APPLIED CROP PROTECTION 2021

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Preface

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

The series of reports was initiated in 1991 when the Danish Research Service for Plant and Soil Science (Statens Planteavlsforsøg) as part of the Ministry of Agriculture was responsible for biological testing of pesticides and provided a certificate for biological efficacy based on the level of efficacy in field trials. Later this system was replaced by the EU's legislation for efficacy data. Efficacy testing of pesticides was opened 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. The data on which the writing is based are coming from many sources, depending on the individual chapter. Below is a list with information on funding sources for each chapter in this report.

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

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

Chapter I: Climate data for the growing season 2020/2021 and specific information on disease attacks in 2021. The information was collected by AU.

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

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

Chapter V: Fungicide resistance-related investigations. Testing for fungicide resistance is carried out based on a shared cost covered by projects and the industry. In 2021 ADAMA, BASF, Bayer Crop Science, Corteva Agriscience and Syngenta were involved from the industry. The Swedish part was financed by the Swedish Board of Agriculture, and AU AGRO was involved.

Chapter VI: Validation of the BlightManager DSS for the control of late blight and early blight. Trials in this chapter were financed by GUDP in the BlightManager project. The trials were performed in collaboration with SEGES (Lars Bødker), KMC (Kristian Elkjær), AKV Langholt (Henrik Pedersen and Claus Nielsen), Ytteborg (Kaj Madsen) and LandboNord (Lars Pedersen).

Chapter VII: Comparative epidemiology of late blight and early blight on potato cultivars. Trials in this chapter were financed by GUDP in the BlightManager project. Seed tubers used in this trial were provided by AKV Langholt (Henrik Pedersen and Claus Nielsen) and KMC (Kristian Elkjær).

Chapter VIII: Results of crop protection trials in minor crops in 2021. The projects were financed by various agricultural tax funds, Interreg, GUDP, the Danish Environmental Protection Agency, Dansk Golf Union and Swedish minor use project funding.

Chapter IX: List of chemicals.

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I Climate data for the growing season 2020/2021

Helene S. Kristjansen

This section evaluates the overall weather conditions in Denmark during the growing season with a separate section describing weather conditions at Flakkebjerg where most Aarhus University (AU) trials are located (September 2020-August 2021).

Overall, Denmark experienced a dry autumn where precipitation increased to 177 mm across the country, which was almost 25% less than the 10-year average of 2011-2020. September recorded high temperatures compared to the average for this month, and temperatures during the autumn (Sept.-Nov.) reached 10.1°C, which made autumn 2020 one of the warmest in history (1847-2020).

In general, temperatures during winter 2020/21 were recorded to be at an average level. December was warm and January and February colder than the 10-year average (2011-2020). The temperature during the three winter months reached an average of 1.8°C. The number of frosty days recorded during the winter was 41, and there were 15.3 days with snow cover. Overall, precipitation was low during winter 2020-2021. 155 mm of rain was recorded, which was 20% lower than the 10-year average (2011-2020).

Spring 2021 was cold. Especially April and May were quite cold with a temperature average of 5.6°C and 9.8°C, respectively. March recorded 50.5 mm of rain, which was close to average. Precipitation in April was very low; only 38.5 mm was recorded, which was 40% lower than the 10-year average (2011-2020). Precipitation in May was very high; 107 mm was recorded, which was 126% above the 10-year average (2011-2020). In general, precipitation during the spring was significantly high. With a total of 180 mm recorded, spring 2021 was among the ten years with the highest precipitation since 1874.

Sunny hours in spring 2021 were recorded to be 12% fewer than the 10-year average (2011-2020), especially caused by very few sunny hours during May, which recorded 43% fewer hours of sunshine than the 10-year average (2011-2020).

June recorded an average temperature of 16.0°C, which was 1.1°C above the 10-year average (2011-2020). Rainfall in June was very low with only 29.4 mm recorded, which was 56% lower than the 10-year average (2011-2020). July was quite warm, and the average temperature increased to 18.3°C, which was 1.6°C above the 10-year average (2011-2020), and 2021 was among the ten years with the highest temperature recorded since 1874. Precipitation in July and August was unevenly distributed across the country and was recorded partly as cloudbursts and mainly in Northern Zealand and Jutland. On average, July recorded 76.5 mm, which was 10% above the 10-year average (2011-2020). 74.1 mm of rain was recorded during August, which was 10% below the 10-year average (2011-2020). August recorded an average temperature of 15.7°C, which was 1.1°C lower than the 10-year average (2011-2020).

At Flakkebjerg, especially September and November were characterised by significantly low precipitation with a total of 117 mm during the autumn; precipitation was 30% below the 10-year average at Flakkebjerg (2011-2020). Temperatures in the autumn were close to normal, and few frosty days were recorded in November. Due to low precipitation and high temperatures, especially in November, work in the fields and establishment of crops went well.

Temperatures during the winter were recorded to be at an average level. The lowest temperature during the winter was -11.7°C in February. February recorded the lowest temperatures with an average of 0.2°C, which was 16% below the 10-year average at Flakkebjerg (2011-2020). The winter in general and especially February had little precipitation; with a total of 121 mm, precipitation was 24% below the 10-year average at Flakkebjerg (2011-2020). Low precipitation continued during April, and low temperatures were generally recorded during the spring. Precipitation increased significantly in May; 93.8 mm was recorded, which was 60% above the 10-year average at Flakkebjerg (2011-2020). High precipitation caused difficulties for applications in the field. The temperature average during the summer reached 17.4°C, which was 4% above the 10-year average (2011-2020). In general, fungicide trials at Flakkebjerg were irrigated 2-3 times during June and July to keep the crops growing and to ensure disease attacks. Harvesting the crops was without complications due to the normal weather conditions. Moderate to high levels of disease attack were observed in almost all fields. Cereal yields were moderate.

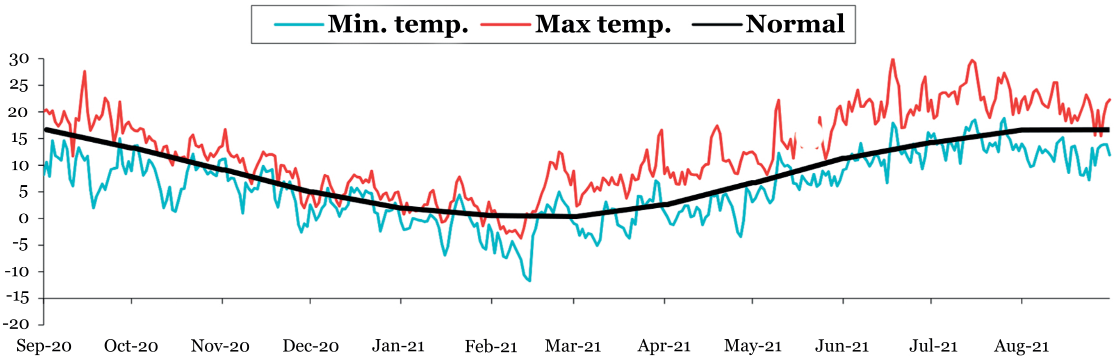


Figure 1. Climate data graph from AU Flakkebjerg for the growing season September 2020-August 2021. The temperature is in °C.

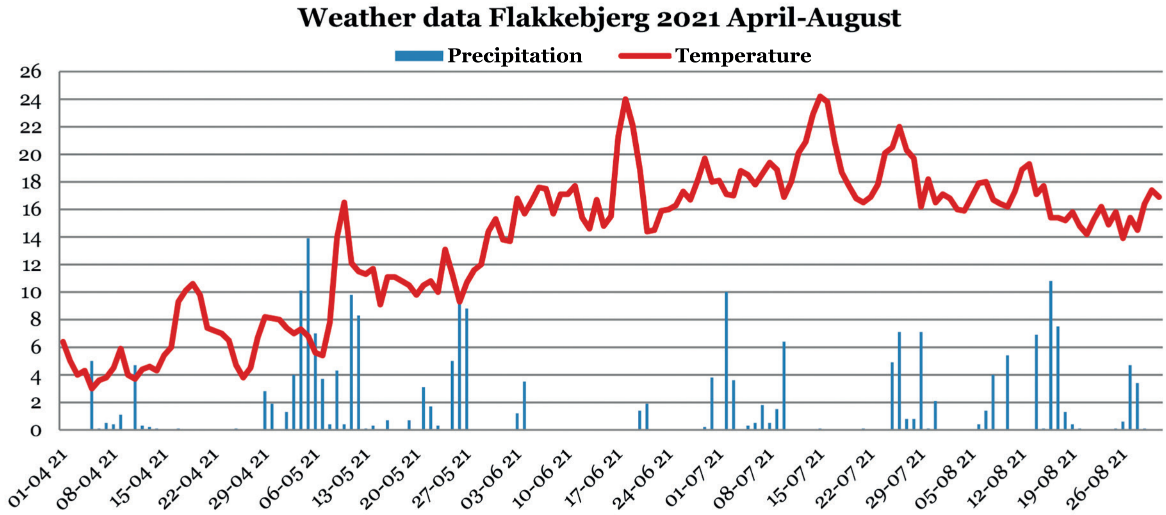


Figure 2. Climate data graph from AU Flakkebjerg for spring and summer 2021. The temperature is in °C and precipitation in mm.

The automatic weather station at Flakkebjerg is located 12 km from the West Zealand coast. The climate at Flakkebjerg is representative of the area in which most of our trials are located. The normal climate is given as an average of forty years (1973-2013).

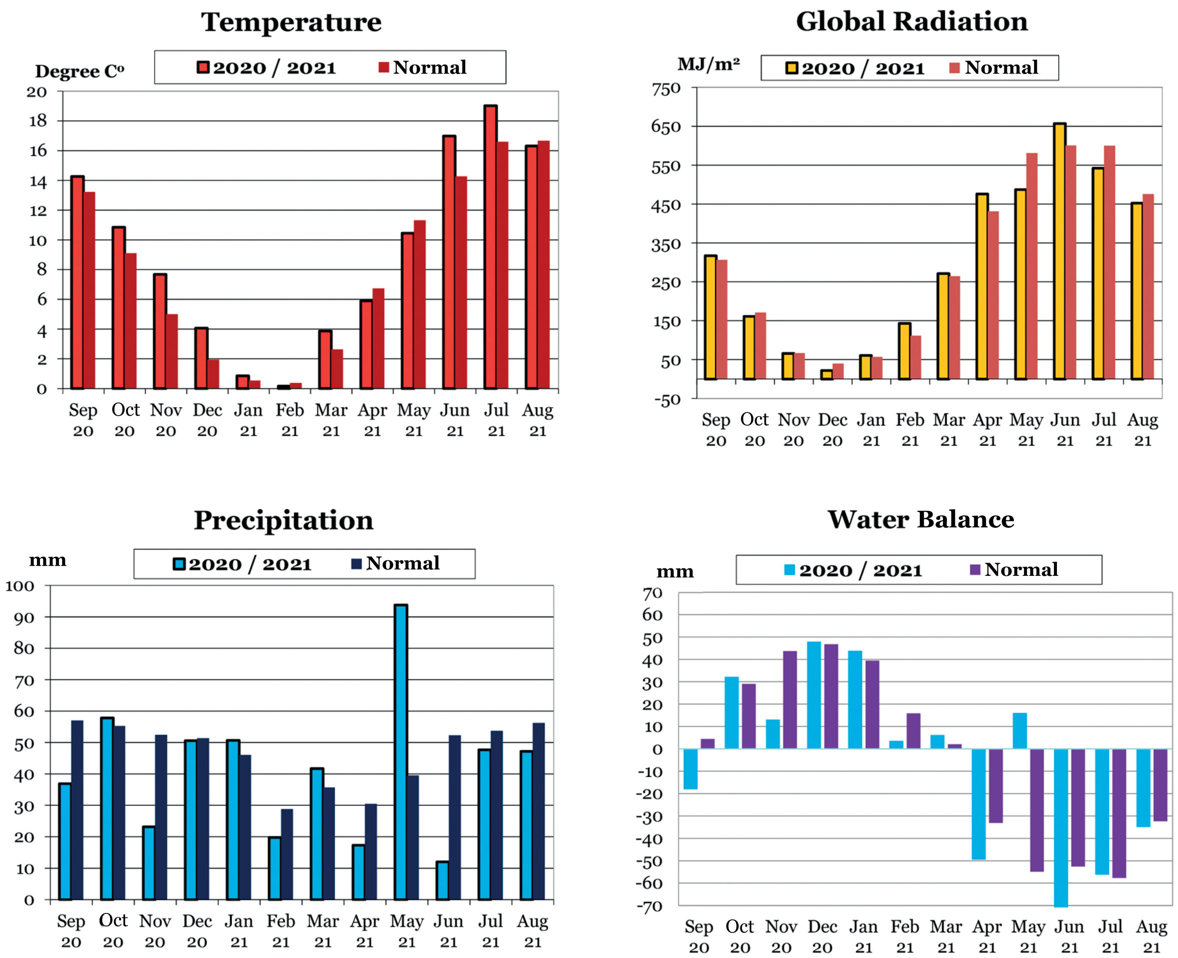
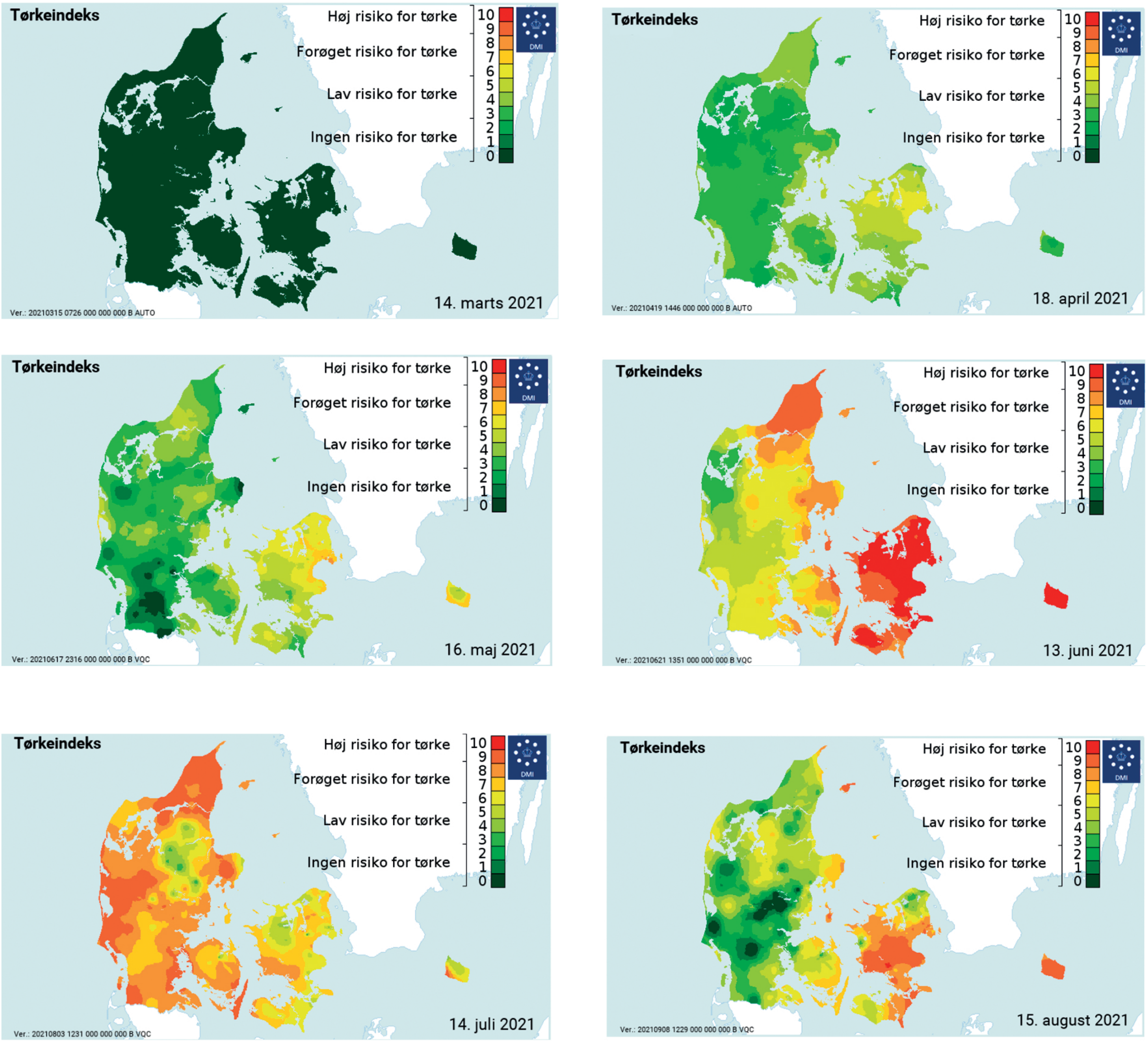


Figure 3. Climate data from AU Flakkebjerg for the growing season September 2020-August 2021. The temperature is in °C, the global radiation is measured in MJ/m2, the precipitation is in mm, and the water balance is the difference between precipitation and potential evaporation.



Drought Index 2021 (DMI)
Scale:

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

Figure 4. Drought index for May-August 2021. Danish Meteorological Institute (DMI).

1. Disease attacks in 2021

Lise N. Jørgensen, Helene S. Kristjansen & Hans-Peter Madsen

Described in this chapter is the occurrence of diseases present in the fungicide trials in 2021. This knowledge is important for evaluating 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*). At the trial station at Jyndevad in Jutland, the sandy soil makes conditions perfect for powdery mildew on cereals. The high infection rate at Jyndevad provided also in 2021 good opportunities for ranking the efficacy of products and cultivars. The average level of attack of powdery mildew was low in the season 2021. This was confirmed by the national monitoring system carried out by the advisors and organised by SEGES. Minor attacks in limited numbers of cultivars were observed during the season, primarily in the cultivar Chevignon. Few and only minor and insignificant attacks of powdery mildew were recorded in trials at Flakkebjerg in 2021.

Septoria tritici blotch (*Zymoseptoria tritici*). Conditions of high humidity with many days of precipitation in May increased the risk of *Septoria* tritici blotch. By the end of May, the attack of *Septoria* was expected to cause a major loss of yield, if not controlled. But due to periods with low temperatures and also very high temperatures (>30°C) together with drought in June, the *Septoria* attack was considerably reduced, especially on the two upper leaves. The level of *Septoria* attack varied depending on sites and cultivars, but in general, across the country, the attacks were moderate. At Flakkebjerg susceptible cultivars like Cleveland and Hereford developed severe attacks at all leaf levels and provided good opportunities for ranking fungicide efficacy. Here, the attack was also stimulated by 1-3 irrigations during dry periods. As a result of the conditions at Flakkebjerg, the attack of *Septoria* reached approx. 5% on leaf 2 and 30% on leaf 1 at growth stage (GS) 71-75.

Yellow rust (*Puccinia striiformis*). In fields at Flakkebjerg, the susceptible cultivars Benchmark and KWS Zyatt were inoculated with yellow rust in late April, using spreader plants. Temperatures were low in May, which delayed the development of yellow rust. First clear development was recorded by the end of May, and by early June the attack was significant. Benchmark is well known for its high susceptibility, and attacks developed to a moderate to high level on the upper leaves. In Benchmark the attack increased to 36% at GS 75. KWS Zyatt is also susceptible to yellow rust, but in trials at Flakkebjerg only a minor attack developed in this cultivar despite inoculation in April. Attacks of yellow rust are known to reduce yields. In the cultivar Benchmark an attack of yellow rust in 2021 reduced yields by 2-3 t/ha.

Brown rust (*Puccinia triticina*). The mild winter 2020/2021 provided good conditions for inoculum to survive the winter. The cultivar Kvium is susceptible, but due to the cold periods in the spring only a minor attack of brown rust was recorded late in the season. Despite use of spreader plants in a trial with Kvium, only a late and insignificant attack developed, which provided limited opportunities for distinguishing differences between fungicides.

Tan spot (*Drechslera tritici repentis*). At Flakkebjerg minimal tillage was simulated by pre-infecting a tan spot susceptible cultivar (KWS Firefly), using straw infected with tan spot. An attack of tan spot in KWS Firefly developed slowly in May due to cold weather, and no early T1 treatments against tan spot were needed. In June, the infection spread to the upper leaves, and a severe attack of tan spot provided good opportunities for distinguishing differences between cultivars and fungicides. Due to dry conditions, senescence was rapid, and assessment ended early - as early as during the first week of July. At the last assessment of tan spot at GS 69, the disease level increased to 22% on the flag leaf and 34% on leaf 2.

Fusarium head blight (*Fusarium* spp.). To ensure attack in trials at Flakkebjerg, we inoculated wheat crops with *Fusarium* spores. Inoculation in combination with irrigation during flowering is an effective method of ensuring attack. The moist conditions from both weather conditions and irrigation ensured a high level of attack of *Fusarium* in 2021, which made it possible to distinguish susceptibility in cultivars and also differences in the efficacy of the fungicides.

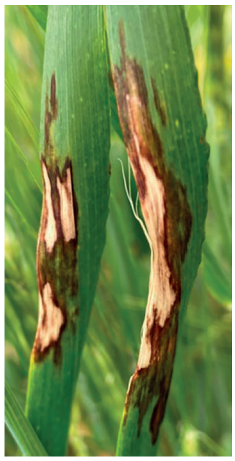
Black ears were a widespread phenomenon in the eastern part of Denmark in winter wheat in 2021. The reason for the development of black ears is still unclear but most likely due to climatic conditions with very high temperatures around flowering and drought during June and July. No links to take-all, eyespot or barley yellow dwarf virus (BYDV) could be seen. The early ripening of ears resulted in secondary fungi attacking the ears. Attacks of secondary fungi (*Alternaria, Cladosporium*) are common but are usually seen in years with high precipitation and delayed harvest. The black ears were seen to impact 5-20% of heads in a field, impacting the yield in a negative way. Some cultivars, e.g. Graham, had slightly more attacked heads than other cultivars, and early sowing also caused higher incidences. At Flakkebjerg black ears were present in all fields with winter wheat. Different fungicide treatments were not seen to influence the incidence of black heads.

Triticale and rye

Yellow rust (*Puccinia striiformis*). Triticale trials at Flakkebjerg were naturally infected with yellow rust. Triticale is severely infected in most years, and 2021 was no exception. Due to the cold weather in May, yellow rust developed slowly, but the attack increased severely at the beginning of June. At GS 71, at the end of June, levels increased to 68% on leaf 1 and 80% on leaf 2. The disease level provided good opportunities for differentiating between the performances of the fungicides.

Glume blotch (*Phaeosphaeria nodorum*) appeared in triticale early in the season on the lower leaves. Glume blotch is of less importance regarding influence on yields in triticale. Attacks were moderate, but due to high humidity during May, the attack spread to the upper leaves. At the beginning of June, the attack of glume blotch increased to 2% on leaf 2 and 25% on leaf 3, which provided good opportunities for differentiating between the performances of the fungicides tested.

***Rhynchosporium* (*Rhynchosporium commune*).** In rye trials, a severe attack of *Rhynchosporium* developed during May and at the begining of June. The disease level gave good opportunities for ranking the performances of the products. By the end of June, at GS 73, the attack of *Rhynchosporium* in rye increased to 52% on leaf 1 and 61% on leaf 2.



Winter barley

***Rhynchosporium* (*Rhynchosporium commune*)** was the most dominant disease in 2021, and the level of attack in winter barley trials was moderate to severe depending on cultivar. A severe attack of *Rhynchosporium* developed in the cultivars KWS Meridian and Neptun. The high incidence of *Rhynchosporium* provided good opportunities for differentiating between the performances of the products. The average attack of *Rhynchosporium* reached a level of 48% on leaves 2-3 at GS 71-77.

Brown rust (*Puccinia hordei*). Brown rust was also a dominant disease in winter barley in 2021. All cultivars showed symptoms of rust. At the field trial site at Flakkebjerg, severe attacks of brown rust developed in the cultivars KWS Meridian and Kosmos, which provided good opportunities for ranking the efficacy of the different fungicides in 2021. The average attack of brown rust in this year's trial at AU reached a level of 24% on leaves 2-3 at GS 75-79.

Powdery mildew (*Blumeria graminis*). Recordings carried out by the advisors in the national monitoring system organised by SEGES showed that the level of mildew attack was very low. Due to a very low level of attack of mildew at Flakkebjerg in 2021, it was not possible to differentiate between the performances of the products.

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 recorded to be widespread in Denmark in the cultivar RGT Planet. In field trials at Flakkebjerg, the level of attack of net blotch was moderate to high due to highly susceptible cultivars such as Chapeau and RGT Planet. In trials, the susceptible cultivars provided good possibilities for ranking the performances of the fungicides. Attack of net blotch in Chapeau and RGT Planet reached an average level of 25% on leaf 2 at GS 71-79.

Brown rust (*Puccinia hordei*). In general, the attack of brown rust was less widespread across the country, and for most sites a demand for control was not seen until late in the season. At Flakkebjerg, all cultivars developed attacks of brown rust, although to a variable extent. The attack of brown rust developed from mid-June, which provided good opportunities for ranking the performances of the fungicides. The attack at Flakkebjerg reached an average of 21% on leaf 2 at GS 75-79.

Ramularia leaf spot (*Ramularia collo-cygni*). *Ramularia* developed late in 2021 but was present in all trials at Flakkebjerg. Especially the cultivars KWS Irina, Fairway and RGT Planet developed severe attacks of *Ramularia* in 2021. Due to the late increase of attack, few assessments were possible. The attacks of *Ramularia* reached an average level of 22% on leaf 2 at GS 77-79.

Yield increases in fungicide trials in cereals

In the western parts of Denmark, farmers experienced unpredictable weather with widespread rainfall during harvest, which complicated harvest. Weather conditions in the eastern parts of Denmark were much more constant with less precipitation which gave good opportunities for harvesting cereal trials at Flakkebjerg in 2021. Average winter wheat yields in Denmark reached 78 hkg, which was a little higher than 2020. In winter wheat trials at Flakkebjerg, yields varied beween 62 hkg/ha and 108 hkg/ha with an average of 80 hkg/ha. Increases from standard fungicide treatments in winter wheat were approx. 9.9 hkg/ha (Table 1), which was about average when looking across many seasons.

No winter barley trials were harvested in 2021 due to a widespread attack of yellow dwarf virus at the trial sites. Spring barley trials showed poor crop stands as a result of late sowing and challenging cropping conditions early in the season. Trials was irrigated twice during the growing season, but yields varied undesirably between trials and cultivars. Spring barley yielded between 35 dt/ha and 75 dt/ha. Increases from standard fungicide treatments in spring barely were approx. 8 hkg/ha.

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 give the number of trials behind the figures. Data originate from SEGES and AU-Flakkebjerg trials.

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

II Disease control in wheat

Lise N. Jørgensen, Thies M. Heick, Niels Matzen, Hans-Peter Madsen, Helene S. Kristjansen, Sidsel Kirkegaard, Christian A. S. Nielsen & Anders Almskou-Dahlgaard

Introduction

In this chapter field trials in cereals carried out with fungicides in 2021 are described in brief, and results are summarised. In graphs or tables are also included results from previous years if the trial plan covers several years. Included are main results on major diseases from both protocols with new fungicides and protocols in which products applied at different dose rates and timings are compared. Some of the trial results are used as a part of the Biological Assessment Dossier, which the companies must prepare for new products or for re-evaluations of old products. Other parts of the results aim at solving questions related to optimised use of fungicides in common control situations for specific diseases. Apart from the tables and figures providing main data, a few comments are given along with some concluding remarks. Most data summarised in this chapter are funded by the companies Bayer, BASF, Corteva and Syngenta, who pay to have their products tested. Data from the activity organised under the umbrella of EuroWheat financed by BASF are also presented. This activity is organised by Aarhus University (AU) in collaboration with different organisations in other countries. Results from the RustWatch project are also presented, and this activity is financed by Horizon 2020 where activities are carried out in collaboration with many partners in Europe. All data from the project are analysed by AU, which also publishes the data. In several trial plans individual treatments are included based on AU's own initiative.

Methods

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

Attack of diseases in the trials are assessed at approximately 10-day intervals during the season. Per cent leaf area attacked by the individual diseases is assessed on specific leaf layers in accordance with EPPO guideline 1/26 (4) for 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 LSD95 values or specific letters are included. Treatments with different letters are significantly different, using the Student-Newman-Keuls model. When a net yield is calculated, it is converted to hkg/ha based on deducting the cost of chemicals used and the cost of application. The cost of application has been set at DKK 70 and the cost of chemicals extracted from the database at SEGES. The grain price used is 150 DKK/hkg wheat and 140 DKK/hkg barley (= dt).

1. Control of diseases in winter wheat

Comparing effects from SDHIs

As part of the EuroWheat activity, 10 trials were carried out following the same protocol and located in different countries. The focus of the trials was to investigate the efficacy of SDHIs (succinate dehydrogenase inhibitors) in areas with different climates and levels of resistance. One trial was located at Flakkebjerg in the cultivar Hereford and treated at GS 37-39 (27 May). The trial developed a severe attack of Septoria tritici blotch. Proline EC 250 and Revysol were both included and provided low and high levels of control, respectively (Table 1). The analysis of the mutations in the trials indicated occurrence of only few SDHI mutations in the Danish trial.

Similar trials were conducted in other countries and showed distinct differences in levels of control, depending on the locality. The average results from nine European trials (France, Poland, Germany, Belgium, the UK, Ireland and Denmark) carried out during two seasons are shown in Figures 1 and 2. The results in Figure 1 indicate similar levels of control as in the Danish trial. The effect in Ireland and the UK indicated less good control from SDHIs (data not shown). In those countries Revysol performed better than SDHIs. Yield responses from the trials reflected the level of disease control (Figure 2).

Table 1. Effect of applications on control of *Septoria* in wheat, using SDHIs and azoles. Treatments were applied at GS 37-39. One trial (21328). EuroWheat.

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase
GS 37-39	Dose	GS 69 Leaf 2	GS 69 Leaf 3	GS 75 Leaf 1	GS 75 Leaf 2	GS 77 Leaf 2	hkg/ha
1. Untreated		15.8	90.0	15.0	47.5	4.3	86.0
2. Revysol	1.0	3.8	52.5	5.3	10.8	37.5	9.6
3. Revysol	1.5	2.9	37.5	3.3	5.3	47.5	8.7
4. Proline EC 250	0.8	11.3	85.0	10.5	23.8	20.0	2.1
5. Questar	2.0	1.4	27.5	1.6	2.8	65.0	7.4
6. Revystar XL	1.5	0.8	22.5	1.1	2.5	62.5	12.1
7. Revytrex	1.5	0.6	22.5	1.6	2.8	53.8	9.9
8. Elatus Era	1.0	1.8	35.0	1.4	3.0	52.5	9.5
9. Ascra Xpro	1.5	0.9	27.5	1.6	3.0	56.3	11.3
10. Imtrex (fluxapyroxad)	2.0	1.4	30.0	1.3	2.8	51.3	8.4
11. Thore (bixafen)	1.0	1.4	27.5	1.9	3.8	52.5	6.8
12. Elatus Plus (solatanol)	0.75	1.1	35.0	1.8	3.3	45.0	9.7
13. Silvron Xpro (bixafen+fluopyram)	1.0	1.4	32.5	1.9	3.0	52.5	6.8
14. Balaya	1.5	3.5	50.0	2.5	5.0	42.5	9.5
LSD_{95}		3.9	13.9	3.4	7.3	16.2	5.4

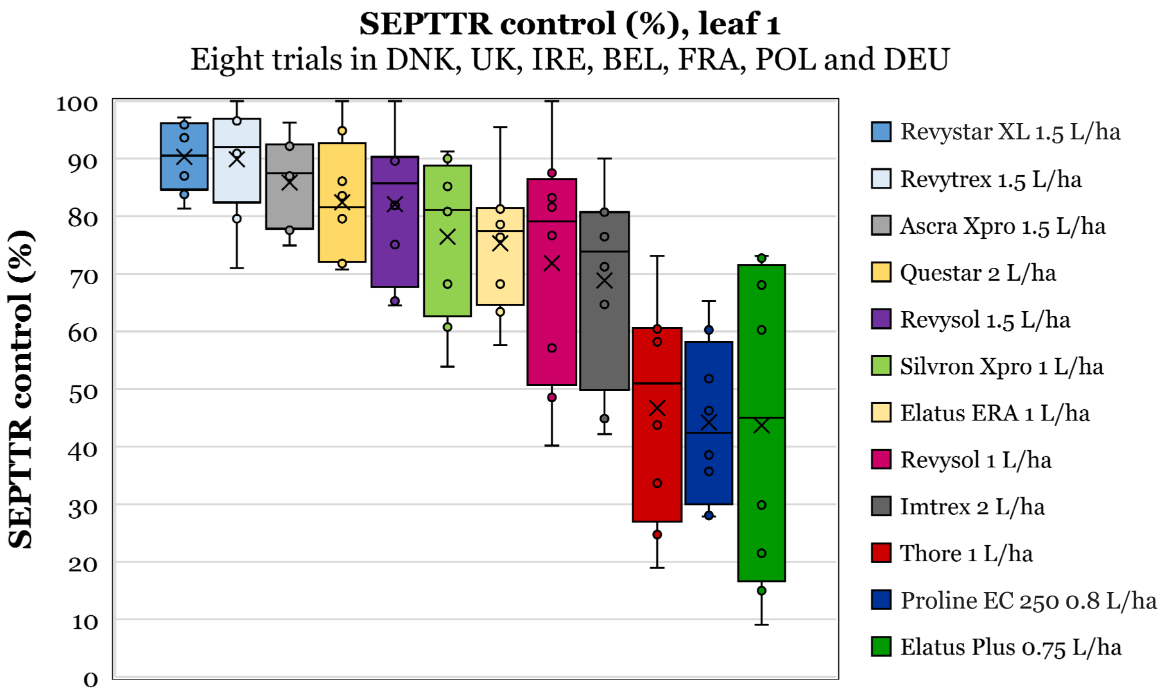


Figure 1. Control of *Septoria*, using azoles, SDHIs and mixtures. Data from eight trials carried out in 2021 as part of EuroWheat. Trials were carried out in France, Germany, Poland, Belgium, Ireland, the UK and Denmark.

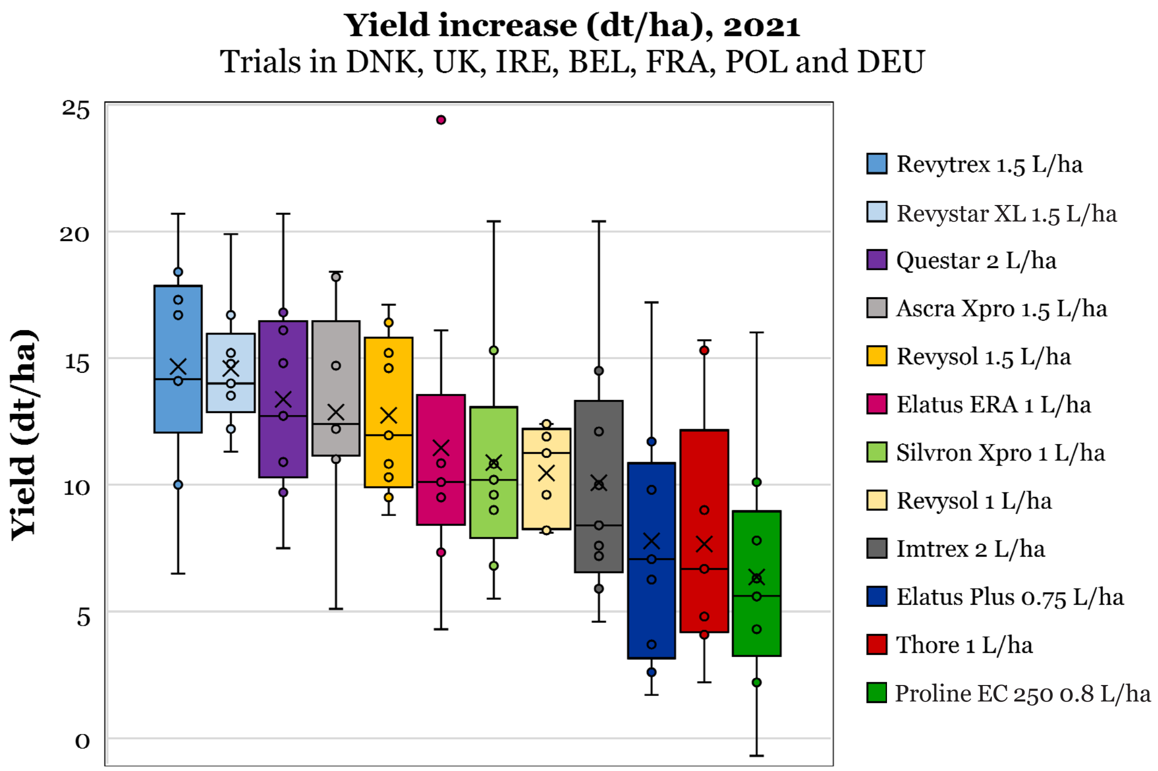


Figure 2. Yield response from treatments with azoles, SDHIs and mixtures. Data from nine trials carried out in 2021 as part of EuroWheat. Trials were carried out in France, Germany, Poland, Belgium, Ireland, the UK and Denmark.

