APPLIED CROP PROTECTION 2020

LISE NISTRUP, THIES MARTEN HEICK, ISAAC KWESI ABULEY, PETER KRYGER JENSEN, HELENE SALTOFT KRISTJANSEN & ANDRIUS HANSEN

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Lise Nistrup, Thies Marten Heick, Isaac Kwesi Abuley, Peter Kryger Jensen, Helene Saltoft Kristjansen & Andrius Hansen

Aarhus University
Department of Agroecology
Forsøgsvej 1
DK-4200 Slagelse

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Author(s):	Lise Nistrup, Thies Marten Heick, Isaac Kwesi Abuley, Peter Kryger Jensen, Helene Saltoft Kristjansen & Andrius Hansen, Department of Agroecology, Aarhus University
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Preface

The publication “Applied Crop Protection” is a yearly 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 advising. 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 from 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 localities with specific targets. Several of the results were also published in newsletters together with SEGES to ensure a fast and direct communication to farmers.

In this publication, new data have been collected and processed, and the report presents results that have not been externally peer-reviewed or published elsewhere. Changes may therefore occur in the event of a later publication in journals with external peer review.

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

Chapter I: Climate data for the growing season 2019/2020 and specific information on disease attacks in 2020. The information was collected by AU.

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

Chapter III: Ranking of *Fusarium* susceptibility. Including a summary from 10 years of screening. Trials in this chapter were financed by AU, Nordic Seed, KWS and Sejet Plant Breeding.

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

Chapter V: Diseases in red fescue. The project was financed by "Frøafgiftsfonden".

Chapter VI: Fungicide resistance-related investigations. Testing for fungicide resistance is carried out based on a shared cost covered by projects and the industry. In 2019 ADAMA, Corteva, Bayer Crop Science, BASF and Syngenta were involved from the industry. The Swedish part was financed by the Swedish Board of Agriculture, and AU-AGRO was involved.

Chapter VII: Fungicide testing against Sclerotinia stem rot (*Sclerotinia sclerotiorum*) in oilseed rape. The project was financed by ADAMA and Corteva.

Chapter VIII: Fungicide strategies against powdery mildew resistance in sugar beet. The project was financed by "Sukkerroeafgiftsfonden".

Chapter IX: Controlling late blight in susceptible and resistant potato cultivars with *BlightManager*. Trials in this chapter were financed by Nordisk Alkali, Bayer Crop Science, BASF and Syngenta. Several of the trial plans were carried out in collaboration with SEGES; these included the testing of DSS.

Chapter X: Influence of boom height on spray drift from conventional sprayers. The investigation was financed by the Danish Environmental Protection Agency.

Chapter XI: Results of crop protection trials in minor crops in 2020. The projects were financed by various agricultural tax funds, GUDP, chemical companies and Swedish minor use funding.

Chapter XII: List of chemicals.

I Climate data for the growing season 2019/2020

Helene Saltoft Kristjansen

This section evaluates the overall weather conditions in Denmark during the growing season and especially in Flakkebjerg where the majority of Aarhus University (AU) trials are located (September 2019 - August 2020).

Denmark experienced particularly high precipitation and average temperatures in the autumn of 2019. Precipitation across the country increased to 349 mm, which set a new record. 24 days with precipitation was recorded in September and October. Significantly high precipitation of 133 and 129 mm, respectively, placed September and October 2019 on the list of the 10 months with most precipitation recorded since 1874.

Winter 2020 recorded high temperatures and more days with precipitation than average. December, January and February showed high temperatures compared with the climate normal average. January set a new temperature record with 5.5°C, which was 3.6°C above average temperature in January (2011-2020). The average temperature during the three winter months was 5.0°C, which was 4.5°C above a 10-year average (2006-2015) and set a new temperature record. Due to the high average temperatures, precipitation during the winter was mainly rain. Only few days with frost were recorded. Precipitation was high during winter 2020. In total, 280.5 mm was recorded, which was 51% above a 10-year average (2006-2015). Both January and February had precipitation above normal. February showed more precipitation than ever recorded between 1961 and 2020. In total, 135 mm was recorded, which was 174% above a 10-year average (2011-2020).

Spring 2020 was dry, sunny and with a temperature average of 7.4°C, which was close to a 10-year average of 7.6°C (2011-2020). Precipitation during the spring was recorded to be significantly low, and precipitation was unevenly distributed across the country. Most precipitation was recorded in Central and Western Jutland with 115.2 mm. Least precipitation recorded was in Western Zealand with 62.0 mm. Spring 2020 was sunny and set a new record. In total, 710 hours of sun was recorded, which was 19% above a 10-year average (2011-2020) and the highest total of sunny hours recorded since 1920.

Summer 2020 was close to average regarding, temperature, precipitation and sunny hours. June recorded high temperatures with an average of 16.3°C, which was 1.4°C above a 10-year average (2011-2020). The highest overall temperatures during the summer were recorded in the eastern parts of Denmark where the average reached 17.2°C, whereas the western parts recorded only 15.9°C. Rainfall was unevenly distributed across the country. Due to a general lack of precipitation in the spring and a continuously dry summer, the drought index increased severely in the eastern parts of Denmark. Central and Western Jutland in particular recorded significant precipitation due to cloudbursts. On average, June and July recorded high precipitation of 72 and 85 mm, respectively, which was 9% and 22% above a 10-year average (2011-2020). August recorded high temperatures and relatively few days with precipitation. The number of days with temperatures above 25°C increased to 12.2, which was far above the normal average of 4.3 days. Precipitation in August fell mainly in Jutland, partly as cloudbursts. In general, the precipitation was only 69 mm, which was 20% below a 10-year average (2011-2020). At Flakkebjerg, especially September and October were characterised by significantly high precipitation with a total of 266 mm, which was 14% above a 10-year average (2006-2015). The high amount of precipitation complicated work in the fields, and winter cereals were sown with some minor difficulties. Establishment of crops in clay/sandy soil was successful; on the other hand, heavy clay soils failed partly if sown late.

Winter 2020 had both high temperatures and precipitation. All winter the temperatures recorded were far above normal with an average of 5.0°C, which was 3.3°C above normal. Snowfall only occurred on a few days during the winter. No 24-hour frosty days were recorded during the winter. Precipitation at Flakkebjerg during the winter was close to average with 187 mm recorded. February had the highest precipitation during the winter with 88 mm, which was 79% above a 10-year average (2011-2020). The high temperatures continued during March and April. Precipitation decreased significantly from March, and lack of precipitation lasted all summer. The temperatures during the summer were close to normal. The temperature average reached 17°C, which was 5% above a 10-year average (2011-2020). Due to lack of precipitation, the drought index was considerably high already in May. In general, fungicide trials at Flakkebjerg were irrigated 2-3 times during the summer to keep the crops growing and to ensure disease attack. Harvest of the crops was without any complications due to the dry weather conditions. Cereal yields were high in irrigated fields and moderate if not irrigated due to periods with drought and moderate disease attacks in almost all fields.

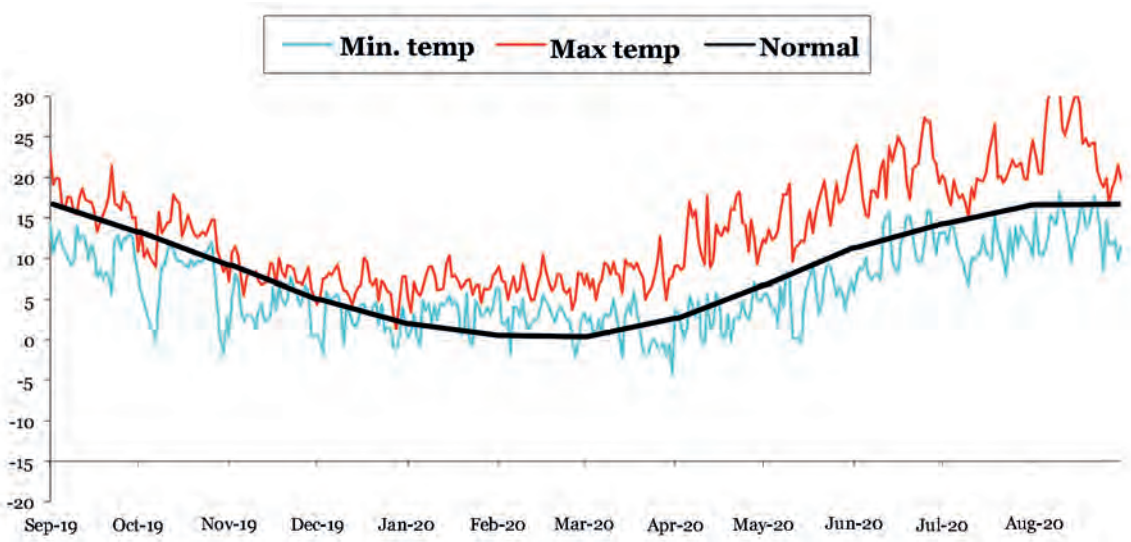


Figure 1. Climate data graph from AU Flakkebjerg for the growing season September 2019-August 2020. The temperature is in °C.

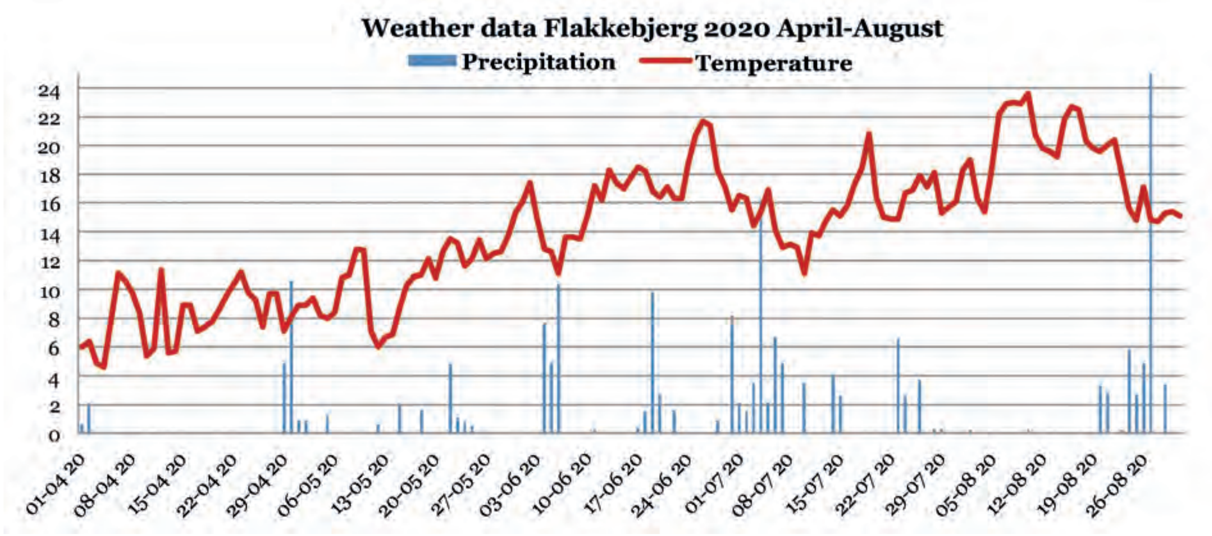


Figure 2. Climate data graph from AU Flakkebjerg for spring and summer 2020. The temperature is in °C and precipitation in mm.

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 situated. The normal climate is given as an average of forty years (1973-2013)

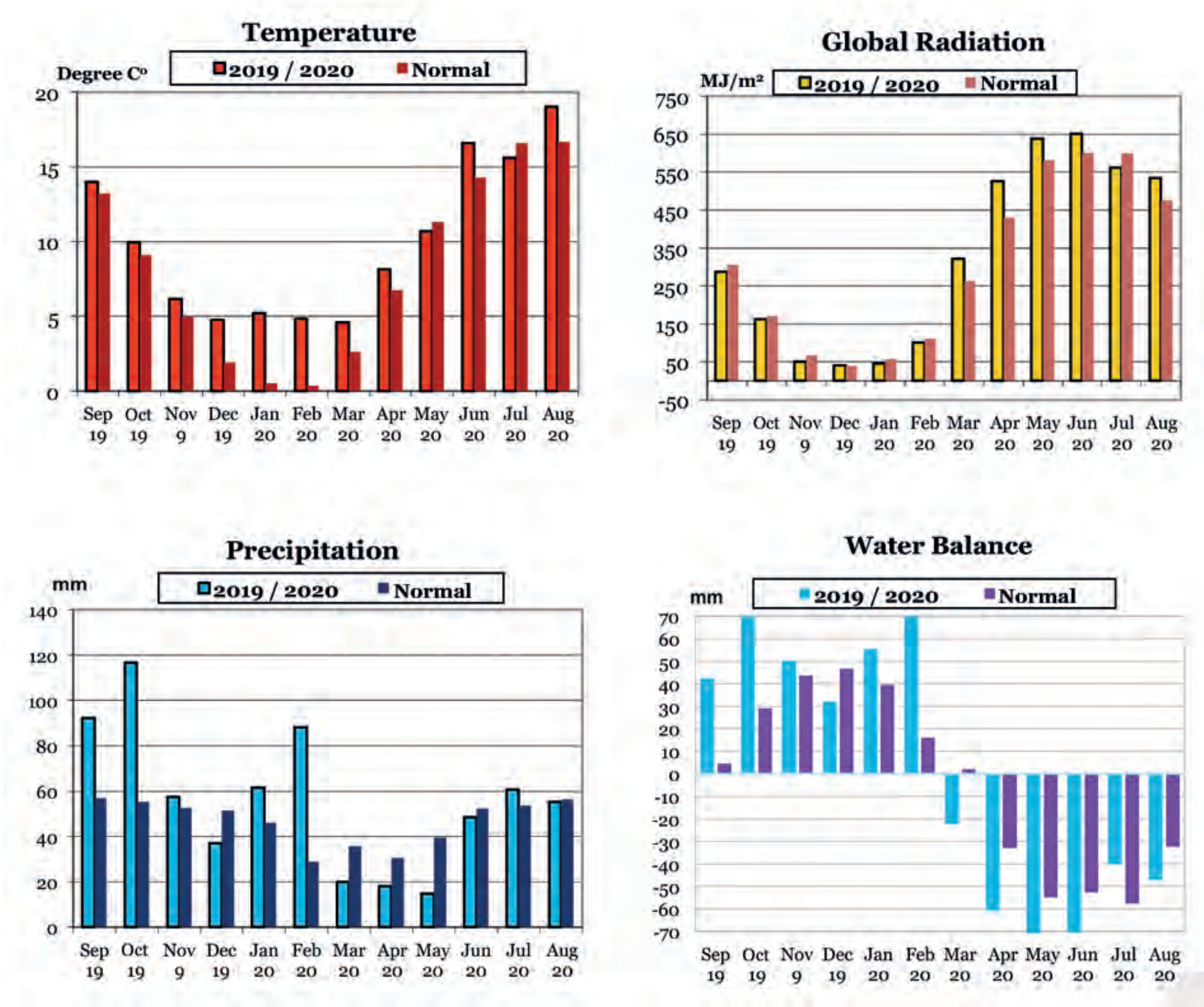
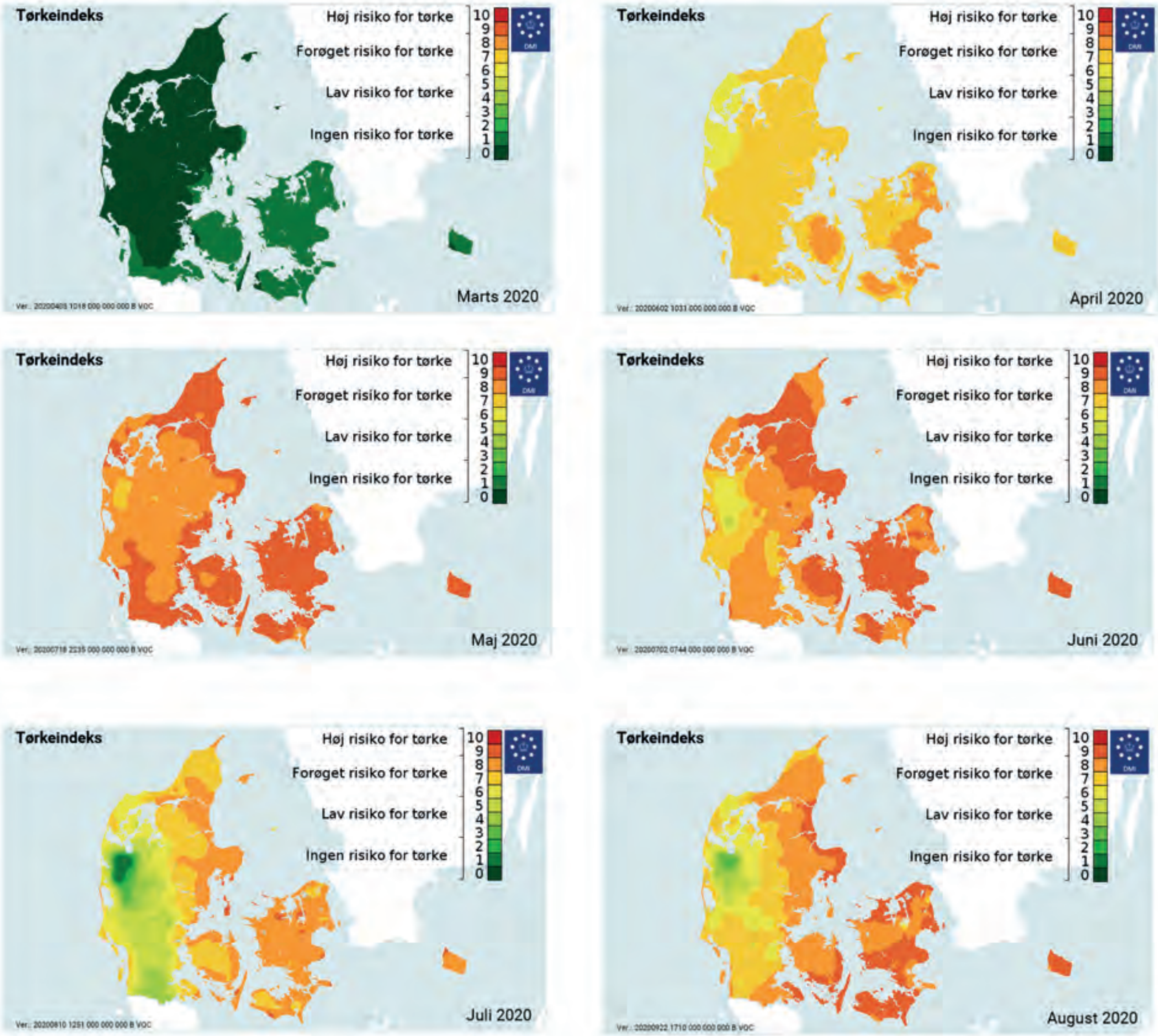


Figure 3. Climate data from AU Flakkebjerg for the growing season September 2019 - August 2020. The temperature is in °C, the global radiation is measured in MJ/m2, the precipitation is in mm, and the water balance is the difference between precipitation and potential evaporation.



Drought index 2020 (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 2020. Danish Meteorological Institute (DMI).

1. Disease attacks in 2020

Helene Saltoft Kristjansen, Lise Nistrup Jørgensen & Isaac Kwesi Abuley

This chapter describes the occurrence of diseases present in the fungicide trials in 2020. This knowledge is important to evaluate whether the target diseases are present at significant levels. Trial efficacy assessments depend on significant disease levels to ensure representative results. Yield levels in cereal trials are ranked and compared with the previous year's responses.

Wheat

Powdery mildew (*Blumeria graminis*). The sandy soil in Southern Denmark is well known for its severe attacks of powdery mildew. As expected, severe attacks of mildew developed in trials at Jyndevad and provided good opportunities for ranking product efficacy. For the country in general, the level of mildew attack was low. Recordings carried out by the advisors in the national monitoring system organised by SEGES showed low levels of mildew attack late in the 2020 season.

Septoria leaf blotch (*Zymoseptoria tritici*). The level of *Septoria* attack varied and depended on sites and cultivars, but in general, across the country, the levels of attack were low to moderate. High temperatures and precipitation during the winter ensured conditions for inoculum to develop. However, due to lack of precipitation during the spring and the summer, the disease was inhibited from developing severe attacks. Most cultivars showed measurable symptoms of *Septoria* on the upper leaves from growth stage (GS) 55 at the beginning of June. Due to several irrigations of the trials at Flakkebjerg, attacks on the upper leaves increased during June, and significant attacks gave good opportunities for assessments in cultivars such as Hereford, Cleveland and Torp. The level of *Septoria* attack increased to a moderate level of 39% on leaf 2 and 16% on leaf 1 at GS 75-77.

Yellow rust (*Puccinia striiformis*). Fields with the susceptible cultivars Substance and Benchmark were inoculated with yellow rust in late April and the inoculation was repeated in May. Temperatures were low in May, which delayed the development of yellow rust. Benchmark is well known for its high susceptibility, and despite cold weather in May, attacks were moderate to severe. In Benchmark trials inoculated with yellow rust, the attack of yellow rust on leaf 1 increased to 56% at GS 75-77. This year, the cultivar Substance developed only a moderate attack of yellow rust. The attack increased to a level of 22% on the flag leaf at GS 75. Attacks of yellow rust are known to reduce yields and attacks in 2020 showed significant yield responses for fungicide treatments.

Brown rust (*Puccinia triticina*). The mild winter 2019/2020 provided good conditions for inoculum to survive the winter. Due to cold weather conditions during May, only a minor attack of brown rust was seen during the spring and summer.

Tan spot (*Drechslera tritici repentis*). Attacks of tan spot developed in April in fields with winter wheat as previous crop and minimal tillage. Due to cold weather and slow development of tan spot, no early T1 treatments against tan spot were needed. In June, the infection spread to the upper leaves. Field trials at Flakkebjerg were established in the cultivar Graham, which is especially susceptible to tan spot. Trials carried out at a trial site which was pre-infected in the autumn with infected straw showed a moderate attack, but not until late in the growing season, which narrowed opportunities for efficacy evaluations. Attacks of tan spot increased late, and in July severe attacks were assessed at all leaf levels. At GS 75, the disease level increased to 12% on the flag leaf and 32% on leaf 2.

Fusarium head blight (*Fusarium* spp.). To ensure attack of Fusarium head blight, trials carried out at Flakkebjerg were inoculated with *Fusarium*. Inoculation together with irrigation during flowering is an effective method to ensure attack. Daily irrigation was possible in small plots where cultivars were tested for susceptibility. The moist conditions in these trials ensured a high level of *Fusarium* attack in 2020, which made it possible to distinguish susceptibility between cultivars. Large-scale fungicide field trials were inoculated during flowering and irrigated 2-3 times during the same period. Due to the optimal weather conditions during flowering, attack levels in inoculated field trials were moderate to high and provided good opportunities for distinguishing differences between fungicides.

Triticale and rye

Yellow rust (*Puccinia striiformis*). A severe attack of yellow rust developed early in the season in the triticale trials in 2020. The triticale trials were carried out in Neogen, which was naturally infected in the spring, and at GS 73 levels increased to 36% on leaf 2. The disease level provided good opportunities for distinguishing the performances of the products.

Brown rust (*Puccinia recondita*) appeared in rye late in June and developed only minor attacks in the trials; this provided no opportunities for distinguishing the performances of the products. At GS 77, the attack increased to 1% on the upper leaves.

***Rhynchosporium* (*Rhynchosporium commune*).** A moderate attack of *Rhynchosporium* developed at the beginning of June. The disease level provided good opportunities for distinguishing the performances of the products. The attack of *Rhynchosporium* in rye increased to 17% on the upper leaves at GS 77.

Winter barley

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 very low levels of mildew attack at Flakkebjerg in 2020, there was no possibility of distinguishing the performances of the products.

Brown rust (*Puccinia hordei*). Brown rust was a dominant disease in winter barley in 2020. All sites and most cultivars showed symptoms of rust. At the field trial site at Flakkebjerg, attacks of brown rust developed in all cultivars except Frigg. The cultivar Kosmos in particular developed a severe attack, which provided good options for separating the efficacy of the different fungicides in 2020. The average attack of brown rust in this year's trial at AU reached a level of 19% on leaves 2-3 at GS 73-75.

***Rhynchosporium* (*Rhynchosporium commune*)** was another dominant disease in 2020. In general, the level of *Rhynchosporium* attack in winter barley was moderate to severe in 2020. A severe attack of *Rhynchosporium* developed particularly in the cultivar Frigg but a moderate attack also developed in Kosmos and Hejmdal. The moderate to high incidence of *Rhynchosporium* provided good opportunities for distinguishing the performance of the products. The average attack of *Rhynchosporium* reached a level of 12% on leaves 2-3 at GS 73-75.

Net blotch (*Drechslera teres*). Only very few symptoms of net blotch were recorded in 2020 in winter barley. At Flakkebjerg, a minor attack of net blotch developed in the cultivar Celtic. Opportunities for separating fungicide performances were limited. In the few trials with net blotch, the average attack in the susceptible cultivars reached a level of 15% on leaves 2-3 at GS 75.

Ramularia leaf spot (*Ramularia collo-cygni*). In general, attack of *Ramularia* developed very late in the season and few cultivars showed symptoms of *Ramularia*. Due to very low levels of attack there was no possibility of distinguishing 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 showed very low levels of net blotch attack in spring barely. In field trials at Flakkebjerg, the attack of net blotch was moderate to high due to highly susceptible cultivars such as Laurikka and especially Chapeau. These cultivars provided good possibilities for ranking the performances of the products. The attack of net blotch in Chapeau and Laurikka reached an average level of 26% on leaves 2-3 at GS 73-75.

Brown rust (*Puccinia hordei*). In general, attacks across the country were moderate and less widespread compared with previous years. Trials at Flakkebjerg in the cultivar Laurikka developed low to moderate levels of attack of brown rust in 2020, which limited the opportunities for separating fungicide performances. The attacks at Flakkebjerg only reached an average of 2% at GS 75-77 on leaf 2.

Ramularia leaf spot (*Ramularia collo-cygni*). *Ramularia* was mainly present in the cultivar KWS Irina in 2020. *Ramularia* developed late in the season. In the trials, KWS Irina provided good possibilities for ranking the performances of the products. Attacks of *Ramularia* reached an average level of 22% on leaf 2 at GS 75-77 in this cultivar.

Yield increases in fungicide trials in cereals

The dry weather in August ensured optimal conditions for harvesting cereals in 2020. The harvest of winter barley was carried out without complications and fine harvest products were sampled during July. The winter wheat trials yielded well due to treatment response and sufficient precipitation. The average yield in winter wheat in 2020 reached 98 hkg/ha and trials yielded in the range of 80-115 dt/ha. Winter barley trials had no irrigation during the growing season and wilted early due to drought and infection of brown rust. Despite dry cropping conditions winter barley still yielded well in the range of 80-100 dt/ha.

Spring barley trials were in good condition. Trials were irrigated twice during the growing season. In spring barley the yield levels were moderate, between 70 dt/ha and 85 dt/ha.

The general yield response was moderate for winter barley. A severe attack of especially brown rust was the reason for increases. Standard treatments in AU winter barley trials yielded an average increase of 6.3 hkg/ha.

Yield increases following fungicide treatments in winter wheat were low to moderate, and only trials with high levels of disease paid off for fungicide treatments. The yield response in AU winter wheat trials showed average increases of 9.6 hkg/ha.

The yield response in spring barley was moderate. The general low levels of disease attack together with drought in many fields reduced yield responses in 2020. On average, standard treatments in spring barley in AU trials increased by 5.9 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 indicate 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)

Sugar beet

Powdery mildew (*Erysiphe betae*). Recordings carried out by the advisors in the national monitoring system organised by SEGES showed a high level of mildew attack. Due to high temperatures both the cultivars Lombok and Pasteur in field trials at Flakkebjerg showed a severe attack of mildew in late August and September. The high level of attack provided good opportunities for distinguishing the performances of the products. During the season, the attack of mildew increased to 87%.

Beet rust (*Uromyces betae*). Brown rust was a dominant disease in beets in 2020. At the field trial site at Flakkebjerg a severe attack of brown rust developed in both Lombok and Pasteur. First symptoms were assessed in August and the attack increased severely during September, which provided good options for separating the efficacy of the different fungicides in 2020. The average brown rust attack in the beet trials at AU reached a level of 36%.

