 Aug.	6 Sep.
Untreated			0	2	16
10 Aug., morning	91	1120	14	20	94
10 Aug., afternoon	91	1120	14	25	96
11 Aug., morning	91	1120	13	20	97
11 Aug., afternoon	91	1120	13	20	97
14 Aug., morning	92	1120	0	10	93
10 Aug., morning	91	560	8	16	81
10 Aug., afternoon	91	560	10	19	86
11 Aug., morning	91	560	10	19	91
11 Aug., afternoon	91	560	9	16	90
14 Aug., morning	92	560	0	8	83
LSD (p=0.05)			3	4	6

Conclusion

Desiccation of potatoes with sodium chloride was studied in two years, using the commercially available product Saltex, which is a concentrated brine solution. In 2022 four experiments tested desiccation of potatoes (cv. Kuras) by applying Saltex under different conditions. Due to crop conditions, desiccation effects were generally very low and did not allow conclusions regarding the tested factors, additives, application technique and weather conditions. The factor responsible for the low effect of Saltex in 2022 is not known but could be due to the cultivar Kuras, the growth conditions with too high a nitrogen application dose rate, too early an application at growth stage 69, or a combination of these factors.

In 2023, generally high desiccation effects of 1120 and 560 l/ha Saltex were found desiccating potato cultivars Spunta, Desiree and Stratos with applications at growth stage 91. The late cultivar, Ydun, was at growth stage 69 at application, and desiccation was limited at this growth stage. The desiccation effect of the cultivar Sava was slightly lower than that of the other cultivars at growth stage 90, whereas an effective desiccation was obtained at growth stage 91-92 with the two Saltex dose rates applied.

The results from 2023 demonstrate that sodium chloride could be a possible desiccant for potatoes. This requires an authorisation. The dose rate necessary to obtain an effective desiccation is very large and makes sodium chloride difficult to use in practice. However, a reduced dose rate of sodium chloride could defoliate the upper part of the potato crop and increase the efficacy of a following chemical treatment. This combination remains to be tested.

Acknowledgements

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References

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XI List of chemicals

Fungicides and adjuvants		
Name	**Active ingredients**	**Gram /l or kg**
Agropol	Adjuvant	-
Amistar	Azoxystrobin	250
Ascra Xpro	Prothioconazole + bixafen + fluopyram	130 + 65 + 65
Balaya = Revycare	Mefentrifluconazole + pyraclostrobin	100 + 100
BAS 754 00F	Prothioconazole + mefentrifluconazole	100 + 50
BAS 768 00F	Revysol + sulphur	600 + 25
BAS 831 00F	Fluxapyroxad + metyltetraprole	40 + 40
Bion 50 WG	Acibenzolar-S-methyl/benzothiazole	500
Charge	Chitosan	30
Comet Pro	Pyraclostrobin	200
Contact	Adjuvant	-
Cymbal WG	Cymoxanil	600
Daxur	Mefentrifluconazole + kresoxim-methyl	100 + 150
Delaro Forte	Prothioconazole + trifloxystrobin	175 + 150
Elatus Era	Azoxystrobin + benzovindiflupyr	30 + 15
Elatus Plus	Benzovindiflupyr	100
Entargo	Boscalid	500
Flexity	Metrafenon	300
Folicur EW 250	Tebuconazole	250
Folicur Xpert	Tebuconazole + prothioconazole	160 + 80
Folpan 500 SC	Folpet	500
Greteg Star	Azoxystrobin + difenoconazole	125 + 125
Imtrex	Fluxapyroxad	62.5
Innox	Prothioconazole	250
Input Triple	Spiroxamine + prothioconazole + proquinazid	200 + 160 + 40
Iodus	Laminarin	45
Juventus 90	Metconazole	90
Kunshi	Fluazinam + cymoxanil	375 + 250
Lalstop G46 WG	*Clonostachys rosea*	1000000000 CFU/kg
Luna Privilege	Fluopyram	500
MCW 406-S	Difenoconazole	250
Navura	Mefentrifluconazole + prothioconazole	50 + 100
Pecari	Prothioconazole	300
Phosphonate	Phosphonic acid	504
Pictor Active	Pyraclostrobin + boscalid	250 + 150
Plexeo 90	Metconazole	90
Polyversum	*Pythium oligandrum* M1	1000000000 CFU/kg
Priaxor	Pyraclostrobin + fluxapyroxad	150 + 75
Proline EC 250	Prothioconazole	250

Fungicides and adjuvants

Name	Active ingredients	Gram /l or kg
Propulse SE 250	Fluopyram + prothioconazole	125 + 125
Prosaro EC 250	Prothioconazole + tebuconazole	125 + 125
Questar	Fenpicoxamid	100
Renol	Adjuvant	-
Revus	Mandipropamid	250
Revycare	Mefentrifluconazole + pyraclostrobin	100 + 100
Revysol	Mefentrifluconazole	100
Revystar XL	Mefentrifluconazole + fluxapyroxad	100 + 50
Revytrex	Mefentrifluconazole + fluxapyroxad	66.7 + 66.7
Revytur	Mefentrifluconazole + sulphur	25 + 600
Serenade ASO	*Bacillus amyloliquefaciens*	7131 x 1012 CFU/l
Shirlan Ultra	Fluazinam	500
Silwet Gold	Adjuvant	-
Sorrento	Adjuvant	-
Sporax	Propamocarb	722
Talius 200 EC	Proquinazid	200
TF2	Biologicals	-
Thiopron 825	Sulphur	825
Thore	Bixafen	125
Univoq	Prothioconazole + fenpicoxamid	100 + 50
V1P	Biologicals	-
Vertipin	Sulphur	700
Zorvec Enicade	Oxathiapiprolin	100

Herbicides

Name	Active ingredients	Gram /l or kg
Agil 100 EC	Propaquizafop	100
Atlantis OD	Mesosulfuron-methyl + iodosulfuron-methyl + mefenpyr-diethyl (safener)	10 + 2 + 30
DFF	Diflufenican	500
Mateno Duo	Aclonifen + diflufenican	500 + 100
Primera Super	Fenoxaprop-p-ethyl + cloquintocet-mexyl (safener)	69 + 33.5
Saltex	2.5% NaCL	-

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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