Comparison of azoles (21329)

In two trials different azoles were tested in the cultivar Hereford at AU Flakkebjerg and VELAS near Horsens. The trials included two treatments using two half recommended rates applied at GS 33 and GS 45-51. Both trials developed significant attacks of *Septoria*, and assessments showed a clear ranking of the efficacy of the products (Table 2; Figure 3). The new azole product, Revysol, has been included in the testing since 2017. In all seasons this product showed very good control (approx. 90%) compared with the old solo azoles as well as the azole mixtures, which only provided *Septoria* control in the range of 30-50%. Generally, prothioconazole is known to be significantly influenced by the current changes in mutation which have taken place in the *CYP51* gene.

Looking at the performance of azoles during a longer space of time, the drop in performance began in 2014, was less pronounced in 2015 but continued in 2016 (Figure 4). Part of the yearly variation can be linked to the levels of attack, but as discussed in chapter IV the *Septoria* populations have changed and do now include far more mutations than previously. The mutations are known to influence the sensitivity to azoles in general but are also seen to influence specific azoles differently. The drop in the efficacy of tebuconazole has been known since about 2000. However, the drop in performance from tebuconazole used alone has changed since 2017 when tebuconazole was seen as the azole gaining some efficacy again. Similarly, difenoconazole gained slightly better efficacy. For both tebuconazole and difenoconazole, this is linked to higher proportions of the azole mutations D134G and V136A in the *Septoria* population. The mixture prothioconazole + tebuconazole has also performed better in previous seasons as the two actives are seen to support each other when it comes to controlling the different strains with different mutations. However, both trials from 2021 now show very similar control from all old azoles, which makes it difficult to differentiate their potential control. This was also the case for the mixture with Prosaro EC 250, which in this year's trials performed similarly to solo azoles.

Table 2. Average *Septoria* and yield responses from treatments in winter wheat. Two trials in 2021 (21329).

Treatments, l/ha		% *Septoria*				Yield & yield increase hkg/ha	Net yield hkg/ha
GS 31-32	GS 51-55	GS 55/61 Leaf 2	GS 72/75 Leaf 2	GS 75 Leaf 1	% GLA Leaf 1		
1. Proline EC 250 0.4	Proline EC 250 0.4	3.5	38.4	23.1	2.5	3.1	-0.1
2. Juventus 90 0.5	Juventus 90 0.5	2.2	35.5	21.9	3.1	3.0	0.5
3. Folicur EW 250 0.5	Folicur EW 250 0.5	3.4	38.8	21.5	2.3	3.1	-
4. Proline EC 250 0.4	MCW 406-S 0.25	2.5	36.8	18.3	5.4	3.2	-
5. Prosaro EC 250 0.5	Prosaro EC 250 0.5	2.3	36.6	20.4	3.1	4.8	3.3
6. Proline EC 250 0.4	Greteg Star 0.5	2.6	37.0	19.1	7.9	2.6	0.5
7. Revysol 0.75	Revysol 0.75	1.5	11.1	2.9	40.6	11.6	-
8. Revysol 0.375 + Proline EC 250 0.2	Revysol 0.375 + Proline EC 250 0.2	1.3	13.6	6.5	30.6	9.9	-
9. Untreated		5.4	52.6	31.9	0.0	74.7	-
No. of trials		2	2	2	2	2	2
LSD_{95}		1.2	5.6	3.2	3.9	2.3	-

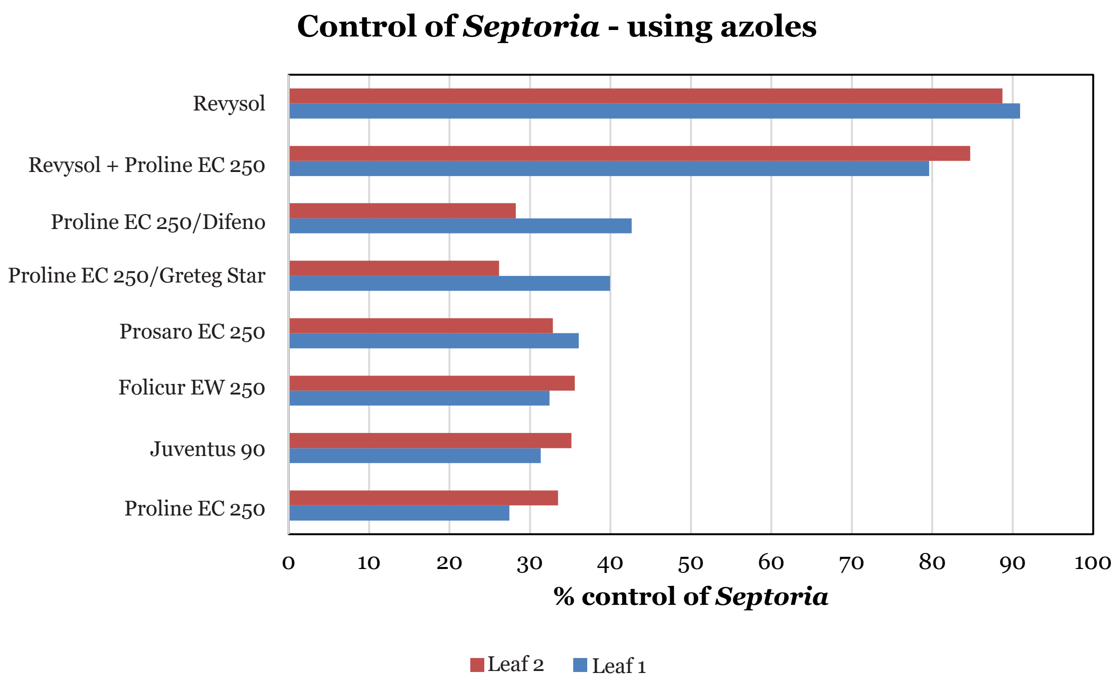


Figure 3. Per cent control of *Septoria*, using two half rates of different azoles. Average of two applications at GS 33-37 and 51-55. Two trials in 2021 (21329).

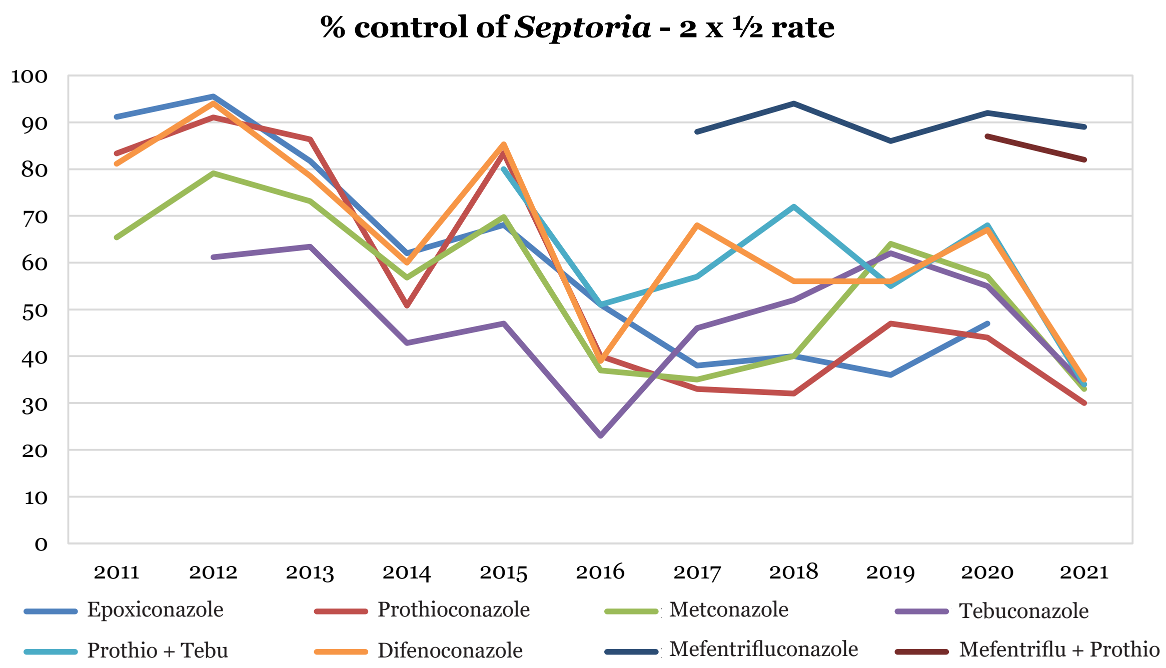


Figure 4. Per cent control of *Septoria*, using two half rates of different azoles. Average of two applications at GS 33-37 and 51-55. Development of efficacy across years (2011-2021).

Comparison of available solutions for ear treatments (21325)

In line with trials from previous years, treatments with different fungicides were tested when applied during heading (GS 45-51) (1 June) (Table 3). Three trials were carried out; two were located at Flakkebjerg in the cultivars Hereford and Cleveland and one near Horsens in the cultivar Hereford. A cover spray was applied at GS 32, using Prosaro EC 250 (0.35 l/ha). In one treatment at T1, Prosaro EC 250 was mixed with Comet Pro followed by Propulse SE 250 (treatment 10).

Septoria developed a significant attack on both the 2nd leaf and the flag leaves. The control level of *Septoria* on the flag leaves varied between 30% and 85% control (Figure 5). New actives with Balaya and Univoq provided the best control, while the older chemistry with Propulse SE 250 provided slightly inferior control. Also, in this year's trials Propulse SE 250 clearly benefited from mixing with Folicur Xpert.

Yields increased significantly but only moderately from treatments, varying between 2 hkg/ha and 8 hkg/ha. The better treatments, which all included new chemistry, increased yields more than the older chemistry. The early season treatment (GS 32) increased yields by 2 hkg/ha. Net yields were small but positive from almost all treatments (Figure 6). Adding 0.375 l/ha Comet Pro to Prosaro EC 250 at T1 improved yields slightly (comparing treatments 1 and 10). This was seen in all three trials and confirms results from previous seasons in which yields also were improved from an early application of Comet Pro.

Table 3. Effect of ear applications on control of *Septoria*, green leaf area (GLA) and yield responses in wheat when treatments were applied at GS 45-51. Three trials (21325).

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha	TGW g
GS 32	GS 45-51	GS 61-69 Leaf 3	GS 61/65 Leaf 1	GS 69-73 Leaf 2	GS 75-79 Leaf 1	GS 75 Leaf 1			
1. Prosaro EC 250 0.35	Propulse SE 250 1.0	17.9	2.2	10.1	18.8	24.6	4.1	0.1	41.7
2. Prosaro EC 250 0.35	Propulse SE 250 + Folicur Xpert 1.0 + 0.25	17.5	1.3	8.6	14.0	30.8	6.6	2.1	42.6
3. Prosaro EC 250 0.35	Propulse SE 250 + Folicur Xpert 0.75 + 0.25	20.6	2.9	7.7	16.0	31.3	4.7	0.9	42.1
4. Prosaro EC 250 0.35	Univoq 0.75	17.1	1.7	7.6	17.2	31.4	5.8	1.8	42.5
5. Prosaro EC 250 0.35	Univoq 1.0	16.7	1.3	4.8	14.1	42.9	6.6	1.8	42.4
6. Prosaro EC 250 0.35	Univoq 1.25	15.6	1.3	4.2	8.0	48.3	6.6	1.0	42.5
7. Prosaro EC 250 0.35	Balaya 1.125	18.1	2.6	5.8	6.9	46.3	5.8	0.2	42.6
8. Prosaro EC 250 0.35	Balaya 0.75	20.9	3.5	6.8	10.3	37.5	6.5	2.5	42.0
9. Prosaro EC 250 0.35	Prosaro EC 250 + Entargo 0.5 + 0.35	19.8	2.8	11.0	23.9	20.4	3.9	0.0	42.2
10. Prosaro EC 250 0.35 + Comet Pro 0.375	Propulse SE 250 1.0	18.5	2.3	8.4	21.8	22.9	8.1	3.1	41.3
11. Prosaro EC 250 0.35	Greteg Star 1.0	23.7	3.9	12.7	30.1	19.2	3.5	-0.1	41.8
12. Prosaro EC 250 0.35	Untreated	25.3	3.9	15.0	39.2	8.3	2.0	0.8	40.7
13. Untreated	Untreated	31.3	5.1	21.0	43.8	7.5	84.6	-	41.3
No. of trials		3	3	3	3	3	3	3	3
LSD_{95}		3.3	0.2	2.5	2.5	9.5	3.1		1.3

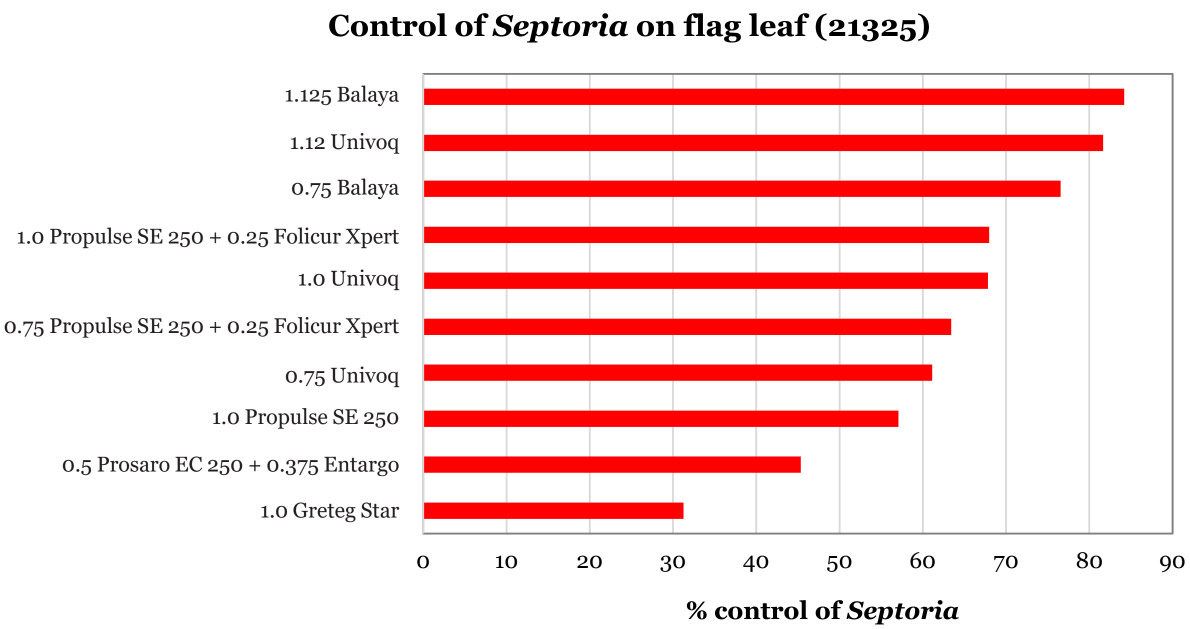


Figure 5. Per cent control of *Septoria* when treated at GS 45-51. Assessed on the flag leaf at GS 75-79. Average of three trials (21325). 44% attack in untreated.

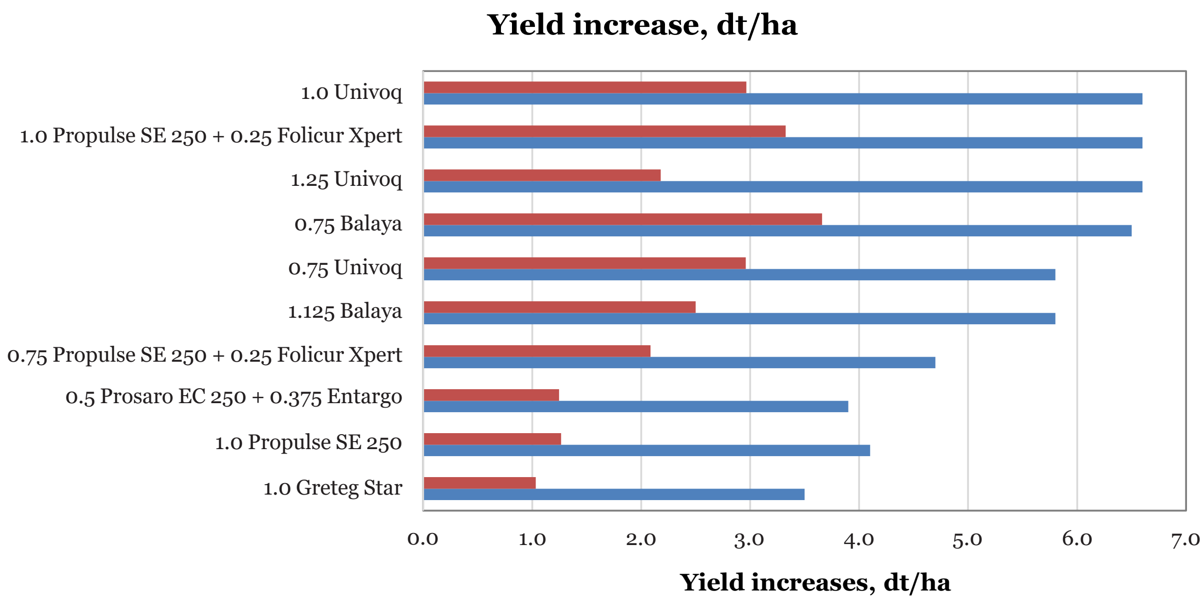
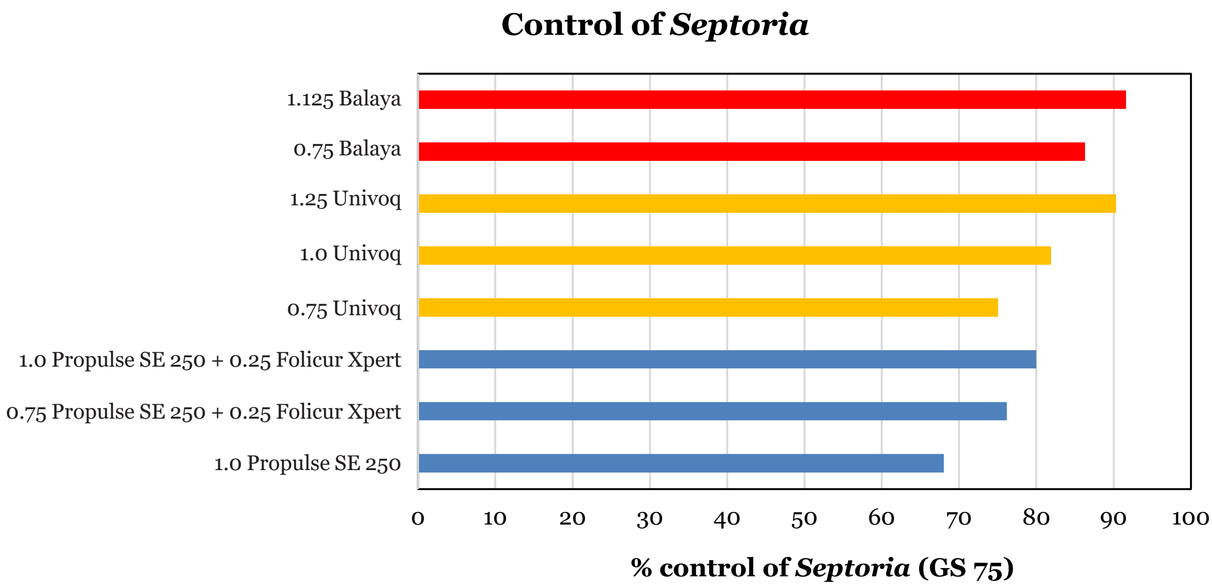


Figure 6. Yield increases (dt/ha) in winter wheat from control of *Septoria* with treatments applied at GS 45-51. Average of three trials (21325). All treatments were also treated at T1 with Prosaro EC 250, 0.35 l/ha. The cost of the early treatment (T1) has not been deducted for the data in the figure.

Summarised data from two seasons' trials with treatments applied at GS 45-51 are shown in Figure 7. Overall, the eight solutions provided good control with limited differences and dose responses. The yield responses in the two seasons were only moderate despite most of the trials being conducted in susceptible cultivars. A minor dose response was seen for Univoq and for Propulse SE 250 + Folicur Xpert but could not be clearly seen for Balaya. In all cases the lower rates were most profitable when focus was on the net yields (Figure 7).



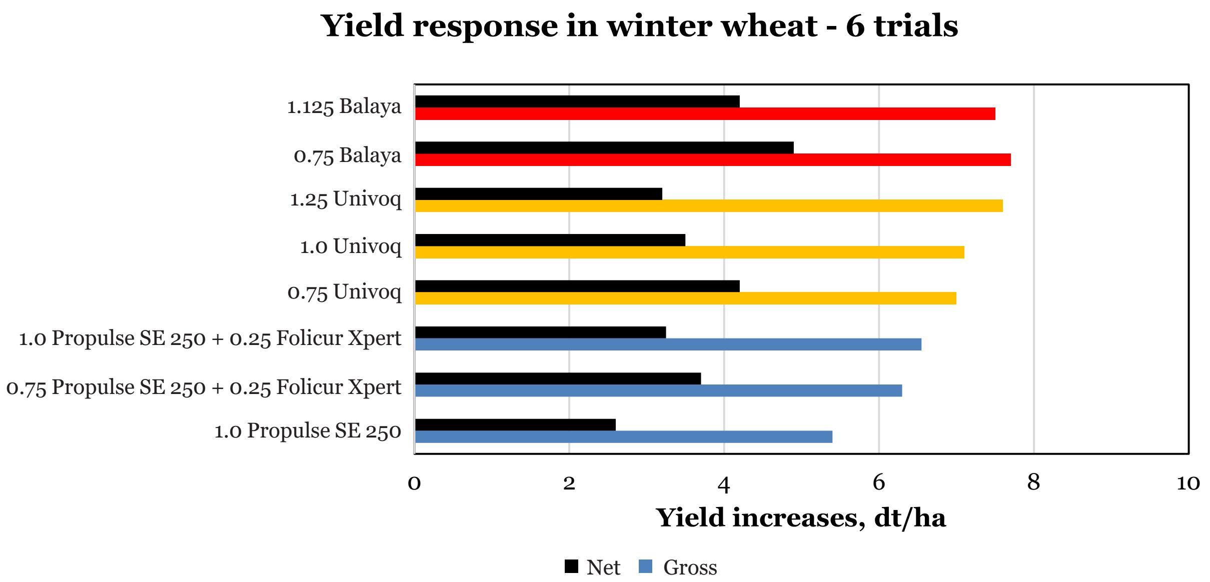


Figure 7. Control of *Septoria* and yield increases (dt/ha) in winter wheat from control of *Septoria* with treatments applied at GS 45-51. Average of six trials from two seasons (20325/21325). All treatments were also treated at T1 with Prosaro EC 250, 0.35 l/ha. This cost has not been deducted for the data in the figure.

Control strategies using two treatments in winter wheat for control of *Septoria* (21326)

Three trials were initiated following the trial plan 21326 (Table 4). The trials were carried out in the cultivars Cleveland (Flakkebjerg) and Hereford (Flakkebjerg and Horsens). The trials compared different treatments using a split ear application applied at GS 37-39 (27 May) and GS 55-61 (10 June). Fifteen different treatments were included in the trials. All treatments including untreated had a cover spray applied at GS 32. Treatments included a mix of new and old chemistry (Table 4).

The trials developed moderate to severe attacks, and most treatments provided acceptable control (Figure 8). When a split ear treatment was used, Univoq or Balaya used in sequence or either of these two used in sequence with Propulse SE 250 + Folicur Xpert gave very similar control of *Septoria*. Combinations which included more of the old azoles (Greteg Star, Prosaro EC 250, Juventus 90 solo or in combination with Entargo) generally gave inferior control. The level of control was nicely reflected in per cent green leaf area (Figure 9).

Yield responses were moderate but significant in the range of 5-14 dt/ha, reflecting the levels of control obtained from the different solutions (Figure 10). Net yield varied between 1 dt/ha and 8 dt/ha. All three trials showed a good correlation between green leaf area and yield responses. Similarly, grain weight increased most following the split ear treatment (Table 4).

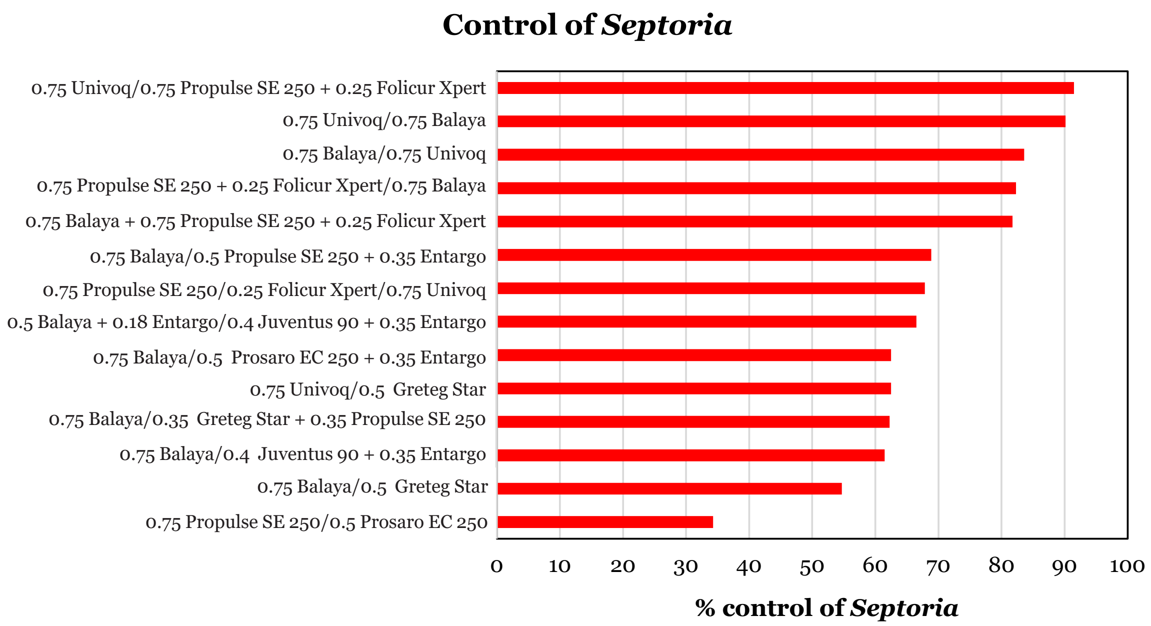


Figure 8. Per cent control of *Septoria* on the flag leaf when treated as a split ear application applied at GS 37-39 and GS 55-61. Average of three trials (21326).

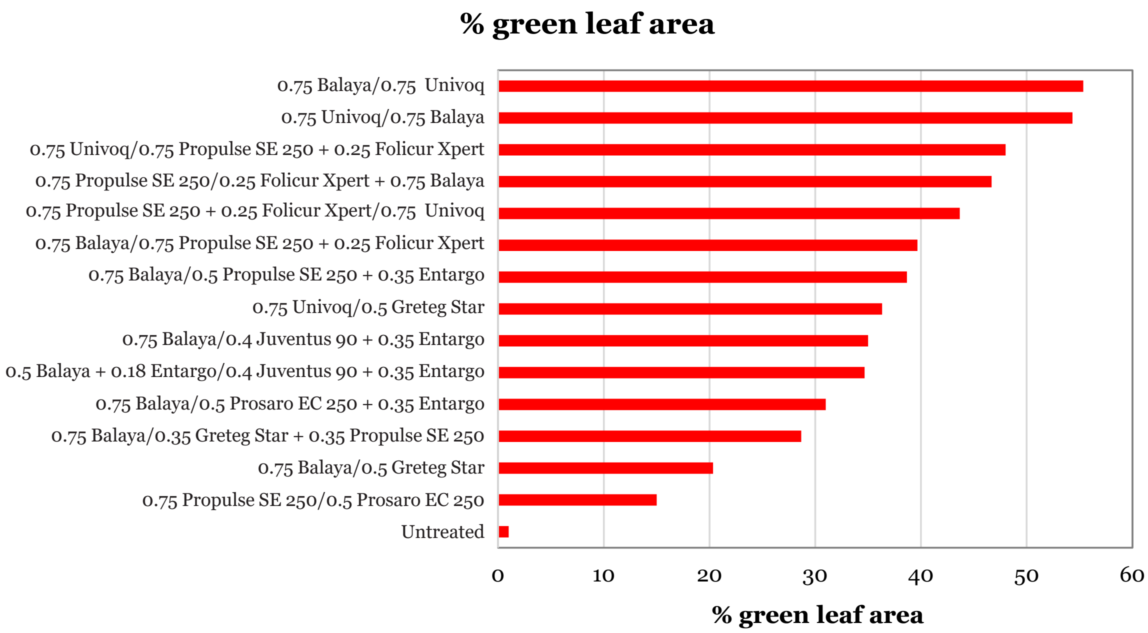


Figure 9. Green leaf area assessed at GS 75-77 on the flag leaf. Average of three trials (21326).

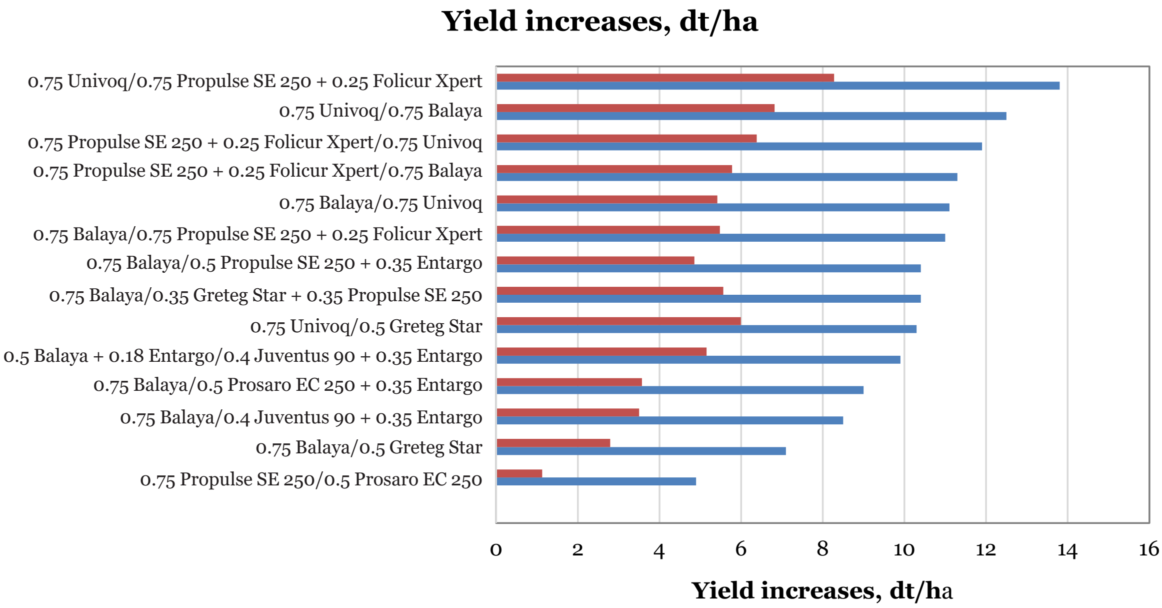


Figure 10. Yield increases in winter wheat (dt/ha) from control of *Septoria*, using split ear treatments applied at GS 37-39 and GS 55-61. Average of three trials (21326).

Table 4. Effect of a split ear applications on control of *Septoria*, green leaf area (GLA), thousand grain weight (TGW) and yield responses in wheat. Three trials (21326). All treatments including untreated were treated with 0.35 l/ha Prosaro EC 250 at GS 32.

Treatments, l/ha 21326		% *Septoria*	% *Septoria*	% *Septoria*	% GLA	TGW g	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 37-39	GS 55-61	GS 69 Leaf 2	GS 69/73 Leaf 1	GS 75/79 Leaf 1	GS 75/79 Leaf 1			
1. Untreated	Untreated	50.4	16.1	62.1	1.0	36.5	79.2	-
2. Propulse SE 250 0.75	Prosaro EC 250 0.5	30.2	10.1	45.5	14.6	36.9	4.9	-0.1
3. Balaya 0.75	Greteg Star 0.5	14.8	4.5	42.4	20.0	38.4	7.1	1.6
4. Univoq 0.75	Greteg Star 0.5	12.8	4.2	27.0	35.8	38.8	10.3	4.8
5. Balaya 0.75	Greteg Star 0.35 + Propulse SE 250 0.35	18.5	6.0	31.0	28.3	39.4	10.4	4.0
6. Propulse SE 250 0.75 + Folicur Xpert 0.25	Univoq 0.75	21.0	6.6	24.3	43.3	39.5	11.9	5.2
7. Propulse SE 250 0.75 + Folicur Xpert 0.25	Balaya 0.75	17.4	4.6	19.5	46.7	40.3	11.3	4.6
8. Univoq 0.75	Propulse SE 250 0.75 + Folicur Xpert 0.25	7.2	1.8	14.5	47.9	40.3	13.8	7.1
9. Balaya 0.75	Propulse SE 250 0.75 + Folicur Xpert 0.25	10.0	3.3	18.5	39.2	39.5	11.0	4.3
10. Balaya 0.75	Prosaro EC 250 0.5 + Entargo 0.35	16.5	5.2	26.0	30.8	38.9	8.5	1.9
11. Balaya 0.5 + Entargo 0.18	Juventus 90 0.4 + Entargo 0.35	18.2	6.0	23.7	34.2	38.9	9.9	4.0
12. Balaya 0.75	Juventus 90 0.4 + Entargo 0.35	19.0	6.0	28.0	35.0	38.5	9.0	2.8
13. Balaya 0.75	Propulse SE 250 0.5 + Entargo 0.35	17.9	5.2	23.6	38.3	39.4	10.4	3.7
14. Balaya 0.75	Univoq 0.75	13.3	4.3	11.0	55.0	39.4	11.1	4.2
15. Univoq 0.75	Balaya 0.75	8.9	1.8	8.0	54.2	39.3	12.5	5.6
No. of trials		3	3	3	2	3	3	3
LSD_{95}		4.0	1.6	6.9	9.4	1.3	2.2	-

Control of *Septoria* with Univoq and Balaya

In line with a trial carried out in 2020, two trials were carried out in 2021 (21313) and were located in the cultivars Hereford and Cleveland at Flakkebjerg, testing the impact of timing. Univoq and Balaya were tested using two rates and timings (GS 37 (20 May) and GS 39-45 (26 May)) in 2021. The early timing gave the best control on the lower leaves and the later timing the best control on the upper leaves (Table 5). At the early timing, Univoq and Balaya performed very similarly; at the later timing Balaya performed slightly better than Univoq, particularly at the higher rate. The yield responses in the trial were significant when compared with untreated but did not vary significantly between the different treatments (Table 5). However, higher rates increased yields more than lower rates.

Table 5. Effects on *Septoria*, green leaf area (GLA) and yield responses following two timings and two rates of Univoq and Balaya in wheat. Three trials (20307/21313).

Treatments, l/ha 20307-1 + 21313-1			% *Septoria*	% *Septoria*	% *Septoria*	% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 31	GS 37	GS 37 + 1 week	GS 69 Leaf 2	GS 75 Leaf 1	GS 75 Leaf 2	GS 77 Leaf 1		
1. Untreated			36.1	52.7	87.2	6.0	89.0	-
2. Orius Max 0.2	Univoq 0.75		5.8	10.2	26.8	59.1	8.0	4.3
3. Orius Max 0.2	Univoq 1.25		3.1	6.9	17.9	68.2	12.0	6.7
4. Orius Max 0.2	Balaya 0.75		5.2	9.4	26.2	50.1	8.8	4.7
5. Orius Max 0.2	Balaya 1.25		2.6	6.9	19.7	60.7	10.5	4.6
6. Orius Max 0.2		Univoq 0.75	8.4	8.4	29.4	63.5	9.3	5.5
7. Orius Max 0.2		Univoq 1.25	8.1	5.7	25.6	68.9	10.0	4.7
8. Orius Max 0.2		Balaya 0.75	9.6	6.7	29.4	59.4	8.5	5.0
9. Orius Max 0.2		Balaya 1.25	5.5	4.1	15.9	73.2	11.3	5.4
No. of trials			3	3	3	3	3	3
LSD_{95}							2.1	

Attack of *Septoria* in winter wheat.