***Ramularia* (*Ramularia beticola*).** *Ramularia* occurred in all trials in 2020, but the attack levels were low and limited the possibilities for ranking the performances of the products. The attacks of *Ramularia* reached an average level of 3%.

Oil seed rape

Sclerotinia in oilseed rape is caused by the fungal pathogen *Sclerotinia sclerotiorum*. The attack level of *Sclerotinia* was low in most fields during the 2020 season. At Flakkebjerg, the attack developed following artificial inoculation with inoculum during flowering. This provided a significant and reliable attack for ranking the efficacy of the fungicides. The photos show how the attack developed in the crop following inoculation with grain material infested with the fungus.

Potato

Early blight (*Alternaria solani*)

The early blight trials were artificially inoculated with barley kernels infested with mycelia of *Alternaria solani* on 23 and 24 June. However, the first attack on the untreated plots was seen on 14 July, which was about 20 days post-inoculation. Generally, the progress of early blight was very slow until mid-August, when the disease development began to increase. These periods were characterised by high relative humidity and several rainy periods. Generally, the fungicide treatments and models tested for early blight control were good.

Late blight (*Phytophthora infestans*)

Spreader rows in the field were artificially inoculated with a sporongial suspension of *Phytophthora infestans* on 1 July to establish late blight in the field. The days after the inoculation were generally dry and thus it took about 20 days before the first attack was observed in the spreader rows. However, the overall development of late blight was severe in the season, although it started late (mid-August). From mid-August, days were generally associated with high humidity, conducive temperature and rainy days, which thus favoured the development of late blight.

II Disease control in cereals

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

Introduction

This chapter briefly describes fungicide field trials in cereals carried out in 2020 and summarises the results. Graphs and tables also include results from additional years for trial plans covering several years. Included are main results on major diseases from protocols with new fungicides as well as from protocols which compare different dose rates and application timings. Some of the trial results are used as a part of the Biological Assessment Dossier, which the companies have to 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. A few comments and concluding remarks are given together with the main data presented in the tables and figures. The companies Bayer, BASF, Corteva and Syngenta, who pay for having their products tested, funded the majority of data summarised in this chapter. 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 European countries. Results are also presented from the RustWatch project, which is financed by Horizon 2020, where activities are carried out in collaboration with many partners in Europe. All data from the projects are analysed by AU, who also publishes the data. In several trial plans, individual treatments are included based on AU's own initiative.

Methods

All field trials with fungicides are carried out as GEP trials. Most of the trials are carried out as field trials at AU Flakkebjerg. Some trials are also situated 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 to 35 m^2, depending on the individual unit's equipment. The trials are placed 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, 150 or 200 l of water per ha and a nozzle pressure of 1.7-2.2 bar and a speed of 4.6 km/hour.

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 in 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 certain 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 based on the Student-Newman-Keuls model. When a net yield is calculated, it is converted to dt/ha based on deducting the cost of used chemicals and the cost of application. The cost of driving has been set at DKK 70 and the cost of chemicals extracted from the database at SEGES. The grain price used is DKK 120/dt (= dt).

1. Control of diseases in winter wheat

Comparing effects from SDHIs

As part of the EuroWheat activity, seven trials were carried out in different countries following the same protocol. The focus of the trials was to investigate the efficacy of SDHIs in areas with different climates and levels of resistance. One trial was placed at Flakkebjerg in the cultivar Hereford and treated at GS 37-39 (26 May). The trial developed a severe attack of *Septoria*. With the exception of Luna (fluopyram) the other SDHIs performed well. The two azoles Proline EC 250 and Revysol were both included and provided low and high levels of control respectively (Table 1; Figure 1). The analysis of the resistant mutations in the trials have indicated occurrence of only few SDHI resistant mutations in the Danish trial.

Similar trials were conducted in other countries; these trials showed distinct differences in levels of control depending on the locality. The average results from seven European trials (France, Poland, Germany and Denmark) carried out during 2 seasons are shown in Figure 2. The results in Figure 2 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). Revysol performed better than SDHIs in those countries.

Table 1. Effect of applications for control of *Septoria* in wheat using SDHIs and azoles. Treatments were applied at GS 37-39. One trial (20334). EuroWheat.

Treatments		% *Septoria*				% GLA	Yield & yield increase
GS 37-39	Dose l/ha	GS 73 L1	GS 73 L2	GS 75 L1	GS 75 L2	GS 80 L1	Dt/ha
1.Untreated		6.3	26.3	61.3	85.0	5.8	99.9
2. Imtrex (fluxapyroxad)	1.0	0.4	3.5	3.5	23.8	72.5	12.5
3. Imtrex (fluxapyroxad)	2.0	0.4	4.0	2.5	20.0	70.0	12.1
4. Luna (fluopyram)	0.2	2.3	12.3	17.3	66.3	17.5	5.3
5. Thore (bixafen)	1.0	0.5	4.0	4.5	19.8	63.8	10.1
6. Silvron Xpro (bixafen + fluopyram)	0.75	0.3	2.5	2.8	13.5	70.0	11.5
7. Silvron Xpro (bixafen + fluopyram)	1.0	0.1	1.3	1.0	7.8	70.0	12.8
8. Elatus Plus (solatanol)	0.75	1.0	8.8	5.0	26.8	73.8	11.7
9. Proline EC 250	0.8	3.0	14.3	25.5	70.0	17.5	3.0
10. Revysol	1.0	0.7	3.8	5.0	17.3	52.5	10.6
11. Revysol	1.5	0.4	2.8	2.0	9.8	67.5	12.6
LSD_{95}		1.1	2.5	6.3	6.8	10.1	3.4

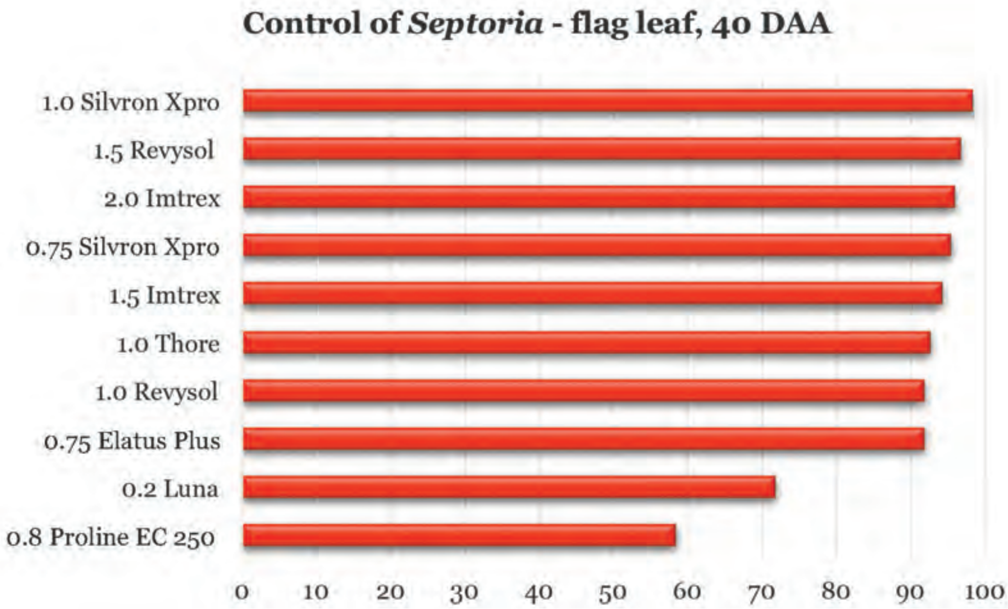


Figure 1. Control of *Septoria* in wheat using different SDHIs and azoles. Treatments were applied at GS 37-39. Data represent assessments on the flag leaf - 40 DAA. Data from one trial (20334).

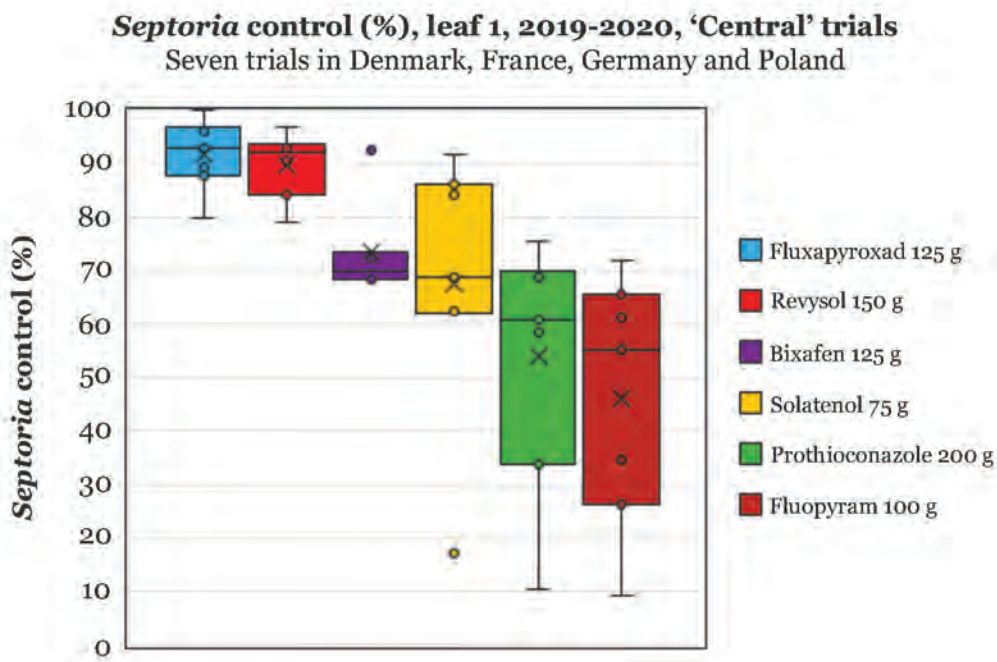


Figure 2. Control of *Septoria* using SDHIs. Data from seven trials carried out in 2019-2020 as part of EuroWheat. Trials were carried out in France, Germany, Poland and Denmark.

Comparing effects of new actives in Euro-Res

As part of the Euro-Res activity, trials were carried out following the same protocol. The trials were located in Belgium, Sweden, Ireland and Denmark. The focus of the trials was to investigate the efficacy of new actives and the level of resistance (Table 2; Figure 3). One trial was placed at Flakkebjerg in the cultivar Hereford and treated at three different timings. The trial developed a moderate attack of *Septoria*. The efficacy was better from two treatments with new chemistry compared with one treatment. Among the single treatments, Ascra Xpro, Balaya, Imtrex and Univoq performed similarly well, providing control above 90% control. Proline EC 250 gave approximately 50% control, while sulphur gave 40% control. With the exception of sulphur, all treatments gave statistically significant yield increases at moderate levels. Double treatments (trt. 8 + 9) with new chemistry provided control superior to double treatments with old chemistry.

Table 2. Per cent attack of *Septoria* and yield responses following treatments in wheat with different fungicides (20308).

Treatments, l/ha				% *Septoria*	% *Septoria*	% *Septoria*	% *Septoria*	Yield & yield increase	Net yield	TGW (g)
	GS 32-33	GS 39	GS 55	GS 73 L 2	GS 73 L 3	GS 79 L 1	GS 77 L 2	Dt/ha	Dt/ha	
1.	Untreated			11.3	40.0	33.8	58.8	109.7	-	44.4
2.		Proline EC 250 0.8		3.5	20.0	16.3	35.0	6.0	2.3	45.7
3.		Balaya 1.5		0.1	3.3	1.1	2.0	8.2	1.4	47.6
4.		Ascra Xpro 1.5		0.0	2.8	2.0	1.8	7.8	1.6	46.2
5.		Imtrex 2.0		0.0	2.5	1.3	4.0	8.6	-	46.9
6.		Univoq 1.5		0.3	7.5	3.0	11.3	6.9	1.3	46.1
7.		Thiopron 5.0		4.5	22.5	20.0	40.0	2.7	-	44.7
8.	Ascra Xpro 0.75		Balaya 0.75	0.0	1.8	0.9	1.8	12.2	5.1	45.3
9.	Ascra Xpro 0.75		Univoq 0.75	0.0	2.0	1.0	1.8	8.4	1.9	49.2
10.	Propulse SE 250 0.5		Proline EC 250 0.8	1.5	16.3	11.3	22.5	5.6	-1.8	45.1
LSD_{95}				1.3	7.0	4.1	8.1	4.1	-	2.6

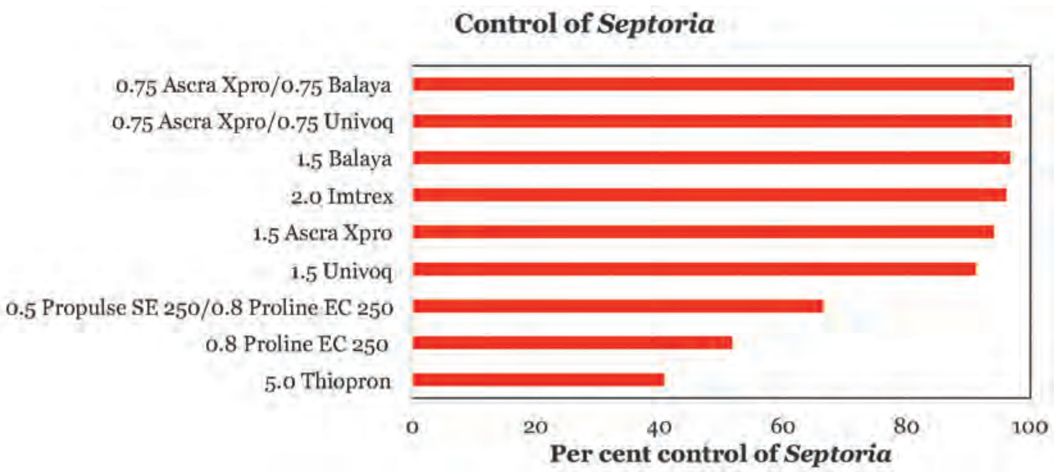


Figure 3. Control of *Septoria* on flag leaf following either one (GS 39) or two treatments (GS 37 & 61) (20308). Attack on untreated, flag leaf = 33.8% at GS 79.

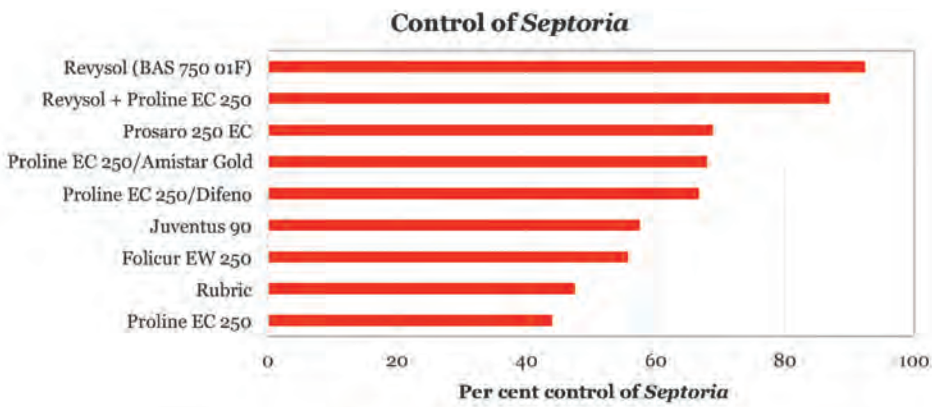
Comparison of azoles (20329)

In two trials, different azoles were tested in the cultivars KWS Cleveland at AU Flakkebjerg and Hereford at Velas near Horsens. The trials included two treatments using two times half the recommended rate applied at GS 33 and 45-51. Both trials developed significant attacks of *Septoria* and were suitable for the ranking of the efficacy of the products. The ranking in efficacy is shown in Figure 4 and Table 3. The new azole product, Revysol, has been included in the testing since 2017. In all years, 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, both epoxiconazole and prothioconazole are known to be significantly influenced by the changes in the *CYP51* mutation profile.

Looking at the performance of azoles over time, the drop in performance began in 2014, was less pronounced in 2015 but continued in 2016 (Figure 5). Some 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 many 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 efficacy of tebuconazole has been known since about 2000. However, the drop in performance from tebuconazole used alone has changed since 2017, when this azole regained some efficacy. Similarly, difenoconazole gained slightly better efficacy. For both tebuconazole and difenoconazole this is linked to higher proportions of D134G and V136A in the *Septoria* population. The mixture prothioconazole + tebuconazole has also performed better as the two actives are seen to support each other when it comes to controlling the different strains with different mutations. However, trials from both 2020 and 2019 showed very similar control from tebuconazole alone as well as in mixture with prothioconazole.

Table 3. Average *Septoria* severity and yield responses from treatments in winter wheat. Two trials in 2020 (20329).

Treatments, l/ha		% *Septoria*				Yield & yield increase	Net yield
GS 31-32	GS 51-55	GS 71-75 L3	GS 71-75 L2	GS 71-75 L1	GLA L1	Dt/ha	Dt/ha
1. Rubric 0.5	Rubric 0.5	46.9	6.9	0.7	23.8	6.7	2.5
2. Proline EC 250 0.4	Proline EC 250 0.4	42.5	8.3	1.1	24.4	6.3	2.0
3. Juventus 90 0.5	Juventus 90 0.5	30.0	4.4	0.2	20.6	4.7	1.6
4. Folicur EW 250 0.5	Folicur EW 250 0.5	33.8	6.6	0.6	27.5	6.5	3.3
5. Proline EC 250 0.4	MCW 406-s 0.25	29.4	8.1	0.5	22.5	5.8	-
6. Prosaro EC 250 0.5	Prosaro EC 250 0.5	30.0	3.4	0.1	33.8	7.2	3.3
7. Proline EC 250 0.4	Amistar Gold 0.5	23.1	3.6	0.2	35.6	6.8	-1.2
8. Revysol 0.75	Revysol 0.75	9.8	1.0	0.0	55.6	12.5	-
9. Revysol 0.375 + Proline EC 250 0.2	Revysol 0.375 + Proline EC 250 0.2	11.3	1.5	0.0	56.9	12.6	-
10. Untreated		53.8	16.0	2.1	9.4	85.0	-
No. of trials		2	2	2	2	2	2
LSD_{95}		5.8	2.5	0.5	11.0	4.2	-



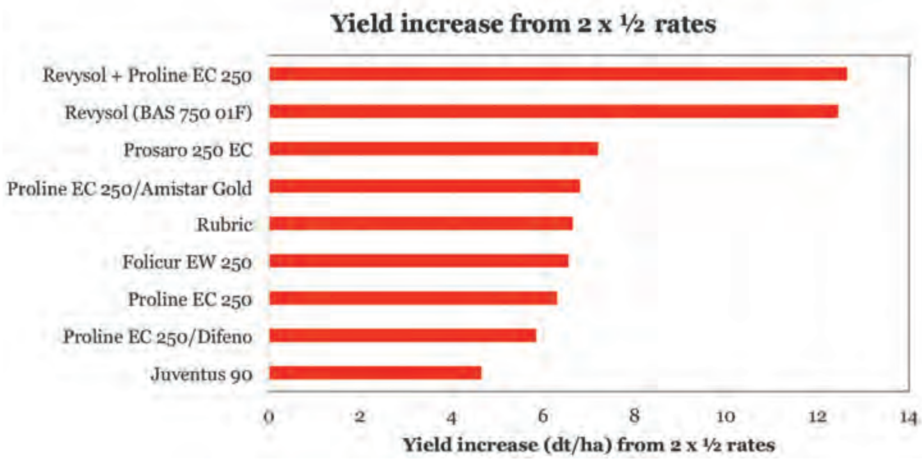


Figure 4. Per cent control of *Septoria* using two half rates of different azoles (top). Average of two applications at GS 33-37 and 51-55. Yield increases in wheat (bottom). Two trials in 2020 (20329).

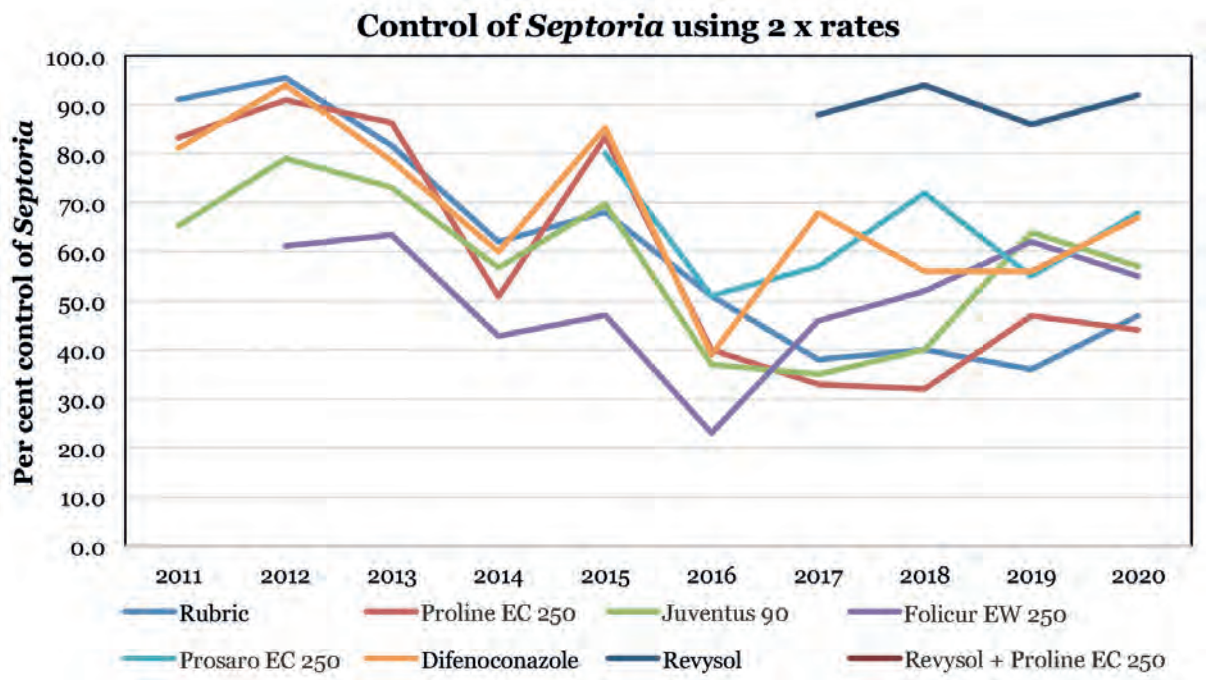


Figure 5. Per cent control of *Septoria* using two half rates of different azoles. Average of two applications at GS 33-37 and 51-55. Development of efficacy across years (2011-2020).

Amistar Gold

Amistar Gold (125 g difenoconazole + 125 g azoxystrobin) is expected to be put on the market for the 2021 season. Amistar Gold has been included in the trial plans with azoles during 3 seasons. Difenoconazole (DIF) is recognised as performing similarly to tebuconazole (TEB) and the two azoles have shown a clear pattern of cross-resistance (Figure 6). Regarding cross-resistance to prothioconazole (PTZ-des) and epoxiconazole (EPX) the pattern is different. Due to strobilurin resistance, the content of azoxystrobin in the co-formulation is expected to add little with respect to control of *Septoria*. Adding azoxystrobin can, however, improve the efficacy on rust diseases. Due to the potential phytotoxicity from difenoconazole, Amistar Gold has only been included at the last of the two treatments. Table 4 summarises the effect from the three seasons.

Table 4. Average *Septoria* severity and yield responses from treatments in winter wheat. Five trials in 2018-20.

Treatments, l/ha		% *Septoria*		GLA L1	Yield & yield increase	TGW (g)
GS 32-33	GS 45-53	GS 71-75 L2	GS 71-75 L1	GS 77-79	Dt/ha	
1. Untreated		26.4	14.0	6.3	82.2	36.3
2. Proline EC 250 0.4	Proline EC 250 0.4	17.9	6.4	23.3	4.3	38.6
3. Folicur EW 250 0.5	Folicur EW 250 0.5	13.2	4.3	22.9	7.6	38.9
4. Prosaro EC 250 0.5	Prosaro EC 250 0.5	13.1	3.6	26.7	7.0	38.1
5. Proline EC 250 0.4	Amistar Gold 0.5	15.4	4.9	31.7	6.8	38.2
6. Juventus 90 0.5	Juventus 90 0.5	13.4	4.1	21.3	5.6	37.9
7. Revysol 0.75	Revysol 0.75	4.5	1.8	67.9	15.1	39.8
Number of trials		4	5	3	5	5
LSD_{95}		4.1	12	7.9	2.5	1.1

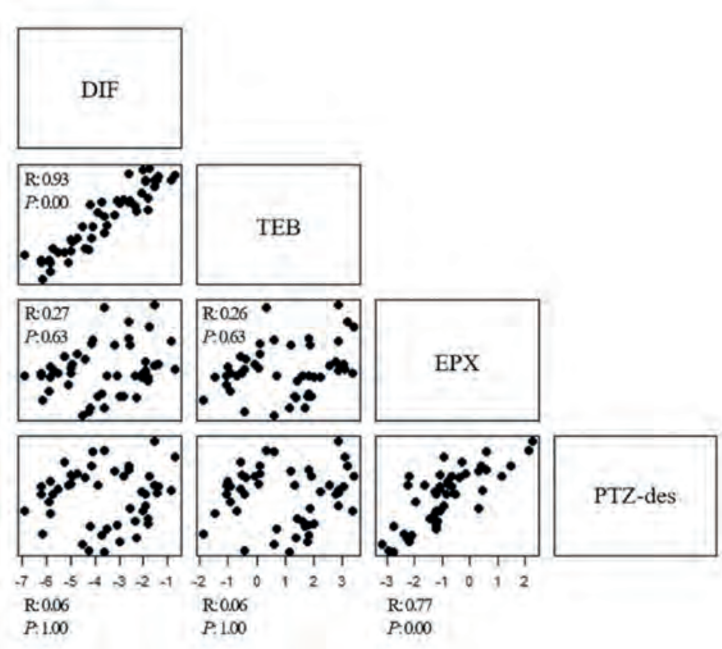


Figure 6. Scatter plot matrix of sensitivity log (EC50 ppm) of *Z. tritici* isolates to four different azoles in 2019. DIF = difenoconazole, TEB = tebuconazole, EPX = epoxiconazole and PTZ = prothioconazole (Heick et al., 2020).

Comparison of available solutions for ear treatments (20325)

In line with trials from previous years, treatments with different fungicides were tested when applied during heading (GS 45-55 on 27 May) (Table 5). Three trials were carried out; two were placed at Flakkebjerg in Hereford and Cleveland and one in Hereford near Horsens. A cover spray was applied at GS 32 using Prosaro EC 250 (0.35 l/ha). In two treatments at T1 (GS 32), Prosaro EC 250 was mixed with Comet Pro.

Septoria developed a significant attack on both 2nd leaf and flag leaf. The control of *Septoria* on the flag leaf varied between 80% and nearly 100% control (Figure 7). New actives with Balaya and Univoq provided the best control, while the older chemistry with Propulse SE 250 provided slightly inferior control. Propulse SE 250 clearly benefited from mixing with Folicur Xpert.

Yields increased significantly, but only moderately from treatments. The better treatments, which all included new chemistry increased yields more than the older chemistry. The early season treatment (GS 32) increased yields by 3.4 dt/ha. Net yields were positive from all treatments (Figure 8). Adding Comet Pro to Prosaro EC 250 at T1 did not improve yields significantly, but a tendency to better control and yields was seen comparing treatment 1 with treatment 12.

Table 5. Effect of ear applications for control of *Septoria* and yield responses in wheat when applying treatments at GS 45-51. Three trials (20325).