Ear treatments in different combinations

Trial 21343-1 was carried out in the cultivar Cleveland and treated on 31 May. A cover spray using 0.35 l/ha Prosaro EC 250 was applied at GS 32 in all treatments including untreated. All treatments applied at GS 39-45 improved control of *Septoria* significantly, but it was not possible to differentiate the effects from the different treatments clearly from each other. However, the combination of Balaya + Propulse SE 250 at two different ratios provided control in line with Balaya used alone. This was similarly the case for the yield responses (Table 6), although the newer chemistry gave slightly better yields than the old chemistry (trt. 2).

Table 6. Effects on *Septoria* and yield responses, following one timing and different combinations of Univoq, Balaya and Propulse SE 250 in wheat. One trial in 2021 (21343).

Treatments, l/ha 21343-1		% *Septoria*				Yield & yield increase hkg/ha	Net yield hkg/ha
GS 39-45	Dose	GS 65 Leaf 1	GS 65 Leaf 2	GS 73 Leaf 1	GS 73 Leaf 2		
1. Untreated		2.0	13.8	12.5	60.0	80.1	-
2. Propulse SE 250 + Folicur Xpert	0.75 + 0.25	0.1	3.5	2.3	9.0	7.3	4.6
3. Balaya	0.75	0.1	3.8	2.0	6.8	10.2	7.4
4. Univoq	0.75	0.1	4.0	4.5	10.8	10.1	7.3
5. Balaya + Propulse SE 250	0.35 + 0.5	0.0	1.5	1.8	5.0	12.2	9.4
6. Balaya + Propulse SE 250	0.5 + 0.3	0.1	2.3	1.3	4.0	9.0	6.2
LSD_{95}		0.0	1.6	1.8	4.2	5.9	-

Addition of Entargo, Folpan or Leander to *Septoria* solutions

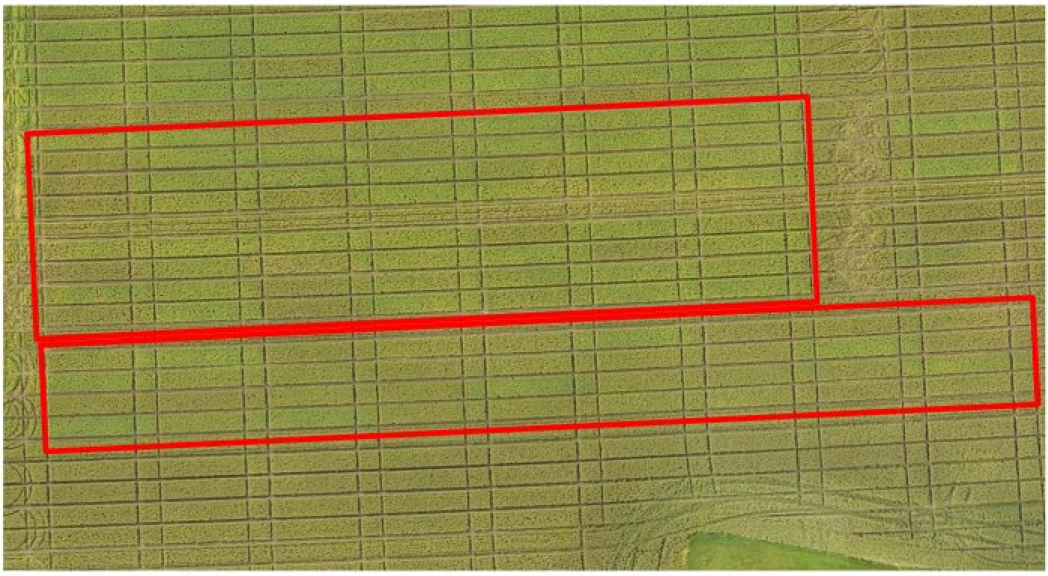
In two trials different input of Entargo, Folpan 500 SC or Leander (fenpropidin) was added to either substitute part of the dose of the core *Septoria* product (Propulse SE 250 and Univoq) (21316) (Table 7) or strengthen the weaker azole solutions for control of *Septoria* (21315). In this trial the aim was to substitute the old Bell solutions with equivalent azole+boscalid solutions (Table 8). Core treatments in both trials were applied on 1 June. Both trials developed only a minor to moderate attack of *Septoria*.

In trial 21316-1 all treatments improved control significantly, but it was not possible to differentiate the treatments from each other. This was similarly the case for the yield responses (Table 7).

In the second trial (Table 8), which was carried out in the cultivar Torp, only minor differences were observed in % control and in yield responses. Prosaro EC 250 + Entargo, Juventus 90 + Entargo, Propulse SE 250 and Greteg Star + Entargo provided similar or slightly better control of *Septoria* compared with the old Bell formulations, which were used as references. All treatments improved yields significantly, but none of the treatments could be differentiated significantly from each other.

Table 7. Effects on *Septoria*, brown rust, green leaf area (GLA), yield responses and thousand grain weight (TGW), following one timing with different *Septoria* combinations in wheat. One trial in 2021 in Kvium (21316).

Treatments, l/ha 21316-1		% *Septoria*			% brown rust	% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha	TGW g
GS 31-32	GS 51-55	GS 69 Leaf 2	GS 69 Leaf 3	GS 77 Leaf 1	GS 77 Leaf 1	GS 77 Leaf 1			
1. Prosaro EC 250 0.35	Untreated	2.2	31.3	30.0	5.0	60.0	107.3	106.1	39.0
2. Prosaro EC 250 0.35	Propulse SE 250 0.75	0.6	14.3	11.3	3.5	76.3	4.2	1.7	38.5
3. Prosaro EC 250 0.35	Propulse SE 250 0.5 + Folpan 500 SC 1.0	0.6	16.8	13.8	1.8	73.8	3.5	-0.4	39.4
4. Prosaro EC 250 0.35	Propulse SE 250 0.5 + Leander 0.25	0.4	11.3	15.0	4.8	70.0	3.9	-	39.6
5. Prosaro EC 250 0.35	Propulse SE 250 0.5 + Entargo 0.375	0.6	20.0	13.8	2.0	75.0	4.5	0.6	40.2
6. Prosaro EC 250 0.35	Propulse SE 250 0.5 + Folicur Xpert 0.25	0.6	18.8	10.0	1.5	73.8	5.3	2.0	39.0
7. Prosaro EC 250 0.35	Propulse SE 250 0.5 + Folicur Xpert 0.25 + Folpan 500 SC 0.75	0.5	11.0	8.0	0.8	78.8	3.9	-0.2	39.1
8. Prosaro EC 250 0.35	Univoq 1.0	0.6	11.8	13.8	1.8	70.0	8.7	3.9	39.1
9. Prosaro EC 250 0.35	Univoq 0.75 + Folpan 500 SC 1.0	0.8	20.0	14.3	3.5	72.5	4.9	-0.2	37.8
10. Prosaro EC 250 0.35	Univoq 0.75 + Entargo 0.375	0.4	10.5	11.8	1.8	71.3	4.1	-1.8	39.6
11. Prosaro EC 250 0.35	Univoq 0.75 + Leander 0.25	0.5	15.0	9.3	0.8	72.5	4.5	-	39.2
LSD_{95}		0.6	7.2	7.0	2.5	9.8	NS	-	NS



Trials 21329-1 and 21325-1.

Table 8. Effects on *Septoria*, green leaf area (GLA) and yield responses, following one timing with different *Septoria* combinations in wheat. One trial in 2021 in Torp (21315).

Treatments, l/ha 21315		% *Septoria*				% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 39-45	Dose	GS 63 Leaf 2	GS 63 Leaf 1	GS 75 Leaf 1	GS 75 Leaf 2	GS 75 Leaf 1		
1. Untreated		13.0	4.8	10.0	28.8	22.5	108.1	-
2. Bell	0.5	5.0	2.0	2.8	15.0	40.0	7.3	-
3. Bell	0.75	7.0	2.0	3.0	15.0	40.0	8.1	-
4. Orius Max + Entargo	0.33 + 0.24	9.0	2.0	3.0	16.3	42.5	5.0	3.5
5. Orius Max + Entargo	0.5 + 0.35	7.0	1.5	3.0	16.3	35.0	7.3	5.3
6. Juventus 90 + Entargo	0.26 + 0.24	5.0	1.3	2.5	15.0	40.0	3.4	1.8
7. Juventus 90 + Entargo	0.4 + 0.35	6.0	1.5	3.0	13.5	32.5	6.7	4.6
8. Proline EC 250 + Entargo	0.19 + 0.24	8.0	2.0	4.0	18.8	27.5	5.0	3.3
9. Proline EC 250 + Entargo	0.32 + 0.35	10.0	3.3	2.8	15.0	35.0	5.6	3.2
10. Prosaro EC 250 +Entargo	0.26 + 0.24	8.0	2.0	3.3	14.8	40.0	5.0	3.3
11. Prosaro EC 250 + Entargo	0.4 + 0.35	7.0	0.9	2.3	13.5	52.5	6.2	3.9
12. Propulse SE 250	0.5	6.0	1.8	2.5	13.0	35.0	5.9	4.3
13. Orius Max	1.125	8.0	1.3	2.8	16.3	30.0	4.9	3.2
14. Greteg Star + Entargo	0.4 + 0.35	7.0	1.8	2.3	13.8	52.5	9.3	7.0
15. Propulse SE 250 + Entargo	0.3 + 0.24	4.0	1.5	2.3	13.0	40.0	6.4	4.5
LSD_{95}		3.1	1.3	1.3	3.3	18.6	4.1	-

Different T1 treatments

One trial compared two different solutions applied at T1 (GS 31-32). The trial was carried out in the cultivar Cleveland (Table 9). Applied at T1 Pictor Active + Juventus 90 performed in line with Prosaro EC 250 at the early assessments but slightly better at the later assessments. Balaya was a better T2 treatment compared with the mixture Propulse SE 250 + Folicur Xpert. The different solutions gave similar yield responses, which did not differ significantly from each other.

Table 9. Effect of treatments at GS 31-32 on control of *Septoria*, green leaf area (GLA) and yield responses in wheat. One trial (21344).

Treatments, l/ha 21344-1		% *Septoria*				% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 31-32	GS 39	GS 71 Leaf 1	GS 71 Leaf 2	GS 75 Leaf 1	GS 75 Leaf 2	GS 77 Leaf 1		
1. Untreated		41.0	55.0	81.0	99.0	13	75.1	-
2. Pictor Active 0.2 + Agropol 0.2 + Juventus 90 0.2	Balaya 0.75	9.0	14.0	16.0	51.0	73	20.5	16.3
3. Prosaro EC 250 0.4	Balaya 0.75	8.0	14.0	23.0	74.0	63	20.9	16.7
4. Pictor Active 0.2 + Juventus 90 0.2 + Agropol 0.2	Propulse SE 250 0.5 + Folicur Xpert 0.25	15.0	25.0	24.0	78.0	53	18.5	15.1
5. Prosaro EC 250 0.4	Propulse SE 250 0.5 + Folicur Xpert 0.25	17.0	28.0	31.0	86.0	48	16.0	12.6
LSD_{95}		6.4	11.9	8.7	11.4	9.7	4.3	-

Baltic T1 and T2 solutions for control of *Septoria*

In two trials different solutions available in the Baltic countries were compared, using a T1 and a T2 treatment. All solutions in 21337-1 provided high levels of control in the cultivar Hereford (Table 10). Balaya used at T2 was slightly inferior to solutions when it was applied at T1. Revytrex and Revystar were both strong elements in the different control strategies and provided the best control when included at T2.

In the trial carried out in the cultivar Cleveland (21338-1), the level of *Septoria* attack was very severe and the yield responses were high, varying from 16 dt/ha to 35 dt/ha (Table 11). Revytrex and Balaya solutions provided the best control. Some of the T1 treatments gave less good control. Prothio 300 + Amistar/Elatus Era and Input Triple/Ascra Xpro gave least control on the lower leaves, which also impacted the flag leaf, which again led to lower yields.

Table 10. Effect of treatments at GS 31-32 and GS 39-45 on control of *Septoria*, green leaf area (GLA) and yield responses in wheat. One trial in Hereford (21337). Baltic solutions.

Treatments, l/ha 21337-1		% *Septoria*				% GLA	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 31-32	GS 45-51	GS 55 Leaf 3	GS 71 Leaf 2	GS 71 Leaf 3	GS 77 Leaf 1	GS 79 Leaf 1		
1. Untreated	Untreated	31.0	17.5	50.0	44.0	0	87.1	-
2. Balaya 0.5 + Flexity 0.25	Balaya 0.75	13.0	3.0	26.0	7.0	56	6.7	0.8
3. Priaxor 0.4 + Curbatur 0.4	Balaya 0.75	9.0	1.3	10.0	3.0	68	9.7	-
4. Input 0.8	Balaya 0.75	19.0	2.3	26.0	8.0	58	5.4	-0.2
5. Input Triple 0.75	Balaya 0.75	15.0	2.8	29.0	6.0	58	8.0	-
6. Prothio 300 0.4 + Amistar 0.4	Balaya 0.75	21.0	2.8	25.0	6.0	53	5.6	-
7. Revystar XL 0.4 + Priaxor 0.4	Balaya 0.75	4.0	0.0	8.0	3.0	65	14.0	-
8. Balaya 0.75	Balaya 0.75	6.0	0.0	11.0	8.0	64	9.0	3.3
9. Balaya 0.75	Balaya 1.0	6.0	0.4	9.0	4.0	74	8.6	2.1
10. Balaya 0.75	Priaxor 0.5 + Curbatur 0.5	6.0	´0.6	11.0	3.0	66	10.9	-
11. Balaya 0.75	Revytrex 1.0	6.0	0.0	5.0	1.0	88	10.6	-
12. Balaya 0.75	Ascra Xpro 1.0	7.0	0.3	15.0	3.0	88	9.0	2.7
13. Balaya 0.75	Elatus Era 0.75	5.0	0.0	8.0	9.0	74	9.3	-
14. Balaya 0.75	Revystar XL 1.0	7.0	0.0	10.0	1.0	89	12.9	-
No. of trials		1	1	1	1	1	1	1
LSD_{95}		3.9	1.2	4.3	3.9	15.0	4.6	-

Table 11. Effect of treatments at GS 31-32 and GS 45-51 for control of *Septoria*, green leaf area (GLA), yield responses and thousand grain weight (TGW) in wheat. One trial in Cleveland (21338).

Treatments, l/ha 21338-1		% *Septoria*				% GLA	Yield & yield increase hkg/ha	TGW g
GS 31-32	GS 45-51	GS 65 Leaf 2	GS 73 Leaf 1	GS 73 Leaf 2	GS 77 Leaf 1	GS 77 Leaf 1		
1. Untreated	Untreated	31.3	48.0	81.0	93.0	7.0	73.9	27.1
2. Balaya 0.5 + Flexity 0.25	Revytrex 1.0	2.8	4.0	9.0	8.0	85.0	35.4	33.4
3. Priaxor 0.4 + Curbatur 0.4	Priaxor 0.5 + Curbatur 0.5	5.0	8.0	18.0	36.0	61.0	25.3	31.6
4. Priaxor 0.4 + Curbatur 0.4	Revytrex 1.0	3.3	3.0	10.0	10.0	84.0	33.4	34.8
5. Prothio 300 0.4 + Amistar 0.4	Elatus Era 0.75	16.0	19.0	58.0	53.0	45.0	16.8	30.9
6. Input Triple 0.75	Ascra Xpro 1.0	13.0	14.0	39.0	44.0	53.0	21.7	31.5
7. Priaxor 0.4 + Curbatur 0.4	Balaya 0.75	5.5	5.0	11.0	18.0	76.0	30.7	32.8
8. Priaxor 0.4 + Curbatur 0.4	Balaya 1.0	5.0	5.0	11.0	19.0	76.0	30.2	34.0
9. Revystar XL 0.4 + Priaxor 0.4	Revytrex 1.0	1.1	2.0	4.0	7.0	88.0	37.6	34.0
10. Balaya 0.5	Revytrex 1.0	2.8	5.0	10.0	10.0	83.0	34.0	33.8
LSD_{95}		4.5	7.7	8.0	12.3	12.9	3.9	3.1

Efficacy of Proline EC 250

Proline EC 250 was used as a reference in many trials where various products were tested (Table 12). The trials were all treated at GS 37-39. In the 15 trials *Septoria* was assessed on either leaf 1 or leaf 2. The single treatment provided 33% and 26% control of leaf 1 and leaf 2, respectively. The treatment gave 8.1 hkg/ha in yield response.

Table 12. Data from reference treatments in winter wheat trials. Treatments were applied at GS 37-39.

Treatments, l/ha GS 37-39	% *Septoria* (GS 75)		Yield & yield increase
	Leaf 1	Leaf 2	hkg/ha
Untreated	28.3	65	79.5
Proline EC 250 0.8	19 (33%)	48 (26%)	+8.1
No. of trials	13	11	15

Results with control of yellow rust

One trial was carried out testing a wide range of fungicides for control of yellow rust in the susceptible cultivar Benchmark. Treatments were applied at GS 37. The trials developed a significant attack of yellow rust, following artificial inoculations with spreader plants. The results from the trial are given in Table 13 and Figure 11. Most treatments provided a high level of control. Only at the very late assessment – five weeks after spraying – could the effect of the weaker fungicides on yellow rust be seen. Mainly products based on prothioconazole and difenoconazole did not provide a very long-lasting control. *Septoria* also developed in the trial, and clear differences could also be seen against this disease. Univoq and Balaya provided the best levels of *Septoria* control. Yield increases from treatments were significant and reflected the control assessed for both yellow rust and *Septoria* (Figure 12).

In a second trial different timing of rust control was investigated. The data from this trial are shown in Table 14. Delaying the control of yellow rust by 1 or 2 weeks reduced the level of control significantly, which also impacted the yield response.

Table 13. Effects on yellow rust, *Septoria* and yield responses, following one timing using different products. One trial in 2021 (21311).

Treatments, l/ha 21311-1		% yellow rust				% *Septoria*	Yield & yield increase hkg/ha	Net yield hkg/ha
GS 37	Dose	GS 65 Leaf 1	GS 65 Leaf 2	GS 75 Leaf 1	GS 75 Leaf 2	GS 75 Leaf 1		
1. Untreated	Untreated	50.0	70.0	50.0	50.0	26.3	64.7	-
2. Orius Max	0.65	0.0	0.0	0.4	0.0	15.8	20.6	19.4
3. Prosaro EC 250	0.75	0.0	0.0	0.6	0.0	12.0	24.5	22.4
4. Folicur Xpert	0.75	0.0	0.0	0.5	0.0	7.0	22.8	21.0
5. Balaya	1.125	0.1	0.3	0.9	0.0	0.9	28.2	24.2
6. Univoq	1.125	0.1	0.4	12.0	5.0	1.3	25.8	21.8
7. Propulse SE 250	0.75	0.2	1.8	13.8	6.8	3.0	24.2	22.0
8. Greteg Star	0.75	4.5	20.0	16.3	18.8	7.0	22.5	20.5
9. Comet Pro	0.94	0.0	0.0	1.5	2.3	18.8	23.9	21.4
10. Amistar	0.75	2.1	5.0	5.0	7.5	18.8	19.2	17.6
11. Proline EC 250	0.6	0.1	1.3	16.3	10.8	9.5	19.9	17.7
12. Juventus 90	0.75	0.3	0.6	2.3	4.3	6.5	21.6	19.9
13. Pictor Active + Agropol	1.125 + 0.2	1.8	7.0	2.8	5.0	10.3	24.7	21.4
LSD_{95}		1.0	5.2	4.1	4.7	6.2	4.5	-

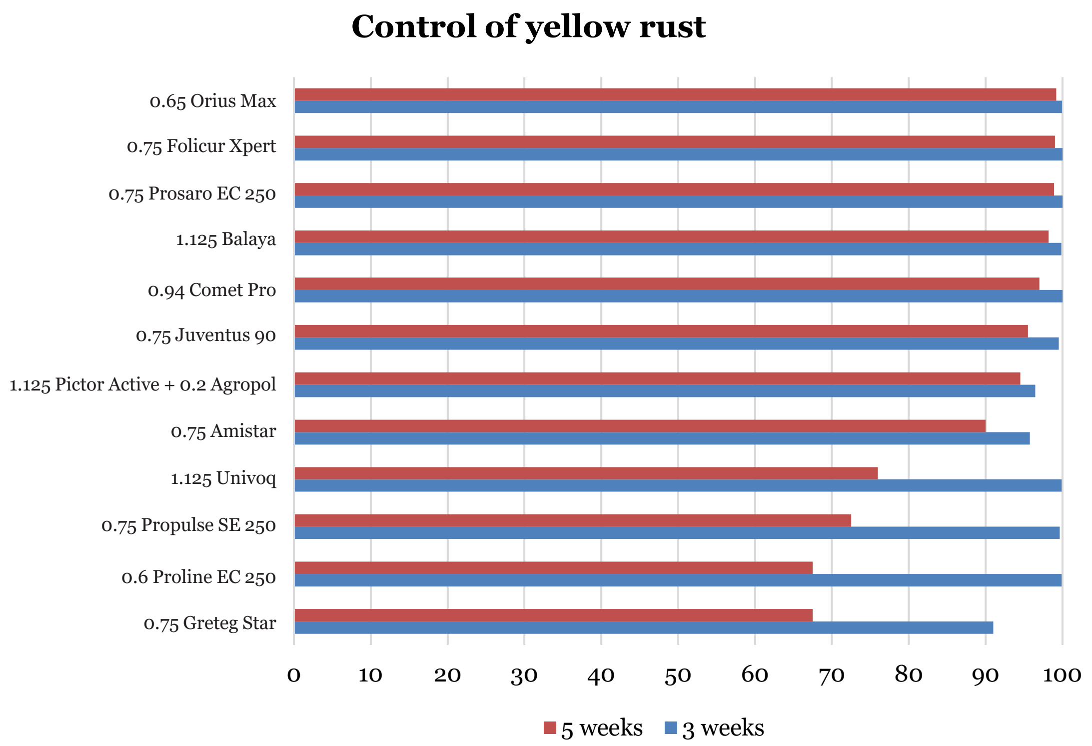


Figure 11. Per cent control of yellow rust, following one treatment applied at GS 37. The attack on both 1st and 2nd leaf was 50% (21311).

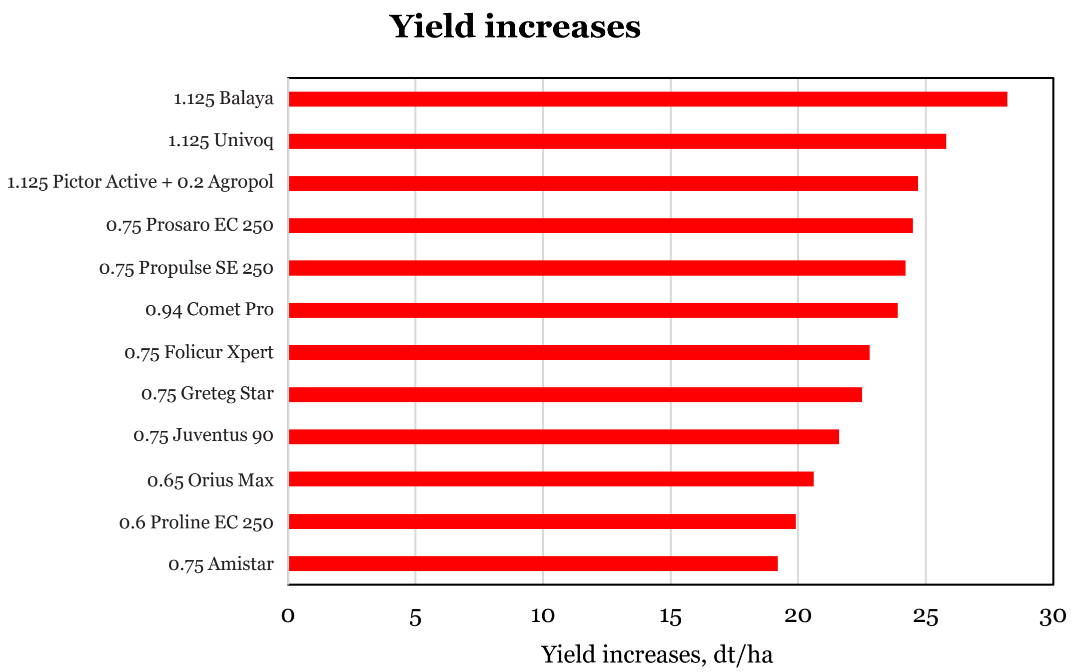


Figure 12. Yield responses following control of yellow rust, using one treatment applied at GS 37 (21311).


Table 14. Effect of timing on control of yellow rust, green leaf area (GLA) and yield responses, using an effective fungicide.

Timing of treatments	% control of rust, 2nd leaf	% control of rust, flag leaf	% GLA, GS 79	Yield response, hkg/ha
Untreated	0 (53%)	0 (49%)	2	66 (100)
Timing A (25 May)	100	98	78	+31 (147)
Timing B (31 May)	76	77	80	+27 (141)
Timing C (7 June)	29	15	58	+13 (120)

Results from RustWatch (Horizon 2020 trial)

As part of the RustWatch project (Horizon 2020), trials were carried out in nine different countries in 2021, following the same protocol. The aim of this activity was to investigate different IPM control strategies for control of yellow rust in different countries and regions. Trials were similarly carried out in 2020. In this section, the Danish trial from 2021 is presented.

Using a split plot design, four cultivars were tested using different control strategies to minimise outbreak and yield losses from attack of rust diseases. In Denmark the trial included a yellow rust susceptible cultivar (Benchmark), a cultivar with low risk of yellow rust attack (Sheriff), a rust resistant cultivar (Informer) and a mixture of the three cultivars. For each cultivar a full fungicide programme (TFI = 2) was tested and compared with the control achieved by using reduced rates of fungicides (TFI = 1), alternative chemistry and the use of control thresholds.

1. 0.6 l/ha Comet Pro (GS 31-32) / 0.75 l/ha Balaya (GS 33-37) / 0.5 l/ha Elatus Era (GS 45-51) / 0.5 l/ha Folicur (GS 65) (TFI = 2.0)
2. 0.3 l/ha Comet Pro (GS 31-32) / 0.375 l/ha Balaya (GS 33-37) / 0.25 l/ha Elatus Era (GS 45-51) / 0.25 l/ha Folicur (GS 65) (TFI = 1.0)
3. Alternative product (orange oil)
4. Treatment according to Decision Support System (DSS)

When comparing the different control strategies, it was found that full control and completely acceptable control was achieved from traditional chemistry, using four treatments with both normal and reduced rates. In comparison, the control from the strategy using four treatments with alternative chemistry (orange oil) gave poor and generally insufficient control. Use of DSS provided reliable and good control when treatments were applied according to the need for control of yellow rust (Table 15).

In the Danish trial 0.5 l/ha Elatus Era was applied to all cultivars following a risk of *Septoria* and rust (28 May). Later, Benchmark was treated once more with 0.3 l/ha Orius Max on 16 June. Sheriff only developed very few signs of rust; the mixture developed a clear but still reduced attack compared with Benchmark grown alone. The yield responses from the trial reflect to a great extent the visual attack of yellow rust scored in the trial, and only Benchmark gave significant yield increases.

Table 15. Control of *Septoria* and yellow rust and yield responses in the RustWatch trial, which included four cultivars and five different treatments. Letters indicate if treatments are significantly different.

	% *Septoria* – flag leaf (GS 75)				
	Untreated	Standard 4 x ½ rates	Standard 4 x ¼ rates	Alternative chemistry	DSS
Mixture of cultivars	16.7	2.3	4.3	16.0	11.0
Benchmark	30.0	10.0	11.7	26.7	7.7
Sheriff	4.3	0.8	2.7	3.0	2.7
Informer	3.7	1.4	2.3	1.0	1.0
Average of 3 cultivars	13.7 a	3.6 b	5.3 b	11.7 a	5.6 b

	% yellow rust – flag leaf (GS 75)				
	Untreated	Standard 4 x ½ rates	Standard 4 x ¼ rates	Alternative chemistry	DSS
Mixture of cultivars	7.3	0	0	0	3.3
Benchmark	46.7	0	0	43.3	0
Sheriff	0	0	0	0	0
Informer	0	0	0	0	0
Average of 3 cultivars	13.5 a	0 b	0 b	10.8 a	0.8 b

	Yield & yield increase, hkg/ha					
	Untreated	Standard 4 x ½ rates	Standard 4 x ¼ rates	Alternative chemistry	DSS	Average of trt.
Mixture of cultivars	105.0	7.4	8.3	0	0.1	108.2
Benchmark	90.1	19.5	17.1	-0.6	16.0	100.5
Sheriff	109.1	4.5	0.8	-5.0	2.5	109.6
Informer	105.9	7.3	4.6	-1.0	-0,6	107.9
Average of 3 cultivars	102.5	9.7	7.7	-1.8	4.5	106.5
LSD_{95}						

Cultivar mixtures reduced the attack compared with the average values for the three individual cultivars. The benefit from the mixtures on yellow rust was most pronounced in untreated where attack was reduced by 46%. The yield in the cultivar mixture (105 hkg/ha) was also better (2.4%) than for the average of the three individual cultivars (102.5 hkg/ha).

Yield data indicate that reduced rates were sufficient for control of even severe attack of rust diseases, providing the best net yield results. The high input was in comparison too expensive and not economically sustainable. The insufficient control from the alternative strategy was reflected in an unacceptably low yield response.

Based on similar data collected in nine other countries in two seasons across Europa, cultivar mixtures showed a clear reducing effect on both yellow rust and brown rust diseases compared with the average of the cultivars included in the mixtures (Figure 13).

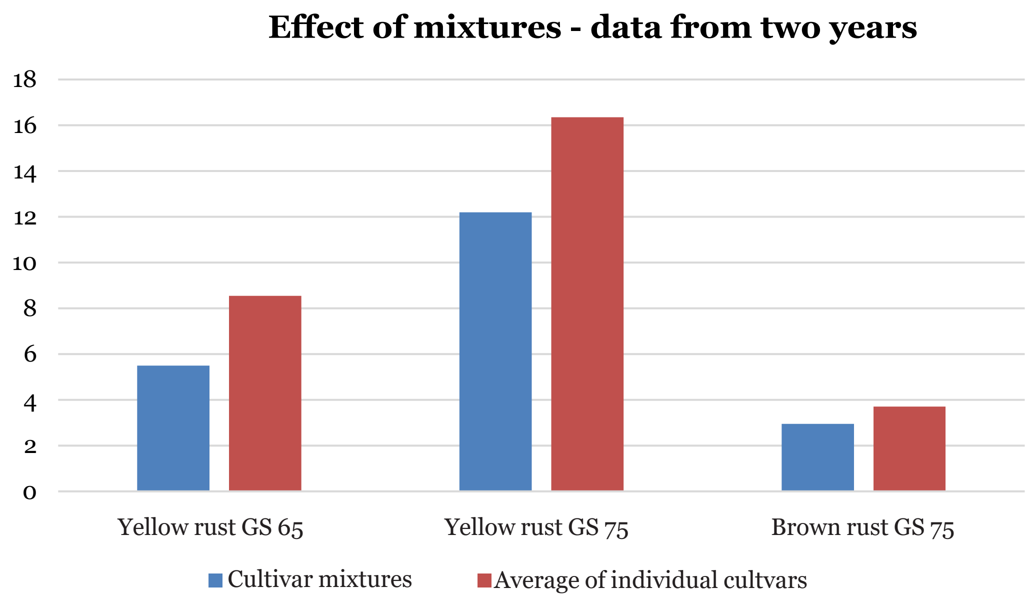


Figure 13. Average per cent rust attack from two seasons in nine countries. Impact of mixtures on control of yellow rust and brown rust (data from the RustWatch project).

Control of tan spot with different fungicides

Two trials were located in the cultivar Graham and inoculated with straw debris contaminated with tan spot (21308 and 21339). The trials tested different products for their ability to control tan spot. The products included Univoq, Proline EC 250, Balaya and Ascra Xpro. Two dose rates were tested of Univoq, Proline EC 250, Balaya, Questar + Elatus Plus and Questar + Juventus 90, respectively (Table 16). The products which included prothioconazole provided the best control (Figure 14) and showed that Balaya is inferior for control of tan spot. The lower rates of the tested products performed less well. The yield responses in the trial were significant. The data from the second trial (21339) are shown in Table 17 and led to very similar conclusions.

Table 16. Effect of applications on control of tan spot, GLA and yield responses in wheat. One trial (21308).

Treatments, l/ha 21308-1		% tan spot				% GLA	Yield & yield increase hkg/ha
GS 33-37 & 51-55	Dose	GS 61-65 Leaf 3	GS 61-65 Leaf 2	GS 65-69 Leaf 3	GS 65-69 Leaf 2	GS 75 Leaf 1	
1. Untreated		12.5	6.5	35.0	25.0	3.5	84.4
2. Proline EC 250	0.8	2.8	0.7	9.3	1.9	36.3	11.7
3. Proline EC 250	0.4	5.8	2.1	17.0	10.5	20.0	6.8
4. Univoq	1.5	4.0	0.9	11.3	4.0	50.0	8.8
5. Univoq	0.75	4.5	1.8	17.8	11.3	27.5	8.4
6. Questar + Elatus Plus	1.5 + 0.75	6.5	1.6	11.8	5.3	72.5	10.8
7. Questar + Elatus Plus	0.75 + 0.375	7.3	2.3	17.8	11.8	56.3	10.3
8. Questar + Juventus 90	1.5 + 0.75	4.8	0.9	14.3	8.3	52.5	10.4
9. Questar + Juventus 90	0.75 + 0.375	6.5	2.3	17.3	8.8	35.0	6.5
10. Balaya	1.5	4.8	1.6	22.5	14.0	12.5	6.1
11. Balaya	0.75	7.8	3.0	23.3	17.5	13.8	6.2
12. Ascra Xpro	0.75	2.8	0.6	7.3	1.3	50.0	12.4
13. Revytrex	0.75	7.3	3.4	18.8	11.8	28.8	7.3
14. Elatus Era	0.5	6.5	2.0	16.3	9.5	58.8	10.2
15. Input Triple	0.47	4.0	0.9	15.0	11.0	20.0	9.0
LSD_{95}		2.6	1.4	3.7	4.5	16.5	0.5

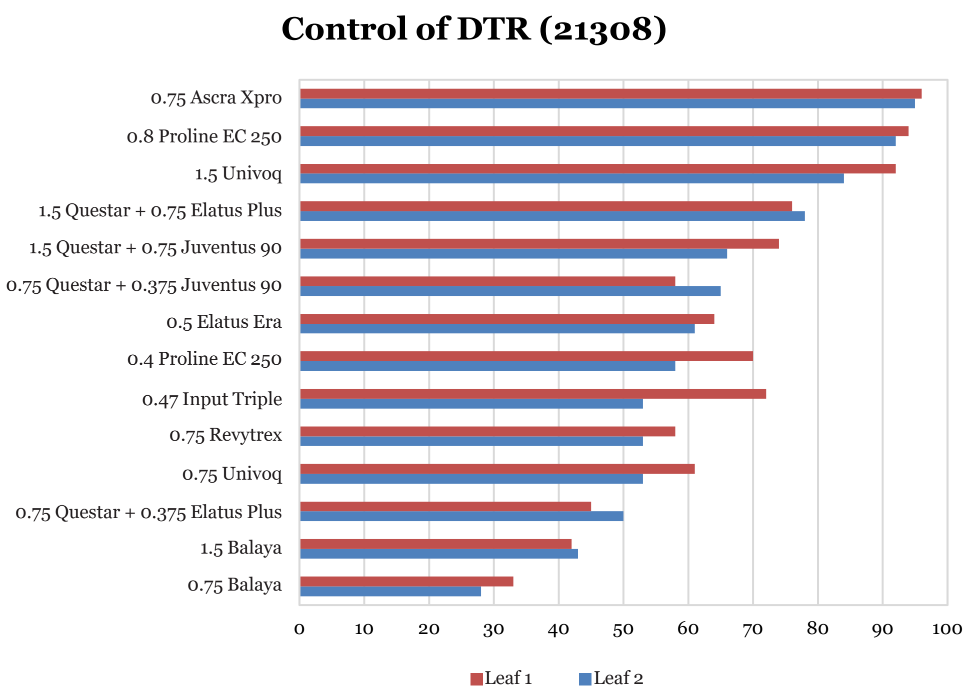


Figure 14. Per cent control of tan spot, using different fungicides. Data from trial 21308.