Treatments, l/ha		% *Septoria*				% GLA	Yield & yield increase	Net yield	TGW (g)
GS 31-32	GS 51-55	GS 69 L3	GS 71-73 L2	GS 77-83 L2	GS 77-83 L1	GS 69 L3	Dt/ha	Dt/ha	
1. Prosaro EC 250 0.35	Propulse SE 250 1.0	21.2	1.6	18.6	14.0	43.8	6.5	1.3	44.4
2. Prosaro EC 250 0.35	Propulse SE 250 + Folicur Xpert 1.0 + 0.25	19.2	1.3	11.2	11.0	52.1	6.5	0.7	44.7
3. Prosaro EC 250 0.35	Propulse SE250 + Folicur Xpert 0.75 + 0.25	17.2	1.2	14.6	12.1	50.0	6.6	1.6	45.7
4. Prosaro EC 250 0.35	Univoq 0.75	15.1	1.4	12.3	9.8	57.5	8.2	3.6	44.9
5. Prosaro EC 250 0.35	Univoq 1.0	15.6	1.4	10.5	4.6	67.9	7.4	3.0	45.4
6. Prosaro EC 250 0.35	Univoq 1.25	14.9	0.6	9.5	4.6	68.6	8.6	2.3	44.8
7. Prosaro EC 250 0.35	Balaya 1.125	13.7	0.5	2.4	2.5	69.6	9.0	2.2	45.3
8. Prosaro EC 250 0.35	Balaya 0.75	16.0	0.4	6.9	8.0	65.0	8.8	3.5	44.8
9. Prosaro EC 250 0.35	Balaya + Entargo 0.75 + 0.375	16.3	0.4	3.1	3.4	71.3	8.2	1.1	46.3
10. Prosaro EC 250 0.35 + Comet Pro 0.35	Balaya 0.75	13.2	0.7	8.2	7.9	62.9	8.2	1.5	45.2
11. Prosaro EC 250 0.35	Balaya + Propulse SE 250 0.75 + 0.35	14.4	0.5	3.7	7.2	67.5	8.5	2.2	46.5
12. Prosaro EC 250 0.35 + Comet Pro 0.5	Propulse SE 250 1.0	16.5	1.2	10.6	12.1	52.7	8.3	1.7	44.0
13. Prosaro EC 250 0.35	Untreated	23.1	11.4	43.2	33.4	15.5	3.4	1.9	42.8
14. Untreated	Untreated	24.9	11.4	50.0	33.3	13.8	94.9	-	43.8
No. of trials		3	3	3	3	3	3	3	3
LSD_{95}		3.3	0.9	3.3	3.2	7.7	2.2	-	1.3

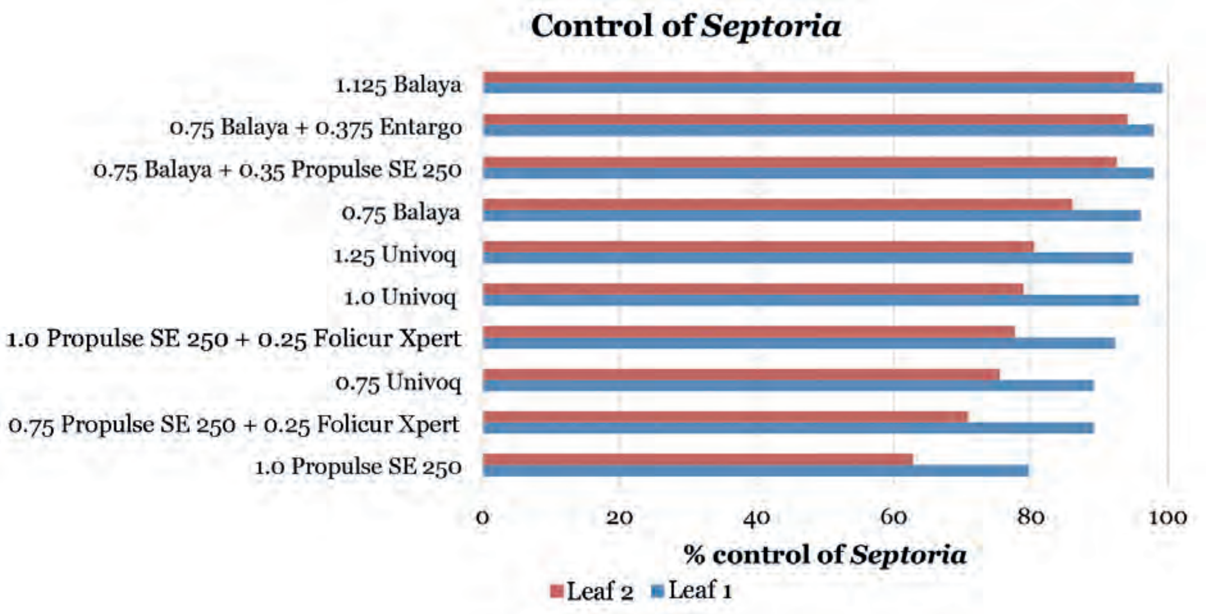


Figure 7. Per cent control of *Septoria* at GS 75-77 when treated at GS 45-51. Assessed on both 1st and 2nd leaf. Average of three trials from series 20325.

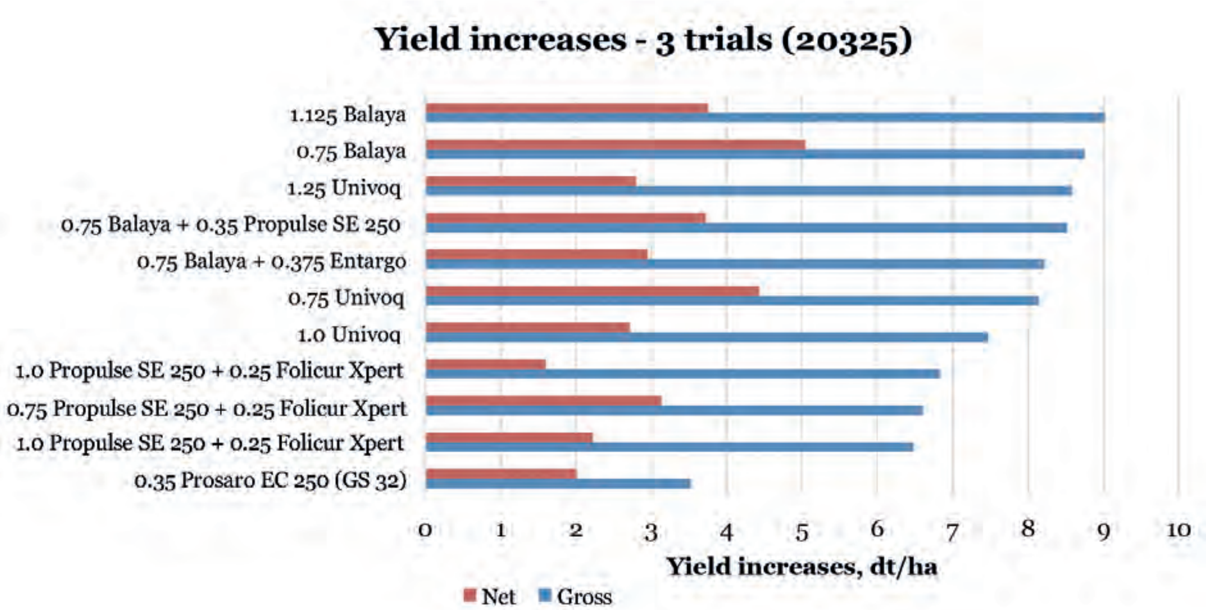


Figure 8. Yield increases (dt/ha) in winter wheat from control of *Septoria* with treatments applied at GS 45-51. Average of three trials (20325). All treatments were also treated at T1 with Prosaro EC 250, 0.35 l/ha.

Control strategies using one or two treatments in winter wheat (20326 and 20328)

Two trials were initiated following the trial plan 20326. The trials were carried out in Cleveland (Flakkebjerg) and Torp (Horsens). The trial compared different treatments using a split ear application applied at GS 37-39 (20 May) and GS 51-55 (9 June) or a single flag leaf treatment at GS 45 (3 June). All treatments including untreated had a cover spray applied at GS 32. Treatments included a mix of new and old chemistry.

The trials developed a moderate attack and only minor differences were seen between the tested solutions (Figure 9). When only a single ear treatment was used, the new actives generally provided better control compared with old chemistry, as seen in Table 6 and Figure 10. When using a split ear treatment Balaya followed by Univoq or Univoq followed by Balaya gave very similar control of *Septoria*. Also Propulse SE 250 + Folicur Xpert performed well, particularly when used as part of a split treatment (Figure 9).

Yield responses were moderate but significant in the range of 7-11 dt/ha, reflecting the levels of control obtained from the different solutions. The single ear applications generally gave lower responses (approx. 7 dt/ha) compared with the split treatments (10-11 dt/ha). The split ear treatment also gave the highest grain weight increases (Table 6).

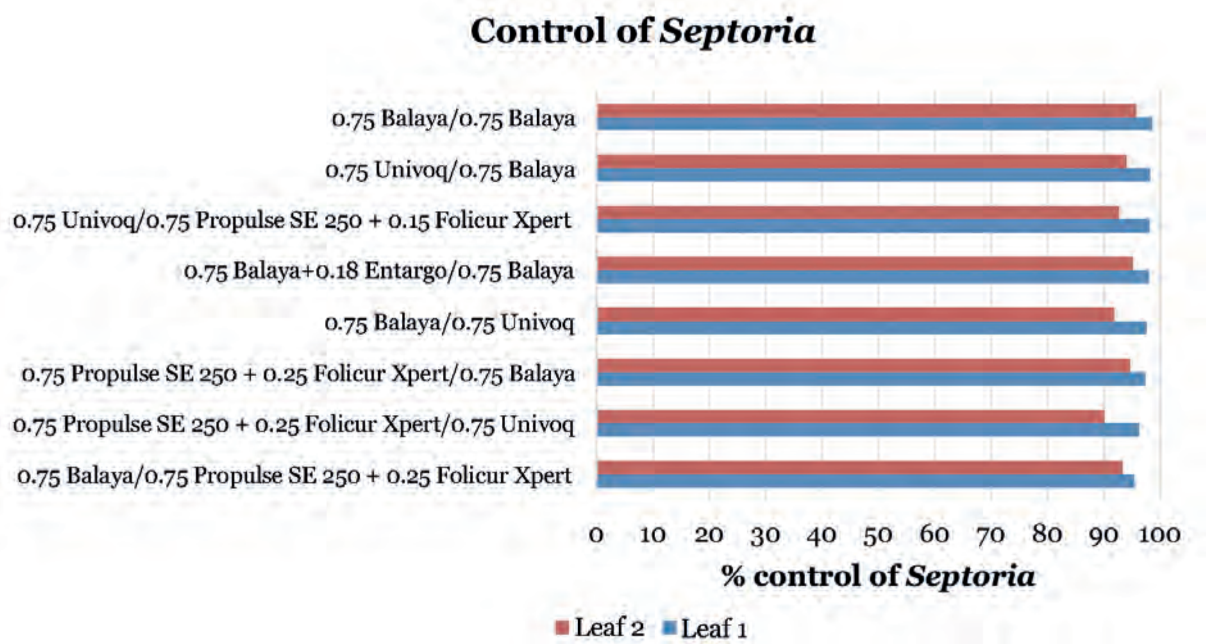
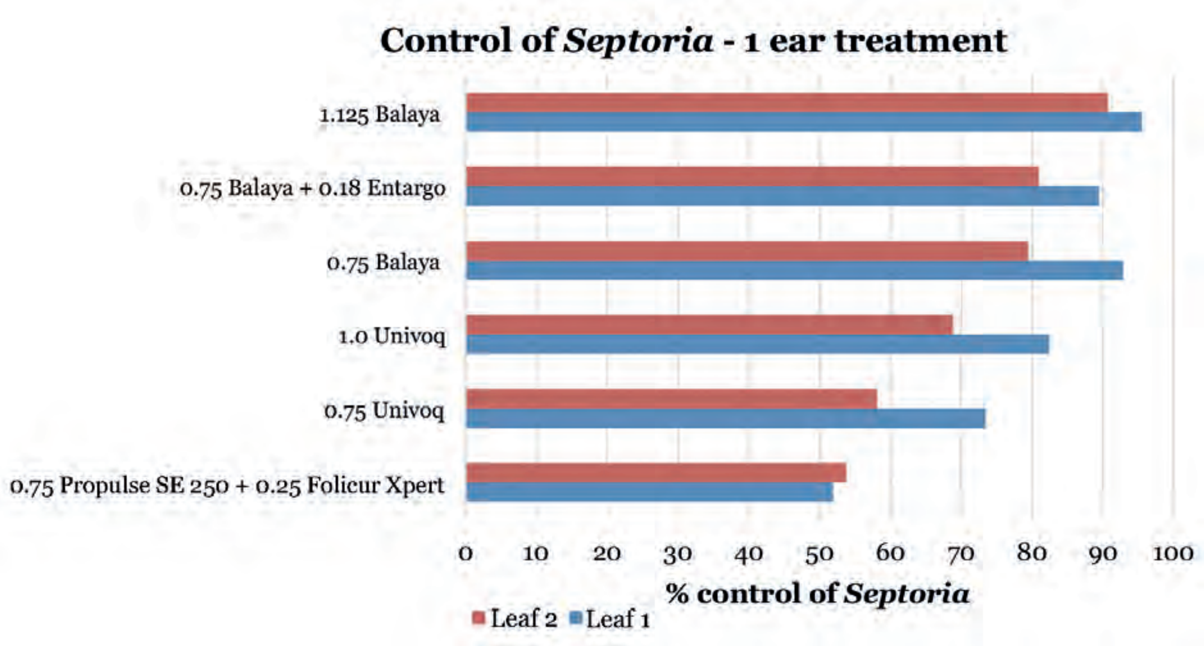


Figure 9. Per cent control of *Septoria* when treated as a split ear application applied at GS 37-39 and GS 51-55. Average of two trials (20326).



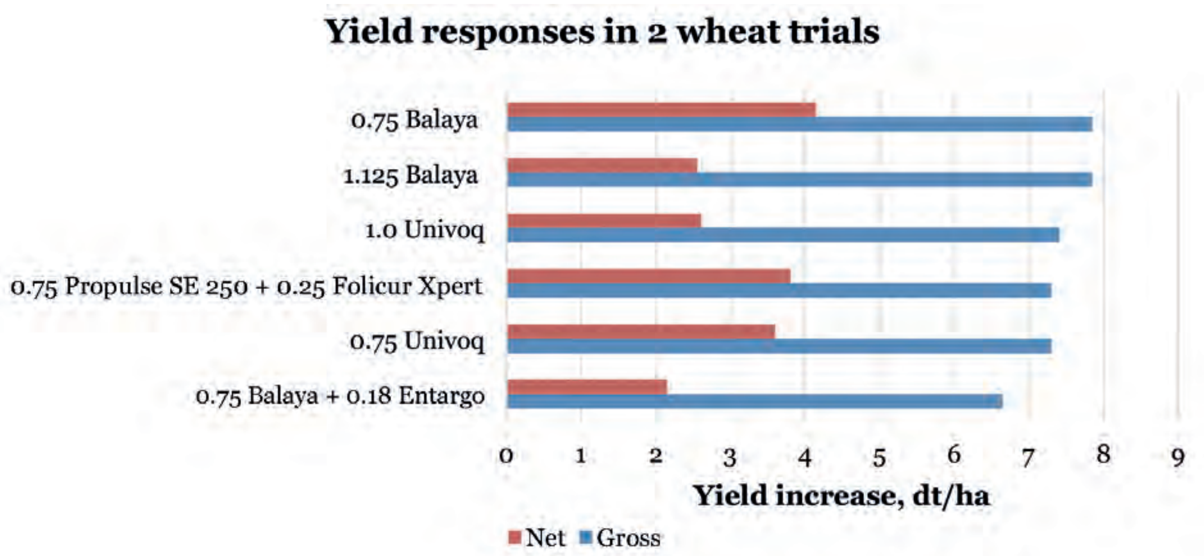


Figure 10. Per cent control of *Septoria* and yield responses when treated as a solo ear treatment applied at GS 45. Average of two trials (20326).

Table 6. Effects on *Septoria* and yield responses following a split ear treatment or a single ear treatment in wheat. Two trials (20326). The whole trial was cover sprayed with 0.35 l/ha Prosaro EC 250 at GS 31-32.

Treatments, l/ha				% *Septoria*			Yield & yield increase	Net yield	TGW (g)
	GS 37-39	GS 45-51	GS 61-65	GS 71-72 L3	GS 75-83 L2	GS 79-83 L1	Dt/ha	Dt/ha	
1.	Untreated			38.1	41.9	36.8	102.1	-	44.1
2.		Propulse SE 250 + Folicur Xpert 0.75 + 0.25		23.6	19.5	17.7	7.3	2.3	45.8
3.		Univoq 1.0		21.3	13.1	6.4	7.4	2.0	46.1
4.		Univoq 0.7		20.0	17.6	9.8	7.3	2.9	46.6
5.		Balaya + Entargo 0.75 + 0.18		18.0	8.0	3.9	6.6	0.5	46.4
6.		Balaya 1.125		17.4	3.9	1.7	7.9	1.1	46.9
7.		Balaya 0.75		21.1	8.7	2.7	7.8	2.6	46.9
8.	Propulse SE 250 + Folicur Xpert 0.75 + 0.25		Univoq 0.75	10.1	3.6	1.2	9.6	1.5	47.5
9.	Propulse SE 250 + Folicur Xpert 0.75 + 0.25		Balaya 0.75	11.5	2.5	1.7	9.8	1.0	47.5
10.	Univoq 0.75		Propulse SE 250 + Folicur Xpert 0.75 + 0.25	10.4	3.1	0.9	10.7	2.6	47.7
11.	Balaya 0.75		Propulse SE 250 + Folicur Xpert 0.75 + 0.25	11.4	2.8	2.3	10.4	1.7	47.4
12.	Balaya + Entargo 0.5 + 0.18		Balaya 0.75	10.0	2.0	1.0	10.5	0.7	47.4
13.	Balaya 0.75		Balaya 0.75	14.3	1.8	0.7	10.3	1.4	48.3
14.	Balaya 0.75		Univoq 0.75	12.3	3.0	1.0	10.4	2.1	47.0
15.	Univoq 0.75		Balaya 0.75	14.3	2.5	0.8	11.4	3.1	47.0
LSD_{95}				4.0	3.2	2.3	2.7	-	0.8

Two additional trials were carried out in Hereford and Torp (20328). Split ear treatments were applied in all treatments using a 50-75% recommended rate at the first application and a 50% rate at the second timing (Table 7). All tested solutions gave very high and similar levels of control (>90%). Only solutions using Prosaro EC 250 and Propulse SE 250 at both timings provided inferior control (Figure 11). The yield responses also reflected the reduced control from these treatments. Only minor insignificant differences were seen between all other treatments. In addition, no clear differences were seen between the net yields (Figure 12).

Table 7. Effect of a split ear application for control of *Septoria* and yield response in wheat. Two trials (20328).

Treatments, l/ha		% *Septoria*			% GLA	Yield & yield increase	Net yield
GS 37	GS 51-55	GS 75-80 L3	GS 75-80 L2	GS 75-80 L1	GS 84 L1	Dt/ha	Dt/ha
1. Untreated	-	93.8	38.1	5.1	8.5	97.9	-
2. Prosaro EC 250 0.75	Prosaro EC 250 0.5	30.0	6.4	1.1	46.3	8.1	3.6
3. Propulse SE 250 0.75	Prosaro EC 250 0.5	40.0	6.8	1.2	49.4	9.0	4.1
4. Balaya 0.75	Amistar Gold 0.5	15.0	3.0	1.3	55.0	10.7	5.2
5. Balaya 0.75	Balaya 0.75	13.8	2.0	0.5	67.5	12.0	5.6
6. Balaya 0.75	Propulse SE 250 0.35 + Folicur Xpert 0.15	19.4	3.0	0.5	64.4	11.8	6.1
7. Balaya + Entargo 0.5 + 0.18	Propulse SE 250 0.35 + Folicur Xpert 0.15	13.8	2.3	0.5	63.8	12.2	6.6
8. Balaya 0.75	Univoq 0.75	9.1	1.5	0.4	70.3	12.1	5.3
9. Propulse SE 250 + Folicur Xpert 0.75 + 0.25	Univoq 0.75	11.9	2.4	0.5	68.1	12.8	6.2
10. Propulse SE 250 + Folicur Xpert 0.75 + 0.25	Balaya 0.75	12.5	2.1	0.5	74.4	13.1	5.9
11. Univoq 0.75	Balaya 0.75	6.3	1.2	0.4	73.8	12.3	5.5
12. Univoq 0.75	Propulse SE 250 0.35 + Folicur Xpert 0.15	10.0	2.1	0.3	68.1	11.5	6.4
13. Imtrex 1.0	Imtrex 1.0	11.3	2.0	0.3	69.4	13.0	-
14. Univoq 0.75	Amistar Gold 0.5	16.9	3.5	0.5	66.9	10.7	5.8
LSD_{95}		2.6	6.6	0.5	8.8	2.8	-

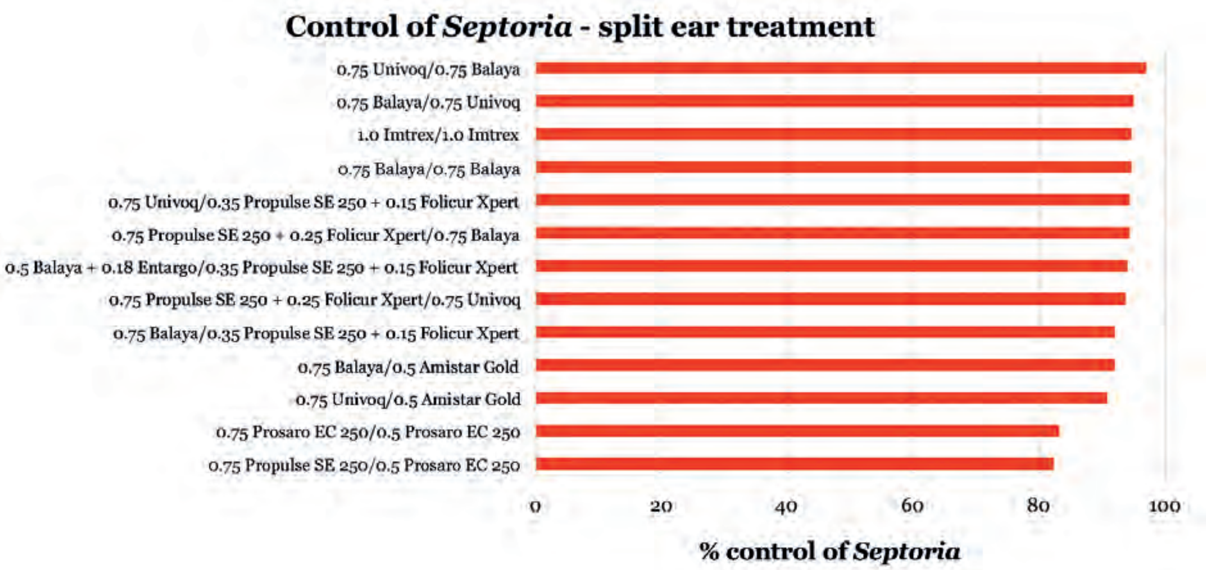


Figure 11. Per cent control of *Septoria* when treated at GS 37-39 and 51-55. Data are based on attack on 2nd leaf at GS 75 (38% in untreated) (20328).

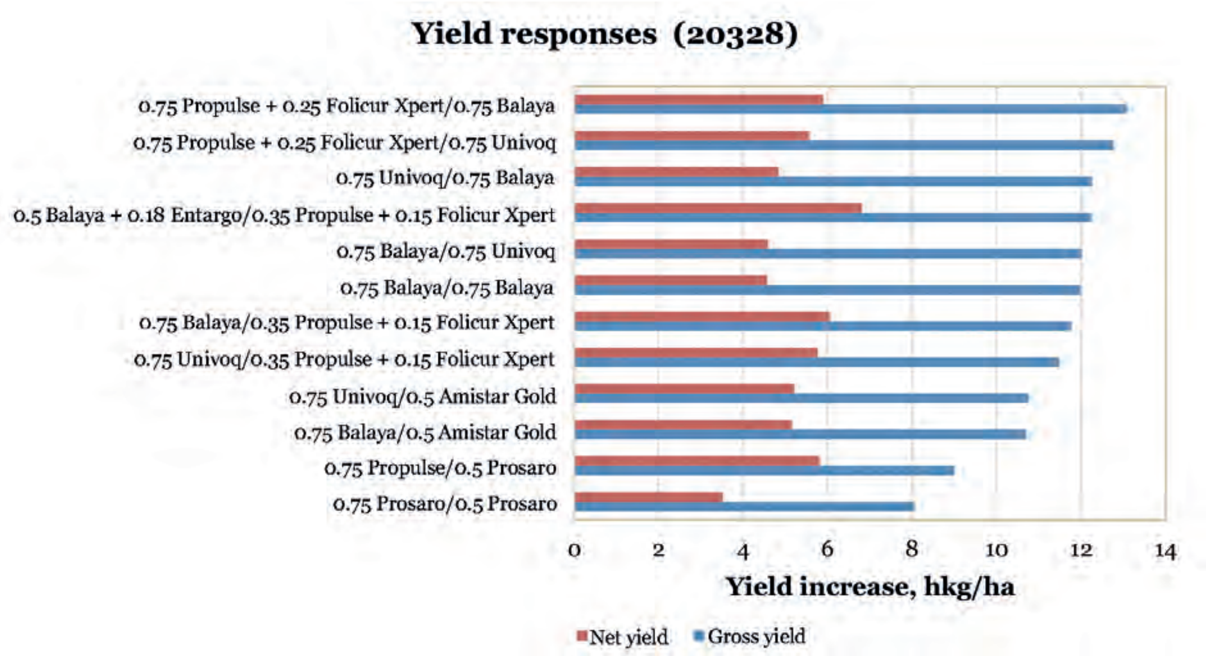


Figure 12. Yield increases in winter wheat from control of *Septoria* using split ear treatments applied at GS 37-39 and GS 55-61. Average of two trials (20328).

Control of *Septoria* with Univoq and Balaya

One trial (20307) was placed in the cultivar Hereford at Flakkebjerg. Univoq and Balaya were tested using two rates and timings (GS 37 (20 May) and 39-45 (26 May). The early timing gave best control on the lower leaves and the later timing on the upper leaves (Figure 13). At the early timing, Univoq and Balaya performed very similarly, but at the later timing Balaya performed slightly better than Univoq. The yield responses in the trial were significant compared with untreated, but did not vary significantly between the different treatments (Table 8).

Attack of *Septoria* in winter wheat.

Table 8. Application timings. Effects on *Septoria* and yield responses following two timings and two rates of Univoq and Balaya in wheat. One trial in 2020 (20307).

Treatments, l/ha			% *Septoria*				Yield & yield increase Dt/ha	Net yield Dt/ha
GS 31-32	GS 37	GS 37 + 1 week	GS 73 L2	GS 77 L1	GS 77 L2	GLA L1		
1. Orius Max 0.2	Untreated		47.5	71.3	100.0	1.3	99.0	-
2. Orius Max 0.2	Univoq 0.75		4.3	11.3	28.8	62.5	4.0	0.0
3. Orius Max 0.2	Univoq 1.25		3.0	9.5	23.8	70.0	10.0	4.4
4. Orius Max 0.2	Balaya 0.75		5.3	12.5	35.0	47.5	5.0	0.4
5. Orius Max 0.2	Balaya 1.25		2.0	10.0	27.5	47.5	7.0	0.3
6. Orius Max 0.2		Univoq 0.75	5.0	8.3	30.0	61.3	7.0	3.0
7. Orius Max 0.2		Univoq 1.25	3.8	3.8	20.0	77.5	7.0	1.4
8. Orius Max 0.2		Balaya 0.75	3.3	4.8	21.3	60.0	7.0	2.4
9. Orius Max 0.2		Balaya 1.25	1.5	2.5	12.5	72.5	8.0	1.3
No. of trials		1	1	1	1	1	1	1
LSD_{95}			3.5	5.9	7.5	12.2	4.0	-

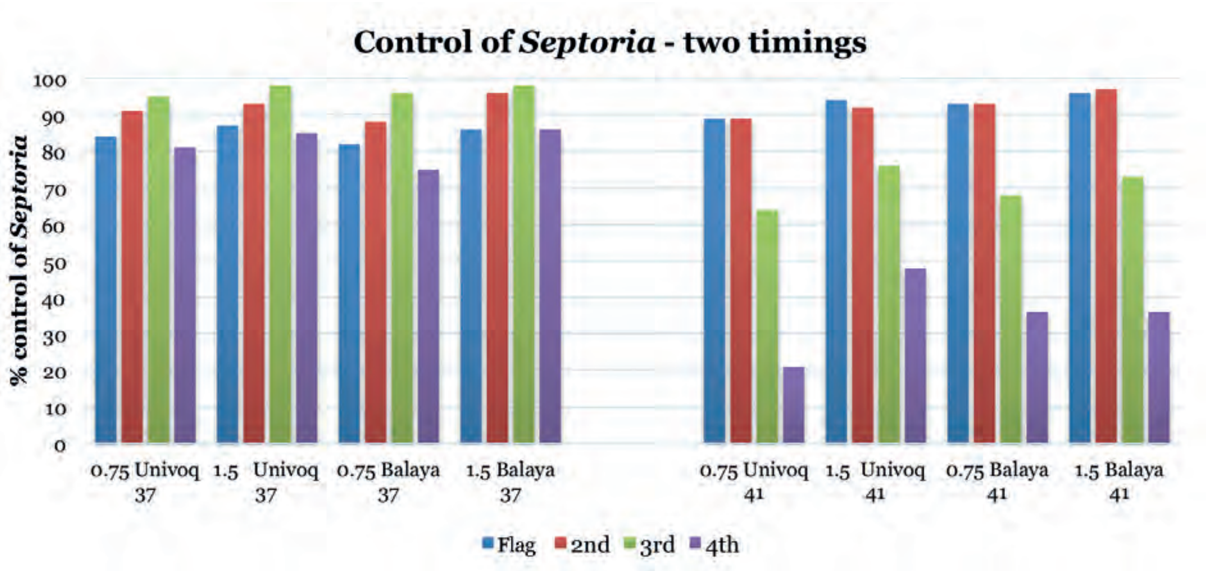


Figure 13. Per cent control of *Septoria* at two timings comparing Univoq and Balaya applied at two dose rates (20307).