Table 17. Effect of applications on control of tan spot and yield responses in wheat. One trial (21339).

Treatments, l/ha 21339-1		% tan spot				Yield & yield increase hkg/ha
GS 33-37 & 51-55	Dose	GS 61 Leaf 2	GS 61 Leaf 1	GS 69 Leaf 2	GS 69 Leaf 1	
1. Untreated		14.3	9.0	33.8	21.3	89.4
2. Proline EC 250 / Revytrex	0.4 / 1.0	9.0	2.1	18.3	10.3	3.7
3. Proline EC 250 / Balaya	0.4 / 1.0	8.8	3.3	21.3	12.8	4.0
4. Proline EC 250 / Priaxor + Curbatur	0.4 / 0.5 + 0.5	7.5	3.1	16.8	10.0	5.5
5. Proline EC 250 / Elatus Era	0.4 / 0.75	4.5	1.1	11.5	6.5	6.8
6. Proline EC 250 / Ascra Xpro	0.4 / 1.0	4.0	0.9	10.5	6.3	7.4
7. Proline EC 250 / Revysol	0.4 / 1.2	11.3	5.0	30.0	18.3	2.2
8. Proline EC 250 / Proline EC 250	0.4 / 0.6	9.0	2.8	17.5	12.5	3.8
9. Proline EC 250 / Revystar XL + Priaxor	0.4 / 0.5 + 0.5	7.3	3.0	18.8	10.8	7.0
10. Proline EC 250 / Revystar XL	0.4 / 1.0	9.3	3.5	22.5	13.0	3.5
LSD_{95}		2.4	2.0	6.3	4.0	3.2

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

The trial was organised with four replicates and 2 x 1 m row per plot. The area was inoculated in the autumn with debris of tan spot inoculum, which is known to provide good attack the following season. The trial in 2021 was attacked by significant infections of tan spot and almost no *Septoria*. The trial was sprayed with Comet Pro (GS 33-37) to ensure that the attack of yellow rust did not disturb the infection. The trial was assessed at three timings (GS 32, 73 and 77) during the season. The weather was moderately conducive to the development of attack.

Most cultivars are known to be quite susceptible to tan spot and only few of the present relevant cultivars (Creator, Informer, Rembrandt and Pondus) had a significantly lower level of attack than average. Figure 15 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.

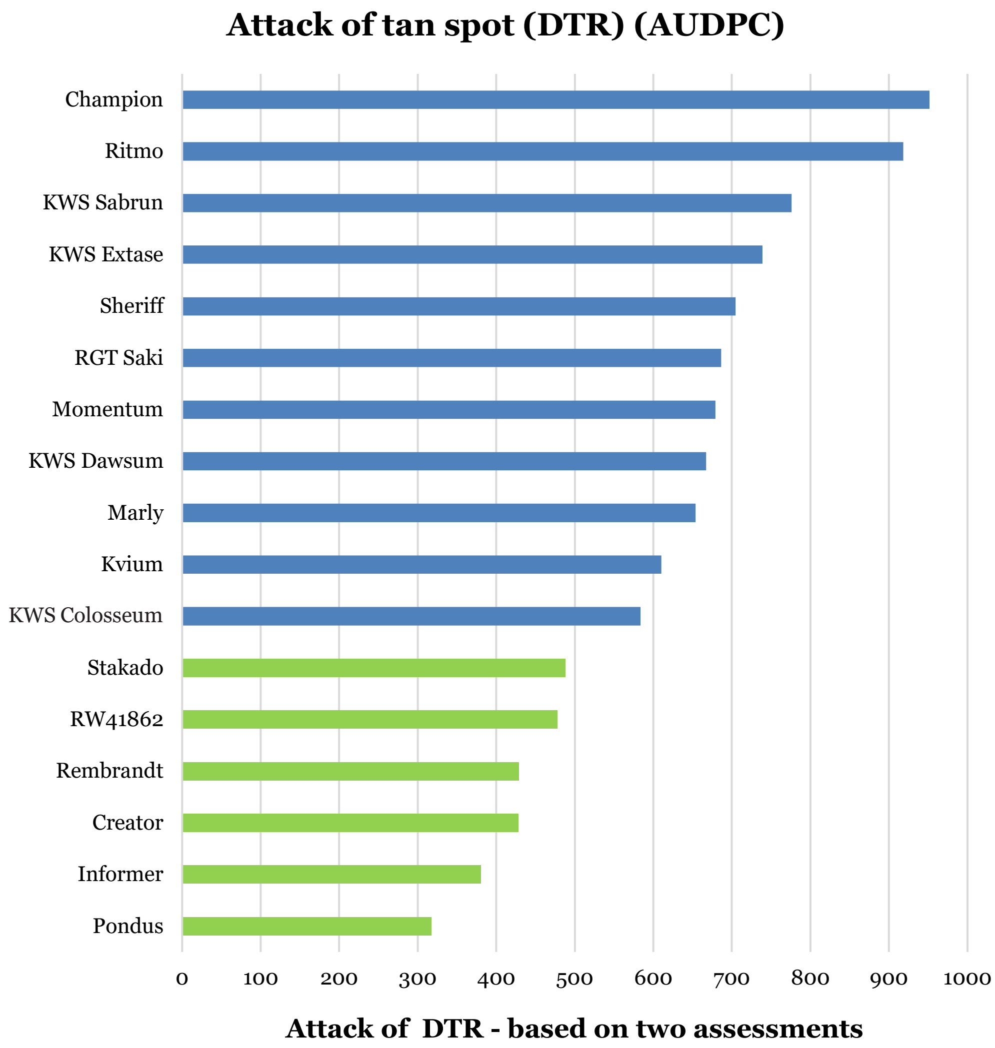


Figure 15. Per cent attack of tan spot in different winter wheat cultivars. Based on two last assessments on the upper leaves (21302-1), calculating AUDPC (Area Under Disease Pressure Curve).

Control of Fusarium head blight

In four trials different *Fusarium* active fungicides were tested and evaluated for their efficacy.

The trials were carried out using artificial inoculation with spores during flowering. Typically, the trials were inoculated twice following the spraying. The results from the reference treatments are shown in Table 18, including data on mycotoxin content. The disease pressure in the trial was extremely high, which was also reflected in the high content of DON. The control of Fusarium head blight (FHB), using prothioconazole or metconazole products, was in the range of 50-70%, while reduction in toxin was in the range of 33% to 66%.

Table 18. Control of Fusarium head blight and yield responses, including impact on grain mycotoxin contents.

	% Fusarium head blight		Yield & yield increase, hkg/ha		DON ppb	
	Trial series 1	Trial series 2	Trial series 1	Trial series 2	Trial series 1	Trial series 2
Untreated	16.2	15.0	73.0	72.7	8940	5924
Librax	5	-	20.5	-	3070	
Proline EC 250 0.8	-	5		16.8		3802
Proline EC 250 0.6	-	6		14.6		4020
Juventus 90 1.0	-	7		14.5		3345
No. of trials	2	2	2	2	2	2

Ranking susceptibility to Fusarium head blight in winter wheat in 2021

In line with previous years the Department of Agroecology, Aarhus University, Flakkebjerg, investigated the susceptibility to FHB in a project partly financed by the breeders. The tested cultivars are commonly grown in Denmark or are cultivars expected to become important in the years to come. In this year's trials, 18 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) (11 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 16, 18 and 21 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 are shown in Figure 16 and Table 19. As seen in Figure 16, the cultivars Champion, Marly, RGT Saki and Rembrandt had the most severe attacks. Least attack was seen in Pondus, KWS Extase and Sheriff. The cultivars Ritmo and Oakley were used as susceptible reference cultivars and Olivin and Skalmeje as the most resistant references. The small plots in both trials were hand harvested and grains were tested for the content of the mycotoxins using HPLC-MSMS. Five toxins were measured: deoxynivalenol (DON), nivalenol (NIV), zearalenone (ZEA), HT-2 and T-2. The contents of HT-2 and T-2 were very low in the trials and therefore not included. All cultivars had DON levels much higher than the maximum acceptable limit of 1250 ppb. The cultivar content of mycotoxins is correlated to some degree with the degree of attack. The content of the different mycotoxins also correlated between them as seen for DON, NIV and ZEA.

In Table 19 the ranking of cultivars to FHB susceptibility is summarised, including also data from previous years in the final ranking. The results from the trials were published in July together with SEGES in order to make the data available for the cultivar choice in autumn 2021.

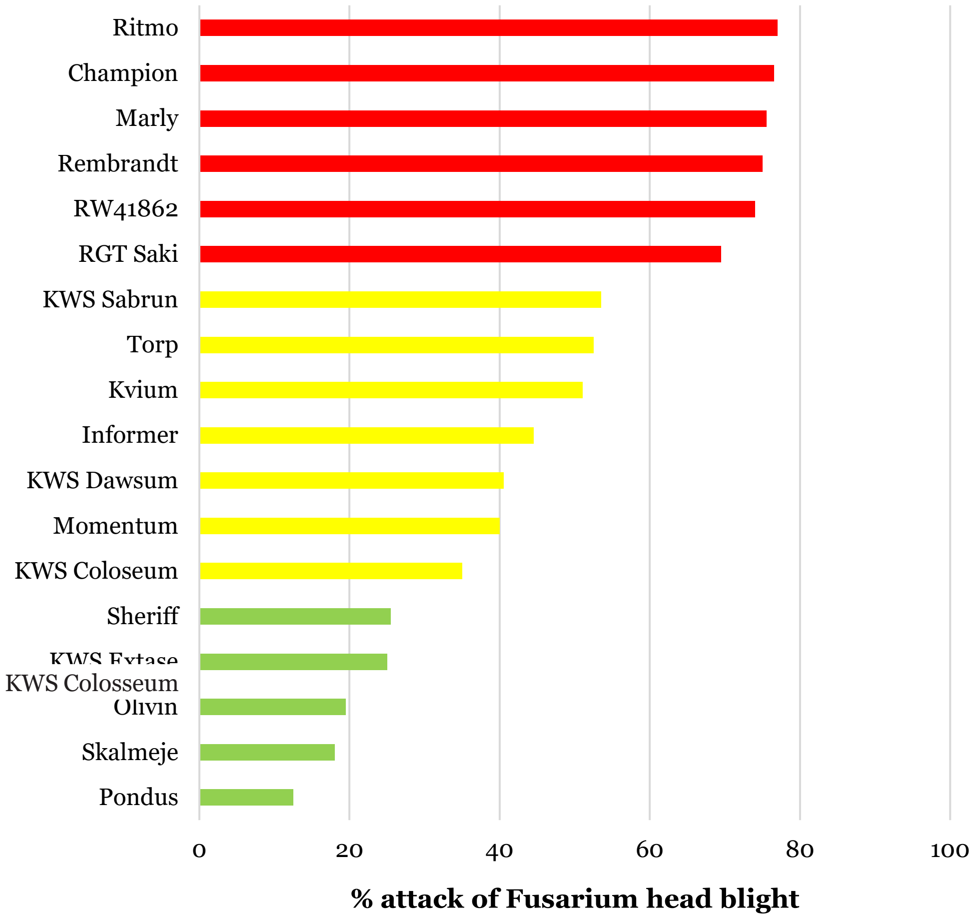


Figure 16. Percentage of attacked ears of Fusarium head blight of cultivars in July 2021. Average of both trials. The LSD_{95} value = 18.5.

In Figure 17 the content of mycotoxin in the grain samples is given as an average of the two trials. The mycotoxin levels are extremely high as a result of the inoculum added to the trials.

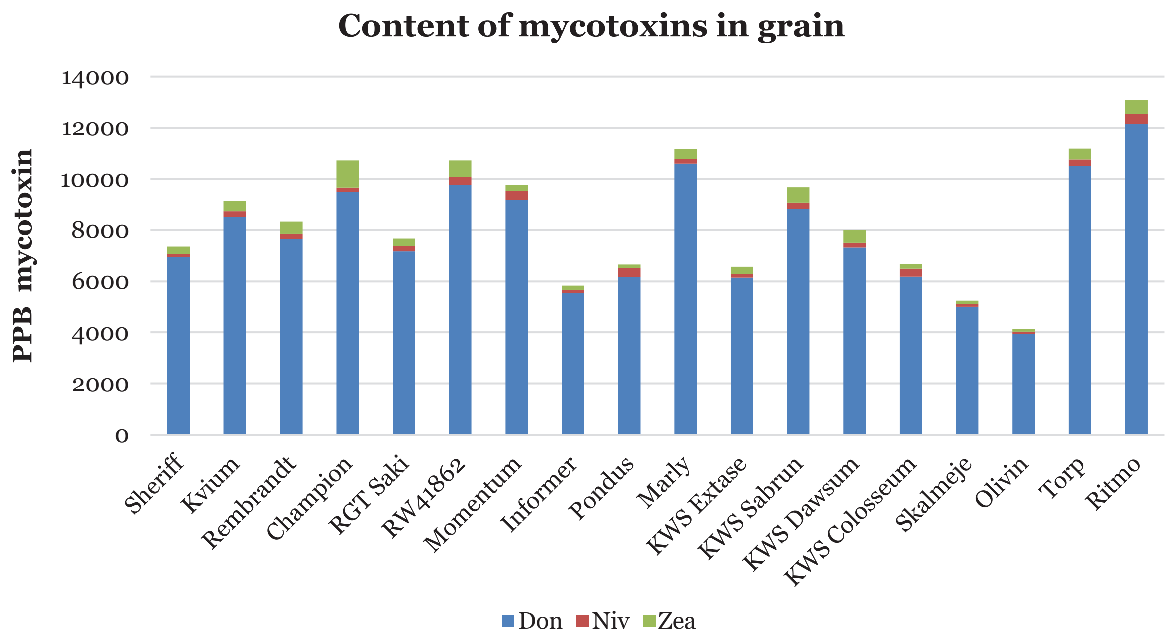


Figure 17. The level of mycotoxins in the cultivar trials 2021. Average of two trials inoculated with *Fusarium* during flowering.

Table 19. Cultivar susceptibility to Fusarium head blight. Including data from several years.

Moderately resistant	Moderately to highly susceptible	Very susceptible
Benchmark, Creator, Drachmann, Sheriff (reference cultivars: Skalmeje, Olivin)	Graham, Heerup, Informer, Kvium, KWS Extase, KWS Lili, KWS Colosseum, KWS Dawsum, KWS Sabrun, KWS Zyatt, LG Skyscraper, Momentum, Pondus, Rembrandt	Torp, KWS Firefly, KWS Scimitar, Marly, Champion, RGT Saki (reference cultivars: Oakley, Ritmo)

III Disease control in barley, rye and triticale

Lise N. Jørgensen, Niels Matzen, Hans-Peter Madsen, Helene S. Kristjansen, Sidsel Kirkegaard, Christian A. S. Nielsen & Anders Almskou-Dahlgaard

In four trials in spring barley, different fungicide solutions using half approved rates were compared for control of specific diseases in 2021. Results from the four trials are shown in Table 1. The trials were carried out in the cultivars Chapeau, Fairway, RGT Planet and KWS Irina. All trials developed moderate attacks of net blotch (*Pyrenophora teres*) and brown rust (*Puccinia hordei*). Late in the season also a minor attack of Ramularia leaf spot (*Ramularia collo-cygni*) developed. As shown in Table 1, most of the tested solutions provided very similar and good control of the diseases. The effect on net blotch, brown rust and *Ramularia* is shown in Figure 1. Yield responses were significant but did not differ significantly for the different treatments (Table 1).

Three trials were also carried out in winter barley. These trials gave good opportunities for assessing efficacy on *Rhynchosporium*, brown rust and Ramularia leaf spot. The winter barley trials were not harvested due to a severe attack of BYDV (barley yellow dwarf virus), which created uneven crop stands. Results are shown in Table 2.

Table 1. Disease control, green leaf area (GLA), thousand grain weight (TGW) and yield responses, using different fungicides applied at half rates at GS 37 in spring barley. Four trials 2021 (21384).

Treatments, l/ha 21384		% net blotch		% brown rust	% *Ramularia*	% GLA	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 37	Dose	GS 71/72 Leaf 2-3/ Leaf 3-4	GS 75 Leaf 2-3/ Leaf 2	GS 75-81 Leaf 2	GS 75/77 Leaf 2	Leaf 2			
1. Propulse SE 250 + Comet Pro	0.5 + 0.2	0.7	0.7	6.0	1.0	10.0	46.4	+9.3	7.1
2. Propulse SE 250 + Comet Pro	0.25 + 0.3	2.1	0.9	4.8	2.5	25.0	46.3	+9.9	8.1
3. Balaya + Propulse SE 250	0.5 + 0.25	1.3	0.5	4.4	0.4	20.0	45.9	+10.7	7.9
4. Lenvyor + Pictor Active + Agropol	0.3 + 0.3 + 0.2	2.1	1.2	3.2	1.2	25.0	46.1	+7.9	-
5. Balaya	0.75	3.1	2.0	6.7	0.3	1.5	45.2	+8.0	5.0
6. Curbatur + Pictor Active + Agropol	0.25 + 0.25 + 0.2	2.2	1.0	6.6	1.6	15.0	45.4	+6.4	4.4
7. Propulse SE 250 + Pictor Active + Agropol	0.2 + 0.3 + 0.2	1.7	0.4	3.2	1.8	25.0	47.1	+9.5	7.6
8. Balaya + Entargo	0.5 + 0.18	2.1	0.5	4.7	0.4	15.0	46.0	+9.1	6.4
9. Untreated		16.2	23.1	25.3	8.3	0.0	42.3	43.0	-
No. of trials		4	2	4	2	1	4	4	4
LSD_{95}		1.3	1.9	2.3	1.2	11.1	-	2.7	-

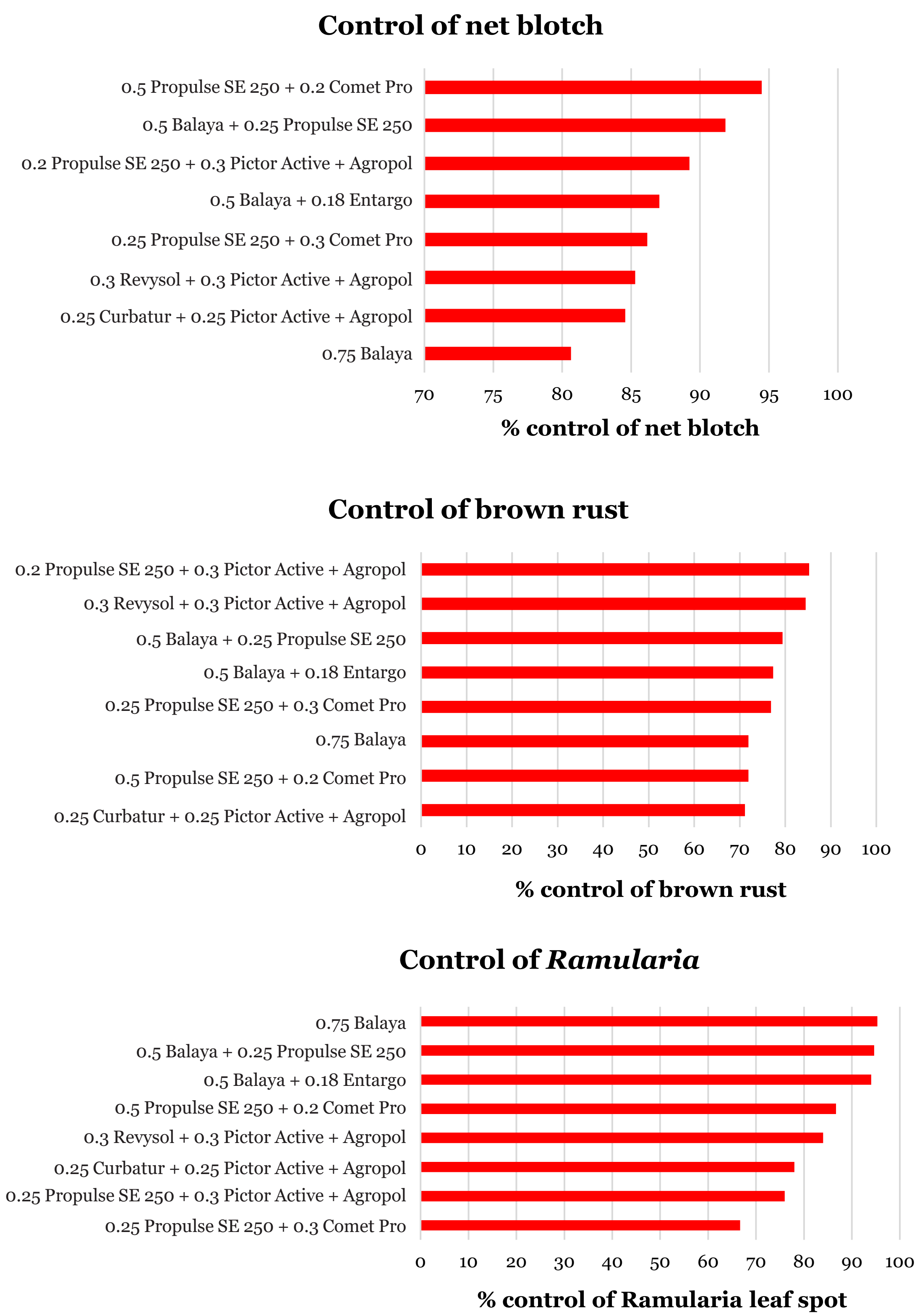


Figure 1. Control of net blotch, brown rust and *Ramularia* in spring barley trials. Attack in untreated was 22% of net blotch in three trials, 39% attack of brown rust in three trials and 8% of Ramularia leaf spot in two trials (21384).

Table 2. Disease control, using different fungicides applied at half rates at GS 37 in winter barley. Three trials 2021 (21370). Due to a severe attack of BYDV, the trial was not harvested.

Treatments, l/ha 21370		% *Rhynchosporium*		% rust	% *Ramularia*	% GLA
GS 37	Dose	GS 69/71 Leaf 2	GS 75/79 Leaf 1-2	GS 69 Leaf 2	GS 73/75/79 Leaf 1/ Leaf 1-2	Leaf 1-2/ Leaf 2
1. Propulse SE 250 + Comet Pro	0.5 + 0.2	3.9	10.1	0.3	11.8	30.8
2. Propulse SE 250 + Comet Pro	0.25 + 0.3	4.5	10.1	1.3	10.3	29.6
3. Balaya + Propulse SE 250	0.5 + 0.25	2.7	10.8	0.4	6.6	41.7
4. Lenvyor + Pictor Active + Agropol	0.5 + 0.2 +0.2	3.9	8.3	0.3	9.7	50.0
5. Balaya	0.75	7.8	17.3	0.2	5.1	44.2
6. Curbatur + Pictor Active + Agropol	0.25 + 0.25 + 0.2	5.6	12.8	0.6	14.5	22.3
7. Propulse + Pictor Active + Agropol	0.2 + 0.3 + 0.2	5.9	9.3	0.7	15.4	26.5
8. Balaya + Entargo	0.5 + 0.18	6.5	7.8	0.6	7.4	35.0
9. Untreated	10.0	15.7	34.5	10.7	25.8	2.4
No. of trials		3	2	2	3	3
LSD_{95}		2.3	4.2	2.0	3.5	9.2

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

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

Ramularia leaf spot has already acquired resistance to strobilurins (QoIs), which originally had good efficacy against RLS in the past. Several mutations in the target genes of SDHIs have been detected in the population of *R. collo-cygni* (e.g. B-H266Y/R, B-T267I, B-I268V, C-N87S, C-H146R and C-H153R) with increasing frequencies since 2014. Additionally, azole-adapted isolates of *R. collo-cygni* have been found with high frequencies in several European countries. Fifteen different *CYP51* haplotypes were detected in the set of isolates from 2009 to 2017, which showed a substantial increase in EC_{50} values to azoles compared with other isolates.

In two specific trials several different combinations of fungicides were tested in 2021 when applied at GS 45-51. In both trials 0.5 l/ha Comet Pro was applied during elongation to keep down attack of rust and other leaf blotch diseases.

The first trial was part of the Eurobarley project, where a similar trial plan was carried out in four countries. The Danish trial developed a late but still significant attack of Ramularia leaf spot and provided good opportunities for ranking the efficacy of the products (Table 3; Figure 2). More than 80% control was achieved by most products. Solutions with Revysol and Pavecto (BAS 831) used as solo products or in combination with other actives provided very good control. Data from the four trials carried out in Ireland, Scotland, Bavaria and Denmark are summarised in Figure 3. Proline EC 250 provided only moderate levels of control in line with the achieved effects from Folpan. The high level of control from the Pavecto solution shows that although this product belongs to the strobilurins, the mode of activity is different and apparently has the ability to control strobe-resistant populations.

Due to the late development of Ramularia leaf spot in the Danish trial, only minor and non-significant yield benefits were observed as a result of the control levels achieved (Table 3). The solution which included Pavecto did, however, provide the best yield response.

In a second trial plan, two trials were carried out testing the effect of different solutions on Ramularia leaf spot (21389). These trials included various solo products as well as mixtures. Results are shown in Table 4 and Figure 3. Again, Revysol-based products performed well. Adding folpan to solutions with Proline EC 250 or Propulse SE 250 provided an improved control. This improvement did, however, not provide an increase in yields or net yields.

Table 3. Control of Ramularia leaf spot and yield responses, using different fungicides applied at GS 39-49 in spring barley (21386). Danish trial as part of the Eurobarley project.

Treatments, l/ha 21386		% rust	% *Ramularia*	% *Ramularia*	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 39-49	Dose	GS 80 Leaf 2	GS 79 Leaf 2	GS 81 Leaf 2			
1. Untreated		10.5	5.8	22.5	45.5	37.3	-
2. Revysol	1.0	1.9	0.6	1.5	47.4	2.9	-
3. Revysol	1.5	0.9	0.4	1.3	46.3	4.4	-
4. Proline EC 250	0.54	0.6	3.5	10.3	48.1	0.4	-1.8
5. Proline EC 250	0.8	1.4	4.3	9.0	48.7	3.1	0.1
6. Folpan 500 SC	1.5	6.3	2.8	8.3	46.0	6.8	4.6
7. Elatus Era	1.0	0.1	2.6	5.8	46.6	7.0	-
8. Ascra Xpro	1.2	0.2	2.6	5.8	48.5	6.2	1.8
9. Revytrex	1.5	0.3	0.1	1.8	47.8	0.6	-
10. Revystar XL	1.5	0.2	0.2	1.8	47.0	4.0	-
11. Balaya/Revycare	1.5	0.4	0.7	3.0	47.8	4.9	-
12. BAS 768 00F	4.0	4.0	0.4	3.0	46.8	1.2	-
13. BAS 831 00F	2.25	0.0	0.1	0.4	48.7	7.6	-
LSD_{95}		3.6	1.8	2.7	3.5	NS	-

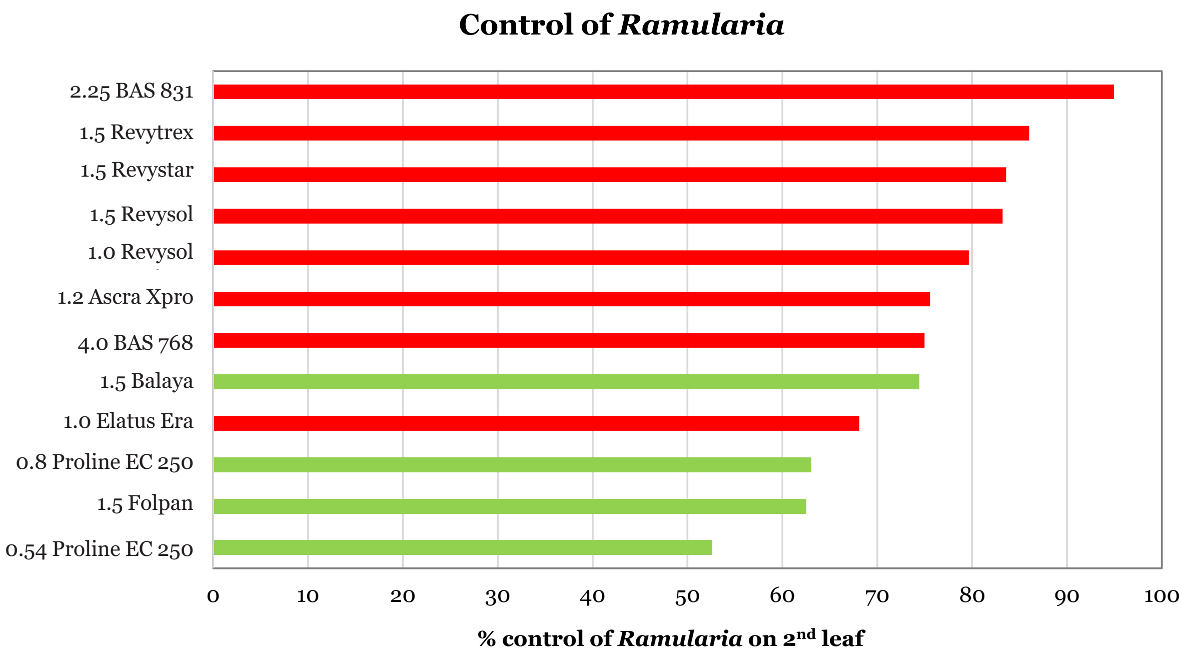


Figure 2. Control of Ramularia leaf spot in spring barley (21385). 13.4% attack on 2nd leaf in four trials assessed at GS 79-81 in untreated. The trials were located in Danmark, Scotland, Ireland and Germany. Red solutions are not authorised in Denmark.

Table 4. Control of Ramularia leaf spot and other diseases, using different fungicides applied at GS 45-51 in spring barley. Two trials in Denmark (21389).

Treatments, l/ha 21389		% rust	% net blotch	% net blotch	% *Ramularia*	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 32-33	GS 45-51	GS 77 Leaf 2	GS 71 Leaf 2	GS 77 Leaf 2	GS 77 Leaf 2			
1. Comet Pro 0.5		12.5	5.8	27.5	16.3	46.8	57.3	-
2. Comet Pro 0.5	Ascra Xpro 1.0	0.8	0.2	0.4	1.6	48.2	7.7	2.3
3. Comet Pro 0.5	Propulse SE 250 0.8	3.5	0.6	0.5	3.6	48.2	5.1	0.9
4. Comet Pro 0.5	Univoq 0.75	1.5	1.8	15.0	6.4	48.2	3.8	-0.9
5. Comet Pro 0.5	Folpan 500 SC 1.0	12.0	2.0	22.5	10.4	47.1	-1.5	-4.8
6. Comet Pro 0.5	Balaya 1.5	0.6	0.3	2.0	0.3	49.1	2.5	-4.8
7. Comet Pro 0.5	Balaya 0.75	0.9	0.3	5.8	0.9	49.1	4.0	-0.7
8. Comet Pro 0.5	Lenvyor 0.75	1.5	2.8	20.0	1.3	48.1	3.0	-
9. Comet Pro 0.5	Proline EC 250 0.4	2.8	2.0	13.3	9.2	46.8	-0.5	-3.9
10. Comet Pro 0.5	Proline EC 250 0.4 + Folpan 500 SC 0.75	2.5	2.8	15.0	5.2	47.8	2.0	-2.2
11. Comet Pro 0.5	Propulse SE 250 0.4 + Folpan 500 SC 0.75	4.0	1.0	1.8	3.7	47.1	1.9	-2.1
No. of trials		1	1	1	2	2	2	2
LSD_{95}		2.7	1.3	5.4	-	-	2.2	-

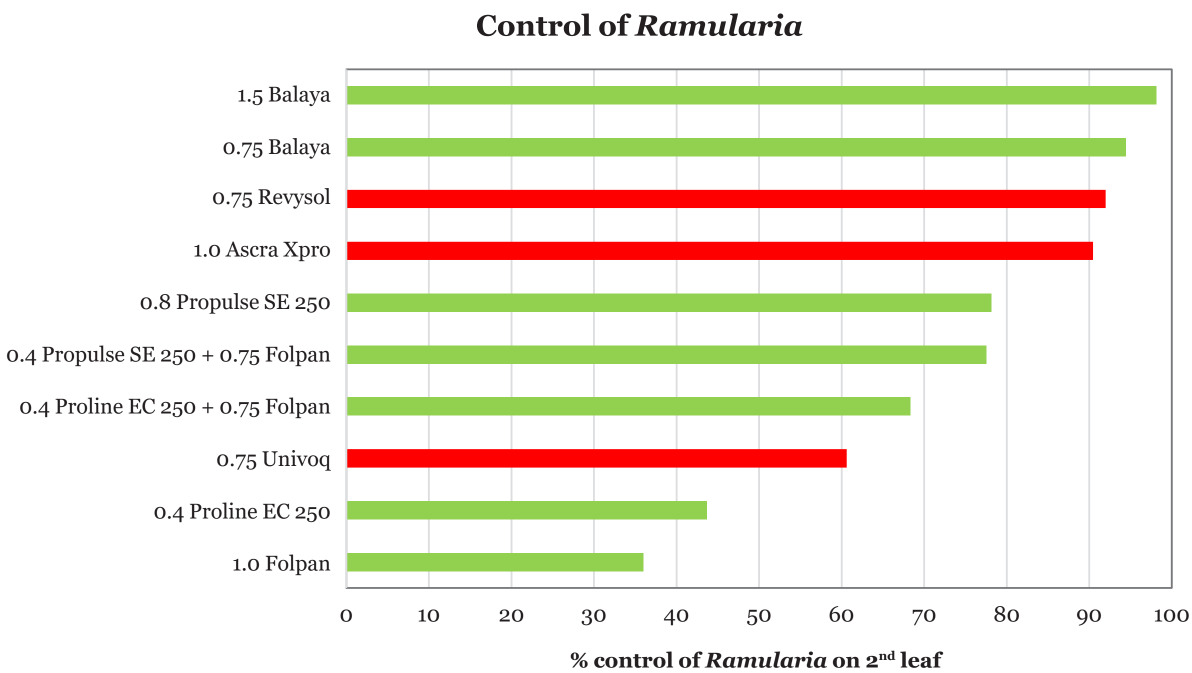


Figure 3. Control of Ramularia leaf spot in spring barley (21389). 16% attack in two trials assessed at GS 81 in untreated. Red solutions are not authorised in Denmark.

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

Control of net blotch and *Rhynchosporium* in barley

In several trials the focus was to get a good ranking of the efficacy of the fungicides on net blotch and *Rhynchosporium*. For each of the two diseases, two trials were carried out. Against net blotch a trial was also carried out as part of the Eurobarley project (21385-1). In the winter barley cultivar Neptun, good efficacy ranking was seen for *Rhynchosporium* (Table 5; Figure 4).

The attack of net blotch was significant, and in this trial it was clear that the products which included prothioconazole provided the better effects (Propulse SE 250, Proline EC 250 and Univoq). The ranking of the efficacy is shown in Figure 5.

Table 5. Control of *Rhynchosporium* and Ramularia leaf spot in winter and spring barley (21372). Average of two trials (21372).

Treatments, l/ha 21372		% *Rhynchosporium*	% *Rhynchosporium*	% *Ramularia*	% GLA	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 37-39	Dose	GS 55 Leaf 2	GS 75 Leaf 2	GS 75 Leaf 2	GS 81 Leaf 2			
1. Untreated		33.8	66.3	14.5	0.7	46.9	48.9	-
2. Orius Max	0.93	21.3	45.0	8.9	22.5	51.6	12.7	11.1
3. Prosaro EC 250	0.75	13.8	8.3	4.3	40.7	52.1	7.8	5.6
4. Balaya	1.125	10.0	15.0	1.6	44.4	51.3	9.4	5.1
5. Balaya + Entargo	0.75 + 0.18	5.0	20.0	1.9	47.5	51.7	11.3	7.7
6. Univoq	1.125	11.3	12.5	7.7	26.3	50.3	4.8	0.5
7. Propulse SE 250	0.75	6.3	8.3	5.8	35.1	52.0	4.2	1.8
8. Mirador Forte	1.125	12.0	36.3	9.2	22.5	52.4	6.1	3.7
9. Comet Pro	0.93	10.0	23.8	8.5	30.1	50.1	8.8	6.1
10. Amistar	0.75	17.5	46.3	9.2	24.3	51.7	10.8	9.0
11. Proline EC 250	0.6	10.8	12.5	5.1	30.1	51.7	9.5	7.2
12. Entargo	0.525	16.3	37.5	9.4	6.8	47.0	0.7	-1.4
13. Pictor Active + Agropol	1.125 + 0.2	6.3	16.3	5.1	56.4	50.8	10.0	9.4
No. of trials		1	1	2	2	1	1	1
LSD_{95}		6.0	7.7	-	-	3.3	5.0	-

Untreated.

Treated with 1.0 l/ha Propulse SE 250.

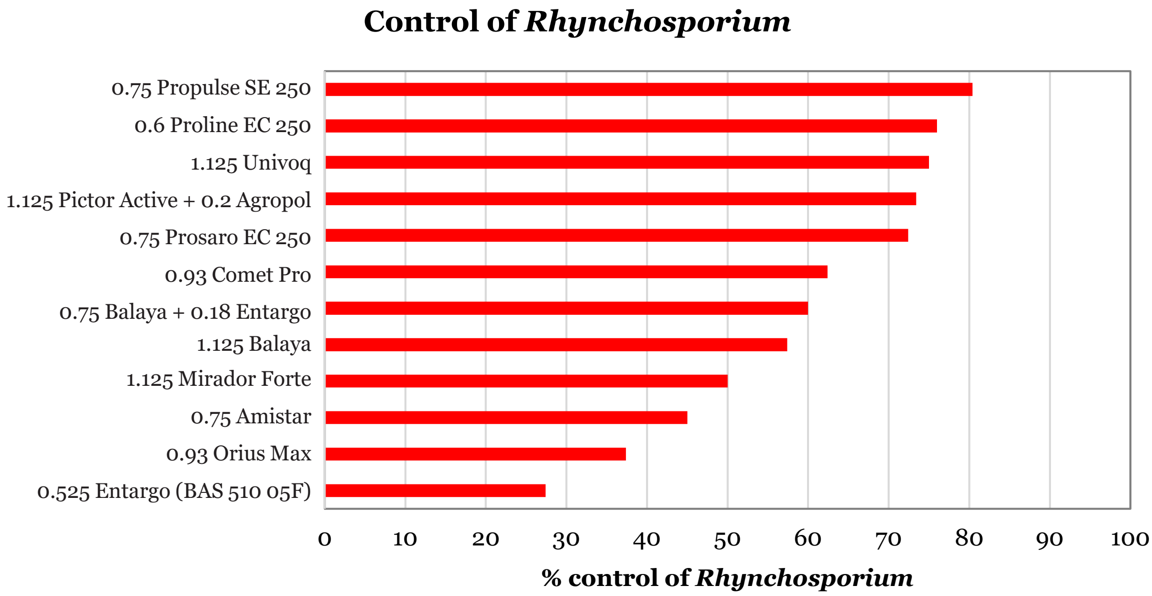


Figure 4. Control of *Rhynchosporium* in winter barley (21372). 50% attack at GS 71 in untreated.

Also, against net blotch a wide range of products was tested and provided a highly variable level of control. This was the case both in the Eurobarley trial and in the two Danish ranking trials. In the Eurobarley trial solutions based on BAS 831 00F (Pavecto solution), Priaxor, Revytrex and Ascra Xpro gave the best performance (Table 6). In the two Danish trials carried out in the cultivars RGT Planet and Chapeau, Propulse SE 250, Pictor Active and Balaya + Entargo gave the best control of net blotch (Table 7; Figure 5). Yield levels were low, and there were no clear differences between treatments.

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

Treatments, l/ha 21385		% brown rust	% net blotch	% *Ramularia*	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
GS 37-49	Dose	GS 79 Leaf 2	GS 73 Leaf 2	GS 79 Leaf 2			
1. Untreated		30.0	50.0	15.0	42.3		-
2. Revytrex	1.5	4.8	1.0	0.8	45.8	8.9	-
3. Revytrex + Comet Pro	1.5 + 0.5	7.0	1.3	1.0	45.6	7.4	-
4. Revystar XL + Comet Pro	1.5 + 0.75	5.0	1.5	0.9	46.1	6.7	-
5. Proline EC 250	0.8	12.5	9.5	5.0	43.3	3.7	0.7
6. Elatus Era	1.0	0.8	4.3	2.0	47.3	9.3	-
7. Aviator Xpro	1.0	7.8	2.8	1.8	45.1	5.5	-
8. Ascra Xpro	1.2	6.5	1.5	1.5	45.4	9.3	-
9. Fandango S	1.75	2.8	9.5	7.3	46.0	8.9	-
10. Madison	1.0	3.0	5.3	6.3	46.4	10.1	-
11. Revycare	1.5	5.8	4.3	2.3	45.0	7.1	-
12. Priaxor	1.5	4.3	1.8	2.5	46.4	8.4	-
13. BAS 831 00F	2.25	3.0	0.9	1.0	45.7	11.7	-
14. Comet Pro	0.75	10.0	6.3	9.0	44.0	7.5	5.2
LSD_{95}		3.6	2.5		2.2	5.3	-

Table 7. Control of net blotch and brown rust in spring barley (21382). Carried out in the cultivars Chapeau and RGT Planet.

Treatments, l/ha 21382 GS 37-39	Dose	% net blotch GS 51 Leaf 4-5	% net blotch GS 51 Leaf 2-3	% net blotch GS 75 Leaf 1-2/ Leaf2-3	% brown rust GS 77 Leaf 2-3	TGW g	Yield & yield increase hkg/ha	Net increase hkg/ha
1. Untreated		20.0	6.8	15.0	7.8	41.4	31.7	-
2. Orius Max	0.93	16.8	3.4	9.6	0.5	39.7	2.5	0.9
3. Prosaro EC 250	0.75	11.0	1.0	3.6	0.6	42.0	8.3	6.1
4. Balaya	1.125	7.3	0.6	2.6	0.5	42.8	9.5	5.2
5. Balaya + Entargo	0.75 + 0.18	7.3	0.3	1.5	0.3	42.3	9.2	5.6
6. Univoq	1.125	10.0	1.2	3.3	1.3	42.9	5.8	1.5
7. Propulse SE 250	0.75	8.5	0.3	0.8	0.1	41.4	8.5	6.1
8. Mirador Forte	1.125	7.0	0.7	3.3	0.2	43.1	6.0	3.6
9. Comet Pro	0.93	9.5	0.4	2.1	0.3	43.4	12.1	9.4
10. Amistar	0.75	9.5	1.6	5.5	0.5	43.4	10.6	8.8
11. Proline EC 250	0.6	9.5	0.5	1.8	0.5	43.8	6.8	4.5
12. Pictor Active + Agropol	1.125 + 0.2	8.5	0.3	0.6	0.3	44.1	4.8	1.2
No. of trials		1	2	2	2	1	2	2
LSD_{95}		2.2	0.7	2.3	1.0	2.4	6.3	-

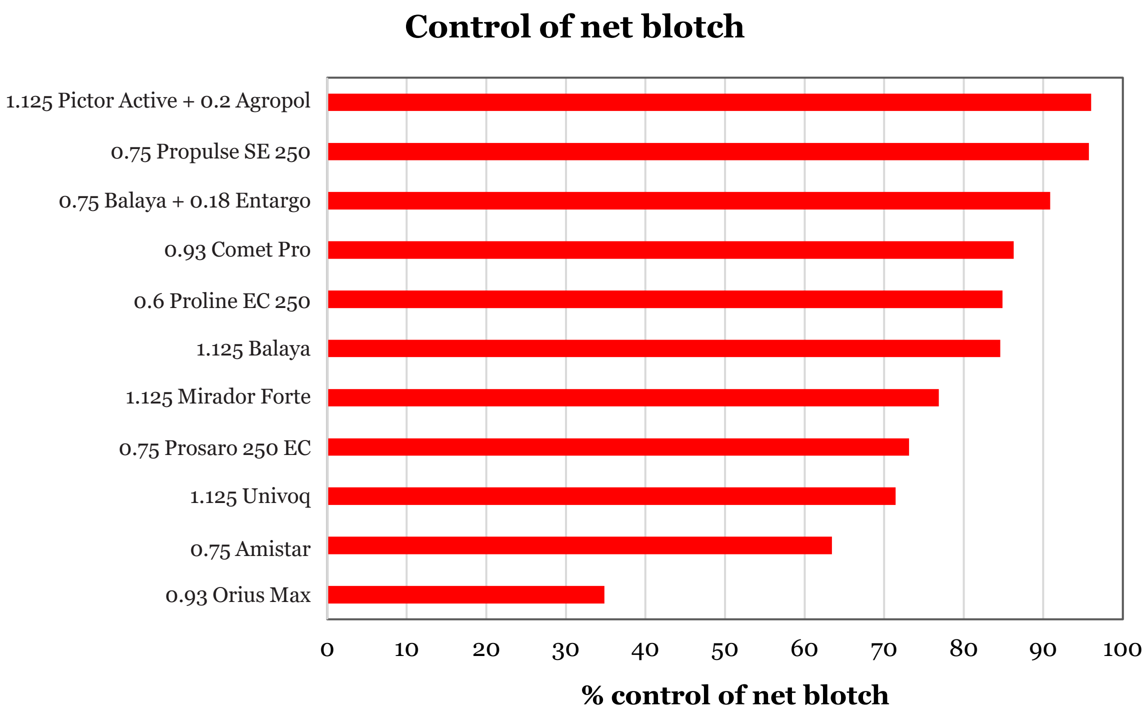


Figure 5. Control of net blotch in spring barley (21382). Average of two trials with 17.8% net blotch in untreated at GS 71-72.

Results from fungicide trials in rye and triticale

Two trials were carried out in 2021 - one in rye and one in triticale, testing different commonly used fungicides (21364).

The trial carried out in triticale (21364-1) was treated twice as the attack of yellow rust in the cultivar began very early and was driven by natural infection. The attack also spread to the ears. All treatments provided high levels of control. Also, glume blotch (*Stagonospora nodorum*) developed to some extent in the trial. The yield responses were large and significant and varied between 27 dt/ha and 36 dt/ha (Table 8). Overall, solutions with Prosaro EC 250 provided slightly better control.

Table 8. Control of diseases in triticale, GLA and yield responses, using different fungicides applied at GS 32 and GS 51-55 (21364-1).

Treatments, l/ha 21364-1		% yellow rust			% glume blotch	% GLA	TGW g	Yield & yield increase hkg	Net increase hkg
GS 32 & 51-55	Dose	GS 65 Leaf 1	GS 65 Leaf 2	GS 71 Leaf 2	GS 59 Leaf 3				
1. Prosaro EC 250 + Comet Pro	0.25 + 0.3	7.5	15.0	21.3	5.0	63.8	30.7	+36.9	33.1
2. Propulse SE 250 + Comet Pro	0.35 + 0.2	10.5	20.0	23.8	10.0	58.8	30.0	+31.0	27.0
3. Balaya	0.75	11.3	23.8	30.0	15.0	67.5	30.5	+31.2	24.6
4. Prosaro EC 250	0.5	6.3	16.3	22.5	5.0	70.0	29.7	+36.2	32.7
5. Comet Pro	0.6	15.0	26.3	35.0	10.0	63.8	27.3	+27.5	23.4
6. Untreated		81.3	86.3	92.5	25.0	0.0	26.4	36.7	-
LSD_{95}		9.0	8.6	12.1	4.95	17.0	2.5	8.0	-

The rye trial (21364-2) was treated twice. The trial developed mainly an attack of *Rhynchosporium* and only a very minor attack of brown rust. The five different treatments provided significant and almost similarly good control of *Rhynchosporium* (Table 9). The yield increased only moderately and not significantly.

Table 9. Control of *Rhynchosporium* in triticale, GLA and yield responses, using different fungicides applied at GS 32 and 51-55 (20364-1).

Treatments, l/ha 21364-2		% *Rhynchosporium*		% *Rhynchosporium*		% GLA	TGW g	Yield & yield increase hkg	Net Increase hkg/ha
GS 32 & 51-55	Dose	GS 65 Leaf 2	GS 65 Leaf 3	GS 73 Leaf 1	GS 73 Leaf 2				
1. Prosaro EC 250 + Comet Pro	0.25 + 0.3	5.0	5.0	25.0	30.0	5.0	25.3	5.4	1.6
2. Propulse SE 250 + Comet Pro	0.35 + 0.2	2.0	5.0	22.5	30.0	3.8	25.9	6.1	2.1
3. Balaya	0.75	2.8	4.8	25.0	30.0	3.8	26.2	4.5	-2.1
4. Prosaro EC 250	0.5	2.8	6.3	40.0	41.3	6.3	26.4	5.5	-2.0
5. Comet Pro	0.6	2.8	10.0	38.8	36.3	1.3	27.6	9.9	5.8
6. Untreated		15.0	26.3	52.5	61.3	0.0	25.7	64.9	-
LSD_{95}		1.4	3.0	5.9	3.3	4.4	1.8	5.2	-

Ranking of cultivar susceptibility to ergot

In a project partly financed by the breeders, the Department of Agroecology, Aarhus University, Flakkebjerg, has investigated the susceptibility to ergot among the rye cultivars most commonly grown in Denmark. In this year's trials, 14 cultivars were included, sown in 1-m² plots and tested in two replicates with buffer zones of triticale between all plots (21303). The trial was inoculated four times on 31 May and 2, 4 and 6 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 (Table 10). Data are also shown in Figure 6, which provides a ranking of the tested cultivars.

In some cultivars the average number of ergots per head was higher than one. This was the case for the cultivars Stannos and SU Performer 90 + 10% population. Cultivars from KWS showed the best level of resistance in the test. Heads from the plots were harvested and threshed. Following this, both samples with the separated ergots, the cleaned seed and the raw sample were analysed in Germany in collaboration with KWS. No alkaloids were found in the raw and the cleaned seeds, with the exception of content in the cultivar KWS Jethro. The level of alkaloids in the ergot samples varied to a great extent, which indicates that the different cultivars lead to different levels of alkaloids.

Table 10. Number of ergots per 100 ears and alkaloid content in ergots and seed samples in rye inoculated with ergot (20303).

Cultivars	Ergots, number	Ergots, number	Alkaloids in ergots, µg/kg	Alkaloids in clean seeds	Alkaloids in raw samples, µg/kg
Helltop	29.5	38	771	0	0
SU Performer 90 + 10% population	84	114	941	0	0
SU Arvid 90 + 10% population	19	34	56	0	0
SU Pluralis 90 + 10% population	45	59.5	26	0	0
KWS Serafino	13.5	20.5	0	0	0
KWS Tayo	17.5	21.5	6	0	0
KWS Berado	7	12.5	0	0	0
KWS Jethro	9	12.5	2.112	0	141
KWS Receptor	16.5	17.5	6	0	0
KWS Initiator	6	9	8	0	0
KWS Teodor	19.5	22	34	0	0
KWS Tutor	9	11	2.022	0	0
DH 386	21.5	18.5	455	0	0
Stannos	137.5	146	327	0	0

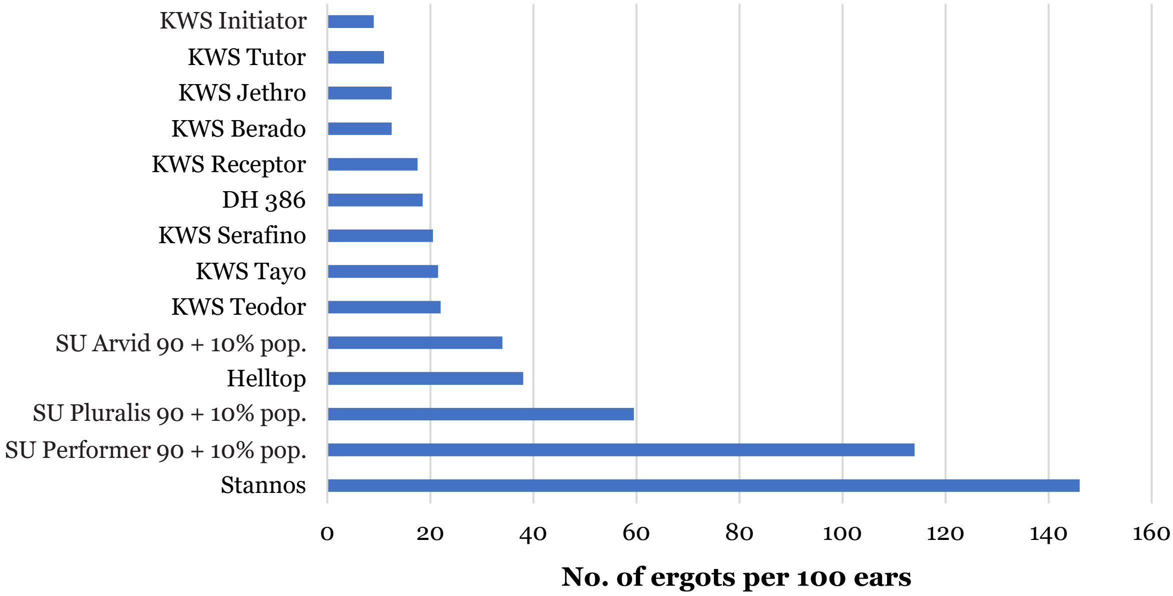


Figure 6. Ranking of cultivar susceptibility to ergot, based on count from 100 heads.

IV Control strategies in different cereal cultivars

Lise N. Jørgensen, Thies M. Heick, Niels Matzen, Hans-Peter Madsen, Helene S. Kristjansen, Sidsel Kirkegaard, Christian A. S. Nielsen & Anders Almskou-Dahlgaard

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 the four most resistant cultivars (Informer, Sheriff, KWS Extase and Kvium). One of the treatments included the use of the decision support system Crop Protection Online to evaluate the need for treatments. The trials were placed at two locations - one at AU Flakkebjerg and one near Fredericia at VELAS.

The following strategies were tested:
1. Untreated
2. 1.25 l/ha Balaya (GS 45-51) (TFI = 1.3); cost: 4.4 dt/ha
3. 1.38 l/ha Univoq (GS 45-51) (TFI = 1.38); cost: (4.8 dt/ha)
4. 0.5 l/ha Balaya / 0.5 l/ha Univoq (GS 37-39 / 55-61) (TFI = 1.04); cost: 4.1 dt/ha
5. 0.75 l/ha Balaya / 0.5 l/ha Propulse SE 250 + 0.25 l/ha Folicur Xpert (GS 37-39 / 55-61) (TFI = 1.63); cost: 4.9 dt/ha
6. 0.75 l/ha Univoq / 0.5 l/ha Propulse SE 250 + 0.25 l/ha Folicur Xpert (GS 37-39 / 55-61) (TFI = 1.58); cost: 4.9 dt/ha
7. 0.35 l/ha Propulse SE 250 / 0.75 l/ha Balaya / 0.75 l/ha Univoq (GS 31 / 37-39 / 55-61) (TFI = 1.95); cost: 7.0 dt/ha
8. Treatments according to Crop Protection Online (Table 1)

The trials initially only developed moderate levels of attack. Only the cultivar Benchmark was seen as very susceptible to both yellow rust and *Septoria*. All treatments reduced disease attack adequately, although treatments with the highest input on average reduced attacks the most.

Table 1. Treatments applied following recommendations from Crop Protection Online (CPO), treatment frequency index (TFI) and costs excl. application (21350-1 and 21350-2).

Cultivars (21350-1)	Date and GS	Products, l/ha	TFI	Costs, hkg/ha
Cultivar mixture (Mix)	19-05-2021 GS 33	0.35 Propulse SE 250 + 0.2 Folicur Xpert	0.59	1.65
Benchmark	19-05-2021 GS 33	0.35 Propulse SE 250 + 0.2 Folicur Xpert	0.59	1.65
Kvium	19-05-2021 GS 33	0.35 Propulse SE 250 + 0.2 Folicur Xpert	0.59	1.65
Sheriff	19-05-2021 GS 33	0.35 Propulse SE 250 + 0.2 Folicur Xpert	0.59	1.65
Informer	19-05-2021 GS 33	0.35 Propulse SE 250 + 0.2 Folicur Xpert	0.59	1.65
KWS Extase	19-05-2021 GS 33	0.35 Propulse SE 250 + 0.2 Folicur Xpert	0.59	1.65

Cultivars (21350-2)	Date and GS	Products, l/ha	TFI	Costs, hkg/ha
Cultivar mixture (Mix)	15-06-2021 GS 39	0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.82	2.09
Benchmark	01-06-2021 GS 39 15-06-2021 GS 61	0.7 Balaya 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 0.82	2.68 2.09
Kvium	15-06-2020 GS 39	0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.82	2.09
Sheriff	01-06-2021 GS 39 15-06-2021 GS 61	0.7 Balaya 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 0.82	2.68 2.09
Informer	15-06-2021 GS 39	0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.82	2.09
KWS Extase	15-06-2021 GS 39	0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.82	2.09

Disease attacks were moderate in the trials in which only Benchmark developed significant attacks of yellow rust and Septoria tritici blotch. Control from different treatments is shown in Figure 1. Yield levels were generally high, and increases following fungicide applications were low to moderate (Figure 2; Table 2). Only Benchmark increased yields significantly in the range of 10-13 dt/ha. None of the treatments increased yields significantly in the cultivar mixture in which none of the treatments gave a positive net yield return.

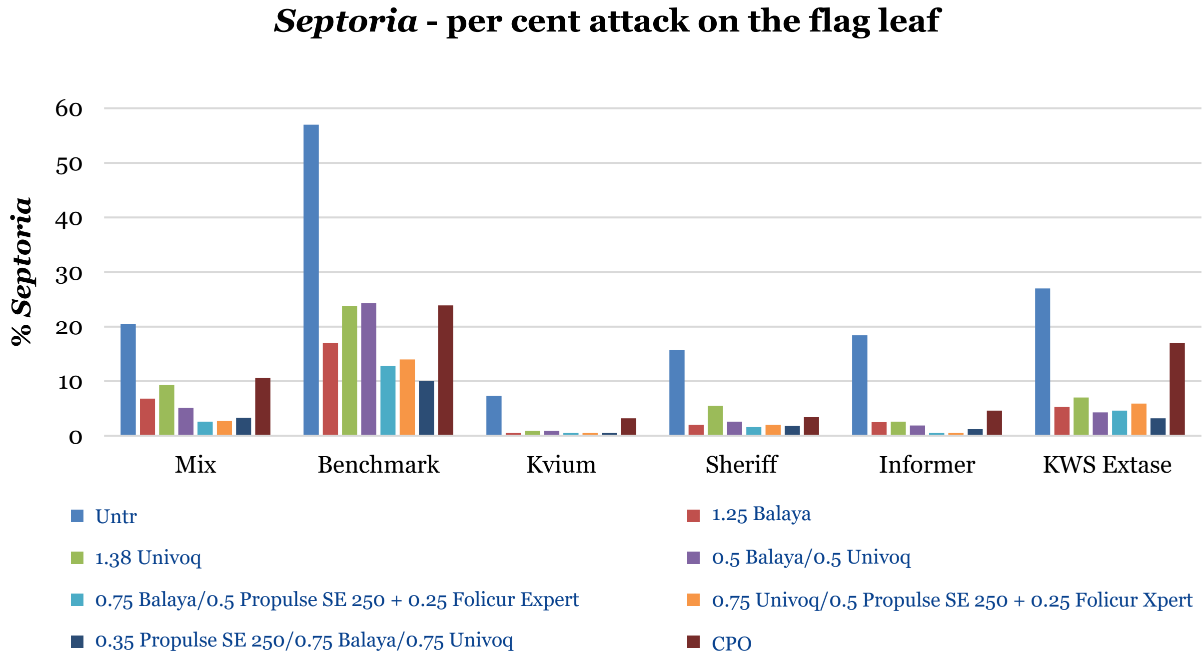


Figure 1. Attack of *Septoria* assessed on the flag leaf at GS 75. All treatments reduced the attack. The level of attack varied very much between the cultivars.

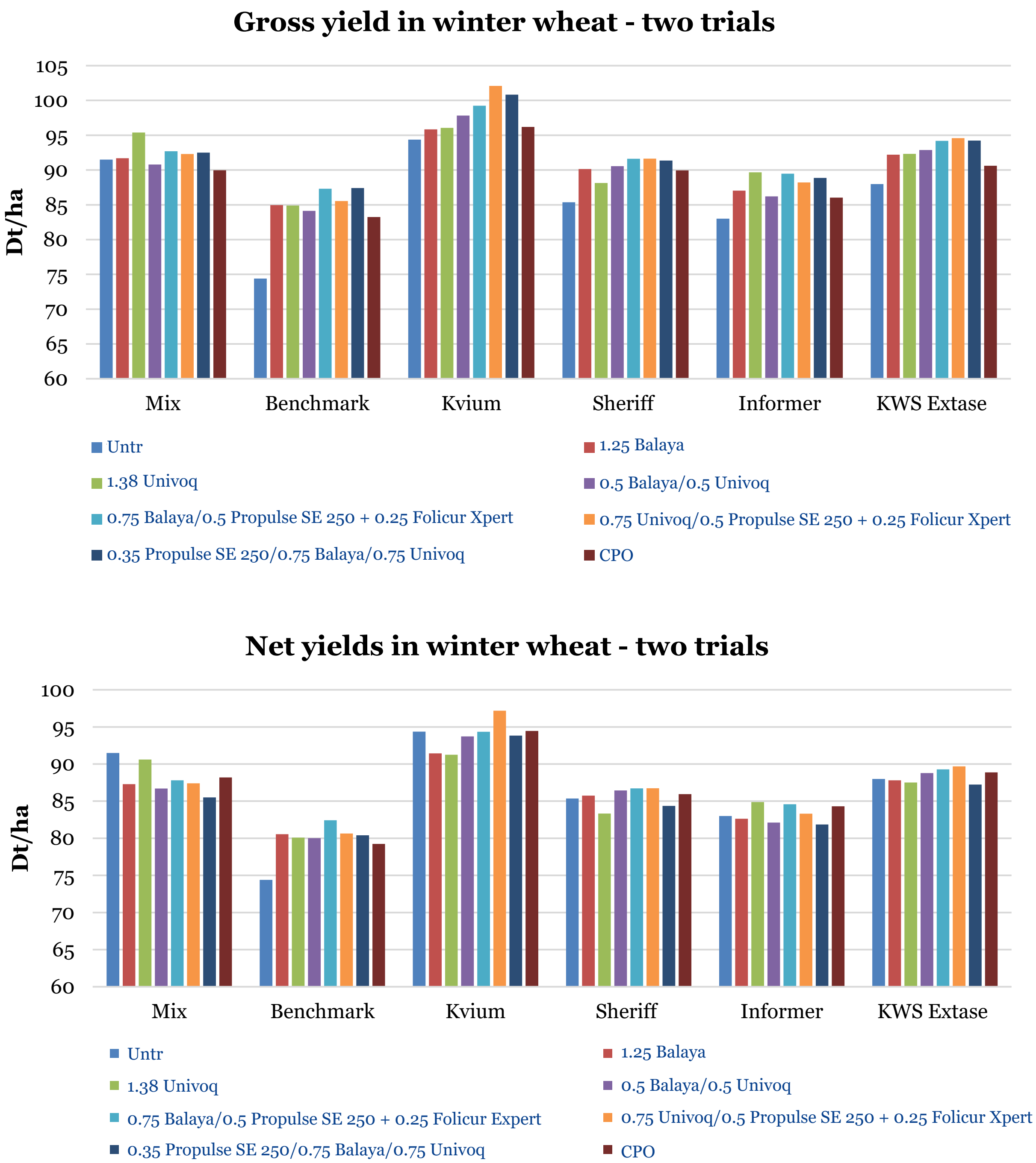


Figure 2. Gross yield and net yields following treatments with different treatments in six different cultivars. Average of two trials.

Table 2. % *Septoria*, yellow rust, green leaf area (GLA) and yield responses. One trial at VELAS in Jutland and one trial at Flakkebjerg with six winter wheat cultivars, using eight different fungicide treatments (21350). (Continues on the next page).

Cultivars	% *Septoria*, leaf 2, GS 69								% *Septoria*, leaf 2, GS 75							
	Untr.	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO	Untr.	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO
Cultivar mixture	9.8	4.2	5.2	3.8	2.5	2.7	1.5	5.3	46.5	18.8	22.7	19.2	8.5	9.3	8.1	26.7
Benchmark	33.3	15.8	16.3	13.7	9.2	10.2	10.8	13.3	100	48.0	53.8	49.6	32.1	39.2	30.0	45.9
Kvium	5.7	1.3	1.5	1.3	1.0	1.7	1.0	3.0	27.7	3.5	6.2	6.3	1.8	6.2	2.3	13.0
Sheriff	16.7	5.2	5.7	3.7	2.3	3.2	2.7	4.2	37.5	11.8	20.5	10.0	4.7	7.0	5.2	13.5
Informer	6.5	1.5	0.7	0.4	0.4	0.4	0.5	2.0	42.7	8.2	11.5	6.5	2.4	3.0	3.8	22.8
KWS Extase	15.3	9.8	8.0	6.8	6.2	9.3	6.0	12.5	60.0	21.9	17.7	13.5	9.3	14.8	7.6	33.3
Average	14.6	6.3	6.2	5.0	3.6	4.6	3.8	6.7	52.4	18.7	22.1	17.5	9.8	13.3	9.5	25.9
No. of trials	2								2							

Cultivars	% Septoria, leaf 1, GS 75								% yellow rust, leaf 1, GS 75							
	Untr.	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO	Untr.	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO
Cultivar mixture	20.5	6.8	9.3	5.1	2.6	2.7	3.3	10.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benchmark	53.9	17.0	23.8	24.3	12.8	14.0	10.9	23.9	23.3	3.0	3.7	3.0	3.0	3.0	3.0	3.0
Kvium	7.3	0.5	0.9	1.0	0.5	0.5	0.5	3.2	10.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Sheriff	15.7	2.0	5.5	2.6	1.6	2.0	1.8	3.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Informer	18.4	2.5	2.6	1.9	0.5	0.5	1.2	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KWS Extase	25.6	5.3	7.0	4.3	4.1	5.5	2.9	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	23.6	5.7	8.2	6.5	3.7	4.2	3.4	10.5	5.7	0.5	0.7	0.5	0.5	0.5	0.5	0.5
No. of trials	2								1							

Table 2. % *Septoria*, yellow rust, green leaf area (GLA) and yield responses. One trial at VELAS in Jutland and one trial at Flakkebjerg with six winter wheat cultivars, using eight different fungicide treatments (21350). (Continued).

Cultivars	% GLA, leaf 1, GS 75/79								TGW (g)							
	Untr.	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO	Untr.	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO
Cultivar mixture	40.0	62.5	60.0	60.0	53.4	57.5	65.0	47.5	44.2	44.4	46.0	45.8	45.6	45.4	43.5	44.5
Benchmark	0.0	32.5	12.5	27.5	30.0	25.9	28.8	7.1	39.1	40.7	41.2	41.7	41.3	41.9	40.2	41.2
Kvium	50.0	71.7	62.5	75.0	72.5	73.4	73.4	52.5	45.4	46.4	46.3	46.4	47.1	43.3	43.6	46.9
Sheriff	44.2	66.7	57.5	65.0	68.4	68.4	65.0	62.5	38.9	40.3	39.7	40.1	40.9	40.3	40.7	40.0
Informer	37.5	72.5	72.5	71.7	72.5	85.0	70.9	42.5	44.8	46.0	47.9	47.0	47.5	46.3	47.0	47.0
KWS Extase	23.4	44.2	38.4	38.4	40.9	43.4	49.2	28.4	43.7	44.1	45.6	44.7	45.7	44.4	44.0	44.4
Average	32.5	58.4	50.6	56.3	56.3	58.9	58.7	40.1	42.7	43.7	44.5	44.3	44.7	43.6	43.2	44.0
No. of trials	2								2							

Cultivars	Yield & yield increase, hkg/ha								Net increase, hkg/ha						
	Untr.	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO	1.25 Balaya	1.38 Univoq	0.5 Balaya / 0.5 Univoq	0.75 Balaya / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.75 Univoq / 0.5 Propulse SE 250 + 0.25 Folicur Xpert	0.35 Propulse SE 250 / 0.75 Balaya / 0.75 Univoq	CPO
Cultivar mixture	91.5	0.2	3.9	-0.7	1.1	0.8	1.0	-1.6	-4.2	-0.9	-4.8	-3.8	-4.1	-6.0	-3.5
Benchmark	74.4	10.6	10.5	9.8	13.0	11.2	13.0	8.9	6.2	5.7	5.7	8.1	6.3	6.0	5.7
Kvium	94.4	1.5	1.7	3.5	4.9	7.7	6.5	1.8	-2.9	-3.1	-0.6	0.0	2.8	-0.5	-0.1
Sheriff	85.4	4.8	2.8	5.2	6.3	6.3	6.0	4.6	0.4	-2.0	1.1	1.4	1.4	-1.0	1.4
Informer	83.0	4.0	6.7	3.2	6.5	5.2	5.9	3.0	-0.4	1.9	-0.9	1.6	0.3	-1.1	1.1
KWS Extase	88.0	4.2	4.3	4.9	6.2	6.6	6.3	2.6	-0.2	-0.5	0.8	1.3	1.7	-0.7	0.7
Average	86.1	4.2	5.0	4.3	6.3	6.3	6.5	3.2	-0.3	0.2	0.2	1.4	1.4	-3.3	0.9
No. of trials	2								2						

Untr. = Untreated; 1.25 l/ha Balaya, GS 45-51 (costs = 4.4 hkg/ha); 1.38 l/ha Univoq, GS 45-51 (costs = 4.8 hkg/ha); 0.5 l/ha Balaya, GS 37-39 / 0.5 l/ha Univoq, GS 55-61 (costs = 4.1 hkg/ha); 0.75 l/ha Balaya, GS 37-39 / 0.5 l/ha Propulse SE 250 + 0.25 l/ha Folicur Xpert, GS 55-61 (costs = 4.9 hkg/ha); 0.75 l/ha Univoq, GS 37-39 / 0.5 l/ha Propulse SE 250 + 0.25 l/ha Folicur Xpert, GS 55-61 (costs = 4.9 hkg/ha); 0.35 l/ha Propulse SE 250, GS 31 / 0.75 l/ha Balaya, GS 37-39 / 0.75 l/ha Univoq, GS 55-61 (costs = 7.0); CPO = Crop Protection Online.

Control strategies in different winter barley cultivars

In four winter barley cultivars, five different control strategies including control and a decision support system for crop protection were tested. One trial was at Flakkebjerg and one at VELAS - Jutland. The treatments given below were tested in the two trials. Due to a significant attack of barley yellow dwarf virus, the trial at Flakkebjerg was not harvested.

1. Untreated
2. 0.35 l/ha Prosaro EC 250 / 0.4 l/ha Balaya + 0.2 l/ha Entargo (GS 32 / GS 51)
3. 0.5 l/ha Balaya + 0.25 l/ha Entargo (GS 37-39)
4. 0.35 l/ha Prosaro EC 250 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro (GS 32 / GS 51)
5. Treatments according to Crop Protection Online (Table 3)

The cultivars Neptun, KWS Meridian and KWS Infinity developed significant attacks of *Rhynchosporium* and brown rust. All treatments reduced the attacks significantly (Table 4). Only minor yield responses were harvested in the trial at VELAS, and all net yields were low or negative.

Table 3. Treatments applied following recommendations from Crop Protection Online, treatment frequency index (TFI) and cost of the treatments (21351-1 and 21351-2).

Cultivars (21351-1)	Date and GS	Products	TFI	Costs, kg/ha
Neptun	18-05-2021 GS 39	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9
KWS Meridian	18-05-2021 GS 39	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9
KWS Infinity	18-05-2021 GS 39	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9
Kosmos	18-05-2021 GS 39	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9

Cultivars (21351-2)	Date and GS	Products	TFI	Costs, hkg/ha
Neptun	20-05-2021 GS 51	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9
KWS Meridian	20-05-2021 GS 51	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9
KWS Infinity	20-05-2021 GS 51	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9
Kosmos	20-05-2021 GS 51	0.35 Propulse SE 250 + 0.23 Comet Pro	0.57	1.9

Table 4. Control of diseases in winter barley and yield responses from two trials in four winter barley cultivars using four different strategies. (Continues on the next page).