Control of *Septoria* using Miravis Pro (20321)

Miravis Pro is a new test product, which includes the SDHI active adepidin (= pydiflumetofen) mixed with prothioconazole. The trial was carried out in the cultivar Hereford at Flakkebjerg. The product has been very effective for control of *Septoria* as well as Fusarium head blight in in previous testings. In the trial in 2020, two different timings were compared using 4 different dose rates of Miravis Pro in comparison with Revytrex XL (fluxapyroxad + mefentrifluconazole) (Table 9). In case of the later timing an earlier treatment with Prosaro EC 250 had been applied at GS 31-32. The trial has shown high disease control from all treatments. The lowest tested rate of Miravis Pro (0.5 l/ha) provided control in line with 1 litre Revytrex XL. The early timing provided better control than the slightly later timing, reflecting an overall better preventive control profile. The higher rates of Miravis Pro increased yields slightly more than the lowest rate, although differences were not significant. The early timing also increased the TGWs more than the later timing.

Table 9. Effect of an ear application of using Miravis Pro for control of *Septoria* and yield response in wheat. One trial (20321).

Treatments, l/ha			% *Septoria*				Yield & yield increase	TGW (g)
GS 31-32	GS 39	GS 45-51	GS 65 L3	GS 73 L2	GS 73 L3	GS 77 L2	Dt/ha	
1. Untreated			12.5	35.0	57.5	90.0	106.7	45.4
2. Prosaro EC 250 0.35			4.3	35.0	55.0	85.0	1.0	46.0
3. Prosaro EC 250 0.35		Miravis Pro 0.5	2.0	2.3	6.3	20.0	8.7	48.7
4. Prosaro EC 250 0.35		Miravis Pro 1.0	3.0	0.3	4.0	10.5	8.7	50.5
5. Prosaro EC 250 0.35		Miravis Pro 1.5	2.3	0.1	3.3	7.8	12.3	49.9
6. Prosaro EC 250 0.35		Miravis Pro 2.0	1.5	0.0	3.0	3.5	15.8	48.7
7. Prosaro EC 250 0.35		Revytrex XL 1.0	0.3	1.1	7.5	17.5	9.9	49.8
8.	Miravis Pro 0.5		0.8	0.3	4.0	5.5	7.7	50.1
9.	Miravis Pro 1.0		0.6	0.8	1.8	3.4	13.1	49.5
10.	Miravis Pro 1.5		0.4	0.0	1.3	0.6	12.2	50.1
11.	Miravis Pro 2.0		0.1	0.0	1.3	0.5	11.8	50.5
12.	Revytrex XL 1.0		0.1	0.3	4.3	15.0	8.2	48.7
LSD_{95}			1.5	5.5	4.0	7.2	6.2	2.4

Control of *Septoria* using Entargo

Entargo is a new liquid formulation of boscalid, which was authorised in 2021. The product includes 500 g boscalid/litre. The max dose is 0.7 l/ha equivalent to 350 g boscalid, known as the full rate in Bell. The product was tested as a solo product in 2017, 2018 and 2019. Results are summarised in Table 10. The data indicate that Entargo (tested under the name Cumora) provides control in line with or slightly inferior to Proline EC 250 (identical to Curbatur used in the trial) when tested at full rate. As a solo product, Entargo will provide insufficient control of *Septoria* measured in comparison with normal standards. Entargo should be seen as a mixing partner for other solutions as shown in Table 11**.** In a trial from 2019, Entargo was mixed with Balaya. Replacing part of Balaya with Entargo or Proline EC 250 (Curbatur) gave similar control. However, if lowering the dose of Balaya too much (0.5 l/ha), the addition of Entargo/Curbatur will not be able to substitute the effect compared with increasing the dose of Balaya. Data in Tables 5 and 6 in this chapter similarly show that adding Entargo to Balaya only provides limited or no clear improvement in control and yields. This was also seen in trials from 2019 (Tables 8 & 9, Applied Crop Protection 2019, pp. 30 and 32). Using Entargo can be seen as a resistance strategy in line with using fluopyram in Propulse SE 250. Unfortunately, the efficacy and yield improvements from adding Entargo are very limited, which calls for a low pricing if seen to be used in practice.

Table 10. Effect of flag leaf applications using Entargo and reference products for control of *Septoria* and yield response in wheat. Summary of data from 2017-2019.

Treatments, l/ha	% *Septoria*, GS 75-77 (L1+L2)				Yield & yield increase, dt/ha			
GS 37-39	2017	2018	2019	Avg.	2017	2018	2019	Avg.
Untreated (% attack)	(51)	(17.4)	(72)	42	80.8	83.7	81.1	81.9
Entargo 0.2	37	39			7.0	1.5		
Entargo 0.4	50	54			7.5	-0.8		
Entargo 0.7	59	57	28	48.1	9.1	0.9	2.7	4.2
Proline 0.8	66	51	40	52.3	10.5	3.9	3.0	5.8
Folpan 1.8	47				4.1	-		
No. of trials	2	2	1	5	2	2	1	5

Table 11. Effect of applications for control of *Septoria* in wheat. Elements from one trial (19330). All treatments were given a cover spray using 0.5 l/ha Ceando at GS 33-37.

Treatments, l/ha	% *Septoria*			% GLA	Yield & yield increase
GS 55	GS 69 L1	GS 69 L2	GS 75 L1	GS 77 L1	Dt/ha
1. Untreated	13.5	55.0	71.5	0.3	74.3
4. Balaya + Curbatur 1.0 + 0.5	1.1	14.3	23.8	41.3	19.9
5. Balaya + Curbatur 0.5 + 0.25	3.5	27.5	52.5	6.3	10.2
6. Balaya 1.5	1.4	10.5	18.8	58.8	18.6
7. Balaya 0.75	2.5	14.8	45.0	18.8	17.9
10. Balaya + Entargo 1.0 + 0.5	2.3	14.8	22.5	45.0	18.1
11. Balaya + Entargo 0.5 + 0.25	3.5	21.8	36.3	20.0	12.3
16. Propulse SE 250 1.0	5.3	31.3	80	1.0	12.5
17. Propulse SE 250 0.5	8.5	42.5	87.5	0.3	7.5
LSD_{95}	1.8	10.0	18.5	16.0	5.7

Control of tan spot with Univoq and Balaya

One trial was placed in the cultivar Graham and inoculated with straw debris contaminated with tan spot (20327). The trial tested four products: Univoq, Proline EC 250, Balaya and Ascra Xpro. Two dose rates were tested of Univoq, Proline EC 250 and Balaya (Table 2). The three 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 not significant, partly due to the dry season and the fast senescence.

Table 12. Effect of applications for control of tan spot in wheat. One trial (20327).

Treatments, l/ha		% tan spot				% GLA	Yield & yield increase
GS 33-37 & 55	Dose l/ha	GS 73 L1	GS 73 L2-3	GS 77 L1	GS 77 L2	GS 77 L1	Dt/ha
1. Untreated		3.8	27.5	26.3	47.5	5.0	98.0
2. Proline EC 250	0.8	1.3	13.5	7.0	13.3	17.5	5.0
3. Proline EC 250	0.4	3.3	23.8	11.3	21.3	10.0	-3.0
4. Univoq	1.5	0.5	8.5	5.5	12.5	26.3	7.0
5. Univoq	0.75	1.6	11.0	11.8	21.3	21.3	5.0
6. Balaya	1.5	2.0	25.0	16.3	32.5	8.0	0.0
7. Balaya	0.75	2.0	22.5	18.8	37.5	13.8	2.0
8. Ascra Xpro	0.75	0.7	8.3	6.5	13.8	22.5	4.0
LSD_{95}		1.3	3.6	5.8	9.7	15.5	7.0

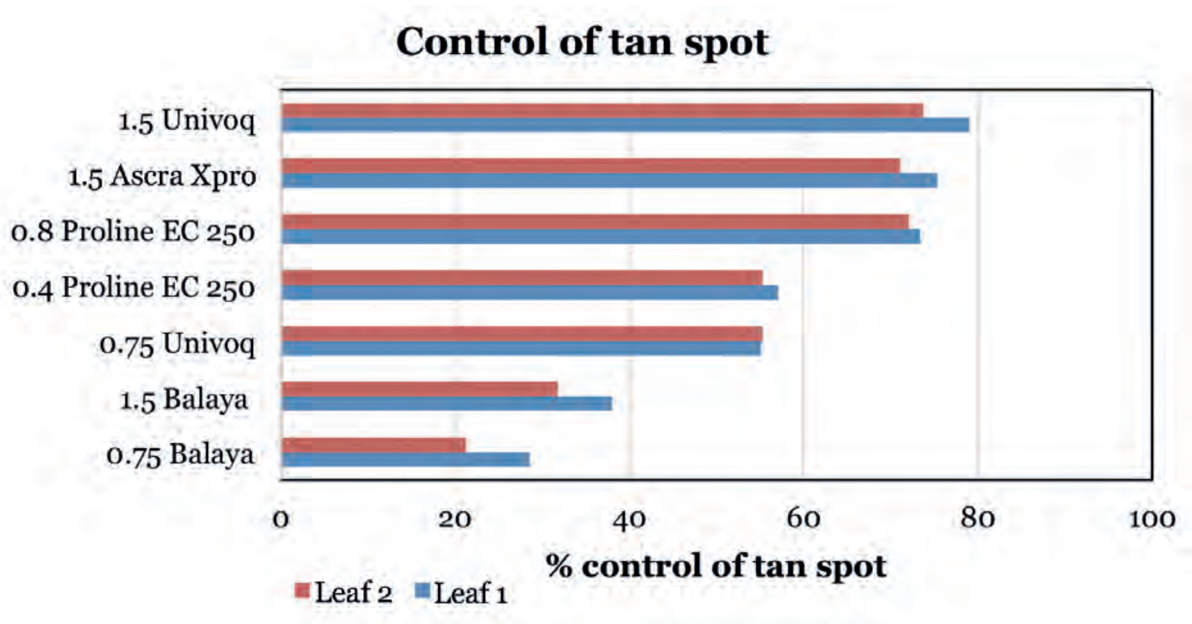
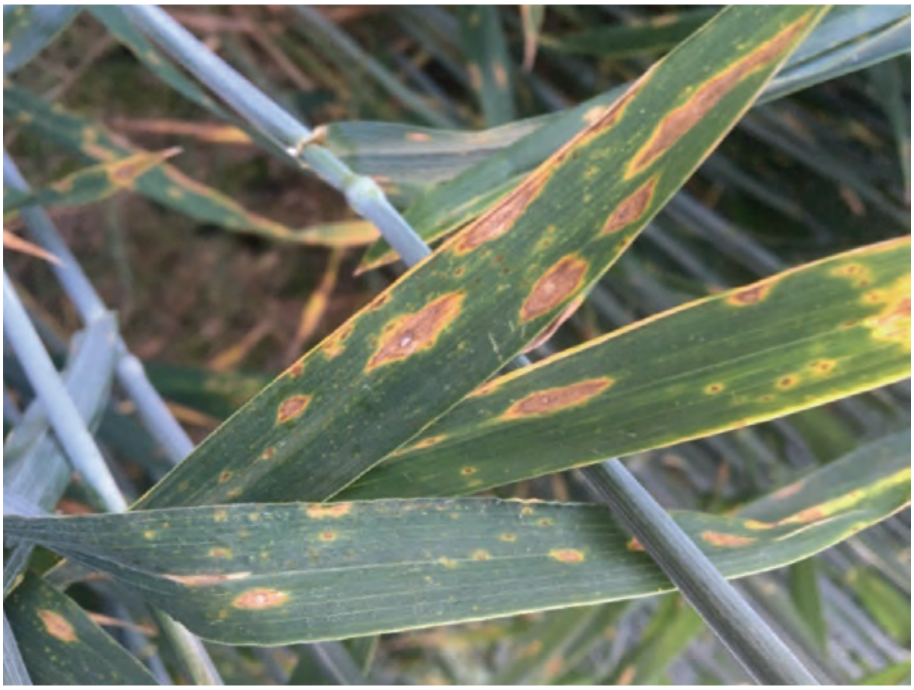


Figure 14. Control of tan spot. The attack on untreated was 48% on 2nd leaf and 26% on 1st leaf. One trial (20327).


Attack of tan spot in wheat.

Results with control of yellow rust

Several trials were carried out in yellow rust susceptible cultivars (Benchmark and Substance) and typically sprayed twice with different fungicide solutions. The trials developed significant attacks of yellow rust following artificial inoculations with solutions with yellow rust spores. Most of the trials were confidential, but 0.8 l/ha Proline EC 250 was used as a reference product across four of the trials. The results from these trials are given in Table 13. Proline EC 250 provided in total 97% control, which was high and slightly surprising – as Proline EC 250 is known not always to provide high levels of control. However, in the 2020 trials, treatments were applied preventatively around flag leaf emergence. Yield increases from treatments with Proline EC 250 were on average 19 dt/ha reflecting the high impact from yellow rust on yields.

Table 13. Results from control of yellow rust in four wheat trials where Proline EC 250 was used as reference.

Treatments, l/ha		% yellow rust				Average
GS 33-37 & 55		20338 L1	20331 L2-3	20311-1 L1	20311-2 L2	
1. Untreated		65	33.8	30	52.5	45.3
2. Proline EC 250	0.8	3.8	0.8	0.9	0	1.4
		Yield & yield increase, dt/ha				
1. Untreated	0.75	73.1	86.9	88.0	70.0	79.5
2. Proline EC 250	1.5	+22.7	+12.1	+14.0	+27.0	+19.0

Results from RustWatch (Horizon 2020 trial)
As part of the Horizon project 2020 RustWatch, trials were carried out in 10 different countries during 2020 following the same protocol. The aim from this activity was to investigate different IPM control strategies for control of yellow rust in different countries and regions. In this section, the Danish trial is presented.

Four cultivars were tested in a split plot design using different control strategies to minimise outbreak and yield losses from attack of rust diseases. In Denmark, the trial included a rust susceptible cultivar (Benchmark), a cultivar with low risk of severe 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 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 EW 250 (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 EW 250 (GS 65) (TFI = 1.0)
3. 7 kg/ha Kumulus S (GS 31-32) / 4.0 l/ha Serenade ASO (GS 33-37) / 7 kg/ha Kumulus S (GS 45-51) / 4.0 l Serenade (GS 65)
4. Treatment according to 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 (the BCA product Serenade and sulphur in alternation) 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 14). AUDPC was calculated for the rust attack – summarising data from the assessments across the season.

In the Danish trial 0.5 l/ha Elatus Era was applied to all cultivars following a risk of *Septoria* and rust (26 May). Later on, Benchmark was treated once more with 0.5 l/ha Folicur EW 250 on 8 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 that the visual attack of yellow rust scored very well in the trial and that only Benchmark gave significant yield increases.

Table 14. Results from control of yellow rust (AUDPC) and yield responses in the RustWatch trial, which included four cultivars and five different treatments.

	Yelllow rust (AUDPC)				
	Untreated	Standard 4 x 1/2	Standard 4 x 1/4	Alternatives	DSS
Cultivar mixture	8	0	0	7	0
Benchmark	48	0	0	43	0
Sheriff	0	0	0	0	0
Informer	0	0	0	0	0

	Yield & yield increase, dt/ha					
	Untreated	Standard 4 x 1/2	Standard 4 x 1/4	Alternatives	DSS	Average of trt.
Cultivar mixture	108	6	7	3	6	4
Benchmark	92	27	29	3	20	20
Sheriff	115	3	4	2	3	2
Informer	107	6	6	3	3	4
Average	105	11	12	3	8	8
LSD_{95}	7.3					

Cultivar mixtures have reduced the attack compared with the average of the three individual cultivars. The benefit from the mixtures was most pronounced in untreated, where attack was reduced by 50%. The yield in the cultivar mixture (108 dt/ha) was also better than for the average of the three individual cultivars (105 dt/ha).

Yield data indicate that reduced rates have been sufficient for control of even severe attack of rust diseases providing the best net yield results. The high input was too expensive and not economically sustainable compared to the reduced rates. The insufficient control from the alternative strategy is reflected in an unacceptably low yield response, and as the cost of the alternative chemistry is still significant, the net yield results become negative. The DSS provided an overall good output as the costs of fungicides were low and net yields were only a little below the treatment using reduced rate.

Control of yellow rust in Benchmark. Clear colour differences were seen in the trial from drone pictures as a result of variable levels of control.

Untreated Benchmark.

Benchmark treated with 4 x ½ rate.

Tan spot (DTR) in wheat

The trial was organised with four replicates and 2 x 1 m row per plot. The area was inoculated with debris tan spot inoculum in the autumn, which is known to provide substantial attack in the following season. The trial in 2020 was attacked by considerable 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 three (Creator, Informer and Pondus) of the tested cultivars had a significantly lower level of attack than the average. Figure 15 shows the result for attack of % tan spot, ranking the cultivars according to susceptibility. Creator and Informer also showed clearly better level of control in 2018 and 2019.

Typical leaf symptoms of tan spot.

Debris with pseudothecia af *Pyrenophora tritici-repentis*.

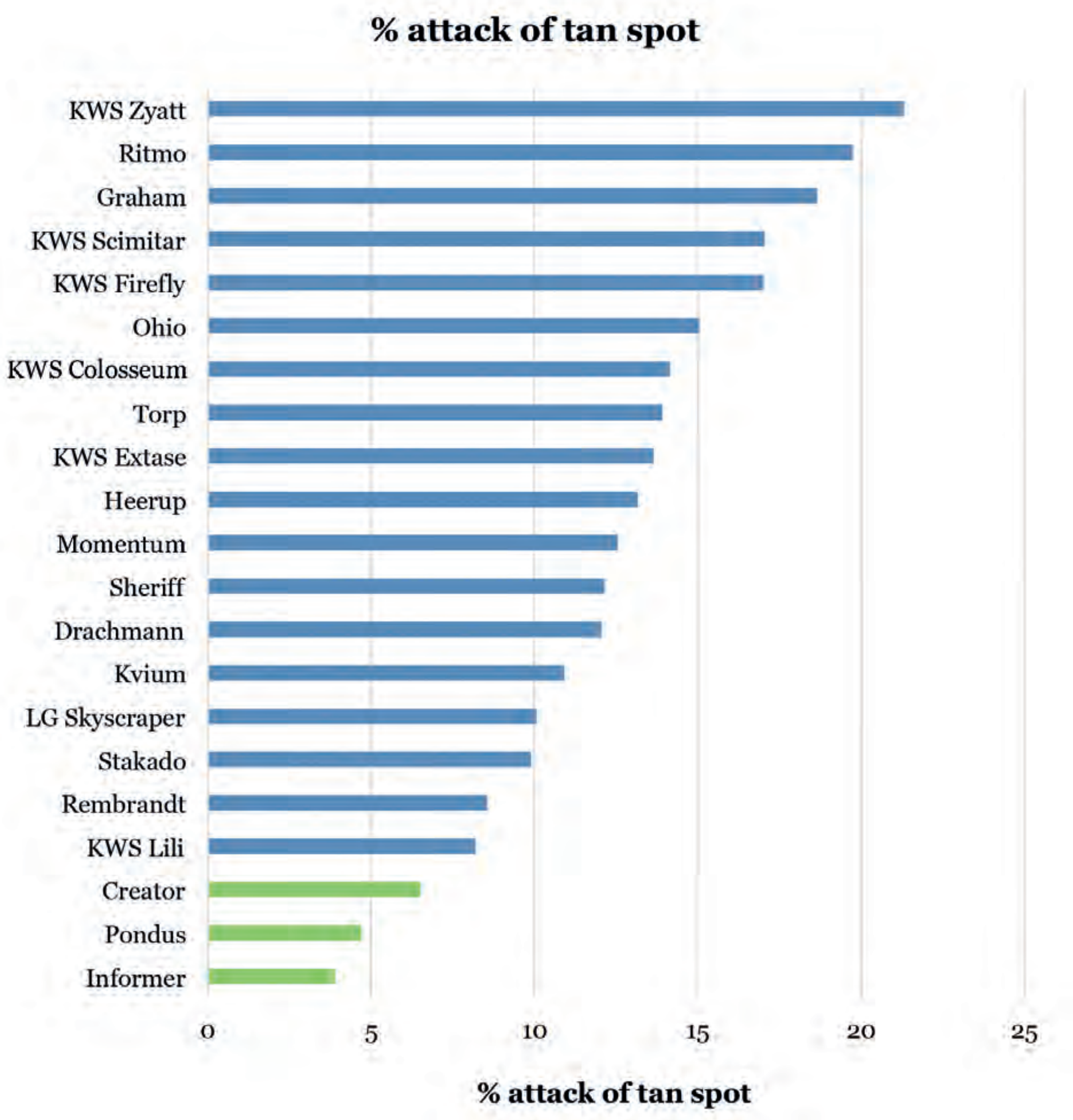


Figure 15. Per cent attack of tan spot in different winter wheat cultivars. Based on the two last assessments on the upper leaves (20302-1).

2. Results from fungicide trials in spring barley

Net blotch was the most severe disease in the spring barley trials followed by late attack of Ramularia leaf spot. Several combinations of fungicides using azoles and strobilurins provided similar control and yield responses. In most seasons, one treatment at GS 37-39 will provide sufficient control using approximately 33-50% rates. In case of early and severe attack of net blotch, *Rhynchosporium* and brown rust and late attack of *Ramularia,* two treatments might be needed.

In three trials in spring barley, different fungicide solutions using half rates were compared for control of specific diseases in 2020. Results from the three trials are shown in Table 15. The trials were carried out in Chapeau, Laurikka and KWS Irina. All trials developed a moderate attack of net blotch (*Pyrenophora teres*), a minor attack of brown rust (*Puccinia hordei*) and a late and minor attack of Ramularia leaf spot (*Ramularia collo-cygni*). As shown in Table 15, most of the tested solutions provided very similar and good control of all assessed diseases. The effect on net blotch is shown in Figure 16**.** Only Elatus Era gave slightly inferior control. Yield responses were small and did not differ significantly for the different treatments.

Table 15. Disease control using different fungicides applied with half dose at GS 37 in spring barley. Three trials in 2020 (20384).

Treatments, l/ha		% net blotch		% *Rhyncho-sporium*	% rust	% *Ramularia*	% GLA	TGW	Yield & yield increase	Net increase
GS 37		GS 59 L2	GS 73-77 L2	GS 73	GS 77	GS 80 L1	L2	g	Dt/ha	Dt/ha
1. Propulse SE 250 + Comet Pro	0.5 + 0.2	0.3	0.9	1.1	0.4	2.1	37.5	52.3	2.8	-0.2
2. Propulse SE 250 + Comet Pro	0.25 + 0.3	0.4	1.1	0.6	0.4	2.1	36.9	52.3	4.3	1.9
3. Balaya + Propulse SE 250	0.5 + 0.25	0.3	0.5	0.2	0.1	2.0	35.0	52.2	3.4	-0.4
4. Balaya + Proline EC 250	0.5 + 0.2	0.5	0.8	0.6	0.2	2.2	33.1	52.4	4.6	0.8
5. Elatus Era	0.5	0.6	2.2	1.3	0.3	2.8	35.6	52.3	3.7	
6. Balaya	0.75	0.3	0.7	0.5	0.3	3.8	38.8	52.5	4.5	0.4
7. Balaya + Entargo	0.5 + 0.175	0.3	0.4	0.3	0.2	3.0	36.9	53.2	4.6	0.7
8. Untreated	0.75	1.8	10.7	1.8	1.8	3.6	26.3	50.8	71.0	-
No. of trials		3	3	2	2	2	2	2	3	3
LSD_{95}		0.2	0.5	1.3	0.2	2.1	14.4	1.2	2.6	-

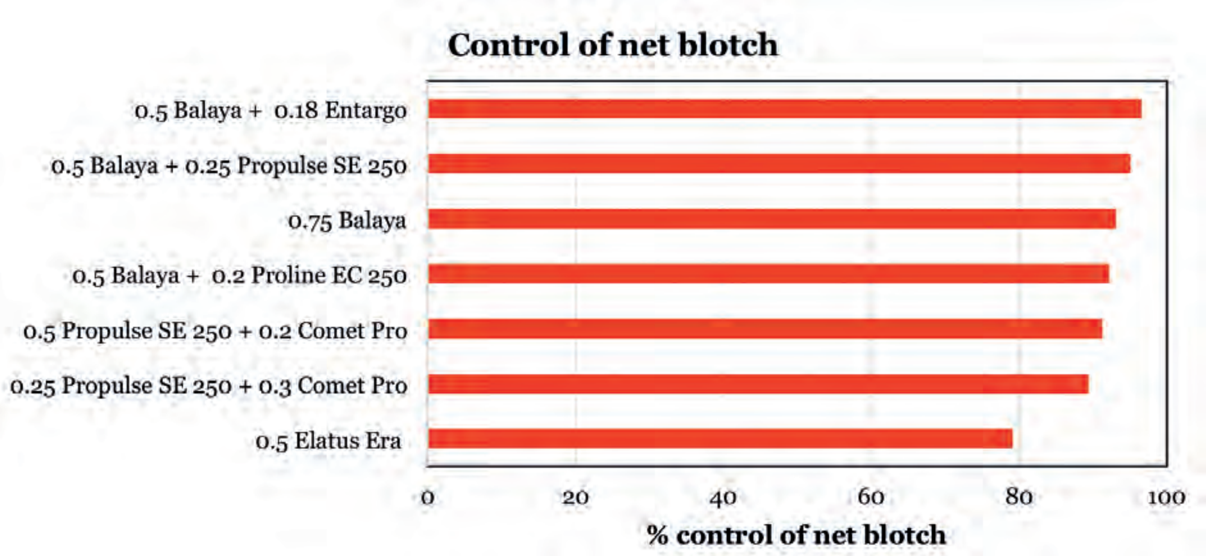


Figure 16. Control of net blotch in spring barley (20384). Average of three trials with 10.8% net blotch in untreated.

Control of leaf diseases in barley using Entargo

Entargo is a new liquid formulation of boscalid, which was authorised in 2021. The product includes 500 g boscalid/litre. The max dose is 0.7 l/ha equivalent to 350 g boscalid, known as the full rate in Bell. The product was tested as a solo product in 2017 and 2018. Results are summarised in Table 16. The data indicate that Entargo (tested under the name Cumora) provides control inferior to Proline EC 250 when tested at full rate. As a solo product, Entargo will provide insufficient control in comparison with normal standards. Entargo should be seen as a mixing partner for other solutions as shown in Table 15. Using Entargo can be seen as a resistance strategy in line with using fluopyram in Propulse SE 250. Unfortunately, the efficacy and yield improvements from adding Entargo are very limited and call for a low pricing if picking up in practice.

Table 16. Disease control using Entargo applied at two rates, applied at GS 37 in barley. Three trials 2020 (20384).

Treatments at GS 37-39	% control		Yield & yield increase, dt/ha
	Net blotch	Brown rust	
Untreated (% attack)	(6.7)	(23)	65.7
Entargo 0.4	52	47	3.6
Entargo 0.7	60	57	4.3
Proline EC 250 0.8	87	95	5.9
No. of trials	3	3	3

Control of Ramularia leaf spot

As *Ramularia* has adapted to several groups of fungicides in many regions in Western Europe, future control is under pressure. The pathogen has been found to be highly diverse and management asks for focus on introduction of new molecules and breeding for resistant varieties.

Ramularia has already acquired resistance to strobilurins (QoIs), which had good efficacy against *Ramularia* 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, C-H153R) with increasing frequencies since 2014. Additionally, azole-adapted isolates of *R. collo-cygni* have been found at high frequencies in several European countries. Fifteen different *CYP51* haplotypes were detected in the set of isolates from 2009 to 2017, which showed a substantially decreased sensitivity to DMIs compared with other isolates.

New data from Denmark have shown an increase in SDHI mutations during 2018-20, which are shown in Chapter VI. This increase will affect the efficacy of Propulse SE 250 and solutions with Entargo.

In two specific trials, several different combinations of fungicides were tested in 2020 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 leaf blotch diseases.

The first trial was part of the Euro-barley project, where a similar trial plan was carried out in five countries. The Danish trial developed a late but still substantial attack of Ramularia leaf spot and provided good opportunities for ranking the efficacy of the products (Table 17). Most products achieved more than 80% control. Solutions with Revysol or Pavecto (BAS 830 01F) used as solo products or in combination with other actives provided very good control. Proline EC 250 differed, providing only moderate levels of control. The high level of control from Pavecto shows that despite this product belonging to the strobilurins, the activity is different and has apparently the ability to control strobe-resistant populations. Adding folpet to Revysol improved the control of *Ramularia* (comparing trt. 2 and 8), which has also been seen in other countries where control of *Ramularia* has been very dependent on chlorothalonil, which will be prohibited in the EU from the coming season. The best control in this trial was obtained from the mixture of BAS 832 01F (Revysol + Pavecto), which provided almost 100% control. Due to the late development of Ramularia leaf spot, no statistically significant yield benefits were measured as a result of the control levels achieved.

The cultivar KWS Irina developed a substantial attack of Ramularia leaf spot late in the season, which was a good basis for differentiating the efficacy of the products.

Table 17. Effects on Ramularia leaf spot using different fungicides applied at GS 39-49 in spring barley. One trial in Euro-barley (20388).

Treatments, l/ha		% *Rhynchosporium*	% net blotch	% *Ramularia*	% *Ramularia*	TGW	Yield & yield increase
GS 37-39		GS 75 L2	GS 77 L2	GS 77 L 2	GS 80 L 2	g	Dt/ha
1. Untreated	0.38 + 0.15	5.0	15.0	21.3	20.0	49.2	85.7
2. Revysol (Myresa)	1.0	1.4	3.0	1.1	5.3	51.0	0.4
3. Revysol (Myresa)	1.5	1.1	1.0	0.5	3.3	50.1	4.2
4. Proline EC 250	0.54	2.3	5.0	8.0	13.0	49.4	0.6
5. Proline EC 250	0.8	3.0	5.8	7.3	8.8	50.1	2.6
6. BAS 830 01F	1.33	0.9	5.8	0.9	4.5	50.2	6.1
7. BAS 830 01F	2.0	1.0	1.8	0.1	2.3	51.1	3.9
8. Revysol (Myresa) + Folpan 500 SC	1.0 + 1.5	0.8	4.3	0.3	2.0	50.4	2.6
9. BAS 750 01F + BAS 175AH F	1.0 2.0	0.9	2.5	0.9	4.8	50.5	4.6
10. Elatus Era	1.0	3.0	10.0	4.5	7.0	49.5	5.1
11. Ascra Xpro	1.5	0.6	0.0	2.3	6.5	51.6	1.1
12. Revystar XL	1.5	0.4	0.0	0.1	2.3	52.2	4.9
13. BAS 832 01F	2.0	0.6	0.0	0.0	0.3	51.4	2.6
14. BAS 831 01F	2.25	0.2	0.0	0.0	2.8	48.9	5.1
LSD_{95}		1.2	2.1	2.2	2.1	2.1	NS

In the second trial, also carried out in KWS Irina, a significant number of different solutions were compared. This trial generally used lower rates and products relevant from a Danish perspective (Table 18 & Figure 17). In this trial, Revysol and Balaya, which both contain mefentrifluconazole, also gave control superior to Proline EC 250. Despite problems with resistance several solutions still offer moderate control of Ramularia leaf spot. The results from the two trials indicate that *CYP51* mutations in *Ramularia collo-cygni* do not influence Revysol to the same extent as they influence Proline EC 250 – analogous with the situation seen for *Septoria*.

Table 18. Disease control using different fungicides applied at GS 45-51 in spring and winter barley. Two trials 2020 (20389).

Treatments, l/ha		% rust	% *Rhyncho-sporium*	% net blotch	% *Ramularia*	TGW	Yield & yield increase	Net increase
GS 32-33	GS 45-51	GS 71-73 L2	GS 73 L2	GS 73 L2	GS 77 L 2	g	Dt/ha	Dt/ha
1. Comet Pro 0.5		1.7	3.5	6.5	22.5	47.0	83.5	-
2. Comet Pro 0.5	Ascra Xpro 1.0	0.0	0.0	1.6	5.8	48.1	2.1	-4.8
3. Comet Pro 0.5	Propulse SE 250 0.8	0.0	0.1	0.5	8.3	47.3	1.6	-4.0
4. Comet Pro 0.5	Bravo 1.0	0.2	0.5	2.0	7.0	48.4	1.3	-
5. Comet Pro 0.5	Univoq 0.75	0.1	0.1	0.2	9.5	48.0	1.0	-3.7
6. Comet Pro 0.5	Folpan 500 SC 1.0	0.6	2.0	1.8	12.3	47.5	-1.2	-
7. Comet Pro 0.5	Balaya 1.0	0.0	0.0	0.1	2.8	48.5	1.5	-5.9
8. Comet Pro 0.5	Balaya 0.5	0.0	0.1	0.3	6.5	48.1	0.4	-4.7
9. Comet Pro 0.5	Revysol 0.75	0.1	0.8	0.1	2.5	48.3	1.2	-
10. Comet Pro 0.5	Proline EC 250 0.4	0.0	0.1	2.3	10.0	47.5	1.5	-3.1
11. Comet Pro 0.5	Vacciplant 1.0 + Thiopron 3.5	0.2	0.2	3.3	17.5	47.1	-0.2	-
12. Comet Pro 0.5	Delaro 0.4 + Propulse SE 250 0.4	0.0	0.0	0.1	11.3	47.7	3.7	-
13. Comet Pro 0.5	Delaro 0.8	0.0	0.1	0.2	6.3	48.6	0.2	-
No. of trials		1	1	1	1	2	1	1
LSD_{95}		0.3	1.4	1.1	3.7	-	5.2	-

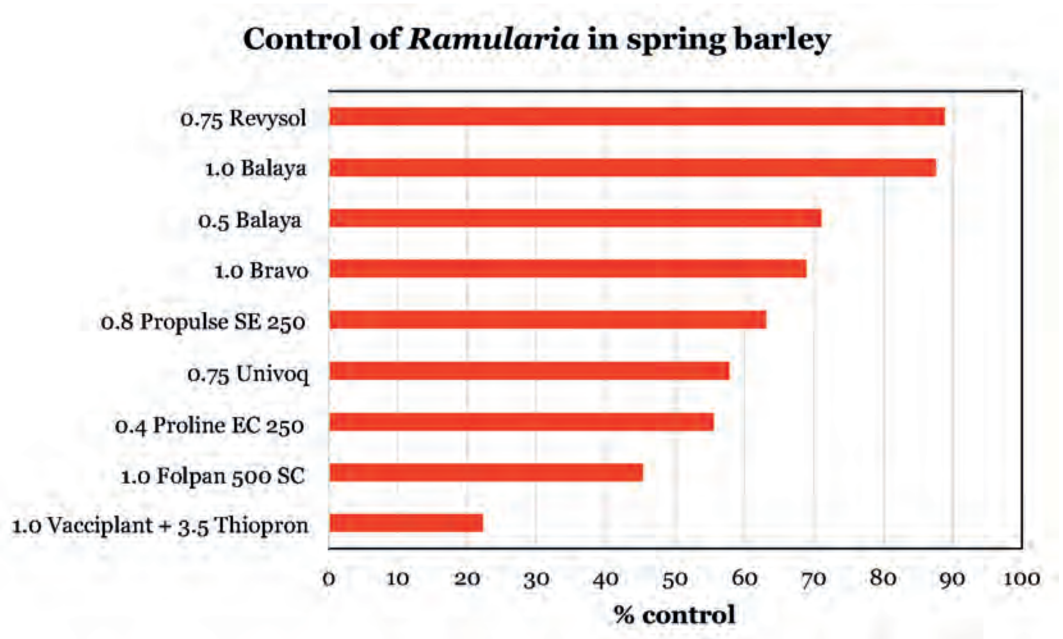


Figure 17. Control of *Ramularia* leaf spot in spring barley (20389-2). 22% attack in untreated in one trial assessed at GS 81.

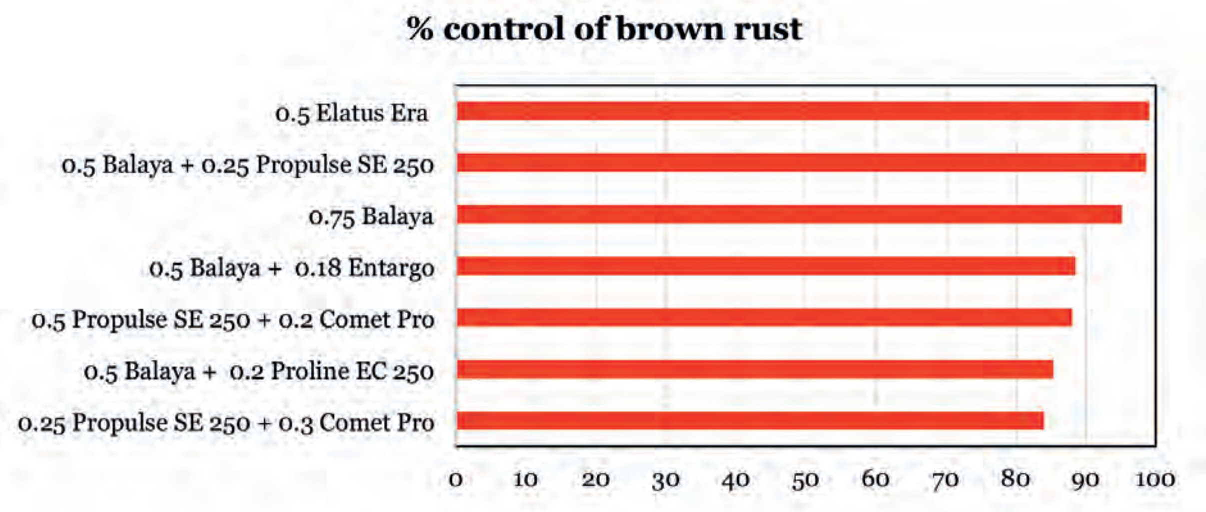
3. Results from fungicide trials in winter barley

Only moderate attacks of brown rust, *Rhynchosporium* and net blotch developed in the winter barley trials. Several combinations of fungicides using SDHIs, azoles and strobilurins provided similar control and yield responses. In most seasons one treatment at GS 37-39 will provide sufficient control using approximately 33-50% rates. In case of early and severe attack of net blotch, *Rhynchosporium* and brown rust and late attack of *Ramularia*, two treatments might be needed.

In 2020, three trials were carried out in winter barley testing different combinations of fungicide solutions against specific diseases. Treatments were applied at GS 37-39 using half rates, which have typically been seen as economically optimal solutions. The trials were carried out in the cultivars Frigg, Celtic and Kosmos. Results from the trials are shown in Table 18. The trials in 2020 were dominated by moderate attack of brown rust (*Puccinia hordei*) and scald (*Rhynchosporium secalis*). As shown in Table 19 and Figure 18 most of the tested solutions provided very similar and good control of all assessed diseases. However, Balaya used as solo product gave inferior control of scald. Yield increases varied between 3-7 dt/ha, but did not vary significantly and only minor net yields were measured.

Table 19. Per cent control of diseases and yield responses in winter barley using half dose rates. (20371). Average of three 3 trials.

Treatments, l/ha		% rust		% *Rhynchosporium*		% GLA		TGW	Yield & yield increase	Net increase
GS 37		GS 73 L2	GS 73 L3	GS 73	GS 77 L2	GS 80 L1	GS 80 L2	g	Dt/ha	Dt/ha
1. Propulse SE 250 + Comet Pro	0.5 + 0.2	1.2	3.0	1.2	4.0	15.6	38.3	44.3	5.8	2.8
2. Propulse SE 250 + Comet Pro	0.25 + 0.3	1.8	3.8	2.2	6.1	16.3	32.5	44.2	3.9	1.5
3. Balaya + Propulse SE 250	0.5 + 0.25	0.2	0.4	0.9	4.3	14.4	42.1	45.0	4.6	0.8
4. Balaya + Proline EC 250	0.5 + 0.2	0.4	1.3	2.1	5.3	11.3	33.8	44.1	3.5	-0.3
5. Elatus Era	0.5	0.1	0.5	1.0	3.3	21.3	45.0	43.8	7.1	-
6. Balaya	0.75	0.4	0.9	2.7	8.9	16.9	29.6	44.1	7.0	3.0
7. Balaya + Entargo	0.5 + 0.175	1.3	2.9	1.5	3.7	24.4	46.7	44.1	5.8	1.9
8. Untreated	0.75	9.4	20.0	11.3	25.4	5.0	6.3	41.8	78.3	-
No. of trials		2	2	3	2	2	3	3	3	3
LSD_{95}		1.2	2.0	1.2	3.2	7.0	8.0	1.3	4.0	-



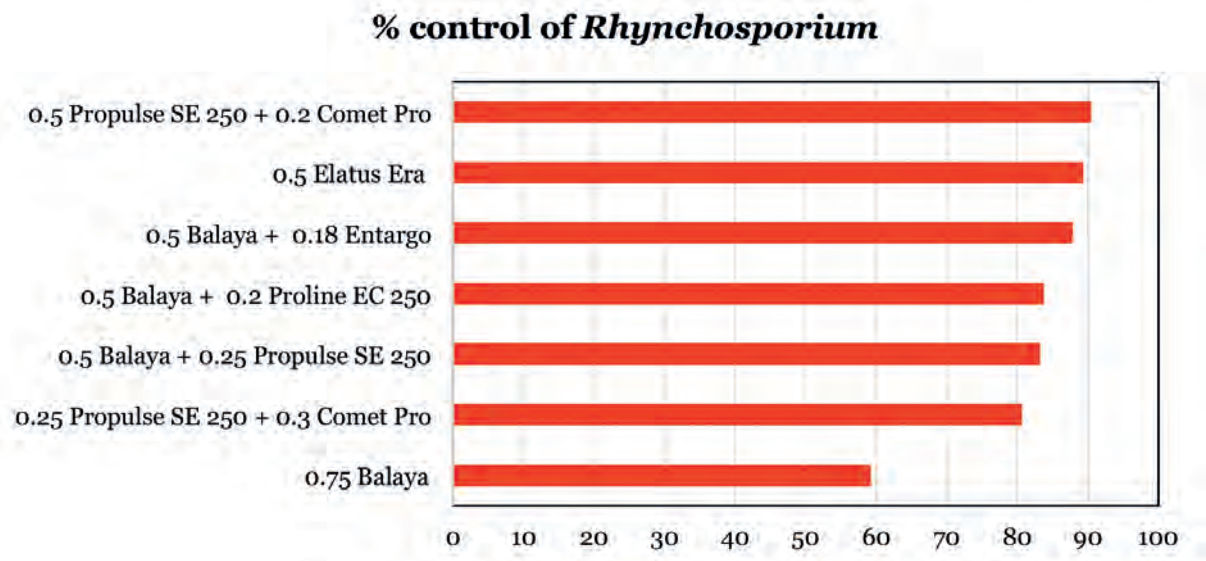


Figure 18. Control of brown rust and *Rhynchosporium* from different solutions in winter barley (20371). Average of two trials, 11% attack of rust in untreated, 17.3 % attack of *Rhynchosporium* in untreated.

4. Results from fungicide trials in rye and triticale

Two trials were carried out in 2020 - one in rye and one in triticale testing different commonly used fungicides (20364).

The trial carried out in triticale (20364-1) was treated three times as the attack of yellow rust in the cultivar started very early and was driven by natural infection. The attack also spread to the ears. All treatments provided high levels of control (Figure 19). The yield responses were large and significant and varied between 22 and 29 dt/ha (Table 20). Solutions with Prosaro 250 EC provided overall slightly better control of yellow rust and better yield responses.

The rye trial (20364-2) was treated twice on 28 April and 13 May, respectively. Despite long dry periods, the trial mainly developed an attack of *Rhynchosporium*. Late in the season, a minor attack of brown rust also appeared but too late to have any impact on yields. The five different treatments provided significant and almost similarly good control of *Rhynchosporium* (Table 21). The yield increased only moderately and not significantly.

Table 20. Control of diseases in triticale using different fungicides applied at GS 39-49 in one trial (20364-1).

Treatments, l/ha		% yellow rust				% GLA	TGW	Yield & yield increase	Net increase
GS 32-33 & 51-55		GS 71 L2-3	GS 71 EAR	GS 75 L2-3	GS 75 EAR		g	Dt/ha	Dt/ha
1. Prosaro 250 EC + Comet Pro	0.25 + 0.3	0.0	4.5	2.5	15.0	75.0	40.6	26.6	19.0
2. Propulse SE 250 + Comet Pro	0.35 + 0.2	0.3	8.8	4.5	22.5	77.5	39.6	22.1	14.0
3. Balaya	0.75	0.0	5.8	4.5	17.5	82.5	38.7	22.0	8.65
4. Prosaro 250 EC	0.5	0.0	7.0	1.8	17.5	82.5	42.4	29.1	22.1
5. Comet Pro	0.6	0.0	6.3	4.0	17.5	72.5	39.7	23.0	14.7
6. Untreated		35.0	30.0	60.0	57.5	8.8	37.3	40.1	-
No. of trials		1	1	1	1	1	1	1	1
LSD_{95}		10.7	10.8	7.8	15.1	11.0	4.4	5.6	

Table 21. Control of diseases in rye using different fungicides applied at GS 39-49 in one trial (20364-2).

Treatments, l/ha		% *Rhynchosporium*		% brown rust		% GLA	TGW	Yield & yield increase	Net increase
GS 32-33 & 51-55		GS 71 L2-3	GS 73 L2-3	GS 71 L 2-3	GS 73 L2-3	Dt/ha	g	Dt/ha	Dt/ha
1. Prosaro 250 EC + Comet Pro	0.25 + 0.3	0.0	3.3	0.0	0.1	47.5	30.0	5.2	0.1
2. Propulse SE 250 + Comet Pro	0.35 + 0.2	0.1	2.0	0.0	0.1	75.0	29.4	5.2	-0.2
3. Balaya	0.75	0.1	1.5	0.0	0.1	52.5	29.1	3.4	-5.5
4. Prosaro 250 EC	0.5	0.1	3.3	0.0	0.1	62.5	29.5	2.5	-2.1
5. Comet Pro	0.6	0.1	3.0	0.0	0.1	50.0	28.9	2.5	-3.0
6. Untreated		5.0	26.3	0.2	0.6	2.5	29.5	98.2	-
No. of trials		1	1	1	1	1	1	1	1
LSD_{95}		0.1	4.2	0.0	0.1	17.7	1.6	6.4	

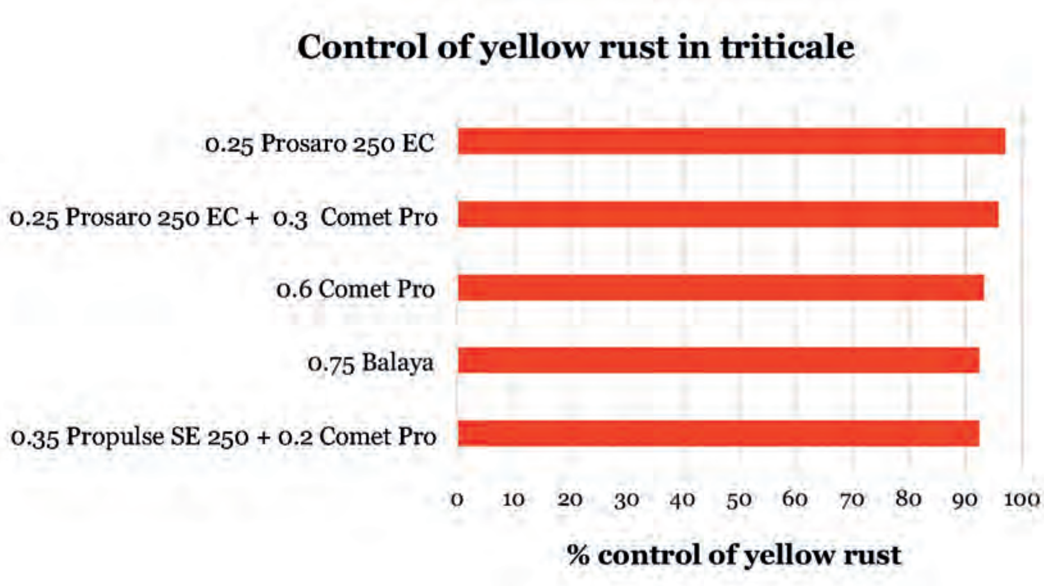


Figure 19. Control of yellow rust from different solutions in triticale following three treatments (20364).

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 most commonly grown rye cultivars in Denmark. In this year's trials, 12 cultivars were included, sown in 1-m² plots and tested in two replicates with buffer zones of triticale between all plots (20303). 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 by counting the number of ergot on 100 heads (Table 22). The average results from two countings (3 and 15 July) are shown in Figure 20.

In some cultivars, the average number of ergots per head was higher than one. Cultivars from KWS showed the best level of resistance in the test. Heads from the plots were harvested and threshed. Subsequently, the weight of ergots per sample was measured. The correlation between ears with ergot and % weight of ergot in the grain samples is shown in Figure 21.

Table 22. Data from the rye trial inoculated with ergot (20303).

	Ergots number/100 ears		Weight, g		Relative weight
	GS 85	GS 87	Healthy grain	Ergots	%
1. Helltop	139.5	157.5	672.5	28.8	4.2
2. SU Performer 90 + 10 population	179.0	217.5	595.8	25.9	4.2
3. SU Arvid 90 + 10 population	88.5	129.0	1042.4	30.7	3.0
4. SU Pluralis 90 + 10 population	125.0	140.5	1202.0	27.7	2.3
5. KWS Livado	99.5	112.0	883.9	22.3	2.4
6. KWS Serafino	62.5	71.0	1237.2	13.8	1.1
7. KWS Vinetto	70.0	85.0	1057.2	25.4	2.4
8. KWS Tayo	77.5	84.0	1361.8	17.4	1.2
9. KWS Berado	58.0	97.5	1195.4	27.4	2.3
10. KWS Jethro	49.0	67.5	1117.8	12.1	1.0
11. KWS Receptor	43.0	51.0	1116.2	16.9	1.5
12. Stannos	148.0	183.5	808.6	76.3	8.6
LSD_{95}	53	55.4	283.5	12.5	1.2

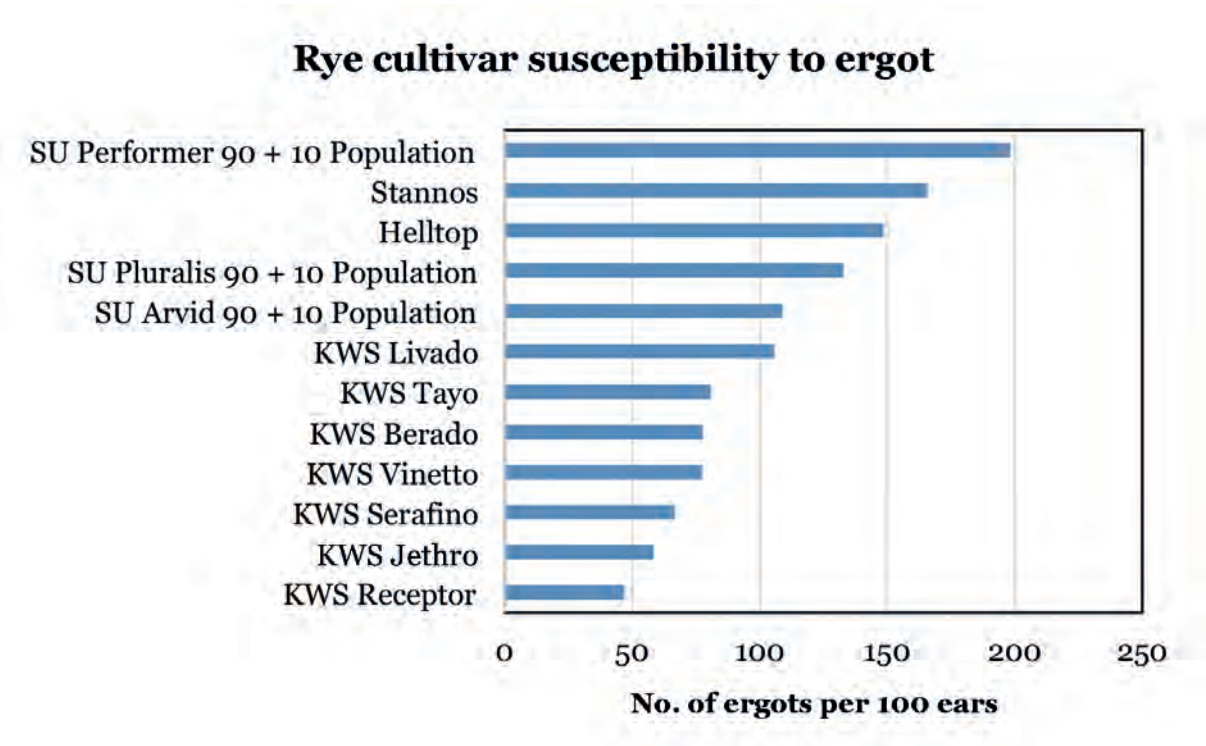


Figure 20. Ranking of cultivar susceptibility to ergot based on count from 100 heads.

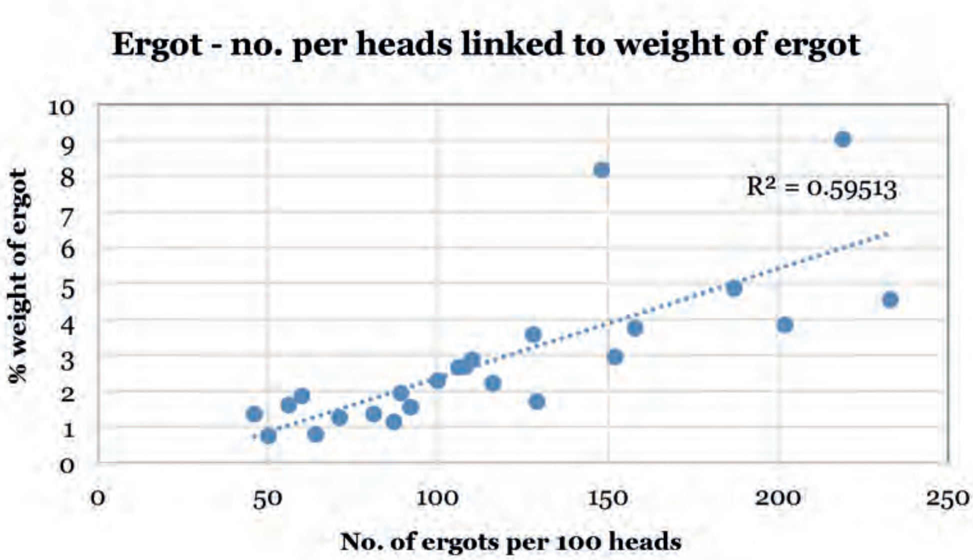


Figure 21. Correlation between number of infected heads and % ergot (weight) in harvested grain sample.