Cultivars	% *Rhynchosporium*, leaf 2/2-4, GS 69					% *Rhynchosporium*, leaf 2/2-3, GS 71/75				
	Untr.	0.35 Prosaro EC 250 / 0.4 Balaya + 0.2 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.4 Balaya + 0.2 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Neptun	26.7	16.0	15.9	9.2	8.4	81.7	44.2	46.7	33.3	43.4
KWS Meridian	9.8	4.4	1.4	2.2	4.0	18.3	10.0	8.8	6.0	8.8
KWS Infinity	8.2	3.6	1.7	2.9	3.5	8.9	4.0	5.3	2.2	3.0
Kosmos	0.5	0.1	0.3	0.2	0.2	9.7	4.2	1.9	2.3	6.5
Average	11.3	6.0	4.8	3.6	4.0	29.7	15.6	15.7	11.0	15.4
No. of trials	2					1				

Table 4. Control of diseases in winter barley and yield responses from two trials in four winter barley cultivars using four different strategies. (Continued).

Cultivars	% brown rust, leaf 2-3, GS 75/71					% GLA, leaf 2-3, GS 75				
	Untr.	0.35 Prosaro EC 250 / 0.4 Balaya + 0.2 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.4 Balaya + 0.2 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Neptun	0.1	0.0	0.0	0.0	0.0	14.2	28.3	25.0	35.0	31.7
KWS Meridian	9.3	0.3	0.2	0.3	1.2	40.3	78.4	65.9	77.5	60.9
KWS Infinity	16.2	0.4	1.1	0.1	1.3	47.5	69.2	75.0	85.5	71.7
Kosmos	0.4	0.1	0.1	0.1	0.2	43.4	63.9	70.0	61.4	41.7
Average	6.5	0.2	0.4	0.1	0.7	36.4	60.0	59.0	64.9	51.5
No. of trials	2					1				

Cultivars	Yield & yield increase, hkg/ha					Net increase, hkg/ha			
	Untr.	0.35 Prosaro EC 250 / 0.4 Balaya + 0.2 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	0.35 Prosaro EC 250 / 0.4 Balaya + 0.2 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Neptun	63.2	4.8	2.2	5.2	2.8	1.0	-0.8	1.8	0.9
KWS Meridian	63.4	3.6	2.7	0.8	0.5	-0.2	-0.3	-2.6	-1.4
KWS Infinity	59.7	8.2	3.7	7.9	9.9	4.4	0.7	4.5	8.0
Kosmos	67.3	0.6	2.2	-1.2	0.8	-3.2	-0.8	-4.6	-1.1
Average	63.4	4.3	2.7	3.2	3.5	0.5	-0.3	-0.2	1.6
No. of trials	1					1			

Untr. = Untreated; 0.35 l/ha Prosaro EC 250, GS 32 / 0.4 l/ha Balaya + 0.2 l/ha Entargo, GS 51 (costs = 3.8 hkg/ha); 0.5 l/ha Balaya + 0.25 l/ha Entargo, GS 37-39 (costs = 3.0 hkg/ha); 0.35 l/ha Prosaro EC 250, GS 32 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 51 (costs = 3.4 hkg/ha); CPO = Crop Protection Online.

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 single cultivars were used as well as a mixture of the three cultivars. The trial was located at Flakkebjerg. The treatments given below were tested in the trial.

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

The trial developed significant attacks of mainly brown rust, but RGT Planet also developed a severe attack of net blotch. The two treatments using double treatments provided the best control, but the single treatment with 0.5 l/ha Balaya + 0.25 l/ha Entargo in particular was insufficient to keep down the disease. This inferior control also resulted in lower green leaf area at the end of the season as well as lower yield responses. CPO recommended one spray in all cultivars and gave acceptable control and yield responses (Table 6).

Table 5. Treatments applied following recommendations from Crop Protection Online, treatment frequency index (TFI) and cost of the treatments (21352-1).

Cultivars	Date and GS	Products, l/ha	TFI	Costs, hkg/ha
Fairway	22-06-2021 GS 53	0.35 Propulse SE 250 + 0.25 Comet Pro	0.6	2.0
RGT Planet	22-06-2021 GS 53	0.35 Propulse SE 250 + 0.25 Comet Pro	0.6	2.0
KWS Irina	22-06-2021 GS 53	0.35 Propulse SE 250 + 0.25 Comet Pro	0.6	2.0
Mixture	22-06-2021 GS 53	0.35 Propulse SE 250 + 0.25 Comet Pro	0.6	2.0

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 (21352-1). (Continues on the next page).

Cultivars	% brown rust, leaf 2, GS 57					% brown rust, leaf 2, GS 80				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Fairway	1.7	0.0	0.0	0.0	0.7	46.7	1.5	30.0	7.3	20.0
RGT Planet	1.0	0.0	0.0	0.0	0.2	33.3	0.7	25.0	1.5	14.0
KWS Irina	0.5	0.0	0.0	0.0	0.3	43.3	2.3	23.3	3.3	16.7
Mixture	1.3	0.0	0.0	0.0	0.5	36.7	2.0	21.7	1.3	26.7
LSD			0.5					12.5		
Average	1.1	0.0	0.0	0.0	0.4	40.0	1.6	25.0	3.4	19.4

Cultivars	% net blotch, leaf 2, GS 57					% Ramularia, leaf 2, GS 80				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Fairway	0.5	0.1	0.1	0.0	0.3	-	3.0	2.7	3.7	4.0
RGT Planet	10.0	0.7	3.0	0.3	3.7	7.0	2.3	1.3	7.0	6.0
KWS Irina	0.1	0.0	0.1	0.0	0.2	-	2.7	3.0	4.3	3.0
Mixture	0.7	0.1	0.0	0.2	4.5	-	2.7	2.0	6.7	7.0
LSD			1.7					3.1		
Average	2.8	0.2	0.8	0.1	2.2	1.8	2.7	2.3	5.4	5.0

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 (21352-1). (Continued).

Cultivars	% GLA, leaf 2, GS 80					TGW, g/1000				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Fairway	8.0	73.3	30.0	68.3	51.7	46.5	55.9	53.3	53.2	53.5
RGT Planet	23.0	84.3	23.3	63.3	41.7	41.6	48.8	47.4	48.2	49.2
KWS Irina	12.3	68.3	31.7	73.3	45.0	42.2	47.2	46.4	47.4	46.3
Mixture	28.3	70.0	40.0	70.0	50.0	44.9	49.5	48.3	49.7	50.1
LSD	30.2					4.2				
Average	17.9	74.0	31.3	68.7	47.1	43.8	50.4	48.9	49.6	49.8

Cultivars	Yield & yield increase, hkg/ha					Net increase, hkg/ha			
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO	0.35 Prosaro EC 250 / 0.5 Balaya + 0.25 Entargo	0.5 Balaya + 0.25 Entargo	0.35 Prosaro EC 250 / 0.35 Propulse SE 250 + 0.3 Comet Pro	CPO
Fairway	44.3	8.5	5.1	9.0	4.1	4.2	2.1	5.6	2.1
RGT Planet	46.5	4.5	-0.3	9.5	5.3	0.2	-3.3	6.1	3.3
KWS Irina	41.5	18.9	-0.8	12.2	7.7	14.6	-3.8	8.8	5.7
Mixture	40.7	10.9	5.0	12.5	11.3	6.6	2.0	9.1	9.3
LSD	12.8								
Average	43.3	10.7	2.3	10.8	7.1	6.4	0.8	7.4	5.1

Untr. = Untreated; 0.35 l/ha Prosaro EC 250, GS 32 / 0.5 l/ha Balaya + 0.25 l/ha Entargo, GS 51 (costs = 4.3 hkg/ha); 0.5 l/ha Balaya + 0.25 l/ha Entargo, GS 37-39 (costs = 3.0 hkg/ha); 0.35 l/ha Prosaro EC 250, GS 32 / 0.35 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro, GS 51 (costs = 3.4 hkg/ha); CPO = Crop Protection Online.

V Fungicide resistance-related investigations

Thies M. Heick, Birgitte B. Frederiksen & Lise N. Jørgensen

Fungicide resistance of *Zymoseptoria tritici* in Denmark and Sweden

The resistance level of the wheat pathogen *Zymoseptoria tritici* against prothioconazole (prothiconazole-desthio; azole group) and fluxapyroxad (SDHI group) was tested *in vitro* to survey the sensitivity of the Danish and Swedish *Z. tritici* populations. Each year, leaf samples with apparent symptoms of *Z. tritici* are collected around growth stage 73-77 in collaboration with SEGES and local advisors in Denmark and Jordbruksverket in Sweden. In 2021, 127 Danish isolates from 21 sites and 210 Swedish isolates from 27 sites were investigated for sensitivity to prothioconazole-desthio and fluxapyroxad (Tables 1-4). The general disease pressure of *Z. tritici* was low to medium in 2021.

The sensitivity testing was carried out on microtitre plates. Single pycnidium isolates were used to produce spore suspensions by scraping off six-day-old *Z. tritici* spores and transferring them into Milli-Q water. Spore suspensions were homogenised and adjusted to a spore concentration of 2.4 x 10^4 spores ml^{-1}. Technical duplicates of each isolate were included in the study. Stock solutions of all three fungicides were made by dissolving the active ingredients (Sigma) in 80% ethanol. Those stock solutions were then utilised to prepare 2 x potato dextrose broth (PDB) mixtures to obtain the following final microtitre plate fungicide concentrations (mg L^{-1}): 6.0, 2.0, 0.6, 0.2, 0.07, 0.008, 0.002 and 0 (prothioconazole-desthio) and 3.0, 1.0, 0.3, 0.1, 0.03, 0.01, 0.0033 and 0 (fluxapyroxad). A total of 100 µl of spore suspension and 100 µl of fungicide solution were added to a 96-deep well microtitre plate. Microtitre plates were wrapped in tinfoil and incubated at 20°C for six days in the dark. Plates were visually analysed in an Elisa reader at 620 nm. Fungicide sensitivities were calculated as the concentration of a fungicidal compound, at which fungal growth *in vitro* is inhibited by 50% (EC_{50}) by a non-linear regression (curve fit) using GraphPad Prism (GraphPad Software, La Jolla, CA, USA). The isolates IPO323 and OP15.1 were used as reference isolates.

Results - Denmark

In our monitoring, we tested resistance to prothioconazole with the metabolite prothioconazole-desthio, which has been included in the testing since 2016. In 2021, the average EC_{50} values for the Danish *Z. tritici* isolates were 0.32 ppm and 0.44 for prothioconazole-desthio and the SDHI fluxapyroxad, respectively (Figures 1 and 2; Table 2). The resistance factor (RF; EC_{50} value isolate / EC_{50} value reference isolate) for prothiconazole-desthio was 32 compared to 44 and 26 in the years before. The resistance levels of the SDHI fluxapyroxad in 2021 were at the same level as in 2018-2020 with an average resistance factor of 5 for the 2021 data, indicating that the Danish *Z. tritici* population remains sensitive to SDHI fungicides although a slight increase has taken place (Figure 2; Table 2). Overall, the results of the monitoring indicate that no shifting has occurred for either of the two active ingredients in 2021. Investigations for SDHI mutations were carried out on both isolates and leaf samples from 2019, 2020 and 2021. Only very few mutations with C-T79N and C-N86S were found at levels below 5%.

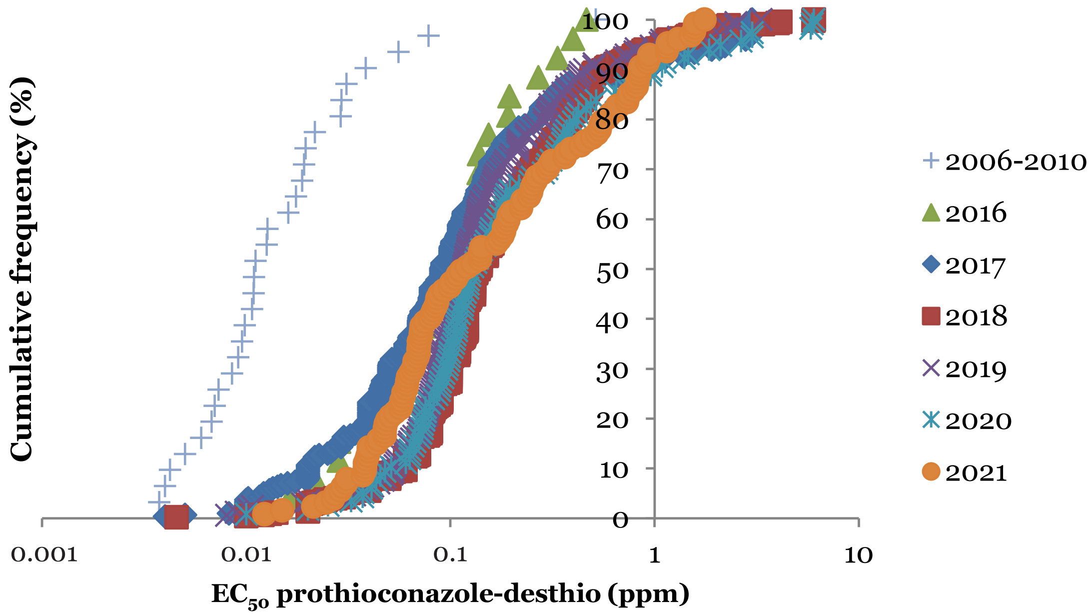


Figure 1. Cumulative frequencies of EC_{50} values of prothioconazole-desthio (ppm) for Danish *Z. tritici* populations 2016-2021 compared to isolates from 2006 to 2010. Each point of the curve represents a single *Z. tritici* isolate.

Table 1. Mean EC_{50} values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad from different sites in Denmark 2021 for *Z. tritici* monitored.

Location			EC_{50} (ppm)						Number of isolates
			Prothio-desthio	RF	Range	Fluxa	RF	Range	
21-ZT-DK-	1	Flakkebjerg	0.35	35	0.01-1.15	0.17	2	0.03-0.94	9
21-ZT-DK-	2	Flakkebjerg	0.36	36	0.04-1.30	0.57	6	0.04-2.80	6
21-ZT-DK-	3	Maribo	0.10	10	0.02-0.31	0.39	4	0.03-1.64	10
21-ZT-DK-	4	Rødby	0.05	5	0.03-0.05	0.04	1	0.03-0.07	2
21-ZT-DK-	5	Holeby	0.28	28	0.03-1.16	0.82	8	0.03-3.00	9
21-ZT-DK-	6	Flakkebjerg	0.22	22	0.04-0.84	0.08	1	0.03-0.20	10
21-ZT-DK-	8	Kolding	0.20	20	0.03-0.60	0.54	5	0.01-2.24	9
21-ZT-DK-	9	Vojens	0.62	62	0.03-1.75	0.57	6	0.04-1.97	10
21-ZT-DK-	10	Gistrup	0.37	37	0.03-0.81	0.72	7	0.02-2.50	6
21-ZT-DK-	11	Aabenraa	0.79	79	0.14-1.57	0.65	7	0.04-3.00	10
21-ZT-DK-	12	Fyn	0.13	13	0.07-0.19	0.18	2	0.03-0.67	5
21-ZT-DK-	13	Ferritslev	0.34	34	0.12-0.54	2.06	21	0.79-3.00	4
21-ZT-DK-	14	Limfjord	0.14	14	0.04-0.46	0.11	1	0.02-0.38	5
21-ZT-DK-	15	Randers	0.58	58	0.05-1.14	0.17	2	0.07-0.36	3
21-ZT-DK-	16	Horsens	0.05	5	0.04-0.06	0.05	1	0.02-0.08	2
21-ZT-DK-	18	Flakkebjerg	0.40	40	0.06-0.75	1.45	14	0.03-2.86	2
21-ZT-DK-	19	Flakkebjerg	0.38	38	0.06-0.85	0.05	1	0.03-0.06	5
21-ZT-DK-	20	Rønde	0.28	28	0.01-1.58	0.34	3	0.02-1.94	10
21-ZT-DK-	21	Flakkebjerg	0.10	10	0.04-0.18	0.26	3	0.03-0.51	3
21-ZT-DK-	22	Vejle	0.09	9	0.04-0.23	0.05	1	0.04-0.08	5
21-ZT-DK-	23	Vejle	0.11	11	0.04-0.18	0.06	1	0.04-0.08	2
Average			0.32	32		0.44	5		127

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

Year	Epoxiconazole	RF	Prothio-desthio	RF	Fluxapyroxad	RF
2012	0.30 (40)	15	-	-	-	-
2013	0.36 (133)	18	-	-	-	-
2014	0.50 (290)	25	-	-	-	-
2015	0.45 (262)	17	-	-	-	-
2016	1.39 (220)	66	0.13 (26)	17	-	-
2017	1.81 (272)	94	0.32 (263)	32	-	-
2018	4.52 (155)	212	0.33 (155)	35	0.26 (155)	2
2019	2.03 (18)	102	0.26 (209)	26	0.27 (209)	2
2020	-	-	0.44 (110)	44	0.36 (110)	3
2021	-	-	0.32 (127)	32	0.44 (127)	5
Ref. IPO323	0.02-0.03	-	0.01	-	0.10-0.20	-

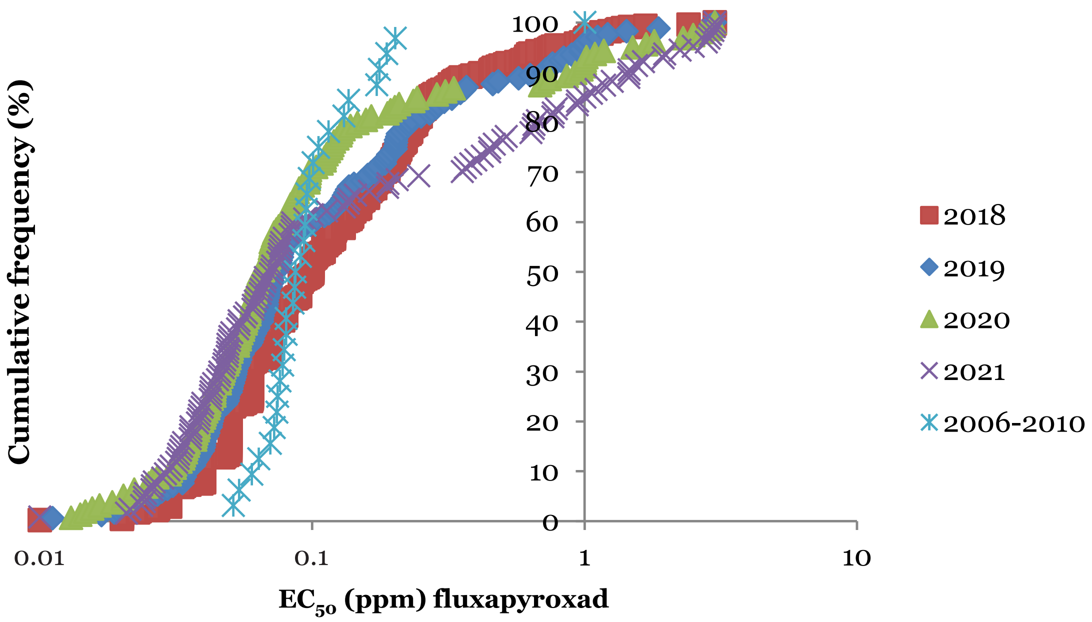


Figure 2. Cumulative frequencies of EC_{50} values of fluxapyroxad (ppm) for *Z. tritici* populations in Denmark from 2018 to 2021 compared to isolates from 2006 to 2010.

Table 3. Mean EC_{50} values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad from different sites in Sweden 2021 for *Z. tritici* monitored.

Location			EC_{50} (ppm)						Number of isolates
			Prothio-desthio	RF	Range	Fluxa	RF	Range	
21-ZT-SW-	1	Kåtorp, Färjestaden	0.07	7	0.02-0.17	0.46	5	0.04-0.95	8
21-ZT-SW-	3	Gärdslösa, Borgholm	0.24	24	0.06-0.43	0.03	1	0.02-0.04	2
21-ZT-SW-	4	Albrunna, Degerhamn	0.13	13	0.03-0.28	0.08	1	0.01-0.57	10
21-ZT-SW-	5	Glättestorp, Norra vånga	0.49	49	0.01-3.00	0.45	4	0.06-3.00	10
21-ZT-SW-	6	Skofteby, Norra härene	0.10	10	0.01-0.34	0.17	2	0.04-0.60	10
21-ZT-SW-	7	Emtunga gård, Emtunga	0.05	5	0.01-0.12	0.33	3	0.04-2.59	10
21-ZT-SW-	8	Håberg, Grästorp	0.17	17	0.01-0.58	0.65	7	0.07-3.00	10
21-ZT-SW-	9	Humlagården, Norra vånga	0.14	14	0.01-0.73	0.15	1	0.03-0.75	8
21-ZT-SW-	10	Kavlås, Tidaholm	0.08	8	0.01-0.50	0.17	2	0.02-1.20	10
21-ZT-SW-	11	Tegalund, Fågelum	0.18	18	0.06-0.43	0.39	4	0.05-2.67	10
21-ZT-SW-	12	Kilagården, Saleby	0.06	6	0.01-0.13	0.05	1	0.01-0.11	5
21-ZT-SW-	13	Häljerud,Brålanda	0.11	11	0.01-0.60	0.30	3	0.02-2.00	10
21-ZT-SW-	14	Svingbolsta, Östervåla	0.17	17	0.01-1.21	0.07	1	0.03-0.14	10
21-ZT-SW-	15	Sandbro, Bjöklinge	0.05	5	0.02-0.21	0.08	1	0.03-0.19	10
21-ZT-SW-	16	Högsts, Uppsala	0.06	6	0.02-0.18	0.06	1	0.02-0.10	7
21-ZT-SW-	17	Tuna,Staby Säteri	0.08	8	0.02-0.31	0.07	1	0.02-0.20	7
21-ZT-SW-	18	Österby	0.05	5	0.01-0.15	0.06	1	0.02-0.11	9
21-ZT-SW-	19	Julita	0.05	5	0.02-0.09	0.08	1	0.04-0.21	10
21-ZT-SW-	20	Vadstena	0.04	4	0.02-0.09	0.08	1	0.04-0.17	10
21-ZT-SW-	21	Linköping	0.05	5	0.02-0.13	0.06	1	0.04-0.10	4
21-ZT-SW-	22	Kattarp, Helsingborg	0.08	8	0.01-0.20	0.76	8	0.02-3.00	6
21-ZT-SW-	23	Bjällerup, Staffanstorp	0.41	41	0.04-0.86	0.12	1	0.06-0.23	3
21-ZT-SW-	24	Hammenhög, Simrishamn	0.14	14	0.03-0.41	0.15	1	0.05-0.11	9
21-ZT-SW-	25	Eriksfält, Löderup	0.19	19	0.03-0.48	0.28	3	0.04-0.68	5
21-ZT-SW-	26	St Isie, Klagstorp	0.23	23	0.06-0.41	0.19	2	0.03-0.58	4
21-ZT-SW-	27	Mörarp, Helsingborg	0.09	9	0.03-0.16	0.21	2	0.03-0.53	3
21-ZT-SW-	29	Lilla Böslid, Halmstad	0.19	19	0.03-0.59	0.35	3	0.03-2.53	10
Average			0.14	14		0.22	2		210

Results - *Sweden*

In 2021, no sensitivity shifting for prothioconazole-desthio has taken place. EC_{50} values for prothioconazole-desthio were with an average of 0.14 ppm at the same level as in 2020 (Figure 3; Table 4) and lower than in the Danish population in 2021 (0.32 ppm). The results varied among sites (0.04-0.49 ppm), with resistance factors of 4–49 (Table 3). Sensitivity towards fluxapyroxad was in line with previous years (Figure 4) with an average resistance factor of 2.

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

Year	Epoxiconazole	RF	Prothio-desthio	RF	Fluxapyroxad	RF
2012	0.36 (211)	18	-	-	-	-
2013	0.65 (170)	33	-	-	-	-
2014	0.27 (337)	35	-	-	-	-
2015	0.33 (227)	12	-	-	-	-
2016	0.52 (212)	24	-	-	-	-
2017	3.17 (163)	170	0.58 (150)	71	-	-
2018	4.53 (127)	181	0.35 (127)	35	0.19 (127)	2
2019	1.15 (25)	58	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
Ref. IPO323	0.02-0.03	-	0.01	-	0.10-0.20	-

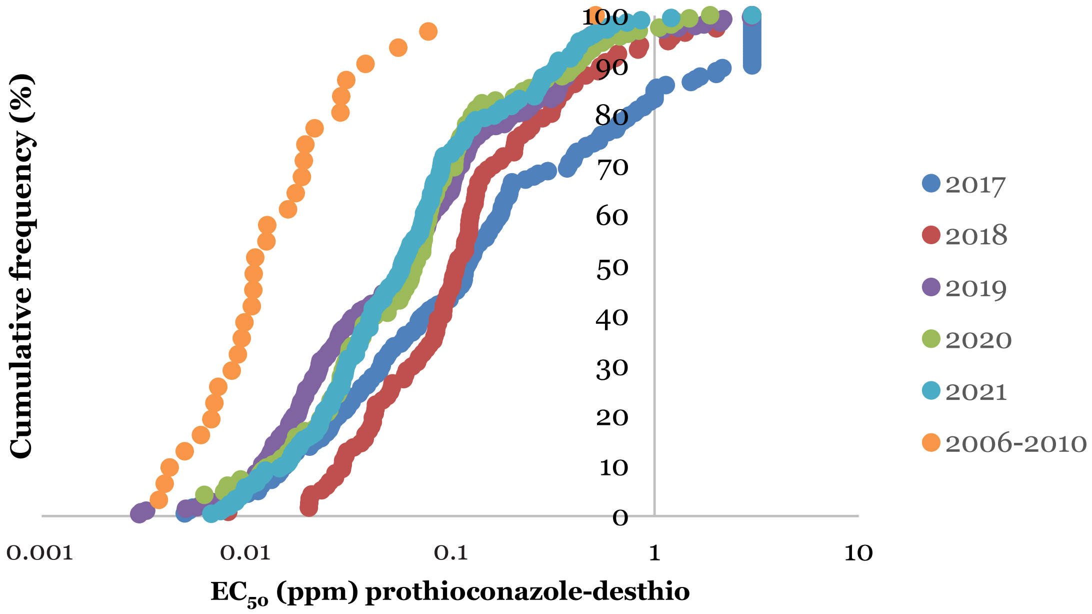


Figure 3. Cumulative frequencies of EC_{50} values of prothioconazole-desthio (ppm) for *Z. tritici* populations in Sweden in 2017-2021 compared to isolates from 2006 to 2010.

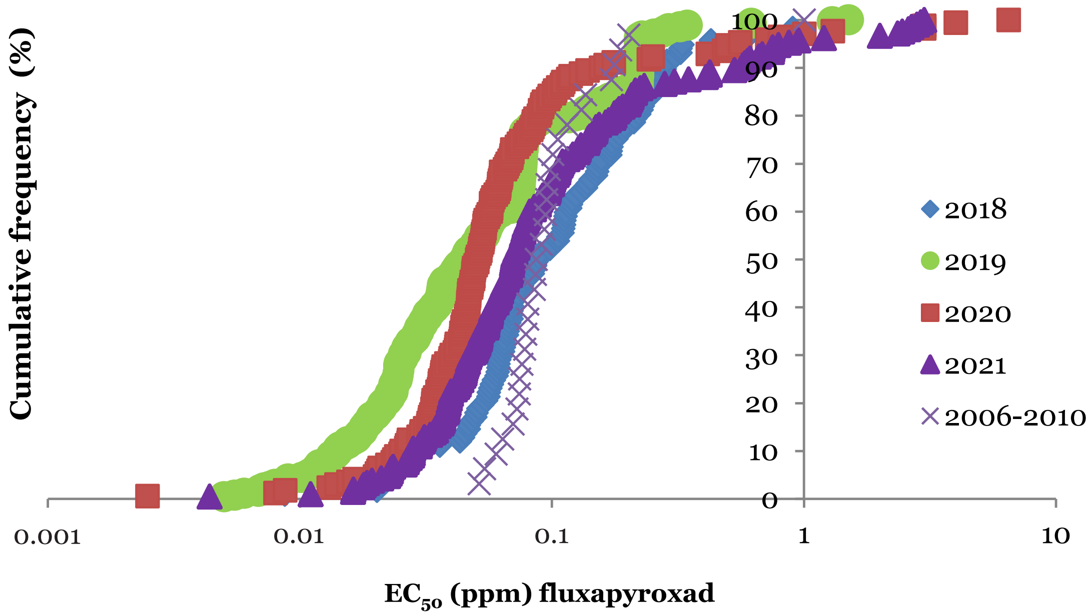


Figure 4. Cumulative frequencies of EC_{50} values of fluxapyroxad (ppm) for *Z. tritici* populations in Sweden from 2018 to 2021 compared to isolates from 2006 to 2010.

Cross-resistance of azole fungicide in the Danish-Swedish *Z. tritici* population

It has previously been described that there are different cross-resistance patterns for *Z. tritici* in the azole fungicide group (Heick et al. 2020). Using the EC_{50} values (log-transformed) of this year's investigation, Figures 5 and 6 show the correlation of resistance patterns of azoles mefentrifluconazole to tebuconazole and prothioconazole-desthio. There is a strong correlation between mefentrifluconazole and tebuconazole (R^2 = 0.8067) (Figure 5). No correlation of resistance is seen between prothioconazole-desthio and mefentrifluconazole with an R^2 value of 0.0327, confirming other investigations (Figure 6).

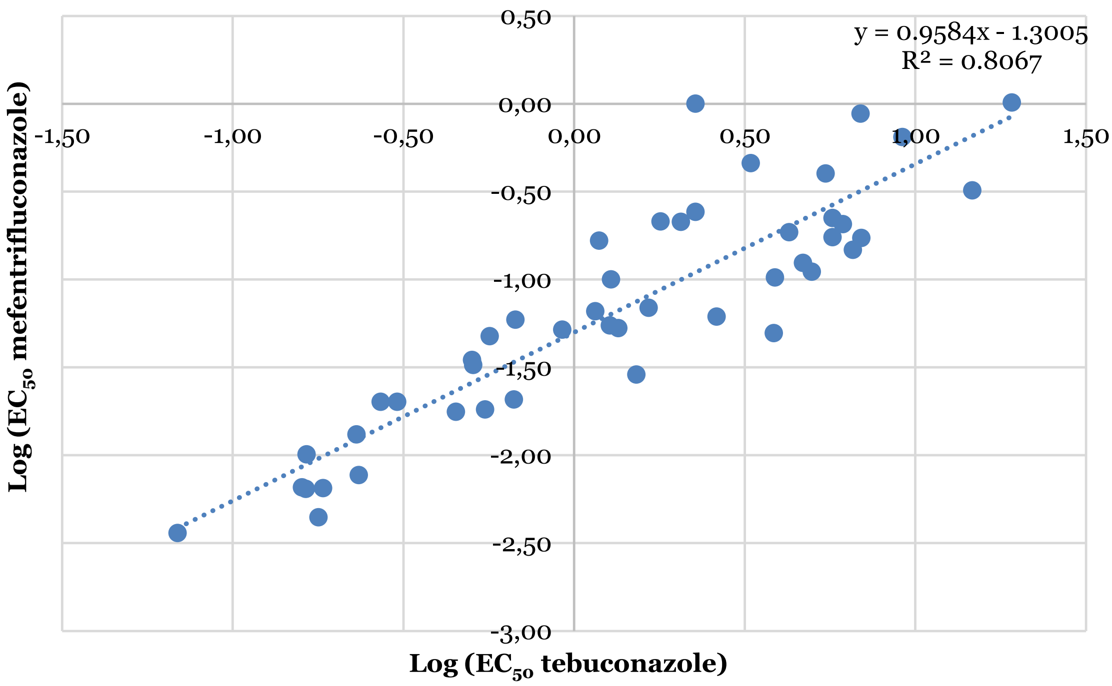


Figure 5. Correlations of resistance between mefentrifluconazole (mef) and tebuconazole (tebu). EC_{50} values are log transformed. Isolates from Denmark and Sweden (2021).

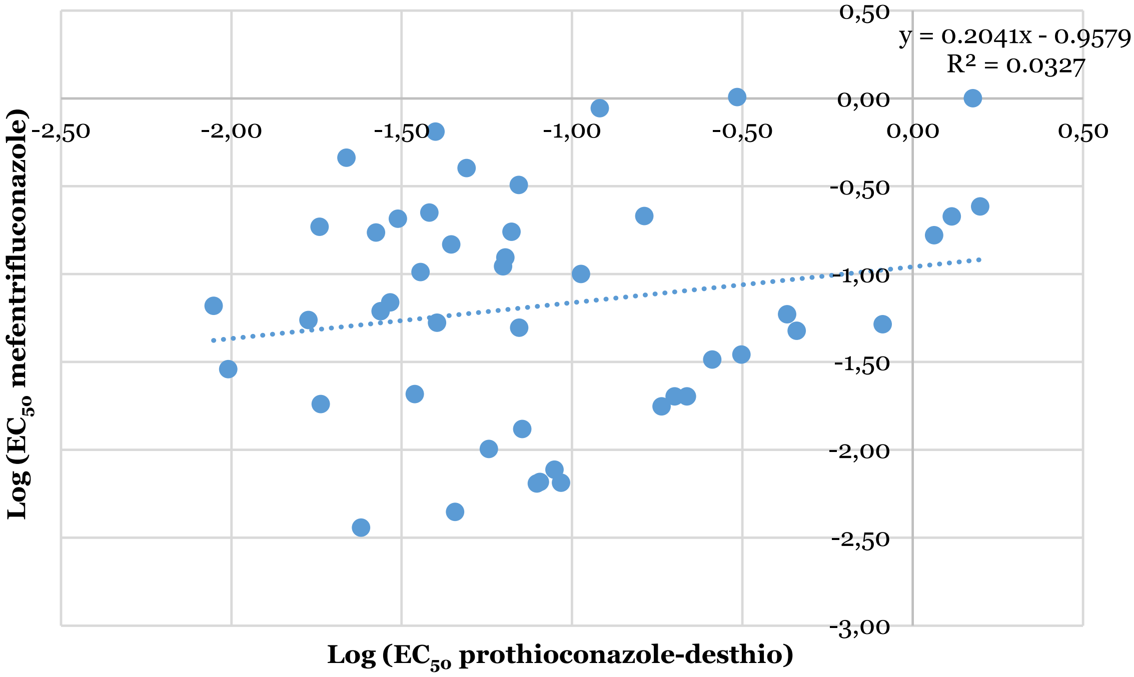


Figure 6. Correlation of resistance between mefentrifluconazole (mef) and prothioconazole-desthio (prothio-desthio). EC_{50} values are log transformed. Isolates from Denmark and Sweden (2021).

Strobilurin and SDHI resistance to net blotch (*Pyrenophora teres*)

Strobilurin resistance

In 2021, two Danish *P. teres* (net blotch) samples were investigated for the frequency of QoI resistance mutation F129L. The mutation F129L is known to be a mutation that only partly influences the field performances of strobilurins. The leaf samples originated from untreated plots in two field trials. The investigation for F129L was carried out by BASF. The data from 2021 indicated that the level of F129L in the population of *P. teres* remains stable with no dramatic changes.

F129L was found in both samples in 2021; however, the sample size was very limited. Data from the last 13 years' monitoring are shown in Table 5. The frequencies of the mutation were 27 and 32%, respectively. Over the past 12 years, the distribution and the frequency of F129L have increased. So far, this has not had a significant impact on the control from Comet Pro (pyraclostrobin), whereas Amistar (azoxystrobin) has been seen to be more influenced by F129L than Comet Pro. Although the number of positive samples is moderate, it can unfortunately not be verified which fields are affected with F129L mutations before treatments, so farmers generally have to go for the most effective products.

Table 5. Summing up results from the strobilurin resistance investigation. F129L incidence in the net blotch fungus (*Pyrenophora teres*) in Denmark.

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

Fungicide sensitivity of *Cercospora beticola* from Danish sugar beet fields

In recent years, more focus has been directed towards the foliar disease Cercospora leaf spot (CLS), caused by *Cercospora beticola*. Whereas it is the primary disease in sugar beet in most sugar beet-growing areas, it has not been a major disease in Denmark. The reason for that is that CLS is favoured by warm temperatures. In 2021, leaf samples with apparent symptoms of CLS were collected from three farmers' fields. *C. beticola* isolates were produced (n=10) and analysed for target site mutations conferring fungicide resistance to strobilurin and azole fungicides. All ten isolates were tested positive for *cytb* mutation G143A, which confers resistance to strobilurins. Furthermore, the isolates were also tested for the presence of *CYP51* mutations, which recently have been linked with reduced sensitivity levels of azole fungicides. All mutations described by Muellender et al. (2021) were found in the Danish isolates, indicating a general resistance level towards azole fungicide.