References

Heick, T. M., N. Matzen and L. N. Jørgensen (2020). Reduced field efficacy and sensitivity of demethylation inhibitors in the Danish and Swedish *Zymoseptoria tritici* populations. European Journal of Plant Pathology 157: 625-636. https://doi.org/10.1007/s10658-020-02029-2.

III Ranking of *Fusarium* susceptibility

Lise Nistrup Jørgensen, Niels Matzen, Hans-Peter Madsen, Helene Saltoft Kristjansen, Sidsel Kirkegaard, Anders Almskou-Dahlgaard & Kirsten Heinrichson

Ranking susceptibility to Fusarium head blight in winter wheat in 2020

In a project partly financed by the breeders, the Department of Agroecology, Aarhus University, Flakkebjerg, has in line with previous years investigated the susceptibility to Fusarium head blight (FHB). The tested cultivars are commonly grown in Denmark or cultivars expected to become important in the years to come. In this year's trials, 22 cultivars were included. One trial was inoculated with infested grain placed on the ground during elongation (GS 33-39) and the other trial was inoculated during flowering (GS 61-65) using a spore solution.

Both trials had a similar layout. Two 1-metre rows of each cultivar were sown in the autumn in four replicates. The trial inoculated with infested grain placed on the ground during elongation was irrigated but otherwise left alone until assessments. The trial which was inoculated with spore solutions during flowering was treated four times, on 11, 12, 15 and 18 June, respectively, using a spore solution consisting of both *Fusarium culmorum* and *Fusarium graminearum*. To stimulate the disease development the trial was irrigated by a mist irrigation system twice a 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. As in previous years, the cultivars Ritmo and Oakley were used as susceptible reference cultivars and Olivin and Skalmeje as the most resistant references. The first symptoms of FHB were seen approximately 15 days after inoculation.

Both trials were assessed by counting the attack on 100 ears per cultivar per replicate. Additionally, the degree of attack was scored as an average of the ears attacked, using a 0-10 scale. The results are shown in Figure 1 and Table 1. The cultivars Torp, KWS Firefly and KWS Scimitar had the most severe attacks (Figure 1). The lowest infection rate was seen in Creator, Benchmark, Drachmann and Sheriff. The reference cultivars Ritmo and Oakley showed very severe attacks and Olivin and Skalmeje showed low levels of attack.

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 resistant cultivar's content of mycotoxins correlated to some extent with the degree of attack. The contents of the different myctoxins also correlated among them as seen for DON, NIV and ZEA (Figure 2). *Fusarium culmorum* and *Fusarium graminearum* are both known to produce DON, NIV and ZEA. DON is traditionally known as the indicator of mycotoxins. The contents of NIV and DON are known to correlate as also shown in these trials. ZEA content generally correlates less with the other toxins.

In Table 1, the ranking of cultivars to FHB susceptibility is summarised, including data from previous years in the final ranking. The results of the trials were published in July together with SEGES in order to make the data available for the cultivar choice in autumn 2020.

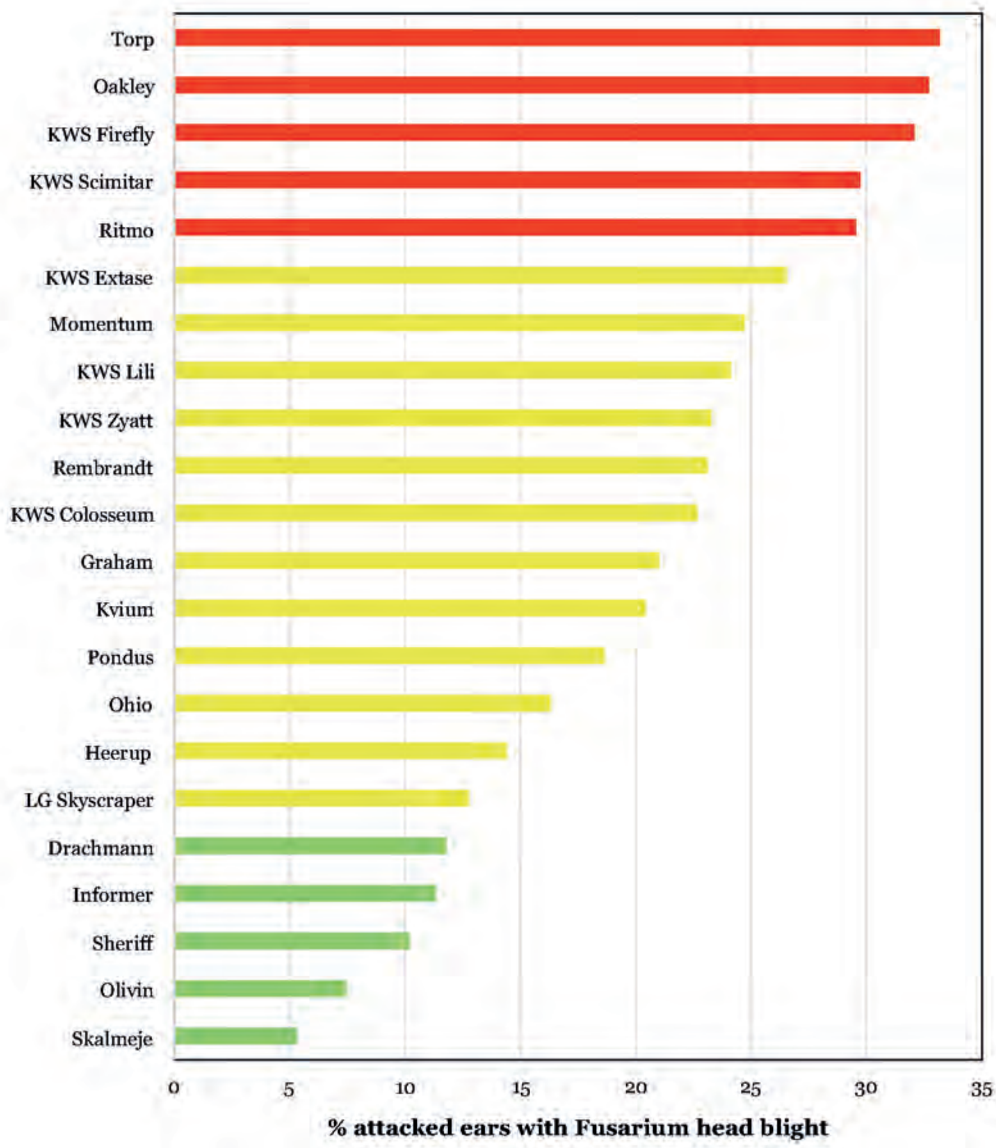


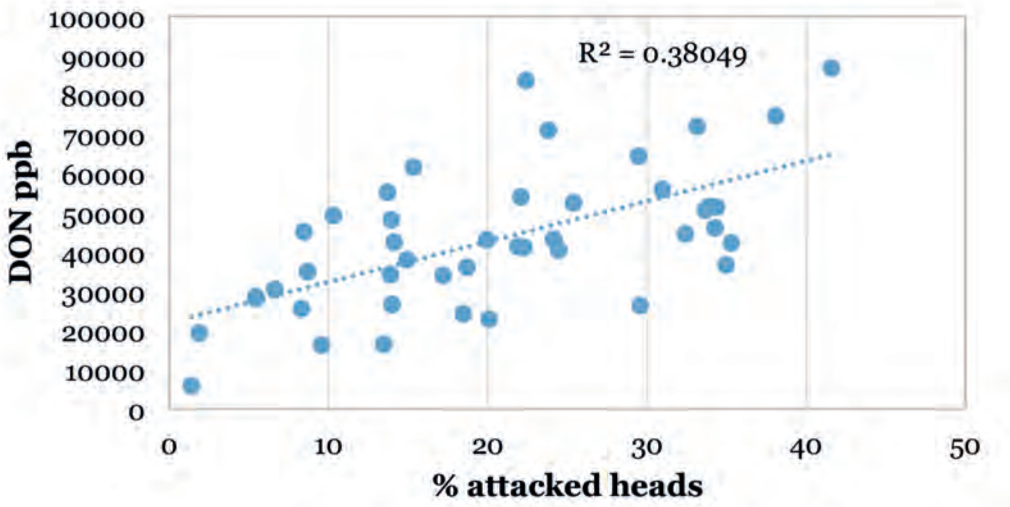
Figure 1. Percentage of attacked ears of Fusarium head blight in cultivars in July. Average of both trials. The LSD_{95} value = 8.5.

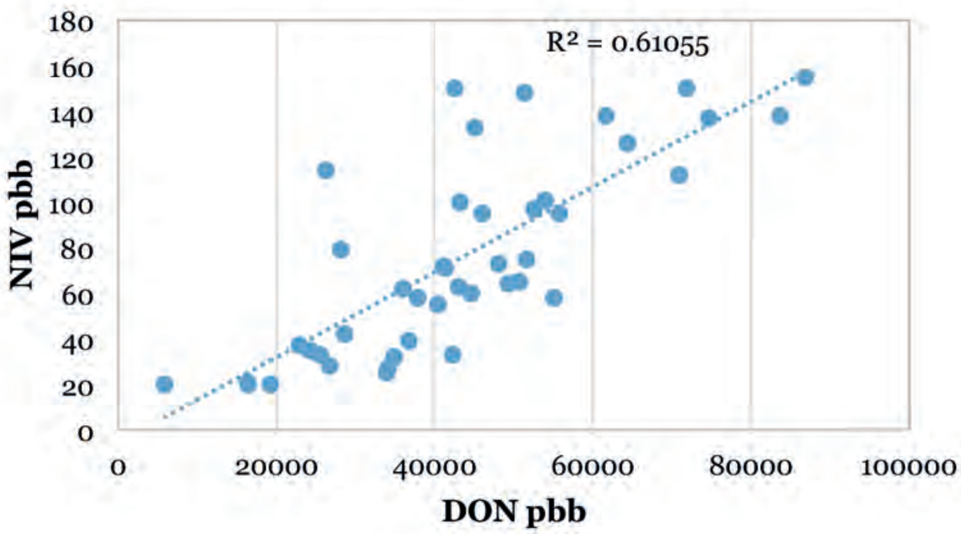
Table 1. Grouping of cultivars by susceptibility to Fusarium head blight. Based on results from both 2020 and previous years.

Low susceptibility	Moderate to high susceptibility	High susceptibility
Benchmark, Creator, Drachmann, Sheriff (reference cultivars: Skalmeje, Olivin)	Graham, Heerup, Informer, Kvium, KWS Extase, KWS Lili, KWS Colosseum, KWS Zyatt, LG Skyscraper, Momentum, Pondus, Rembrandt, Ohio	Torp, KWS Firefly, KWS Scimitar (reference cultivars: Oakley, Ritmo)

Photos from small plot trial with severe attack of Fusarium head blight.

Spores of *Fusarium culmorum*, which are used when the trials are inoculated.





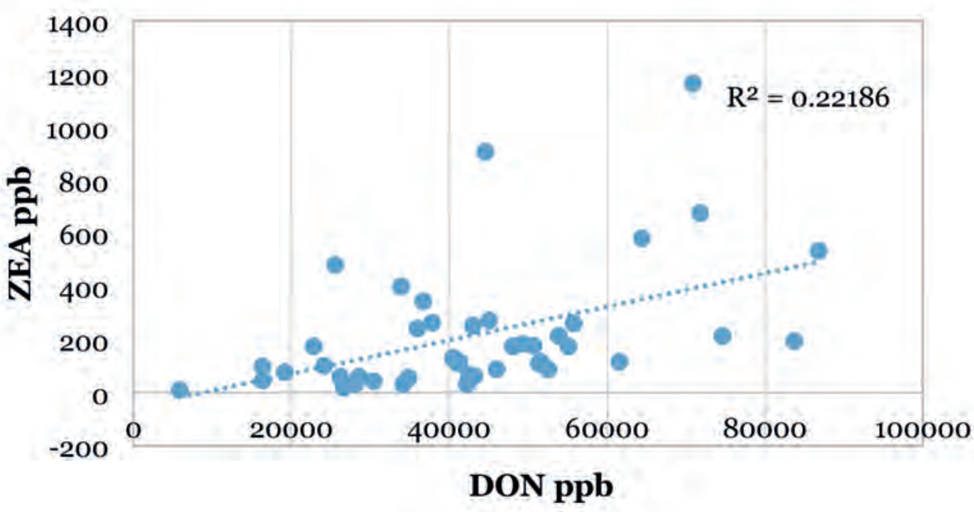


Figure 2. Top: Correlation between % heads attacked by *Fusarium* and content of DON measured in harvested grain (left). Centre and bottom: Correlations between the two mycotoxins DON and NIV and DON and ZEA. Data from two trials in 2020.

Fusarium - screening for susceptibility - 10 years' data

For the last 10 years, cultivars have been screened for susceptibility to Fusarium head blight in winter wheat trials with artificial inoculation. Each year between 20 and 25 cultivars have been included in small plot trials using the same method as described for the 2020 trials at the beginning of this chapter. After inoculation, the level of attack has been assessed based on counting of 100 heads per replicate; this has typically been done at GS 75. In most seasons, a percentage score for attack per plot (%) has also been given, when the crop has reached GS 77, typically 1 week after GS 75. Following ripening, heads from all plots have been harvested, threshed and the content of mycotoxins measured using HPLC MSMS. Five different mycotoxins have been measured but only three (DON, ZEA, NIV) have had significant findings. Data are summarised in Table 2. In all years, the same references have been included, but the specific cultivars have been included in different years. Data have been log transformed or square root transformed ahead of the statistical analysis and in some cases the top and bottom percentiles have been excluded to normalise data. Even though some trends are seen for the ranking of the cultivars, the analysis shows that most cultivars cannot be separated statistically from each other.

Table 2. Average data from 10 years' testing of wheat cultivars' susceptibility to Fusarium head blight (FHB) and for production of mycotoxins DON, NIV and ZEA. The cultivars have been included in different years. Data have been log transformed or square root transformed ahead of the analysis.

Years included		GS 75 % attacked heads with FHB		GS 77-79 % FHB attack (score)		Grain DON ppb		Grain NIV ppb		Grain ZEA ppb	
KWS Lili	2016-20	46	a	51	ab	29559	a	92	a	358	a
Torp	2011-20	41	ab	62	a	19767	ab	70	a	222	a
Oakley	2010-20	41	ab	64	a	19955	ab	82	a	390	a
Ritmo	2010-20	40	ab	58	a	16354	abc	82	a	287	a
Nakskov	2011-17	24	abc	53	ab	13324	abc	52	ab	520	a
Hereford	2010-14	23	abcd	42	abc	5068	abc	28	ab	99	a
Sheriff	2015-20	18	abcd	28	abc	16740	abc	41	ab	271	a
Elixer	2015-19	18	abcd	40	abc	11012	abc	40	ab	272	a
Gedser	2010-14	22	abcd	39	abc	8150	abc	58	ab	106	a
Jensen	2010-16	17	abcd	45	abc	12046	abc	43	ab	105	a
Mariboss	2010-16	16	bcd	45	abc	10489	abc	60	ab	75	a
Benchmark	2014-19	12	cd	27	abc	7949	abc	45	ab	294	a
Tuareg	2010-14	15	cd	39	abc	5617	abc	43	ab	45	a
Creator	2013-19	11	cd	26	abc	9803	abc	51	ab	223	a
Olivin	2010-20	11	cd	15	bc	4588	c	38	ab	68	a
Skalmeje	2010-20	8	d	10	c	5540	bc	16	b	90	a

Across all tested cultivars, the correlation between the frequency of attacked ears and the slightly later score has been analysed (Figure 3). Only a moderate correlation ($R^2 = 0.56$) has been seen between the frequency of attacked heads at GS 75 and the infection rate at GS 77. This indicates that the development during approximately one week can be significant but also that it varies between cultivars. Some cultivars have a better resistance to spreading of attack in the individual ears, which affects the total expression of attack.

In addition, correlations between percentage of attacked heads and content of DON, NIV and ZEA have been analysed across all seasons. DON data varied greatly between seasons and levels were very high in some seasons (10-20000 ppb). In individual years DON correlated relatively well with disease attack, as e.g. seen in Figure 2. Across all seasons, the DON data have been log transformed and have shown moderate correlation with late scoring of attack (Figure 4). The same has been seen for the frequency of *Fusarium* and DON (Figure 5). With few exceptions, NIV has only appeared at significant levels when the level of DON has been high as illustrated in Figure 6.

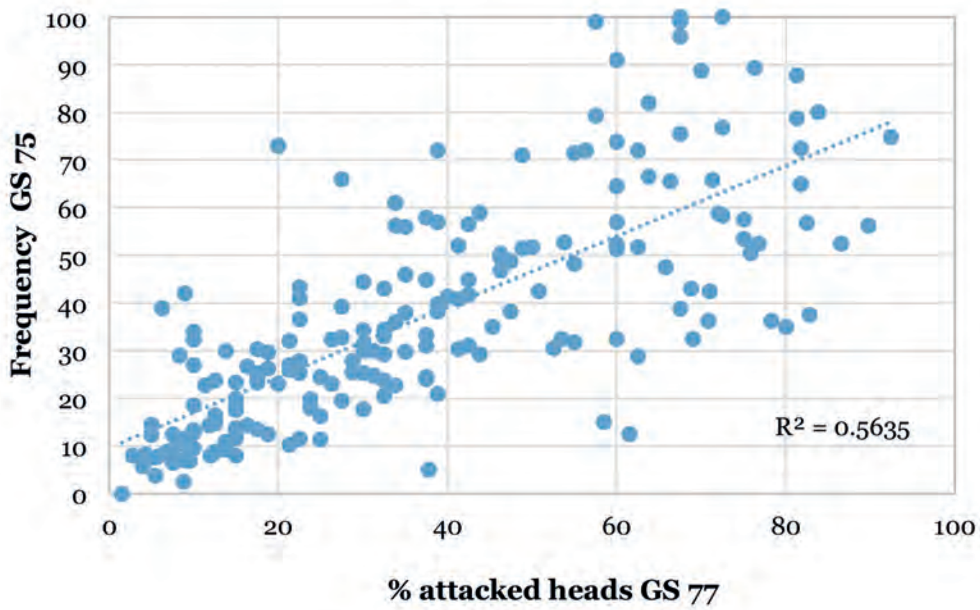


Figure 3. Correlation between % attacked heads with *Fusarium* (typically a week after GS 75) and frequency of attacked heads (GS 75).

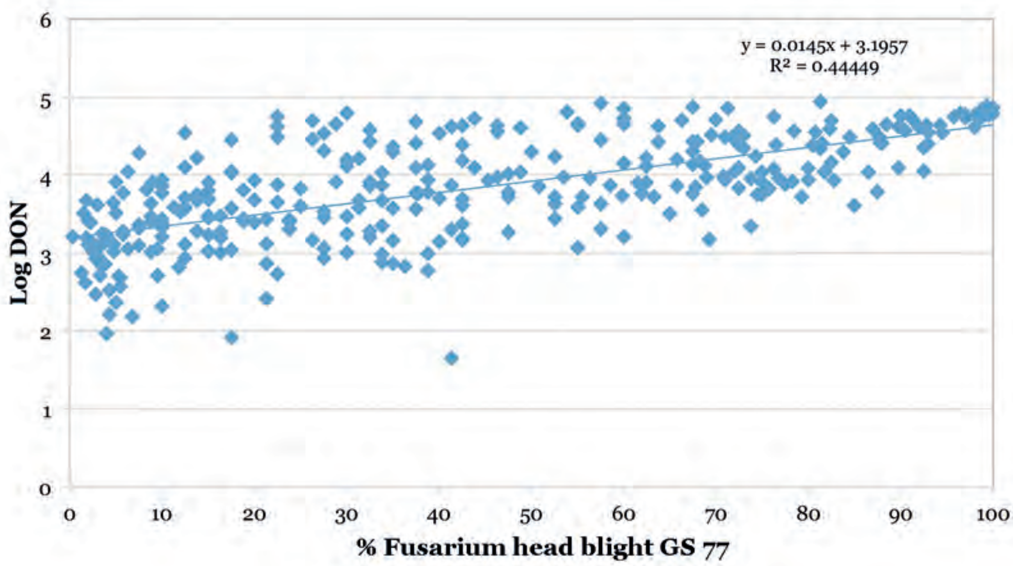


Figure 4. Correlation between % attacked heads at GS 77) and log-transformed DON content.

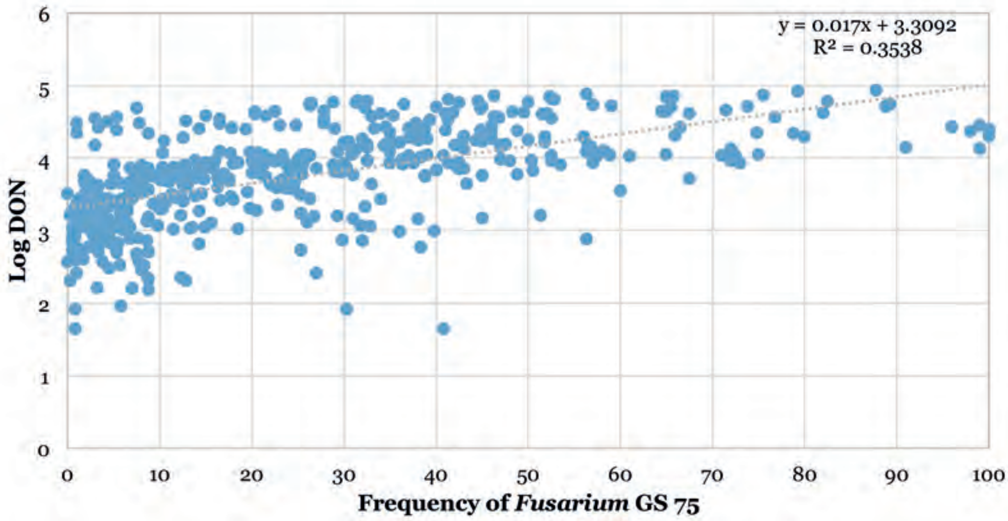


Figure 5. Correlation between frequency of heads with *Fusarium* at GS 75 and log-transformed DON content.

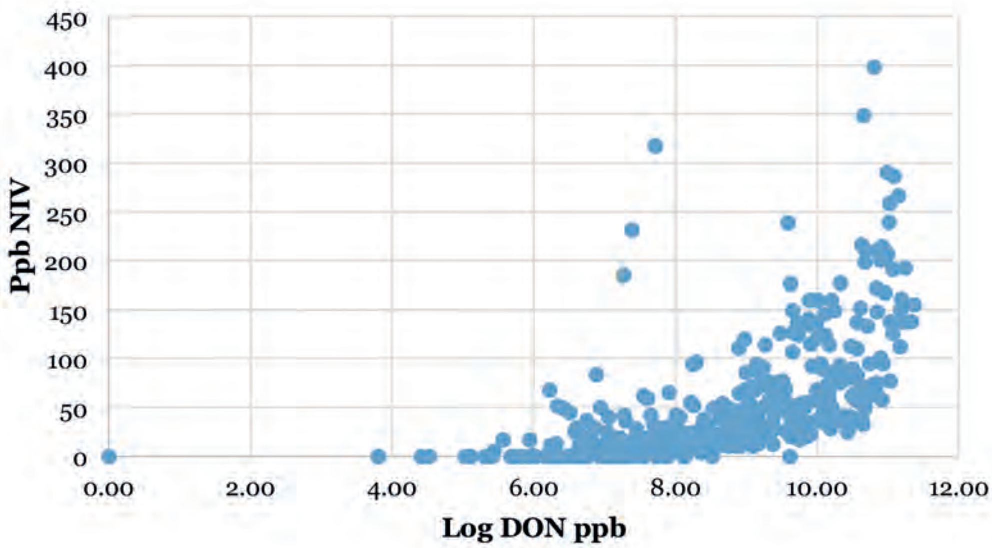


Figure 6. Correlation between log-transformed DON content and content of nivalenol (NIV).

Many different cultivars have been included in the testing across the 10 years. Thirteen cultivars have been included in more than 10 trials, and data from these trials have been compared. Skalmeje and Olivin have been included in all trials as resistant references and Ritmo and Oakley as susceptible references (Figure 7). Of the cultivars which have been marketed, Creator and Benchmark have shown the lowest level of attack, and hence the highest level of tolerance/resistance, while Torp and KWS Lili have shown high susceptibility.

The same ranking has been seen for DON and NIV levels, while the level of ZEA has been more unclear and very low in most seasons (Figures 8, 9, 10). Data indicate that some cultivars have a higher suppressive ability on DON production that others. For example Hereford has had lower DON than what could be expected from the visual attack assessment and in contrast Sheriff has shown higher DON content than expected.

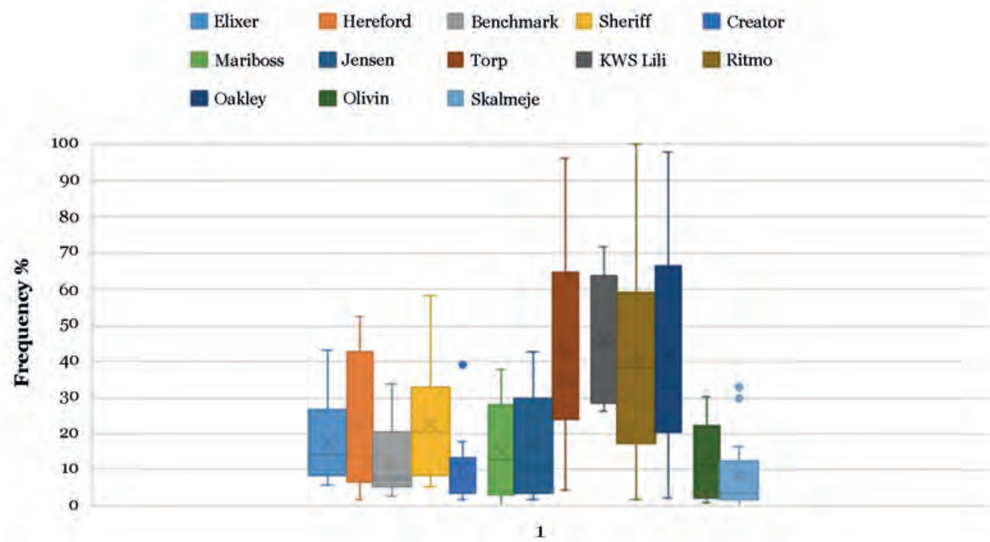


Figure 7. Frequency of Fusarium head blight in 13 cultivars, which each have been included in a minimum of 10 trials.

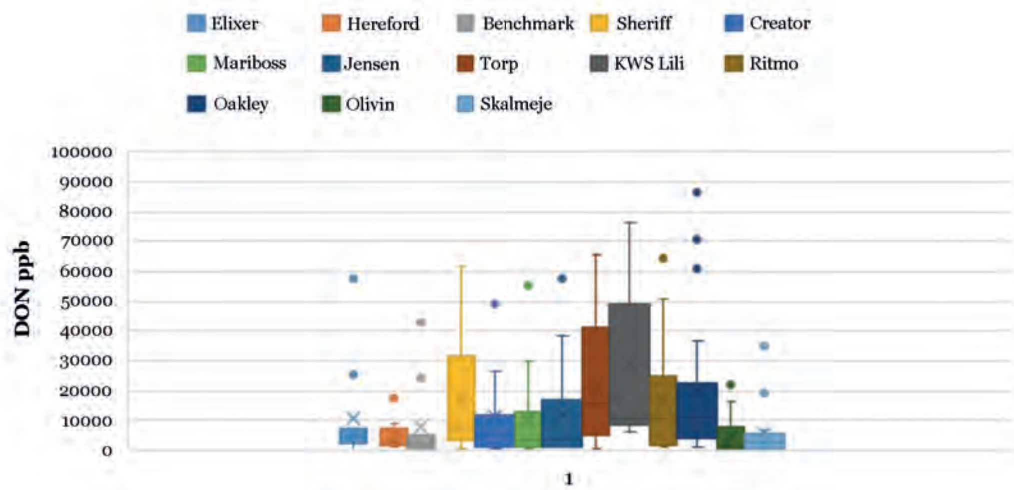


Figure 8. Content of DON in grain from 13 cultivars, which each have been included in a minimum of 10 trials.

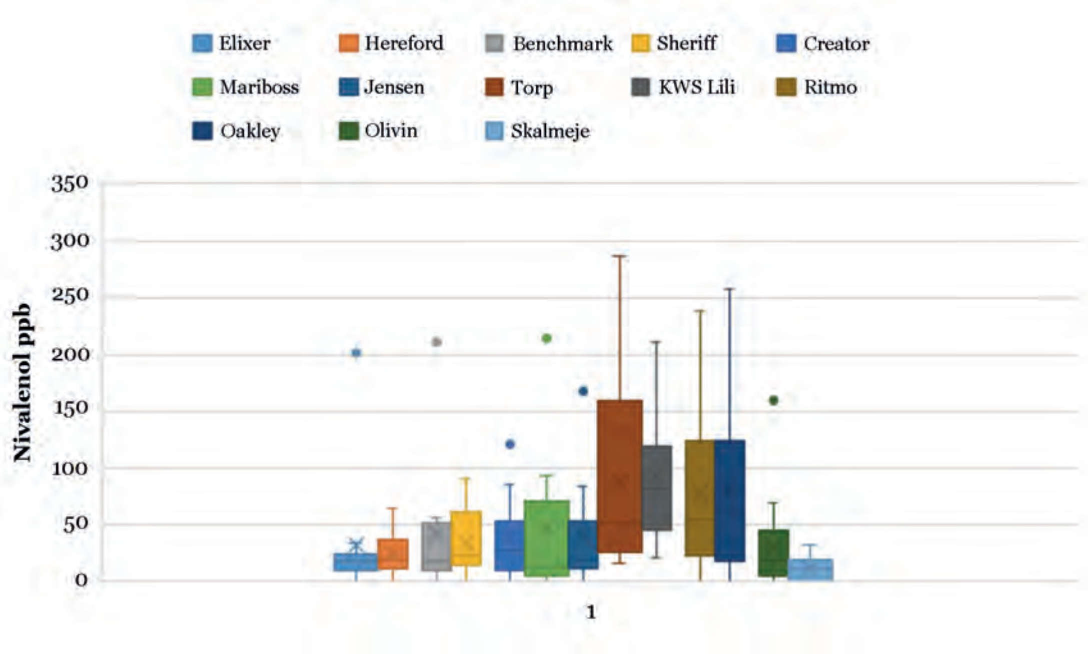


Figure 9. Content of NIV in grain from 13 cultivars, which each have been included in a minimum of 10 trials.

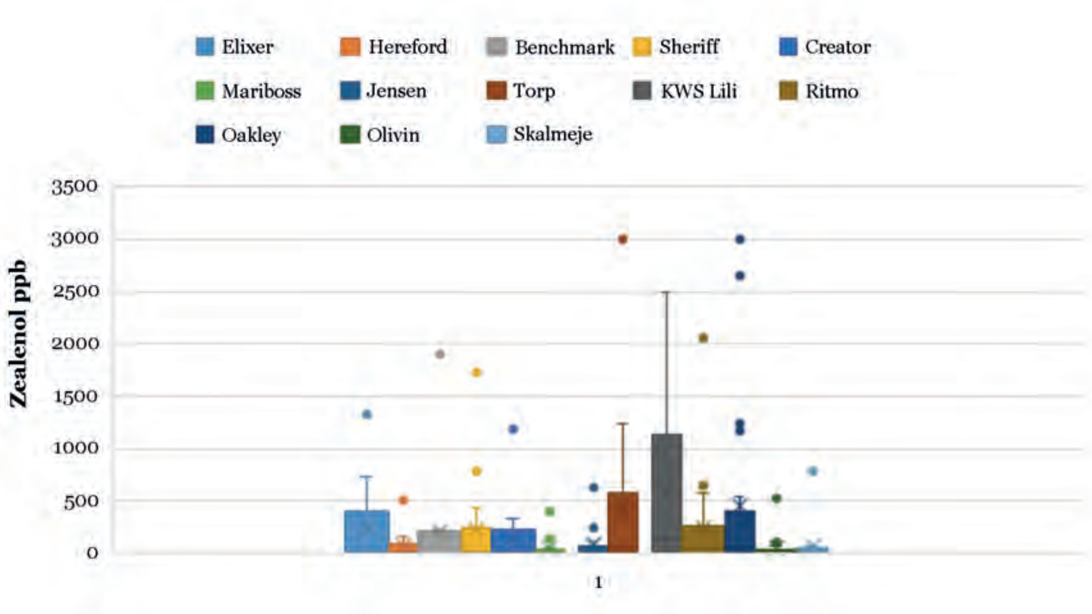


Figure 10. Content of ZEA in grain from 13 cultivars, which each have been included in a minimum of 10 trials.

IV Control strategies in different cultivars of winter wheat and winter and spring barley

Lise Nistrup Jørgensen, Niels Matzen, Hans-Peter Madsen, Helene Saltoft Kristjansen, Sidsel Kirkegaard & Anders Almskou-Dahlgaard

Data from 6 wheat cultivars

Eight different control strategies for control of leaf diseases in winter wheat were compared in 6 different wheat cultivars. The strategies included input with either one, two or three timings. Two trials were initiated, one at Flakkebjerg and one at Velas near Horsens. Unfortunately, the trial at Flakkebjerg was severely hit by take-all and data could not be used. Only data from the trial placed near Horsens will be presented. The following strategies were tested in all 6 cultivars; the content in actives can be seen in Chapter XII; for each strategy information on Treatment Frequency Index (TFI) is given along with the cost of treatment given in dt grain/ha. Cost of chemicals and application is based on a list from SEGES:

1. Untreated
2. 1.25 l/ha Balaya (GS 45-51) (TFI = 1.3); cost: 5.8 dt/ha
3. 1.0 l/ha Propulse SE 250 + 0.5 l/ha Folicur Xpert (GS 45-51) (TFI = 1.65); cost: 4.8 dt/ha
4. 0.75 l/ha Balaya / 0.35 l/ha Propulse SE 250 + 0.15 l/ha Folicur Xpert 250 (GS 37-39 / 55-61) (TFI = 1.35); cost: 5.7 dt/ha
5. 0.75 l/ha Univoq / 0.5 l/ha Balaya (GS 37-39 / 55-61) (TFI = 1.28); cost: 5.8 dt/ha
6. 0.35 l/ha Prosaro EC 250 / 0.75 l/ha Balaya / 0.35 l/ha Propulse SE 250 + 0.15 l/ha Folicur Xpert (GS 31 / 37-39 / 55-61) (TFI = 1.74); cost 7.2 dt/ha.

The trial in Horsens developed only minor to moderate attacks of *Septoria (Zymoseptoria tritici)*. Yellow rust (*Puccinia striiformis*) developed very severe infections in Benchmark and a minor attack in Sheriff, while none of the other cultivars had attacks of yellow rust.

The control of *Septoria* from the strategies was very similar (Table 1) and the level of attack was generally low and did not impact yields. In Benchmark all treatments with the exception of treatments 4 and 6 provided low and insufficient control when assessed at GS 71 on leaves 2 and 3. In Benchmark, the strategies using only one and two timings failed as treatments were applied too late to cope with the severe outbreak. When strategies 4 and 5 were compared, it could be seen that a severe attack of yellow rust can create challenges for the new test products Balaya and Univoq. Even so, strategy 4 gave a better control than strategy 5, probably due to the tebuconazole being included in Folicur Xpert. Treatments with two and three sprays increased yields in Benchmark significantly more compared with the single spray treatment. One spray strategy increased yields by 11-14 dt/ha, two spray strategies increased yields by 19-24 dt/ha and three spray strategies increased yields by more than 36 dt/ha. In the other cultivars yields increased only by less than 10 dt/ha, and most treatments did not provide economic yield benefits once the cost of treatments had been deducted.

Table 1. Per cent attack of *Septoria* and yellow rust, green leaf area, yield increases and net yield increase. Data from 1 trial (Horsens) with 6 winter wheat cultivars, using 5 different fungicide strategies (20350). Strategies with different letters are significantly different. (Continues on the next page).

Cultivars	% *Septoria*, leaf 3, GS 71						% *Septoria*, leaf 2, GS 75					
	Untr.	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	Untr.	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert
Cultivar mixture	5.3	2.2	1.5	0.7	0.8	0.7	0.7	0.2	0.2	0.0	0.0	0.0
Benchmark	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kvium	3.0	0.8	1.7	0.8	1.3	0.7	3.0	0.0	0.0	0.0	0.0	0.0
Sheriff	10.0	2.0	3.0	0.8	1.2	0.3	2.5	0.4	0.2	0.0	0.1	0.2
Informer	6.0	1.2	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
KWS Extase	1.2	0.2	0.0	0.2	0.0	1.7	1.2	0.2	0.0	0.2	0.0	0.0
Average	4.3 a	1.1 b	1.0 b	0.4 b	0.6 b	0.6 b	1.5 a	0.1 b	0.1 b	0.0 b	0.0 b	0.0 b

Cultivars	% yellow rust, leaf 3, GS 71						% yellow rust, leaf 2, GS 71					
	Untr.	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	Untr.	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert
Cultivar mixture	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Benchmark	100.0	100.0	100.0	63.3	98.3	36.7	100.0	86.7	70.0	18.3	43.3	11.7
Kvium	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0
Sheriff	1.0	0.3	0.4	0.2	0.3	0.0	1.2	0.4	0.1	0.0	0.3	0.0
Informer	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
KWS Extase	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	16.8 a	16.7 a	16.7 a	10.6 b	16.4 a	6.1 c	17.3 a	14.5 ab	11.7 b	3.1 c	7.3 b	2.0 d

Table 1. Per cent attack of *Septoria* and yellow rust, green leaf area, yield increases and net yield increase. Data from 1 trial (Horsens) with 6 winter wheat cultivars, using 5 different fungicide strategies (20350). Strategies with different letters are significantly different. (Continued).

Cultivars	% green area, leaf 1, GS 85						TGW (g)					
	Untr.	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	Untr.	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert
Cultivar mixture	41.7	60.0	56.7	53.3	51.7	50.0	48.8	49.0	50.6	51.0	50.8	51.7
Benchmark	0.0	0.0	0.0	0.0	0.0	0.0	37.8	35.0	38.8	40.8	38.8	45.7
Kvium	31.7	65.0	61.7	55.0	61.7	56.7	50.0	49.6	52.3	51.3	47.3	51.9
Sheriff	28.3	46.7	46.7	51.7	50.0	53.3	41.6	42.9	42.5	43.6	43.2	43.0
Informer	53.3	81.7	100.0	100.0	100.0	100.0	52.3	53.4	54.7	54.2	52.9	53.0
KWS Extase	100.0	100.0	100.0	100.0	100.0	100.0	51.0	53.4	53.2	53.6	52.0	53.3
Average	44 a	59 b	61 b	60 b	61 b	60 b	48 a	47 a	49 a	49 a	48 a	50 a

Cultivars	Yield & yield increase, dt/ha						Net increase, dt/ha				
	Untr.	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	1.25 Balaya	1.0 Propulse SE 250 + 0.5 Folicur Xpert	0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert	0.75 Univoq / 0.5 Balaya	0.35 Prosaro EC 250 / 0.75 Balaya / 0.35 Propulse SE 250 + 0.15 Folicur Xpert
Cultivar mixture	97.5	4.1	3.1	3.6	1.0	5.0	-1.7	-1.7	-2.1	-4.8	-2.2
Benchmark	44.9	11.7	14.0	29.3	19.5	36.5	5.9	9.2	23.6	13.7	29.3
Kvium	92.6	10.4	8.5	8.5	2.3	10.8	4.6	3.7	2.8	-3.5	3.6
Sheriff	90.5	5.6	4.0	8.4	7.5	6.3	-0.2	-0.8	2.7	1.7	-0.9
Informer	90.5	2.6	2.1	1.9	1.6	6.1	-3.2	-2.7	-3.8	-4.2	-1.1
KWS Extase	100.4	3.6	1.5	6.8	3.8	3.8	-2.2	-3.3	1.1	-2.0	-3.4
Average	86.1 a	6.3 b	5.5 b	9.8 bc	6.0 b	11.4 c	0.5	0.7	4.1	0.2	4.2

Control strategies in different winter barley cultivars

In 4 winter barley cultivars 5 different control strategies including Crop Protection Online were tested. One trial was at Flakkebjerg and one at Velas in Jutland. The strategies given below were tested in the two trials. In the Velas trial, no treatments were applied following CPO as thresholds were not exceeded. The trial at Flakkebjerg was treated following recommendations from CPO with 0.35 l/ha Propulse SE 250 + 0.2 l/ha Comet Pro in all 4 cultivars on 6 May. This treatment was equal to a TFI of 0.55 and a cost of 2.5 dt/ha.

For each strategy, information on Treatment Frequency Index (TFI) is given along with the cost of treatment given in dt grain/ha. Cost of chemicals and application is based on a list from SEGES:

1. Untreated
2. 0.35 l/ha Prosaro EC 250 / 0.5 l/ha Balaya (GS 32 / GS 51) (TFI = 0.93); cost: 4.6 hkg/ha
3. 0.5 l/ha Balaya (GS 37-39) (TFI = 0.53); cost: 2.9 hkg/ha
4. 0.35 l/ha Prosaro EC 250 / 0.25 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro (GS 32 + GS 51) (TFI = 0.75); cost: 4.1 hkg/ha
5. Crop Protection Online (CPO) (Table 2)

The overall disease attacks of scald (*Rhynchosporium commune*), brown rust (*Puccinia hordei*) and powdery mildew (*Blumeria graminis*) were limited in the trials. Kosmos was the cultivar with most attack of brown rust, Frigg had most scald and Memento most attack of powdery mildew. The overall control from the different control strategies was satisfactory (Table 2).

As a result of the low to moderate levels of disease attack the yield responses from treatments were also moderate and relatively similar. Only Kosmos gave positive net yield responses although still relatively low net returns.

Table 2. Per cent attack of diseases in winter barley and yield increases. Data from 2 trials in 4 winter barley cultivars using 4 different strategies (20351). Strategies with different letters are significantly different.

Cultivars	% *Rhynchosporium*, leaf 2, GS 73-75					% brown rust, leaf 2, GS 73-75				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO
Frigg	7.3	5.1	5.3	2.9	2.7	0.2	0.2	2.0	0.7	0.5
Memento	2.8	1.3	3.7	2.2	1.5	1.8	0.5	0.8	2.2	0.2
Hejmdal	4.7	2.3	3.7	3.9	3.3	0.8	0.5	0.0	0.3	0.2
Kosmos	3.8	1.7	1.1	1.9	1.4	5.5	0.1	0.4	0.7	0.9
Average	4.7 a	2.6 b	3.5 b	2.7 b	2.2 b	2.1 a	0.3 b	0.8 b	1.0 b	0.5 b
No. of trials	2					2				

Cultivars	% mildew, leaf 2-3, GS 73-75					TGW				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO
Frigg	0.0	0.0	0.0	0.0	0.0	44.3	44.9	46.6	42.2	45.7
Memento	10.0	0.4	0.4	0.5	0.8	48.8	48.6	47.3	50.5	47.6
Hejmdal	0.0	0.2	0.0	0.0	0.0	41.4	41.9	41.2	42.6	41.1
Kosmos	0.9	0.1	0.0	0.3	0.2	42.1	42.9	41.7	41.7	41.3
Average	2.7 a	0.2 b	0.1 b	0.2 b	0.3 b	44.2	44.6	44.2	44.3	43.9
No. of trials	2					1				

Cultivars	Yield & yield increase, dt/ha					Net increase, dt/ha			
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO
Frigg	86.48	-9.5	0.7	-2.9	-8.0	-14.1	2.2	-1.9	-9.3
Memento	80.95	-1.2	-4.3	0.7	-2.3	-5,8	-7.2	-11.3	-3,6
Hejmdal	80.62	1.0	4.1	1.4	7.3	-3.6	1.2	-2.9	6.0
Kosmos	80.36	10.3	5.2	6.1	9.7	5.7	2.3	-1.8	8.4
Average	82.1 a	0.1 a	1.4 a	1.3 a	1.7 a	-4.5	-1.5	-5.6	0.4
No. of trials	2					2			

Control of strategies in different spring barley cultivars

In 4 spring barley cultivars 4 different control strategies including control and Crop Protection Online (CPO) were tested. One trial was placed at Flakkebjerg and one at Velas in Jutland. The strategies given below were tested in the two trials. CPO did not recommend any treatment at Flakkebjerg, while the treatments at Velas were 0.35 l/ha Propulse SE 250 + 0.25 l/ha Comet Pro in all 4 cultivars, applied on 10 June. This treatment was equal to a TFI of 0.59 and a cost of 2.6 dt/ha.

For each strategy, information on Treatment Frequency Index (TFI) is given along with the cost of strategies given in dt grain/ha. Cost of chemicals and application is based on a list from SEGES:

1. Untreated
2. 0.35 l/ha Prosaro EC 250 / 0.5 l/ha Balaya (GS 32 / GS 51) (TFI = 0-93); cost: 4.6 dt/ha
3. 0.5 l/ha Balaya (GS 37-39) (TFI = 0.53); cost: 2.9 dt/ha
4. 0.35 l/ha Prosaro EC 250 / 0.25 l/ha Propulse SE 250 + 0.3 l/ha Comet Pro (GS 32 + GS 51) (TFI = 0.75); cost: 4.1 dt/ha
5. Crop Protection Online

The disease attacks of brown rust (*Puccinia hordei*), Ramularia leaf spot (*Ramularia collo-cygni*) and scald (*Rhynchosporium commune*) were limited; only net blotch developed a significant attack, in particular in Laurikka and RGT Planet. The overall control from the different control strategies was satisfactory, including the CPO treatments (Table 3). An exception to this was control of net blotch and *Ramularia*, where the trial at Flakkebjerg developed late attacks of both diseases in the CPO plots, which stayed untreated. However, as a result of the relatively low to moderate level of disease attack the yield responses from treatments were also low to moderate and very similar (1.6-4.3 dt/ha). Only RGT Planet gave positive although still low net yield responses. The three other cultivars in the trials did not need treatments in 2020.

Table 3. Per cent attack of diseases in spring barley and yield responses from 2 trials in 4 different spring barley cultivars using 4 different strategies. Untr. = Untreated. CPO = Crop Protection Online (20352-1 + 20352-2).

Cultivars	% brown rust, leaf 2, GS 73-77					% *Ramularia*, leaf 2, GS 77				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO
Laurikka	1.0	0.4	0.7	0.4	0.4	0.0	0.0	0.0	0.0	0.0
RGT Planet	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KWS Irina	0.6	0.0	0.0	0.0	0.2	4.3	0.0	0.3	0.0	3.7
Milford	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	0.4 a	0.1 a	0.3 a	0.1 a	0.1 a	1.1 a	0.0 b	0.1 b	0.0 b	1.0 a
No. of trials	2					1				

Cultivars	% net blotch, leaf 2, GS 73-77					% *Rhynchosporium*, leaf 2-3, GS 73-77				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO
Laurikka	15.1	0.5	5.4	1.5	16.7	0.9	0.0	0.5	0.1	0.0
RGT Planet	7.2	0.3	2.0	0.2	7.6	0.1	0.0	0.1	0.0	0.2
KWS Irina	6.2	0.2	1.8	0.6	6.4	0.8	0.4	0.4	0.1	0.5
Milford	3.3	0.0	0.8	0.0	2.7	1.0	0.0	0.4	0.0	0.6
Average	8.0 a	0.3 c	2.5 b	0.6 c	2.1 b	0.7 a	0.1 b	0.4 ab	0.0 b	0.3 ab
No. of trials	1					2				

Cultivars	GLA %, leaf 1, GS 87-89					TGW, g/1000				
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO
Laurikka	6.3	16.7	8.5	18.7	12.7	46.8	49.5	48.5	49.1	48.4
RGT Planet	10.8	26.7	26.2	33.3	7.3	50.9	51.4	51.9	53.1	49.8
KWS Irina	13.7	14.0	23.7	24.2	17.2	48.8	50.8	49.6	50.5	50.0
Milford	17.5	25.0	14.0	15.8	17.8	49.2	49.8	48.2	49.8	48.4
Average	12.1 a	20.6 a	18.1 a	23.0 a	13.8 a	49 a	50 b	50 b	51 b	49 a
No. of trials	1					2				

Cultivars	Yield & yield increase, dt/ha					Net increase, dt/ha			
	Untr.	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO	0.35 Prosaro EC 250 / 0.5 Balaya	0.5 Balaya	0.35 Prosaro EC 250 / 0.25 Propulse SE 250 + 0.3 Comet Pro	CPO
Laurikka	62.7	3.3	1.8	4.7	2.4	-1.3	-1.1	0.6	1.1
RGT Planet	62.9	6.7	5.1	4.4	3.8	2.1	2.2	0.3	2.5
KWS Irina	63.3	2.5	1.2	2.6	-0.4	-2.1	-1.7	-1.5	-1.7
Milford	64.6	2.9	1.4	5.5	0.4	-1.7	-1.5	1.4	-0.9
Average	63.4 a	3.9 b	2.4 b	4.3 b	1.6 ab	0.8	-0.5	0.2	0.3
No. of trials	2					2			

V Diseases in red fescue

Lise Nistrup Jørgensen, Hans-Peter Madsen & Birte Boelt

During spring 2018, 2019 and 2020, 86 fields with red fescue distributed across Falster, Zealand and Funen were monitored for attacks of leaf diseases. The focus was to assess for leaf blotch diseases such as *Ascochyta* leaf spot, causing different degrees of senescence in the crops. The attacks were frequent with attack typically in the range of 1-10%. The attack in 2020 was moderate and in line with 2018. The attack in 2^{nd} and 3^{rd} year crops was more severe than in 1^{st} year crops. DNA analysis of the fungi populations on the leaf samples verified a wide range of fungi present in the fields. Application of fungicides has not been economic in 2020, which is in line with results from the two previous seasons. In general, only very few trials have given positive yield responses from fungicide application. In line with good IPM practice, it is recommended not to apply routine fungicide treatments in red fescue.

Red fescue for seed production is grown on a large scale, especially in the eastern part of Denmark. The total area with red fescue typically varies between 15,000 and 20,000 ha per year. Traditionally, we have considered red fescue one of our healthiest herbage grass seed crops, which is rarely affected by serious disease attacks and the reason why red fescue rarely has responded positively to fungicide treatments. In recent years, however, positive yield responses from fungicide application were seen in some cases where a significant attack of leaf spot diseases was present.

In order to gain insight into how many fields are affected by leaf spot diseases, AU Flakkebjerg investigated how commonly and severely fields were affected by leaf disease during three growing seasons. In addition, specific experiments were carried out to investigate whether one or two fungicide treatments in spring can reduce the attacks of leaf spot and improve yield. This activity was funded by "Frøafgiftsfonden".

Diseases of importance

Apart from powdery mildew and rust diseases, Ascochyta leaf spot was the main focus of the investigation. The *Ascochyta* fungus is characterised by production of black spores (pycnidia), which typically form when the leaves wither. By microscopy of infected leaves, two cellular spores are seen, which are spread from the spore housings.

During three growing seasons (2018, 2019 and 2020), monitoring was conducted and levels of leaf diseases in red fescue seed crops were assessed. The fields were chosen in collaboration with consultants from the seed companies. In addition to information on location, cultivar and seed production year (1^{st}, 2^{nd} or 3^{rd}) were recorded. In 2018, 30 fields were surveyed, 34 in 2019 and 22 in 2020. Sites were divided into three regions with typically 10 fields per region (West Zealand, South-East Zealand + Falster, Funen + Tåsinge and Langeland). The data collected showed great variation in the incidence of attacks. For all the fields visited, an assessment was made of the attack rate at 10-20 spots at a cross section of the field. In 2018 and 2019, the fields were visited twice, the first time in April and the second time in June. In 2020, fields were only visited in April as the two previous seasons showed no differences between first and second visit. In general, the attack in 2020 was moderate and in line with the attack in 2018. The attack in 2019 was clearly more widespread (Table 1). On average approx. 20% of all fields had more than 10% attack, 64% had attack between 1 and 10% and only 16% had no attack at all. The prevalence of attacks in the three regions varied between seasons (Table 2), and no clear conclusion can be made regarding risks in different regions.

In total, the monitoring included 15 locations of 1st year crops, 56 locations of 2nd year crops and 13 locations of 3rd year crops. Attack rates were on average 2%, 6% and 12%, respectively (Table 3). Thus, there was a tendency to more attacks in 2nd and 3rd year crops, indicating that the infection built up over time. The monitoring was carried out in more than 20 different cultivars, and it was not possible to extract a clear picture of whether there was any variation of susceptibility depending on the actual cultivar.

The 2018 season was extremely dry and conditions were generally not favourable for disease development. The 2019 season was more normal as regards the weather, but no development was observed in the attacks in the season from April to June. The 2020 spring was very dry, which is expected to have limited the spread of the pathogens. During the assessments in 2020, attack of brown rust was quite pronounced in several of the fields, which was in contrast to the previous seasons where mildew and rust were seen to a very limited extent.

Table 1. Main data from monitoring of attacks of leaf spot in red fescue crops assessed during three seasons. The numbers are frequency of crops attacked in the different categories.

Degree of attack in the crop	Frequency (%) of crops in the different categories			
	2018	2019	2020	Average
More than 10% leaf area attack	13	38	5	19
1-10% attack	60	59	77	65
< 1% attack	27	3	18	16
Number of fields	30	34	22	86

Table 2. Average attack of leaf blotch diseases in red fescue seed crops in three regions in Denmark during 3 seasons. Numbers in brackets describe the number of crops monitored.

Year	Funen, Tåsinge, Langeland	Falster and South-East Zealand	West Zealand
2018	3.9 (10)	7.0 (10)	1.9 (10)
2019	6.9 (11)	6.2 (10)	11.7 (13)
2020	3.1 (10)	5.4 (5)	5.9 (7)

Table 3. Attack of leaf blotch diseases in red fescue seed crops, categorised as 1st, 2nd or 3rd production year.

Production year	Number of crops	Average attack%
1st year	15	1.8
2nd year	56	5.8
3rd year	13	11.7

Ascochyta disease is difficult to determine

From the literature is known that the *Ascochyta* fungus can also attack other grasses, i.a. Kentucky bluegrass (*Poa pratensis* L.). From the United States is described that the fungus survives on dead plant material or debris from trimming or cutting. The pycnidia are drought resistant, and the spores spread in humid weather conditions, including ”splash” from rain. However, even in the United States, it is not clear which factors are the most important for epidemic attacks.

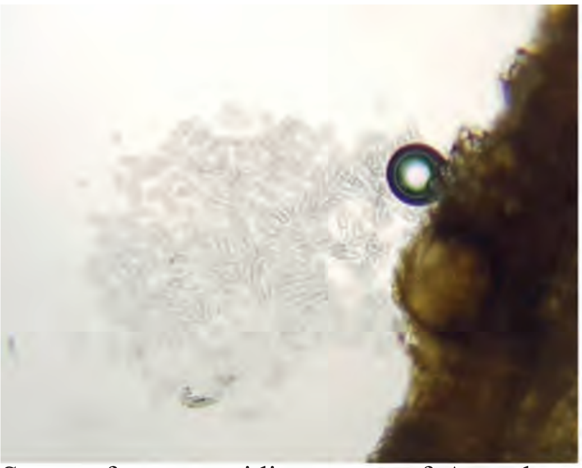
The symptoms of *Ascochyta* in the field are seen as dry leaves that can easily be mistaken for attack by other diseases or for drought stress. As part of the project, plant specimens with infestations were sampled during the monitoring. The samples were subsequently investigated in the laboratory to provide a better understanding of the diseases that appear and dominate in the studied fields.