References

Heick, T. M., N. Matzen and L. N. Jørgensen (2020). Reduced field efficacy and sensitivity of azole fungicides in the Danish and Swedish *Zymoseptoria tritici* populations. European Journal of Plant Pathology 157: 625-636.

Muellender, M. M., A.-K. Mahlein, G. Stammler and M. Varrelmann (2021). Evidence for the association of target-site resistance in *cyp51* with reduced DMI sensitivity in European *Cercospora beticola* field isolates. Pest Management Science 77(4): 1765-1774.

VI Validation of the BlightManager DSS for the control of late blight and early blight

Isaac K. Abuley & Jens G. Hansen

Introduction

Late blight, caused by *Phytophthora infestans*, and early blight, caused by *Alternaria solani*, are two important diseases in potatoes in Denmark. The management of these diseases is heavily reliant on prophylactic fungicides. The recent statistics from the Danish Ministry of Environment show that fungicide usage contributes about 70% of the total treatment frequency index (16.2) in potatoes (Miljøstyrelsen, 2021). This usage of fungicide is unsustainable for social, economic and environmental reasons, and therefore reducing the fungicide usage in potatoes is critical. There is a need to improve the existing decision support systems by including precision agriculture and by analysing the potential of resistant cultivars to reduce the need for disease control with fungicides. These questions were analysed in the GUDP-funded project called BlightManager.

We have previously explained the different components of the BlightManager decision support system (DSS) (Abuley and Hansen, 2020; Abuley et al., 2021); therefore we will only give a brief overview of the DSS. The BlightManager DSS integrates late blight and early blight model calculations as well as disease surveillance information using the BlightTracker APP for recording of attacks of both late blight and early blight and a GIS dashboard for visualisation of disease recordings at field level. The late blight models calculate the weather-based risk of sporulation and infection, and the surveillance system indicates the proximity of active late blight and early blight. The surveillance system is based on an extensive network of advisors and other stakeholders in the potato industry and our well-established Blight Tracker APP for timely reporting of disease outbreaks. The total system is used to advise which fungicide to apply as well as when and how much. The early blight model consists of two sub-models: TOMCAST, which estimates the favourability of the weather to early blight attack, and the physiological age model, which estimates the plant age. The physiological age sub-model is relevant to the timing of the first spray as well as the dosage at a given age.

Our models have traditionally been used with weather data from the Danish Meteorological Institute (DMI), but not all areas in Denmark are well covered with DMI weather stations. Thus, to obtain a field-specific forecast, we were also interested in testing our models with in-field weather stations. For this purpose, we tested the in-field weather stations from FieldSense (FS).

Overview of the experiment

The improved BlightManager DSS was validated in field experiments at three locations in Denmark (Arnborg, Dronninglund and Flakkebjerg). The cultivars in the trials were Folva (medium-maturing, ware potato) and Saprodi (late-maturing, starch potato). The cultivar Allstar (late-maturing, starch potato) was used for the early blight experiment. The experimental set-up was a randomised block design with four replicates at all experimental sites. Except for the location at Flakkebjerg, late blight infections were established naturally. At Flakkebjerg Folva spreader rows were inoculated on 4 July 2021 with a sporangial suspension (1000 sporangia per ml) in the late blight experiment. The early blight experiment was inoculated on 22 June 2021 by placing 110 g of autoclaved barley grains infested with *A. solani* between the rows. All standard agronomic practices for healthy potato production were performed at all experimental sites. The treatments in the experiments were as follows:

Late blight

1. Untreated. No use of fungicides for late blight control.
2. Routine. Weekly application of Ranman Top (0.5 l/ha). This treatment represented the standard control of late blight.
3. Skimmelstyring (BM-old). Fungicide application was according to the previous version of the BlightManager DSS called Skimmelstyring. See Abuley and Hansen (2020) for details of this model.
4. BlightManager model with variable spraying interval and variable dosage (BM-dynamic). This treatment followed the BlightManager model, in which fungicide is sprayed only when infection pressure and infection risk are at least 10 and 93, respectively (Abuley and Hansen, 2020; Abuley et al., 2021).
5. BlightManager model with fixed dosage (full dosage) but variable application intervals. We tested this model with an in-field weather station from FieldSense (BM-FS) or the nearest DMI weather station (BM-DMI).

Early blight

1. Untreated. No use of fungicides for early blight control.
2. Standard. This treatment represented control of early blight and involved the application of 0.4 l/ha Narita, starting from 7 weeks after emergence.
3. TOMCAST model with either DMI (TOMCAST-DMI) or in-field weather data from FieldSense (TOMCAST-FS). Here, fungicide application followed the TOMCAST model as described by Abuley and Hansen (2020). However, we only used full dosage whenever the model recommended fungicide application.

Disease and yield assessment

Late blight and early blight severity per plot were assessed weekly from the onset of attack in the late blight and early blight experiments, respectively. The disease severity assessment data were used to calculate the area under the disease progress curve (AUDPC) with the mid-point method (Shaner and Finney, 1977), and the efficacy (i.e. the percentage of disease control relative to the untreated) was calculated as described by Abuley and Nielsen (2017). Tubers were harvested from the two middle rows (15.75 m^2 at Flakkebjerg and 15 m^2 at Arnborg and Dronninglund) for tuber yield assessment. The starch yield was calculated for the starch cultivar Saprodi, but not for the ware cultivar Folva. As a consequence, for the late blight experiments, we only focused on the tuber yield to allow for a similar analysis for the two cultivars used in the study. Moreover, similar conclusions would be reached for Saprodi with either tuber or starch yield. The yield increase relative to untreated was calculated as in Abuley and Nielsen (2017). We used the yield increase and efficacy for further comparisons of the treatments.

Statistical analyses

All data handling and analysis was done in the R language and environment for programming and statistical computing (hereafter R) (R Core Team, 2020). The pooled efficacy and yield increases from the three locations was analysed with a gaussian linear model ("lm" function in R), and the effect of treatment (α=0.05) was determined via analysis of variance (ANOVA). We calculated the effect size (unstandardised) as the difference between the mean of the models and routine (late blight)/standard (early blight) treatment, and the 95% bootstrapped confidence interval (CI) of the effect sizes was calculated. The bootstrapped CIs were determined by bootstrapping with antithetic simulations (replicates = 1000) with the "boot" function and estimating the percentile CI with the"boot.ci" function (Canty and Ripley, 2021).

Results and discussions

Late blight

Infection pressure

The estimated infection pressure varied between the experimental sites, regardless of the source of weather data (Figure 1), suggesting a different epidemiological consequence on the cultivars depending on the experimental location and thus the need to tailor control strategies to local blight conditions. The estimated infection pressures also varied according to the source of weather data. This was particularly evident at Arnborg, where the FS data showed a linear increase in infection pressures compared to the undulating pattern exhibited by the DMI data (Figure 1). Generally, the infection pressure was higher in September than in the other months.

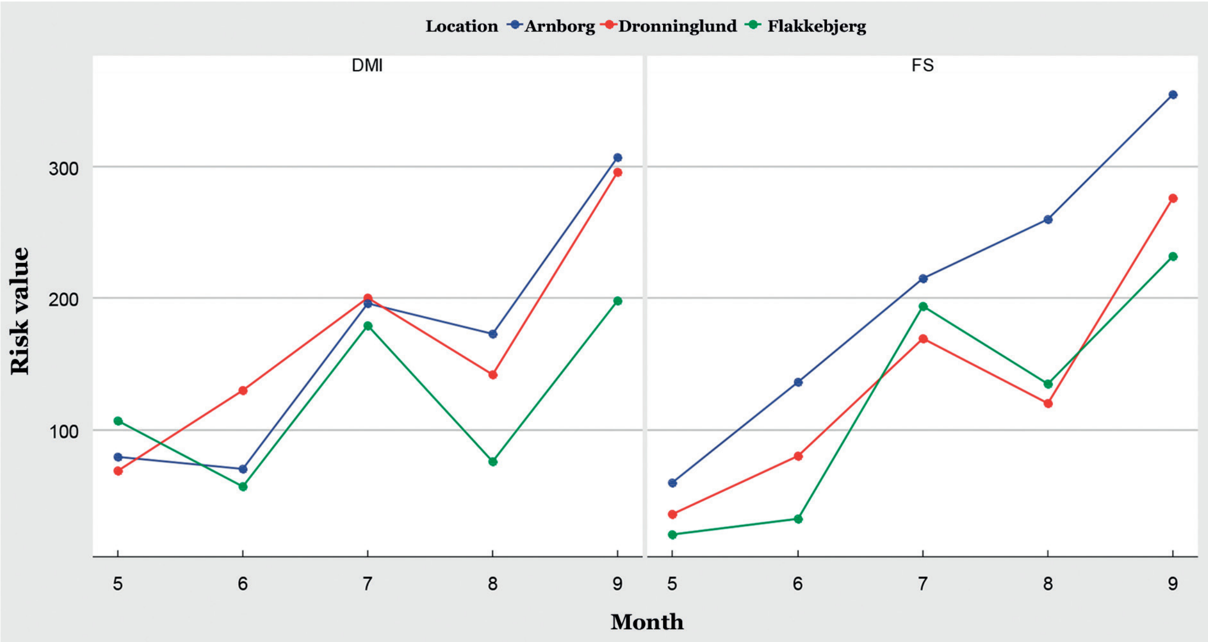


Figure 1. Monthly infection risk at Arnborg, Dronninglund and Flakkebjerg with in-field weather data from FieldSense (FS) or nearest station operated by the Danish Meteorological Institute (DMI).

Disease development

Late blight developed rapidly and reached >95% on the cultivars in the untreated plots (Figure 2). Fungicide application suppressed late blight attacks below 10% on the cultivars at all locations, except at Arnborg, where late blight severity exceeded 70% in the fungicide treatments (Figure 2). We believe that the infection pressure, which was higher at Arnborg than at Flakkebjerg and Dronninglund, might partly explain the higher disease level at Arnborg (Figures 1 & 2). Proxanil, a curative fungicide, was used at Dronninglund and Flakkebjerg but not at Arnborg. Therefore, the omission of Proxanil, which could have ensured a better disease control during the active stages of the disease, might also account for the higher disease levels at Arnborg compared to the other locations.

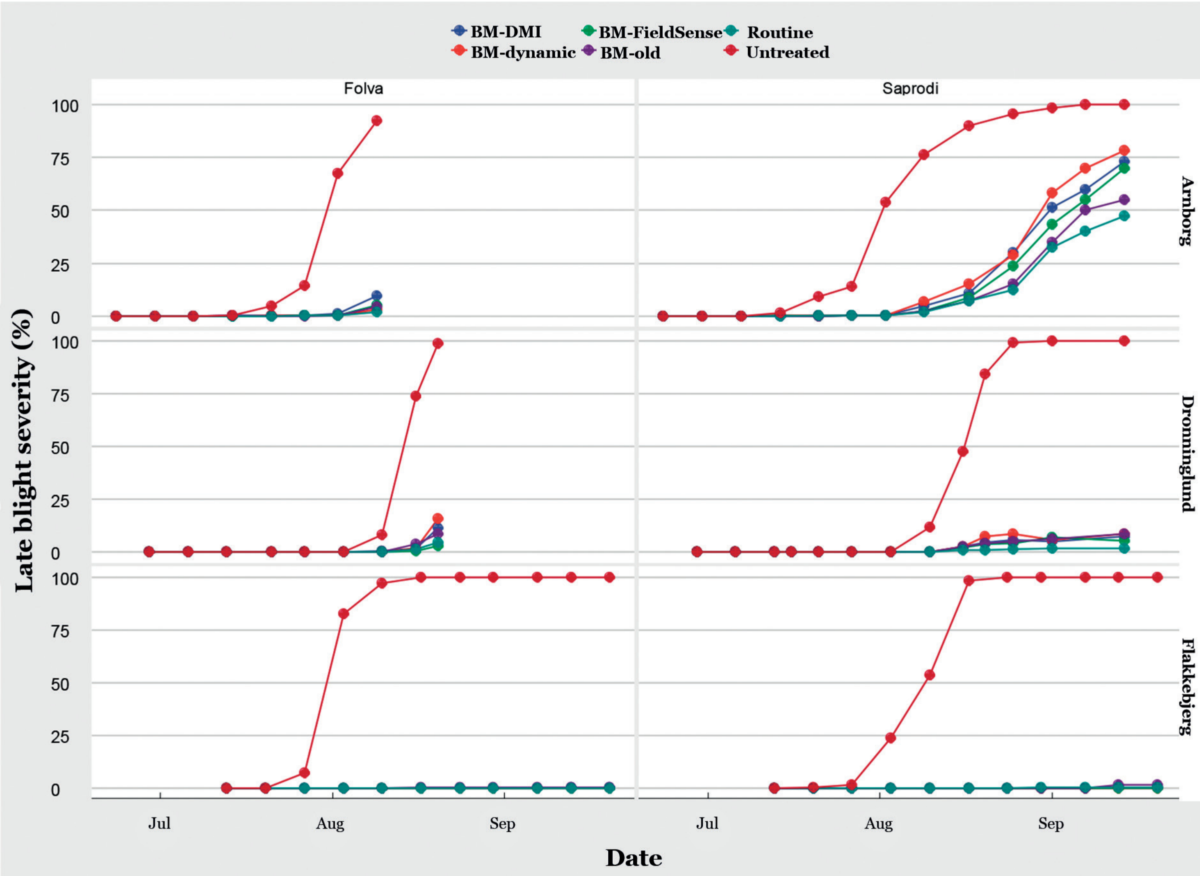


Figure 2. Disease development during the season in the potato cultivars Folva and Saprodi in the different treatments.

Fungicide reduction

The results of fungicide reduction showed average savings of 17-30% (Saprodi) and 12-31% (Folva) (Figure 3). The BM-dynamic model saved the highest amount of fungicide (~30%) in both Saprodi and Folva.

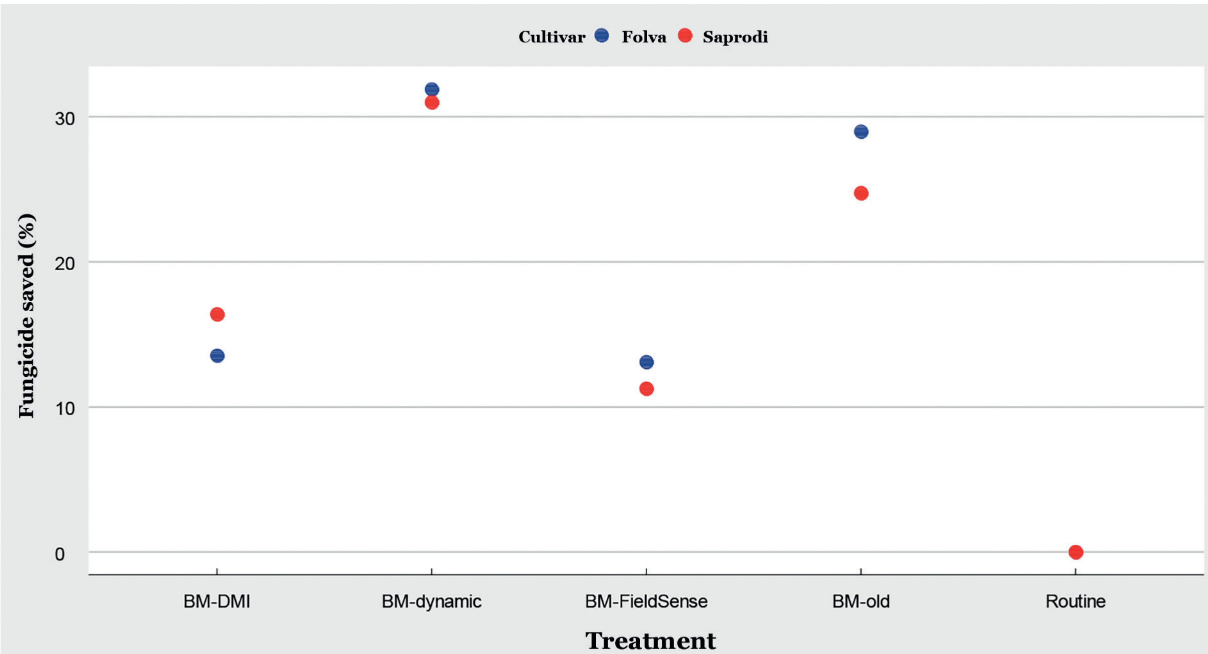


Figure 3. Fungicide saved relative to the routine (standard) treatment.

Efficacy and yield increase

The efficacy of treatments was higher in Folva (>95%) than in Saprodi (<95) (Figure 4). The BM-FS had the highest efficacy in both Folva and Saprodi (Figure 4). The yield increase ranged between 15% and 22% (Folva) and 30% and 35% (Saprodi) (Figure 4). The treatments had a strongly insignificant effect on yield increases (p>0.1). The differences between the routine treatment and models were not statistically significant as their CIs overlapped with the null effect (Figure 4). The statistical analyses showed that fungicide treatment had an insignificant effect (p>0.2) on efficacy and yield in both Folva and Saprodi. The pairwise comparison also confirmed this as CIs of the effect size between the models and the routine treatment overlapped with the null effect (Figure 4). This suggests that there is no significant loss of yield and disease control by using the models to control late blight.

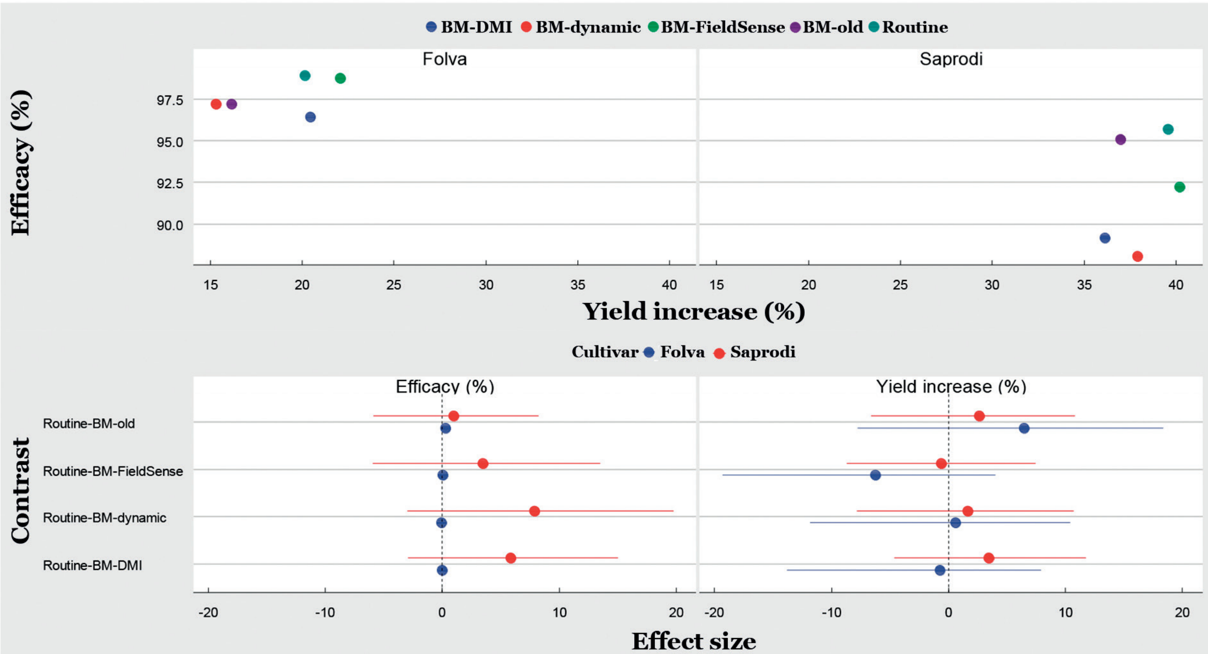


Figure 4. Upper panel: Efficacy and yield increase of the treatments relative to untreated. Lower panel: The effect sizes (difference) and their associated confidence intervals (horizontal bars) between the routine and the late blight models for recommending fungicide application. Effect sizes with confidence intervals that include or overlap with a null effect (dashed black line) are not statistically different and vice versa.

Early blight

The severity of early blight was low in the experiments at Arnborg and Dronninglund compared to Flakkebjerg (Figure 5). At Flakkebjerg, the development of early blight remained slow until the beginning of September (Figure 5).

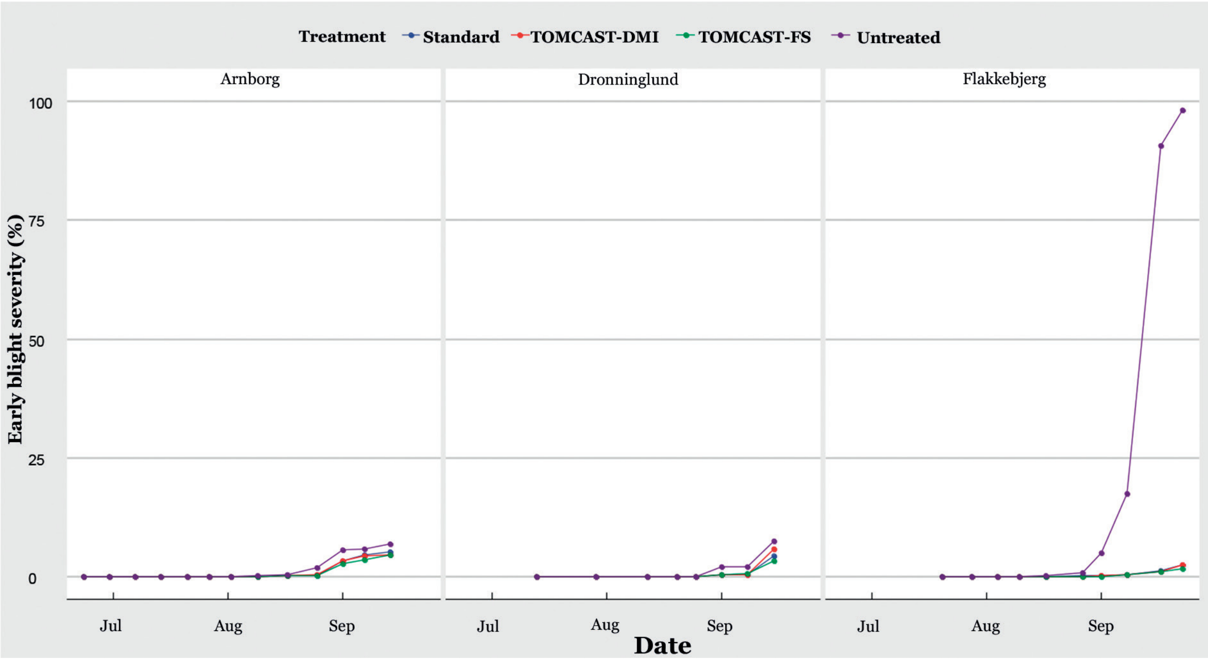


Figure 5. Development of early blight during the season at Arnborg, Dronninglund and Flakkebjerg.

Fungicide saved

The TOMCAST models reduced fungicide usage by about 20-30% fungicide relative to the standard treatment (Figure 6). The TOMCAST-DMI model resulted in the highest fungicide savings (Figure 6).

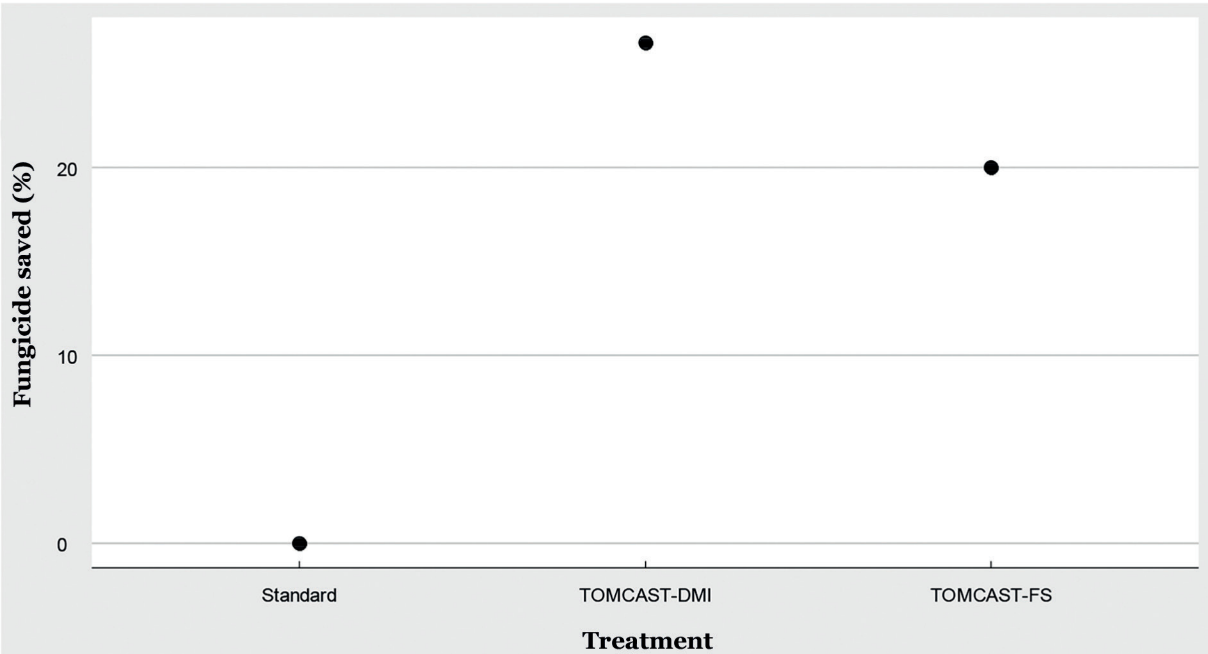


Figure 6. Fungicide saved relative to the routine (standard) treatment.

Efficacy and yield increase

The efficacy of the fungicide treatments in the early blight experiment (Figure 7) was markedly lower compared to what we observed in the late blight experiment (Figure 4). This was mainly due to the low disease development in the early blight experiments. Accordingly, the treatments had no significant effect on efficacy ($p=0.26$). Similarly, the yield increase was below 5% and was not significantly affected by the treatments ($p=0.7$). The pairwise comparisons between the routine and the early blight models also showed overlapping CIs with the null effect for both efficacy and yield increase, suggesting no significant loss of efficacy or yield by using the models.

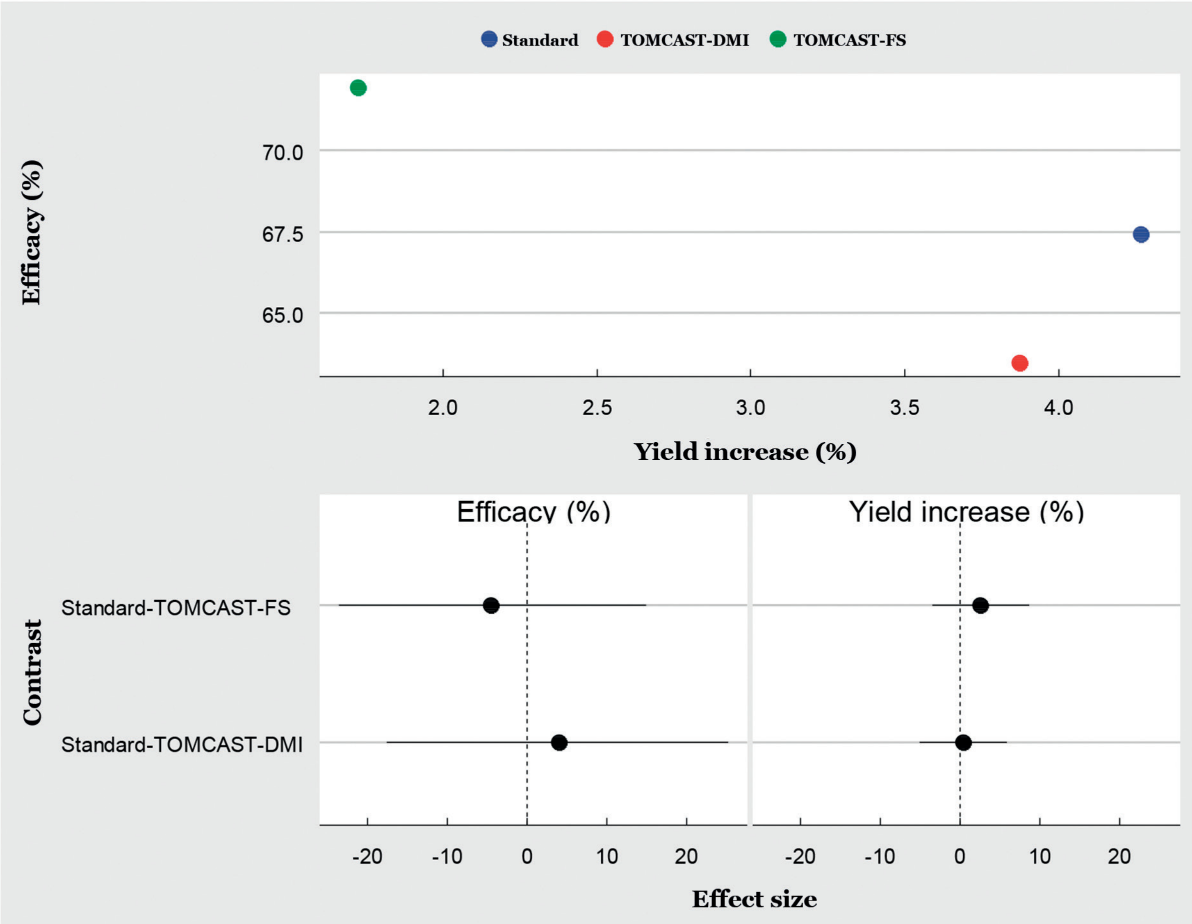


Figure 7. Upper panel: Efficacy and yield increase of the treatments relative to untreated. Lower panel: The effect sizes (difference) and their associated confidence intervals (horizontal bars) between the routine and the early blight models for recommending fungicide application. Effect sizes with confidence intervals that include or overlap with a null effect (dashed black line) are not statistically different and vice versa.

Concluding remarks

We have shown significant fungicide savings (~30%) by using BlightManager for managing late blight and early blight without compromising on efficacy or yield. Indeed, this is remarkable as we seek to minimise the usage of fungicides in the potato production. However, we need to do more to reach the 50% target of the "Farm-to-Fork" strategy. Admittedly, using DSSs is relevant for saving fungicides, but we can achieve further fungicide savings (~60%) if we shift to very resistant potato cultivars as we showed in our previous publication (Abuley and Hansen, 2020) and replace some fungicides with environmentally benign products (e.g. biological control agents).

References

Abuley, I. K. and B. J. Nielsen (2017). Evaluation of models to control potato early blight (*Alternaria solani*) in Denmark. Crop Protection 102: 118-128.

Abuley, I. K. and H. H. Hansen (2020). Control of late blight (*Phytophthora infestans*) and early blight (*Alternaria solani*) in potatoes. In: L. N. Jørgensen, T. M. Heick, I. K. Abuley, S. K. Mathiassen, P. K. Jensen, H. S. Kristjansen & P. Hartvig (eds.). Applied Crop Protection 2019. Aarhus University - DCA - Danish Centre for Food and Agriculture, DCA report, no. 167, pp. 90-98.

Abuley, I. K., J. G. Hansen and H. H. Hansen (2021). Controlling late blight in susceptible and resistant potato cultivars with *BlightManager*. In: L. N. Jørgensen, T. M. Heick, I. K. Abuley, P. K. Jensen, H. S. Kristjansen & A. Hansen (eds.). Applied Crop Protection 2020. Aarhus University - DCA - Danish Centre for Food and Agriculture, DCA report, no. 187, pp. 92-96.

Canty, A. and B. Ripley (2021). boot: Bootstrap R (S-Plus) Functions. R package version 1.3-26.
Miljøstyrelsen (2021). Behandlingshyppighed og pesticidbelastning baseret på salg og forbrug. Miljøstyrelsen.
R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
Shaner, G. and R. E. Finney (1977). The Effect of Nitrogen Fertilization on the Expression of Slow-Mildewing Resistance in Knox Wheat. Phytopathology 77: 1051.

Late blight in potatoes.

VII Comparative epidemiology of late blight and early blight on potato cultivars

Isaac K. Abuley & Jens G. Hansen

Overview of the experiment

Late blight (LB), caused by *Phytophthora infestans*, and early blight (EB), caused by *Alternaria solani*, are the most destructive diseases in potatoes globally and in Denmark. Although the onset of their epidemic might differ, they are both present on potato cultivars in most growing seasons. Thus, it is relevant to assess potato cultivars for their resistance to these major diseases. Accordingly, we evaluated epidemics of LB and EB on some relatively new cultivars (Ardeche, Avito, Fyone, Jacky, Nofy, Sarion, Skawa, Thor and Ydun) and one old potato cultivar (Kuras) in Denmark. We performed field experiments separately for LB and EB at AU Flakkebjerg in 2021. The two experiments were adjacent to each other to allow for similar growth and weather conditions for the disease development. The potatoes were planted on 14 May 2021. The EB trial was inoculated on 22 June 2021 by placing 110 g of autoclaved barley grains infested with *A. solani* between the rows. Spreader rows were artificially inoculated to ensure an even inoculum distribution in the LB trial. Disease severity was assessed once or twice per week as the percentage of leaf area affected, depending on the disease progression.

Data analysis

The diseases severity data were fitted to the Richards growth model (Richards, 1959) (Equation 1), where Y is the severity at a time (t), Yasm is the upper asymptote on the y-axis, k is the growth rate, Tip is the point of inflection on the x-axis, v is a parameter that partly determines the inflection point and e represents the exponent. The model fitting was implemented with the Levenberg-Marquardt non-linear least squares algorithm ("nlsLM" function) (Timur et al., 2016) in the R language and environment for programming and statistical computing (hereafter R) (R Core Team, 2020). The days after 1 June were used as the time variable (x-axis). The weighted mean absolute rate (WMAR) (Equation 2) was calculated to compare the epidemic rate of the diseases on the cultivars. WMAR is a better metric for comparing curves with different shapes (m) and upper asymptotes. The shape parameter (m) was calculated with Equation 3. The relative area under the disease progress curve (rAUDPC) was calculated with Equation 4, where y_i is the disease severity at the i^{th} assessment, t_i is the date/time at the i^{th} assessment, n is the total number of assessments, t_n-t_o is the epidemic duration and Dmax is the maximum potential disease severity (100):

$$Y = \frac{Yasm}{\left[1+ve^{-k(t-Tip)}\right]^{1/v}} \quad (1)$$

$$WMAR = \frac{k}{2m+2} \times Yasm \quad (2)$$

$$m = v + 1 \quad (3)$$

$$rAUDPC = \frac{\sum_{i=1}^{n}\frac{(y_i+y_{i+1})}{2}\times(t_{i+1}-t_i)}{(t_n-t_0)\times Dmax} \quad (4)$$

Results

Disease progress curves

The development of LB and EB on the cultivars is shown in Figure 1.

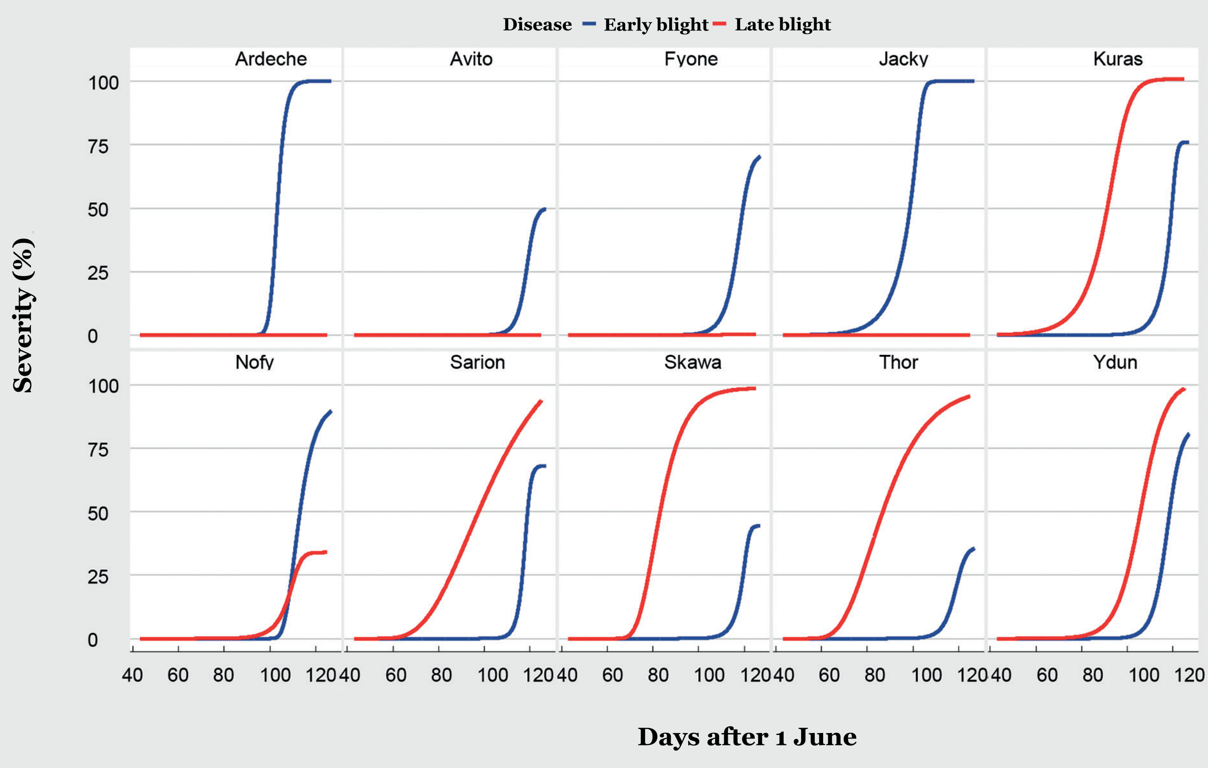


Figure 1. Development of early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*) on different potato cultivars.

Comparing the cultivars for different epidemiological parameters

We compared the cultivars for different epidemiological parameters for assessing their resistance to late blight and early blight (Figure 2). These parameters are a different aspect of the disease progress curve and thus offer a different understanding of the disease development. WMAR is a reflection of the epidemic rate, rAUDPC summarises the diseased area over time relative to the Dmax, Yasm is a measure of the maximum severity and T1 is when 1% severity occurred, and thus it indicates when the epidemic began to rise quickly.

The results showed that, except for the cultivars that restricted LB below 1% (Avito, Ardeche, Jacky and Fyone) or 35% severity (Nofy), the Yasm of LB on the remaining cultivars was >90% (Figure 2). The cultivars with low Yasm are generally more resistant to LB, and thus this observed low Yasm was not surprising. The Yasm of EB for most cultivars ranged between 35% and 90%, with only a few cultivars reaching 100% severity. The rAUDPC values also showed that LB was more severe than EB on most cultivars. The exceptions were the cultivars Avito, Ardeche, Jacky and Fyone, on which EB was higher than LB for rAUDPC (Figure 2).

The results of T1 of LB were markedly shorter than EB for all cultivars but Nofy (Figure 2). In contrast to the other parameters, WMAR was higher for EB than for LB on most cultivars. This suggests that once EB reaches 1% on cultivars, its progress can occur faster or similar to LB on a cultivar. However, the general high epidemic profile of LB might be due to the markedly short T1 as this epidemiological parameter marks the beginning of a critical stage in the epidemic. This is also confirmed by the fact that the onset of LB and EB on the cultivars was either similar or longer for LB in comparison with EB (data not shown).

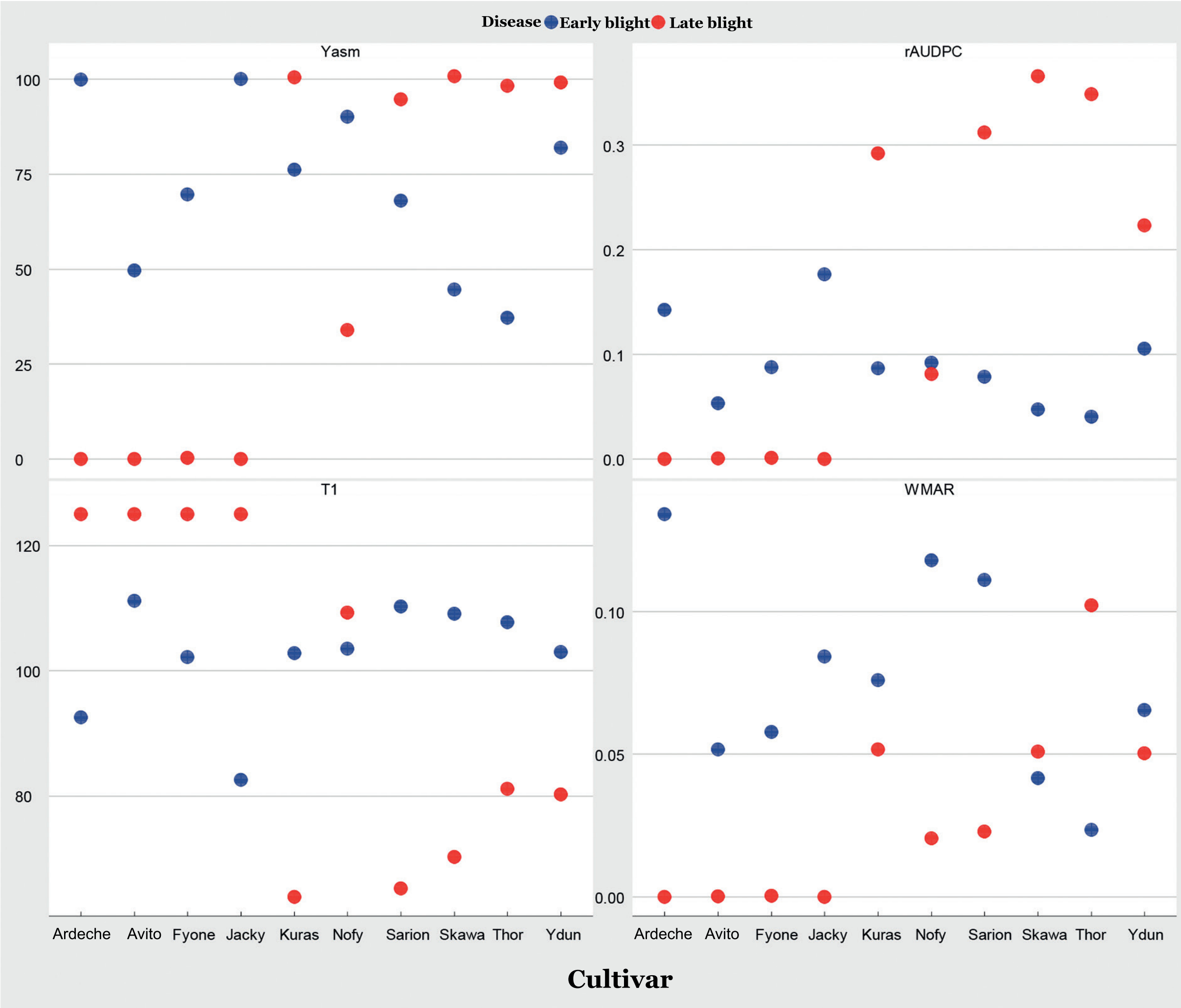


Figure 2. Comparisons of different epidemiological parameters (upper asymptote (Yasm), the relative area under the disease progress curve (rAUDPC), the time taken to reach 1% disease severity (T1) and the weighted mean absolute rate (WMAR)) for assessing the development of late blight and early blight on potato cultivars. For cultivars that did not reach 1% severity, their T1 was expressed as days elapsed from 1 June to the last assessment.

Concluding remarks

This study results in three key conclusions.

- The very resistant LB cultivars such as Avito, Ardeche, Fyone and Jacky are susceptible to EB under the prevailing conditions in Denmark. This is unsurprising because most breeding efforts target LB and not EB. Future efforts must include EB in resistant breeding as EB epidemics are becoming increasingly important under Danish conditions.
- Cultivars such as Skawa and Thor appear to have a good resistance to EB, but are very susceptible to LB. Our previous screenings of cultivar resistance in 2019 and 2020 also confirmed the good resistance of Skawa and Thor to EB.
- The major difference between EB and LB is the onset of their epidemic phase (T1) as EB can develop faster than LB.

References

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Richards, F. J. (1959). A Flexible Growth Function for Empirical Use. Journal of Experimental Botany 10: 290-300.

Timur, V. E., M. M. Katharine, S. Andrej-Nikolai and B. Ben (2016). minpack.lm: R Interface to the Levenberg-Marquardt Nonlinear Least-Squares Algorithm Found in MINPACK, Plus Support for Bounds. R package version 1.5.1.

Early blight (*Alternaria*) in potatoes.

VIII Results of crop protection trials in minor crops in 2021

Andrius H. Kemezys, Peter Hartvig, Kaspar Ingvordsen, Per E. Andersen & Mie Jensen

In 2021, the minor crops group at AU Flakkebjerg carried out 54 field and greenhouse trials. There were 27 trials with weed control in minor crops (including three desiccation trials) and 28 trials with control of fungal diseases and insect pests. The activities of the group are characterised by covering many crops but also all types of pests, i.e. weeds, diseases and insect pests, as well as plant growth regulation. This is the reason that many stakeholders are involved in the trials. The trials are financed by various levy funds, the Danish Agricultural Agency's GUDP programme, the Danish Environmental Protection Agency, ØKS Interreg, agrochemical companies and private trial partners. The Swedish minor use project under LRF has been a major collaborator for many years.

The range of chemical crop protection products has for several years become smaller and smaller, and this development seems especially evident in the minor crops. Denmark is located in the North Zone where agricultural production is small compared to the Central and South Zone, and the market for crop protection products for minor crops is small and of little interest to the agrochemical companies. Therefore, we often see that if a product does not have an authorisation in arable crops, there is a major risk that it will disappear from the market.

Because of this development, the group's activities have become increasingly influenced by the growing interest in alternative products such as microbials. There is also a great interest in products with an effect on a pest, but which are not classified as crop protection products. This includes products on the list of basic substances but also fertilisers, plant elicitors, plant enhancers and biostimulants. Within weed control there is an awareness that the times when chemistry could handle any weed issue are over and that it is necessary to supplement with other forms of weed control.

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

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

The minor crops group has been actively involved in the Interreg project since 2020. In 2021, a total of eight trials were carried out in the Interreg project. The results of the trials with alternatives to diquat and glyphosate in pre-crop emergence application and powdery mildew in potted roses are presented below.

Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

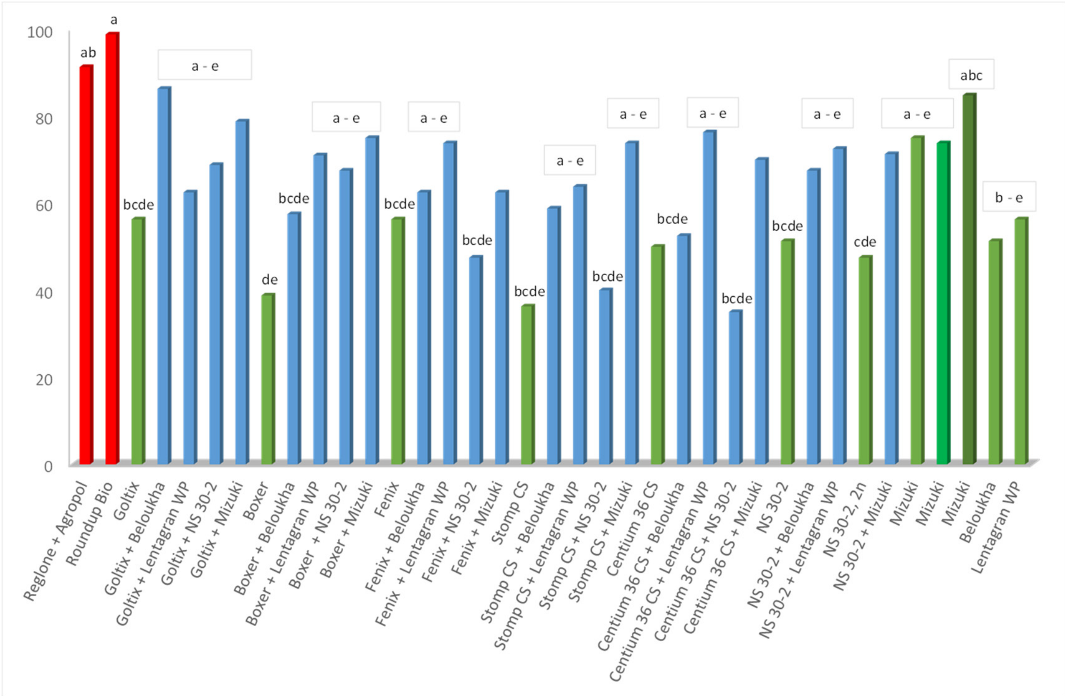
Alternatives to diquat and glyphosate in pre-crop emergence application

The hypothesis behind these trials is that a tank mix of soil-applied herbicides and a reduced dose (50%) of foliar-applied herbicides can be used to achieve high efficacy when applied in pre-crop emergence. The current standard practice in vegetables and seeded nursery crops is that the soil-applied herbicides are applied shortly after sowing, while the glyphosate (previously diquat) application is applied just before the emergence of the crop. The trial treatment plan for the trials can be found in Table 1.

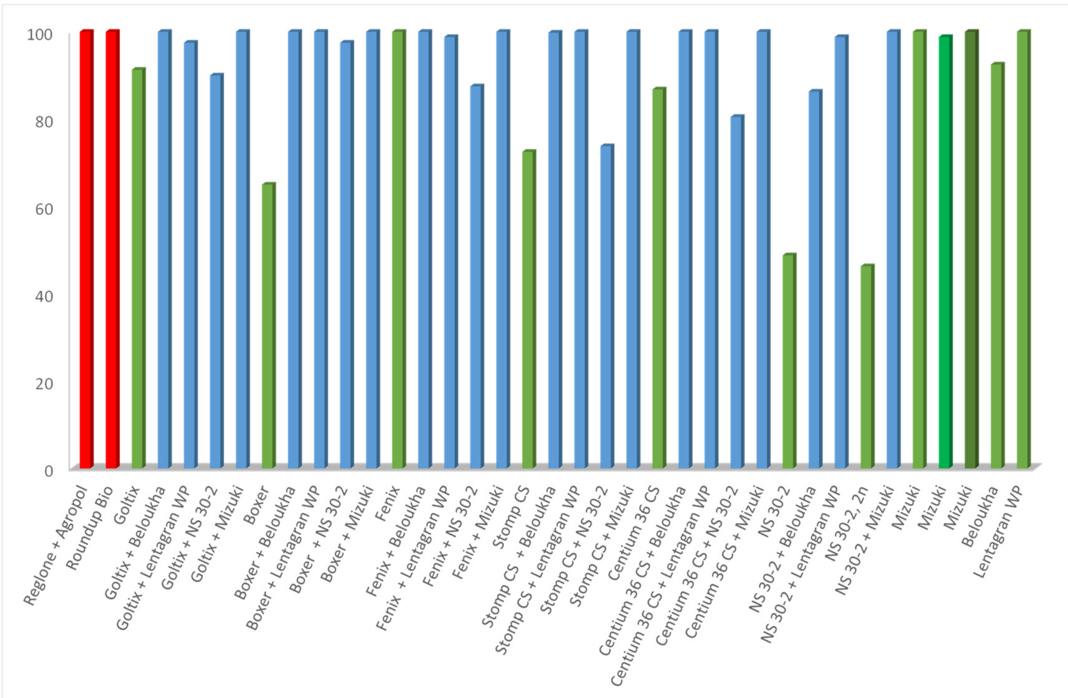
Table 1. Trial treatments.

Factor I: Soil-applied herbicide	Factor II: Foliar-applied herbicide
No soil herbicide	No foliar herbicide
Goltix WG 0.95 kg/ha	Beloukha 8 L/ha
Boxer 0.95 kg/ha	Lentagran WP 0.8 kg/ha
Fenix 0.3 L/ha	Liquid N (NS 30-2) 30 kg N/ha
Stomp CS 0.95 L/ha	Mizuki 0.2 L/ha
Centium 36 CS 0.12 L/ha	
Liquid N (NS 30-2) 30 kg N/ha	
Control & reference treatments	
Untreated	
Reglone + Agropol 2.5 + 0.1%	
Roundup Bio 2 L/ha	
Mizuki 0.2 L/ha	
Mizuki 0.4 L/ha	
Mizuki 0.8 L/ha	

This new technique with tank mixes requires that the application with soil-applied herbicides should be postponed until just a couple of days before crop emergence so that the weeds are present at the time of application. It is especially effective when using false seed bed preparation. The tested soil-applied herbicides were Goltix WG (metamitron), Boxer (prosulfocarb), Fenix (aclonifen), Stomp CS (pendimethalin) and Centium 36 CS (clomazone). The tested foliar herbicides were Beloukha (pelargonic acid), Lentagran WP (pyridate), Liquid N fertiliser and Mizuki (pyraflufen). Some of the results of the trials in 2021 are presented in Figure 1 below.



A. Efficacy (%) on small (BBCH12 or smaller) *Matricaria* species of the tested tank mixes.



B. Efficacy (%) on small *Chenopodium album* of the tested tank mixes.

Figure 1. Tank mixes with soil- and foliar-applied herbicides as an alternative to diquat and glyphosate applied pre-crop emergence. The results are from a trial without a crop showing the efficacy on *Matricaria* species (a) and *Chenopodium album* (b). The letters in the figure with results for *Matricaria* indicate significant differences between the treatments (p = 0.05), while no significant differences were observed for *Chenopodium*, except for treatment with solo NS 30-2.

The soil-applied herbicides possess some foliar efficacy, and by boosting the efficacy with foliar-applied herbicides in tank mixes an efficacy comparable to that of glyphosate (or diquat) can be achieved. The results of the trials in 2020 and 2021 suggest that:

- The tested tank mixes generally provide comparable efficacy on small weeds (up to BBCH 12) to that of glyphosate or diquat.
- The efficacy is, however, not satisfactory when it comes to larger weed plants and not comparable to that of glyphosate or diquat.
- Generally, the tested tank mixes did not increase the phytotoxicity on vegetables (carrots, onions and parsnips) and seeded roses compared to the application of the soil-applied herbicides alone (this is partially based on experiences from the trials in the Swedish Minor Use Project).

Trial with alternatives to diquat and glyphosate in pre-emergence application. The photo is taken in the trial that was carried out without a crop. The results suggest that most of the tank mixes of soil- and foliar-applied herbicides provided good weed control without damaging the crop. However, weed control was not sufficient when it comes to larger weed plants - the efficacy of the tank mixes against large *Matricaria* and *Rumex* plants of the tank mixes was inferior compared to treatments with glyphosate and diquat.

Test of alternative products for control of powdery mildew in potted roses in greenhouses

This trial is in line with the recent development where the need for alternative products in greenhouses is increasing as the currently used pesticides are facing restrictions. The recent restrictions for pesticide use in 'open' greenhouses have triggered the interest in pesticide-free growing.

Eighteen different treatments were tested in this trial, in which most of the treatments were alternative products and their combinations (Table 2). The trial was inoculated on 9 September 2021. Treatments with AgriColle (extract from seaweeds) and Armicarb 85 SP (potassium hydrocarbonate) provided very high control of powdery mildew in roses (>80%). Many of the other treatments showed moderate control of powdery mildew in potted roses in the greenhouse.

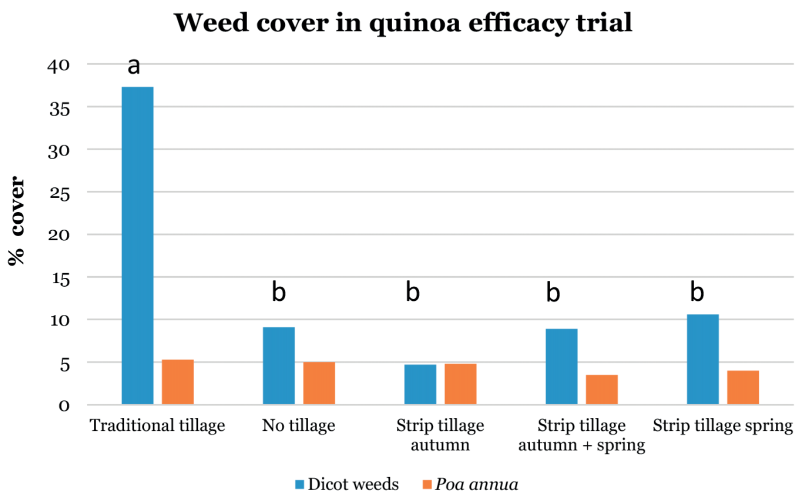
Table 2. Test of alternative products for control of powdery mildew in potted roses in greenhouses. Means followed by same letter do not differ significantly (p = 0.05, Student-Newman-Keuls).

Treatment no.	Treatment name	Rate	Rate unit	Application code	% control of powdery mildew of rose, 24 Sep. 2021	
1	Untreated innoculated				0	g
2	Untreated not innoculated				12.7	fg
3	Flexity	0.05	% V/V	CE	50.8	cde
4	Talius	0.025	% V/V	CE	69.6	abc
5	Revysol (BAS 750 11F)	0.12	% V/V	CE	53.2	cde
6	AgriColle + Borregaard PK	0.4 + 0.4	% V/V	ABCDE	94.3	a
7	AgriColle	0.4	% V/V	ABCDE	86.8	ab
8	Serenade ASO	0.4	% V/V	ABCDE	33.8	def
9	Serenade ASO + Silwet Gold	0.4 + 0.025	% V/V	ABCDE	51.4	cde
10	Serenade ASO + Resibase	0.4 + 0.25	% V/V	ABCDE	61	bcd
11	HC-Magnesium fertiliser	0.4	% V/V	ABCDE	60.7	bcd
12	SalicylPure	0.2	% V/V	ABCDE	50.7	cde
13	HC-Magnesium f. + SalicylPure	0.4 + 0.2	% V/V	ABCDE	62	bcd
14	Silica Power	0.1	% W/W	ABCDE	42.4	cde
15	Wetcit Neo (Oroganic)	0.6	% V/V	ABCDE	72.7	abc
16	Armicarb 85 SP	0.5	% W/V	ABCDE	91.9	a
17	Fyto11	0.4	% V/V	ABCDE	47.4	cde
18	BB Blatt + Terrafert Blatt	1 + 0.5	% V/V	ABCDE	50.7	cde
19	Sunflower oil	0.5	% V/V	ABCDE	53.7	cde
20	AgriCHOS	0.2	% V/V	ABCDE	29.8	ef
LSD p = 0.05				17.9		

	A	B	C	D	E
Application date:	27 Aug. 21	31 Aug. 21	7 Sep. 21	14 Sep. 21	21 Sep. 21

The GUDP project QUISACU (QUInoa SAfe CUltivation)

The group's activities in the quinoa project in 2021 consisted of three trials. Two of the trials were carried out to test how quinoa reacts to no-tillage and strip tillage systems (one efficacy trial (Figure 2a) and one selectivity trial (Figure 2b)). Moreover, a trial was established focusing on cover crops and how they influence the development on quinoa in the succeeding growing season when quinoa was established without ploughing and traditional tillage. In the efficacy trial, the weed cover (dicot weeds and *Poa annua*) was assessed intra-row. The selectivity trial was kept weed free during the growing season and the crop vigour and the yield were assessed.



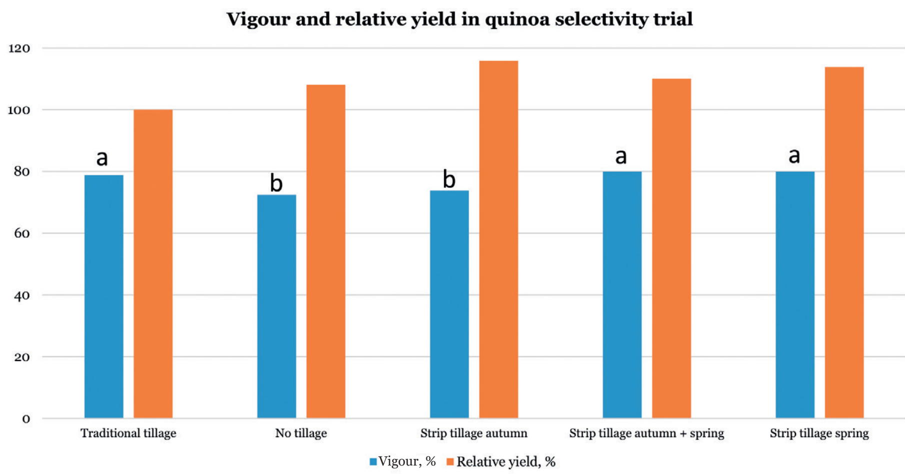
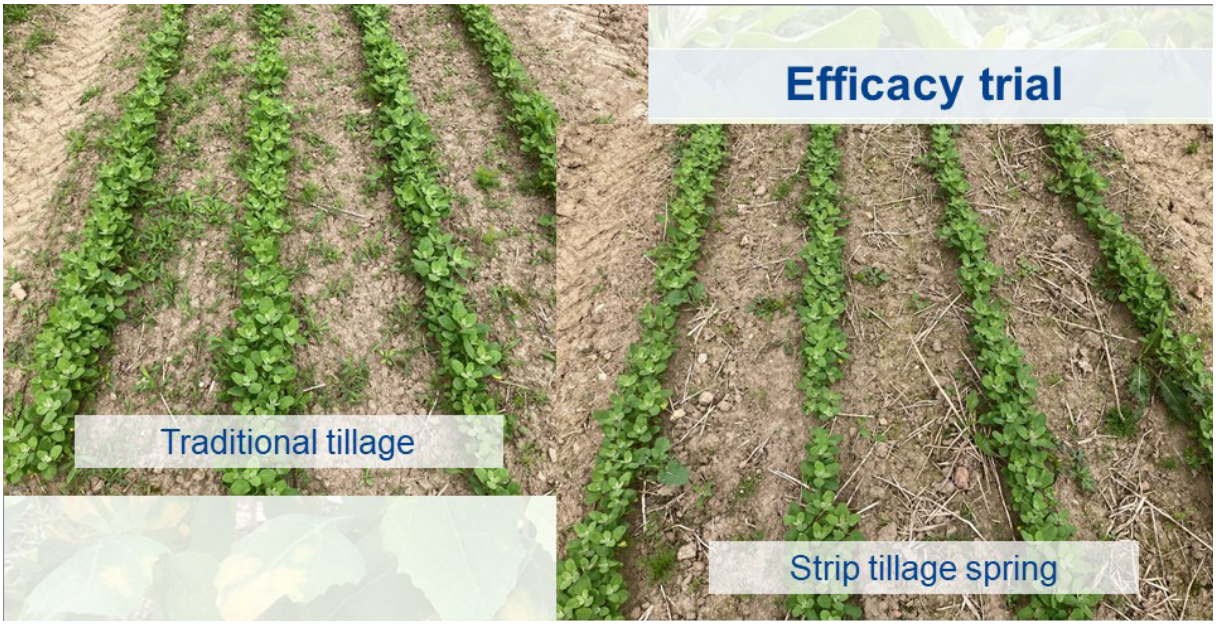


Figure 2. The figure shows that strip tillage techniques reduce dicot weeds by up to 85% (top). The yield in the traditional tillage was 924 kg/ha; the treatments with strip tillage resulted in a yield increase of up to 15.9% (not significant) (bottom). There was no significant difference in the weed cover of *Poa annua* between any of the treatments.



High weed control was achieved by using strip tillage techniques when establishing quinoa. There was up to 85% less weeds in the strip tillage treatments (lower right) compared to the traditional tillage (upper left). Crop vigour was significantly affected but did not lead to yield decrease.

Test of alternative products for control of lawn pest *Tipula paludosa*

The larvae of *Tipula paludosa* are a major problem in certain localities where they cause damage partly directly by damaging the grass roots and partly by being a vector for other pests - above all birds, which in their search for food can destroy larger grass areas. Conventional control of *T. paludosa* larvae has until 2018 been based on the product Merit Turf (imidacloprid). The product belongs to the group of neonicotinoids, which from 2019 have been banned for outdoor use. The trial plan consisted of a total of nine different treatments with input from seven different products. In addition to the chemical references Merit Turf, Coragen and Steward 30 WG, the following products were included: Nemasys Leatherjacket Killer (nematodes), Gnatrol SC (bacteria-based product), BotaniGard WP (fungus) and Flipper (fatty acid).

Three trials were conducted at two different golf clubs with a history of heavy infestations of *T. paludosa* larvae (two trials in Horsens and one trial in Fredericia). In addition, an extra trial was carried out on the lawn at AU Flakkebjerg.

The experiments were carried out considering the life cycle of the *T. paludosa*, which is especially crucial in connection with the use of biological agents, such as nematodes. There were two applications in the trials: first treatment was performed around 1 October and the second treatment was performed approx. three weeks later. Trial results were obtained by examining soil samples approx. three weeks after the last treatment.

The results showed a moderate attack by the larvae of the *T. paludosa* in the experiments at the golf clubs. The experiment on the lawn at AU Flakkebjerg turned out to have a very low level of infestation of the stalk leg larvae (*T. paludosa*) and was unsuitable for assessing the efficacy of the test products.

Treatments with Coragen proved to be very effective in the three trials at the golf clubs (72-85% efficacy) (Table 3). The products Merit Turf and Steward 30 WG showed moderate efficacy of 52-68%, while the alternative products showed low efficacy of 39-48% effect. The efficacy of the alternative agents Nemasys Leatherjacket Killer, Gnatrol SC, Flipper and BotaniGard WP was significantly higher than untreated when analysing data in a 'pooled' dataset.

Table 3. Test of alternative products for control of *T. paludosa* in grass areas.

Product	Efficacy	Avg. number of larvae per 1 m^2	% efficacy
Coragen AB	Good	0.9	85.3
Coragen A	Good	2.5	72.4
Merit Turf	Moderate	23	67.9
Steward 30 WG	Moderate	51	52.2
Nemasys Leatherjacket Killer A	Low	58	47.5
Nemasys Leatherjacket Killer AB	Low	58	42.4
Gnatrol SC	Low	63	41.1
Flipper	Low	53	40.1
BotaniGard WP	Low	63	39.1
Untreated		106	0
LSD p = 0.05		3.12	19.49

IX List of chemicals

Fungicides		
Name	**Active ingredients**	**Gram/L or kg**
AgriColle	Extract from seaweeds	-
Agripol	Adjuvant	-
Amistar	Azoxystrobin	250
Amistar Gold/Greteg Star	Azoxystrobin + difenoconazole	125 + 125
Armicarb 85 SP	Potassium hydrocarbonate	850
Ascra Xpro	Prothioconazole + bixafen + fluopyram	130 + 65 + 65
Aviator Xpro	Prothioconazole + bixafen	150 + 75
Balaya	Mefentrifluconazole + pyraclostrobin	100 + 100
BAS 768 00F	Revysol + sulphur	600 + 25
BAS 831 00F	Xemium + Dev cpd	90 + 90
Bell	Boscalid + epoxiconazole	233 + 37
Comet Pro (Comet 200)	Pyraclostrobin	200
Curbatur	Prothioconazole	250
Elatus Era	Azoxystrobin + benzovindiflupyr	30 + 15
Elatus Plus	Benzovindiflupyr	100
Entargo	Boscalid	500
Fandango S	Prothioconazole + fluoxastrobin	100 + 50
Flexity	Metrafenon	300
Folicur EW 250	Tebuconazole	250
Folicur Xpert	Tebuconazole + prothioconazole	160 + 80
Folpan 500 SC	Folpet	500
Imtrex	Fluxapyroxad	62.5
Input	Prothioconazole + spiroxamine	160 + 300
Input Triple	Spiroxamine + prothioconazole + proquinazid	200 + 160 + 40
Juventus 90	Metconazole	90
Leander	Fenpropidin	750
Librax	Fluxapyroxad + metconazole	62.5 + 45
Madison	Prothioconazole + trifloxystrobin	88 + 175
MCW 406-S	Difenoconazole	250
Mirador Forte	Tebuconazole + azoxystrobin	100 + 60
Narita	Difenoconazole	250
NEU 1143	Pelargonic acid	67.6
Orius Max	Tebuconazole	200
Pictor Active	Pyraclostrobin + boscalid	250 + 150
Priaxor	Pyraclostrobin + fluxapyroxad	150 + 75
Proline EC 250	Prothioconazole	250
Propulse SE 250	Fluopyram + prothioconazole	125 + 125
Prosaro EC 250	Prothioconazole + tebuconazole	125 + 125
Prothio 300	Prothioconazole	300
Proxanil	Propamocarb + cymoxanil	333.6 + 50

Fungicides		
Name	**Active ingredients**	**Gram/L or kg**
Questar	Fenpicoxamid	100
Ranman Top	Cyazofamid	160
Revycare	Mefentrifluconazole + pyraclostrobin	100 + 100
Revysol (BAS 750 01F)	Mefentrifluconazole	100
Revystar XL (BAS 752 00F)	Mefentrifluconazole + fluxapyroxad	100 + 50
Revytrex	Mefentrifluconazole + fluxapyroxad	66.7 + 66.7
Serenade ASO	*Bacillus amyloliquefaciens*	7131 x 1012 CFU/L
Silvron Xpro	Fluopyram + bixafen	100 + 100
Talius	Proquinazid	200
Thore	Bixafen	125
Variano Xpro	Bixafen + prothioconazole + fluoxastrobin	40 + 100 + 50
Univoq	Prothioconazole + fenpicoxamid	100 + 50

Herbicides		
Name	**Active ingredients**	**Gram/L or kg**
Beloukha	Pelargonic acid	680
Boxer	Prosulfocarb	800
Centium CS	Clomazon	360
Cossack OD	Mefenpyr + iodosulfuron + mesosulfuron	2.5 + 7.5 + 7.5
DFF	Diflufenican	500
Fenix	Aclonifen	600
Goltix WG	Metamitron	700
Lentagran WP	Pyridate	450
Mizuki	Pyraflufen	10.6
Reglone	Diquat	374
Roundup Bio	Glyphosate	360
Stomp CS	Pendimethalin	455

Insecticides		
Name	**Active ingredients**	**Gram/L or kg**
BotaniGard WP	*Beauveria bassiana*	44000000000
Coragen	Chlorantraniliprole	184
Flipper	Carboxylic acid potassium	479.8
Gnatrol SC	*Bacillus thuringiensis*	18 x 10^{10} CFU/L
Merit Turf	Imidacloprid	5
Nemasys Leatherjacket Killer	Nematodes	500.000 units/m^2
Steward 30 WG	Indoxacarb	300

About DCA

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

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

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

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

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

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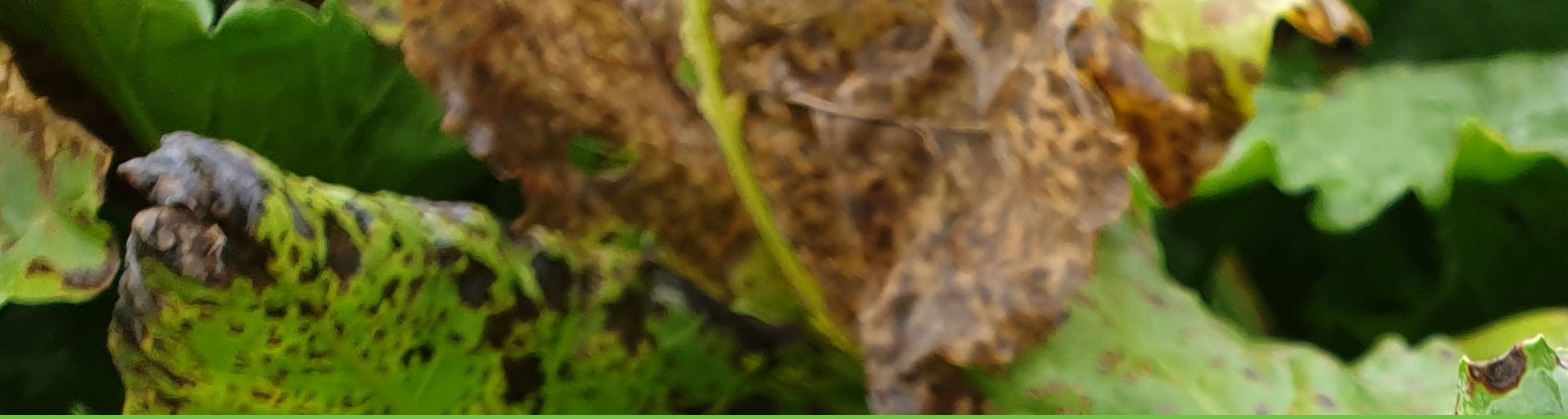

SUMMARY

This publication contains results from crop 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 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