Even after microscopy, it was not possible to distinguish clearly whether the leaf spot attacks were in all cases caused by *Ascochyta*, or whether other leaf spot fungi, e.g. infestation of fungi belonging to the *Helmintosporium* spp. group, were involved. As other leaf fungal species can easily be mistaken for *Ascochyta*, DNA was extracted from infected leaves and DNA libraries were prepared for DNA barcoding and sequenced. By comparing DNA sequences to existing DNA libraries, it was possible to get an overview of the fungi populations found on the ”diseased leaves”. The method provided information on the family and genus of the leaf fungal species. Only in few cases was it possible to track information to specific taxonomic species. The analysis covered all fungi on the leaves, not just those which we regarded as plant pathogens.

In total, 41 samples from the two first seasons were analysed using this technique. Many genera of fungi could be identified from the leaf samples. Most dominant in the samples were *Oculimacula* (closely related to eyespot in cereals), *Neoascochyta* (= *Ascochyta*), *Cladosporium*, *Alternaria*, *Stagonospora*, *Microdochium* and *Puccinia* as well as various yeast fungi - for more details see Applied Crop Protection 2019. Samples from 2020 have not yet been analysed.

Field trials with fungicides

In all three growing seasons, trials were conducted to investigate if fungicides could control the attack. The trials were located in selected crops where leaf spot infestation was detected in early spring. In the experiments, broad-spectrum solutions including pyraclostrobin (Comet Pro) + boscalid + epoxiconazole (Bell) were sprayed at two different times: in early spring and during elongation. After spraying, disease attacks were assessed in the trials. In both 2018 and 2019 it had not been possible to see a clear visual reduction of the attacks in the treated plots compared to untreated plots, nor were significant yield increases obtained after treatment. In 2020, the trials were carried out in a 1st year and a 2nd year crop at Flakkebjerg, in both cases including two cultivars. In neither of these trials were significant attacks of leaf blotch seen, and no clear benefit was seen from treatments. Yield data gave no significant improvements following treatments. The only clear differences were increase of yields in the 2nd year crop compared with the 1st year crop, and Maxima was also seen to give a higher yield compared with Livista (Table 4).



Spores from pycnidia spores of Ascochyta leaf spot can be seen in microscopy. (Photo: Ghita C. Nielsen).

Attack of Ascochyta leaf spot in red fescue. Necrotic leaves with dark lesions. (Photo: Lise Nistrup Jørgensen).

Crop with 15% disease attack.(Photo: Hans-Peter Madsen).

Crop with 1% disease attack. (Photo: Hans-Peter Madsen).

Table 4. Yield responses in two trials (1st year and 2nd year) carried out in two red fescue cultivars and sprayed during 2020 (kg seeds/ha).

Fungicide treatments		2020 1st year field		2020 2nd year field		2020
GS 33-37	GS 51-55	Maxima	Livista	Maxima	Livista	Average
Untreated		1587	1005	1940	1373	1476
Bell + Comet Pro 0.75 + 0.5		1608	963	1898	1523	1498
Bell + Comet Pro 0.375 + 0.25		1777	848	1847	1683	1539
Bell + Comet Pro 0.375 + 0.25	Bell + Comet Pro 0.375 + 0.25	1478	985	1791	1430	1421
	Bell + Comet Pro 0.375 + 0.25	1556	893	1931	1583	1490
Propulse SE 250 0.5	Bell + Comet Pro 0.375 + 0.25	1621	1022	1657	1386	1422
Comet Pro 0.63		1550	966	1788	1733	1509
	Comet Pro 0.63	1527	851	1856	1231	1366
Propulse SE 250 0.5	Comet Pro 0.63	1601	925	1569	1407	1376
Average		1589	940	1808	1483	1455
LSD_{95}		NS	NS	NS	NS	NS
NS: Not significant						

VI Fungicide resistance-related investigations

Thies Marten Heick, Birgitte Boyer Frederiksen & Lise Nistrup Jørgensen

Fungicide resistance in *Zymoseptoria tritici* in Denmark and Sweden

Each year, leaf samples with apparent symptoms of *Z. tritici* (*Septoria*) are collected around growth stage 73-77 in collaboration with SEGES and local advisors in Denmark and Jordbruksverket in Sweden. The resistance level of the wheat pathogen *Zymoseptoria tritici* against prothioconazole (prothioconazole-desthio; azole group) and fluxapyroxad (SDHI group) is tested *in vitro* to survey the sensitivity of the Danish-Swedish *Z. tritici* populations. The resistance testing is carried out at AU Flakkebjerg. In 2020, 110 Danish isolates from 19 sites and 157 Swedish isolates from 24 sites were investigated for sensitivity to prothioconazole-desthio and fluxapyroxad (Tables 1, 2, 3 and 4). The disease pressure of *Septoria* was low to medium in 2020.

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 to 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 (ppm): 6.0, 2.0, 0.6, 0.2, 0.07, 0.008 and 0.002 (prothioconazole-desthio) and 3.0, 1.0, 0.3, 0.1, 0.03, 0.01, 0.0033 and 0 ppm (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* was inhibited by 50% (EC50) 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 test resistance to prothioconazole with the metabolite prothioconazole-desthio, which has been included in the testing since 2016. In 2020, the average EC50 value for the Danish *Z. tritici* isolates with 0.44 ppm was slightly higher than in 2019 (0.26 ppm) and 2018 (0.33 ppm) (Figure 1; Table 2). The resistance factor (RF; EC50 value isolate/EC50 value reference isolate) for prothioconazole-desthio was 44 compared to 26 and 35 in the previous years.

The resistance levels of the SDHI fluxapyroxad in 2020 were at the same level as in 2019 with an average resistance factor of 3, indicating that the Danish *Z. tritici* population remains sensitive towards SDHI fungicides (Figure 2; Table 1). Overall, the results of the monitoring indicate that no shifting has occurred for neither of the two active ingredients. Investigations for SDHI mutations were carried out on both isolates and leaf samples from 2019 and 2020. Only two mutations were detected – T79 and N86S – and at low levels (<5%).

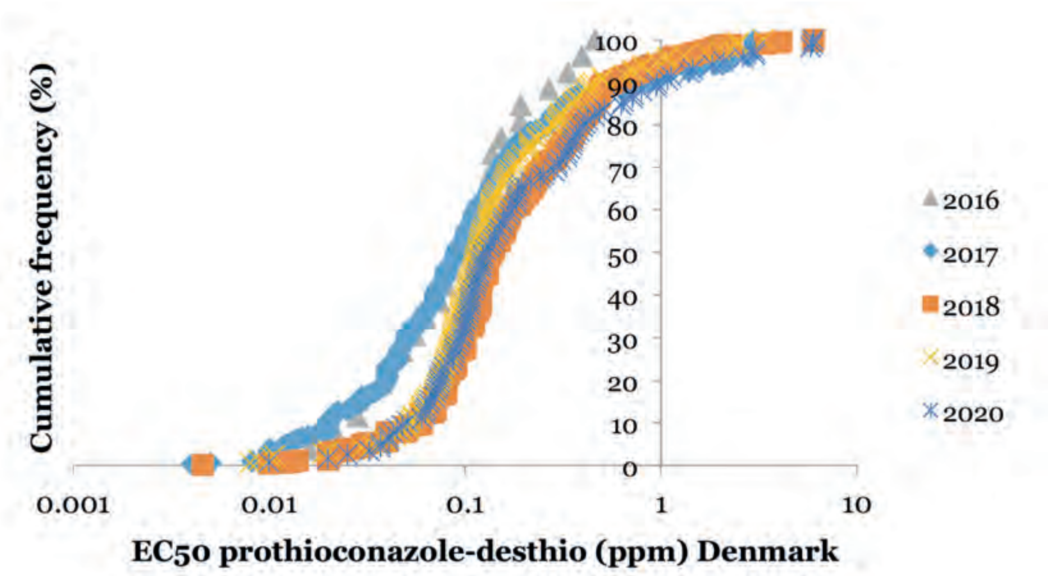


Figure 1. Cumulative frequencies of EC50 values of prothioconazole-desthio (ppm) for Danish *Z. tritici* populations in 2016-2020. Each point of the curve represents a single *Z. tritici* isolate.

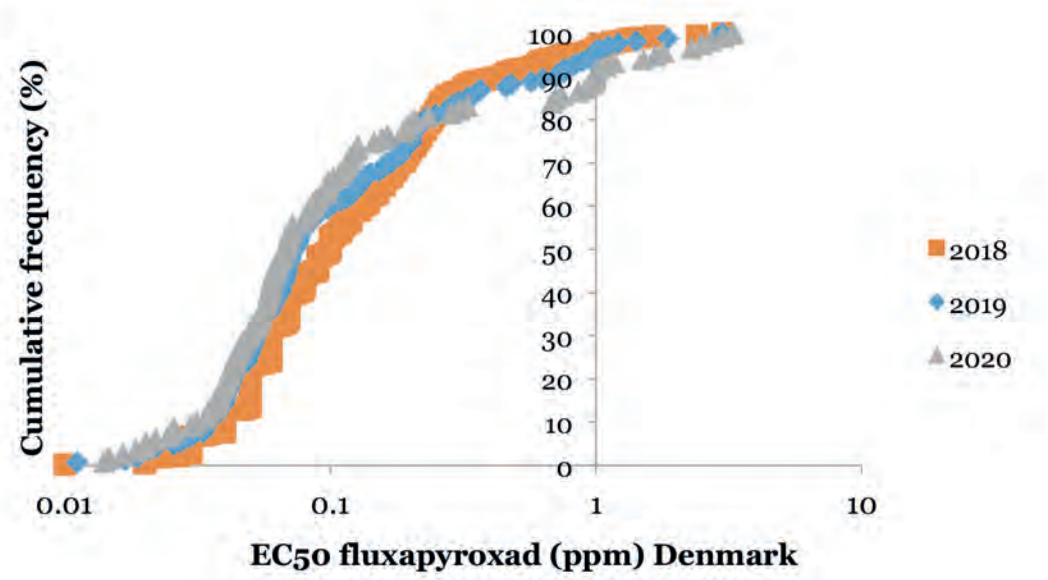


Figure 2. Cumulative frequencies of EC50 values of fluxapyroxad (ppm) for *Z. tritici* populations in Denmark in 2018 to 2020.

Table 1. Mean EC50 values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for *Z. tritici* from different sites in Denmark in 2020.

Location			EC50 (ppm)				Number
			Prothio-desthio	RF	Fluxa	RF	
20-ZT-DK-13	1	Flakkebjerg	0.24	24	0.10	1	1
20-ZT-DK-17	2	Kolind	1.35	135	0.38	4	5
20-ZT-DK-18	3	Hevring	0.20	20	0.16	2	6
20-ZT-DK-19	4	Maribo	0.38	38	0.07	1	5
20-ZT-DK-21	5	Sønderborg	0.21	21	0.30	3	5
20-ZT-DK-22	6	Vojens	0.89	89	0.23	2	9
20-ZT-DK-23	7	Fjerritslev	0.08	8	0.07	1	1
20-ZT-DK-24	8	Bornholm	0.11	11	0.12	1	2
20-ZT-DK-25	9	Bornholm	0.98	98	0.17	2	7
20-ZT-DK-26	10	LandboNord	0.29	29	0.06	1	9
20-ZT-DK-27	11	Agri Nord	1.04	104	1.23	12	4
20-ZT-DK-28	12	SLF	0.41	41	0.68	7	8
20-ZT-DK-30	13	Kolind	0.44	44	0.16	2	10
20-ZT-DK-34	14	SLF	0.18	18	0.13	1	3
20-ZT-DK-35	15	Sjælland	0.56	56	0.38	4	10
20-ZT-DK-36	16	Jylland	0.30	30	0.05	1	5
20-ZT-DK-37	17	Hjerm	0.16	16	0.55	6	6
20-ZT-DK-38	18	Ringsted	0.41	41	0.07	1	4
20-ZT-DK-39	19	Flakkebjerg	0.08	8	0.10	1	10
Average			0.44	44	0.26	3	110

Table 2. Summary of mean EC50 (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
Ref. IPO323	0.02-0.03	-	0.01	-	0.10-0.20	-

Results - *Sweden*

In 2020, no sensitivity shifting for prothioconazole-desthio has taken place. With an average of 0.15 ppm EC50 values for prothioconazole-desthio were at the same level as in 2019 (Figure 3 (prothioconazole-desthio Sverige); Tables 3 and 4), and lower than in the Danish population in 2020 (0.44 ppm). The results varied among sites (0.01-0.42 ppm), with resistance factors of 1–42 (Table 3). Sensitivity towards fluxapyroxad was in line with previous years (Figure 4) with an average resistance factor of 1 showing no resistance.

Table 3. Mean EC50 values and resistance factors (RF) for prothioconazole-desthio and fluxapyroxad for *Z. tritici* from different sites in Sweden in 2020.

Location			EC50 (ppm)				Number
			Prothio-desthio	RF	Fluxa	RF	
20-ZT-SW-01	1	Kavlås, Tidaholm	0.08	8	0.04	1	9
20-ZT-SW-02	2	Arvidsgården, Väring	0.35	35	0.12	1	4
20-ZT-SW-03	3	Håberg, Grästorp	0.06	6	0.07	1	6
20-ZT-SW-04	4	Tegalund, Nossebro	0.09	9	0.46	5	10
20-ZT-SW-05	5	Eke, Hasslösa/Vinninga	0.01	1	0.05	1	3
20-ZT-SW-06	6	Frändefors	0.07	7	0.12	1	9
20-ZT-SW-07	7	Källung, Visby	0.02	2	0.06	1	3
20-ZT-SW-08	8	Kölby, Kalmar	0.33	33	0.46	5	7
20-ZT-SW-09	9	Gärdslösa, Borgholm	0.23	23	0.03	1	1
20-ZT-SW-10	10	Möckleby, Degerhamn	0.28	28	0.17	2	9
20-ZT-SW-12	11	Glyttinge, Linköping	0.05	5	0.04	1	5
20-ZT-SW-13	12	Ullekalv, Mantorp	0.05	5	0.04	1	9
20-ZT-SW-14	13	Karleby, Väderstad	0.02	2	0.08	1	6
20-ZT-SW-15	14	Oxelvärsta, Sköllersta	0.05	5	0.34	3	10
20-ZT-SW-16	15	Klostergården, Berg	0.04	4	0.05	1	8
20-ZT-SW-17	16	Lövsta, Uppsala	0.04	4	0.08	1	10
20-ZT-SW-18	17	Bjällerup, Staffanstorp	0.15	15	0.12	1	9
20-ZT-SW-19	18	Falkenberg	0.18	18	0.04	1	3
20-ZT-SW-20	19	Eriksfält, Löderup	0.40	40	0.05	1	5
20-ZT-SW-21	20	Vranarp, Simrishamn	0.20	20	0.10	2	10
20-ZT-SW-22	21	Linelund, Klagstorp	0.34	34	0.10	2	9
20-ZT-SW-23	22	Mörarp, Helsingborg	0.42	42	0.06	1	6
20-ZT-SW-24	23	Borreby, Simrishamn	0.12	12	0.11	2	2
20-ZT-SW-26	24	Karlskrona	0.01	12	0.05	1	4
Average			0.15	15	0.14	1	157

Table 4. Summary of mean EC50 (ppm) values and resistance factors (RF) for epoxiconazole, prothioconazole-desthio and fluxapyroxad assessed for *Z. tritici* in Sweden. The total numbers of isolates tested are 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
Ref. IPO323	0.02-0.03	-	0.01	-	0.10-0.20	-

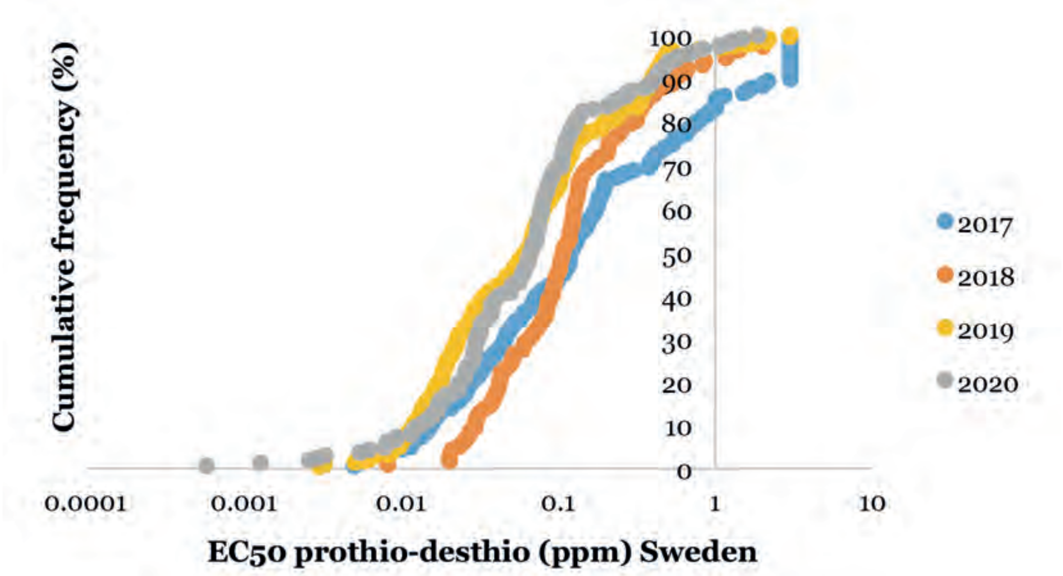


Figure 3. Cumulative frequencies of EC50 values of prothioconazole-desthio (ppm) for *Z. tritici* populations in Sweden in 2017-2019.

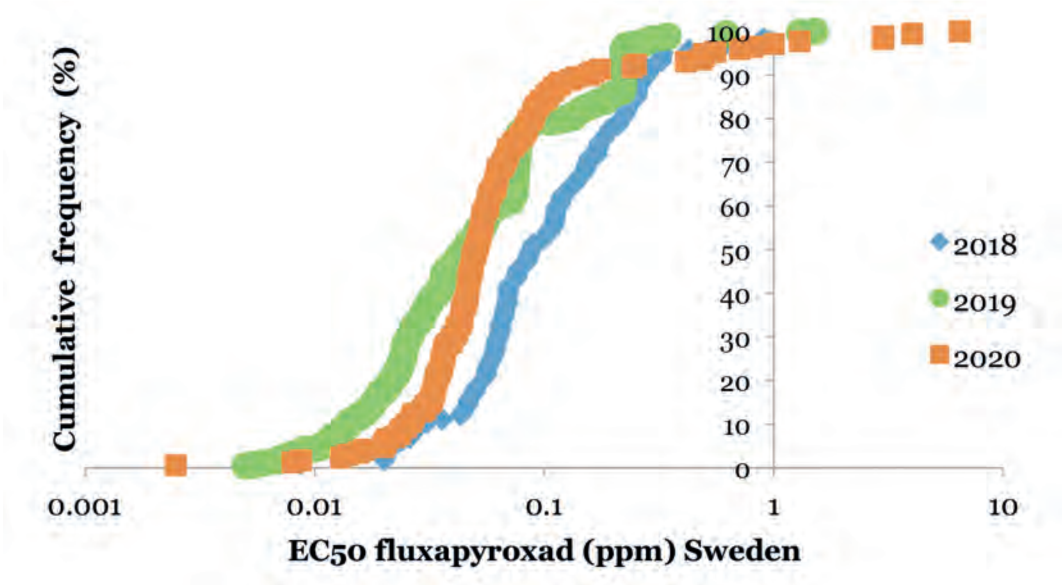


Figure 4. Cumulative frequencies of EC50 values of fluxapyroxad (ppm) for *Z. tritici* populations in Sweden in 2018 to 2020.

The sensitivity of mefentrifluconazole and tebuconazole

A subset of 58 *Z. tritici* isolates from Denmark and Sweden was tested for sensitivity to the azoles tebuconazole and mefentrifluconazole. The resistance level for tebuconazole has been at a high level for many years. In 2020, the average EC50 value was 1.98 ppm with single isolates ranging from 0.07 ppm to 17.17 ppm. This was lower than in 2018 and 2019, with 6.21 ppm and 6.79 ppm, respectively. The average EC50 was higher in Denmark (3.13 ppm) than in Sweden (0.91 ppm). The average RF for tebuconazole was ~ 200 (reference isolate IPO323: 0.006 ppm).

EC50 values for mefentrifluconazole ranged from 0.03 ppm to 3.00 ppm, with an average EC50 value of 0.82 ppm and a resistance factor of 82. In 2019, a subset of Danish and Swedish *Z. tritici* isolates was tested in the same way, where the average EC50 was 0.66 ppm (resistance factor 66). The range of EC50 values indicates a certain pre-adaption in the Danish-Swedish *Z. tritici* populations to mefentrifluconazole. Despite this pre-adaptation the field performance of mefentrifluconazole has been significantly better compared with the performances of the old azoles.

Cross-resistance of azole fungicides in the Danish-Swedish *Z. tritici* populations

It has previously been described that there are different cross-resistance patterns for *Z. tritici* to the azole fungicide group (Heick et al., 2020). Using the EC50 values (log-transformed) of this year's investigation, Figures 5 and 6 show the cross-resistance patterns of azoles mefentrifluconazole to tebuconazole and prothioconazole-desthio. There is a strong correlation between resistance to mefentrifluconazole and tebuconazole (R^2 = 0.8873). In contrast, no cross-resistance is seen between prothioconazole-desthio and mefentrifluconazole with an R^2 value of 0.058.

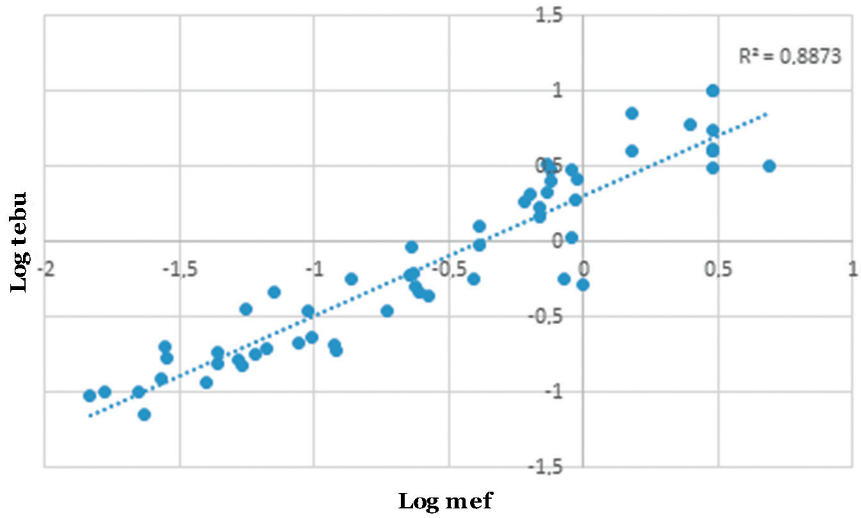


Figure 5. Cross-resistance of mefentrifluconazole and tebuconazole. EC50 values (ppm) are log-transformed.

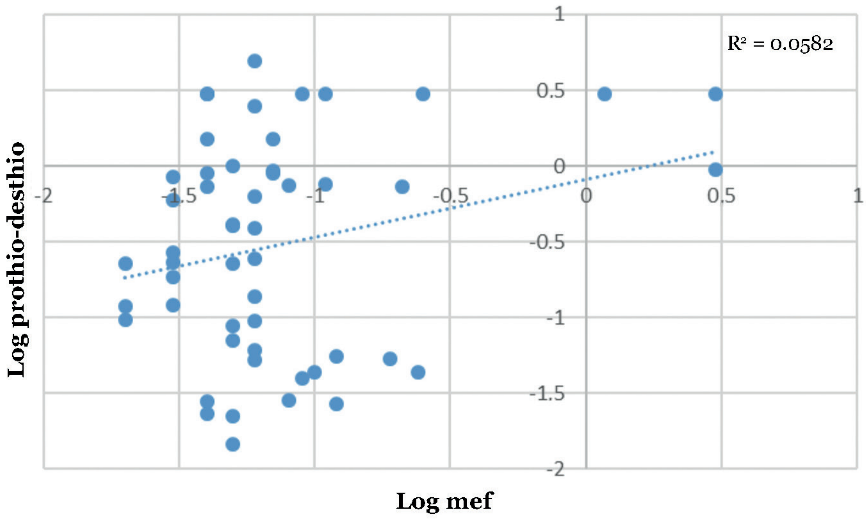


Figure 6. Cross-resistance of mefentrifluconazole and prothioconazole-desthio. EC50 values (ppm) are log-transformed.

CYP51 mutations in the Danish-Swedish *Z. tritici* populations 2020

The decline of azole efficacy has been linked to molecular changes in the target gene *CYP51*. In 2020, leaf samples from Denmark and Sweden were analysed by pyrosequencing (BASF) and qPCR for the frequency of the essential *CYP51* mutations in *Z. tritici*: D134G, V136A/C, I381V and S524T (Figure 7). Mutation I381V continued to dominate throughout the region and was present at frequencies of 90-100%. The frequencies for mutations D134G and V136A/C varied from 0% to 77%. Similarly, the frequencies of mutations S524T varied from 2% to 67%. The evolution of *CYP51* mutations in Denmark is illustrated in Figure 7. Compared to 2018 and 2019, the frequencies of *CYP51* mutations in Danmark and Sweden have remained stable in 2020.

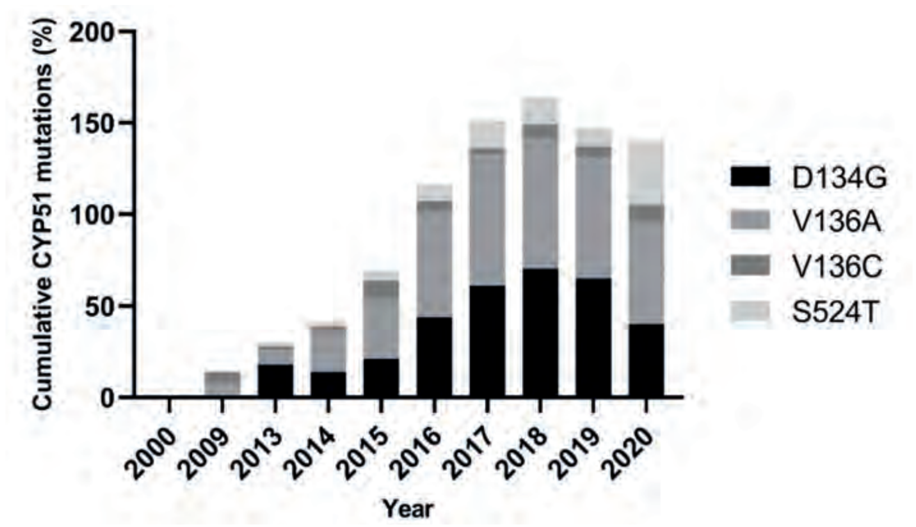


Figure 7. Cumulative frequencies of *CYP51* mutations D134G, V136A/C and S524T for the Danish *Z. tritici* populations 2000-2020.

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

Strobilurin resistance

In 2020, nine Danish net blotch samples from barley 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 were collected by AU Flakkebjerg, SEGES, and Tystofte Foundation and originate from untreated plots in field trials. As in previous years, the investigation for F129L was carried out by BASF. The data from 2020 showed that the level of F129L in the population of *Pyrenophora teres* remains stable with no dramatic changes.

Data showed that F129L was present in all the tested Danish samples. The frequencies of the mutation ranged from 13% to 100%. Data from the last ten years' monitoring are shown in Table 5. Over the past 12 years, the distribution and frequency of F129L has increased. So far this has not been impacting control from Comet Pro (pyraclostrobin). Amistar 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	8	3	0	3	0	38
2016	20	9	3	8	0	55
2017	10	2	4	2	2	80
2019	12	1	5	3	3	92
2020	9	0	2	2	5	100

Additionally, seven *P. teres* samples from Sweden were investigated for F129L. Six samples were tested positive. Those samples came from fields around Dalham (43%), Kalmar (75%), Åsmestad (38%), Skänninge (78%) and Trelleborg (34% and 55%). One sample from a field in Tjerp was tested negative for F129L.

SDHI mutation

Several target-site mutations in the Sdh subunits SDH-B, SDH-C and SDH-D with different impact on SDHI fungicides have been detected (Rehfus et al., 2016). The pattern of mutations varied across Europe between years and regions. The most sensitive Ptm strain did not carry any Sdh mutations known to affect SDHI sensitivity and was only able to grow at 0.1 ppm fluxapyroxad as the highest concentration. Mutations SdhC-S135R and SdhD-H134R, known to affect SDHI binding, were detected in the majority of the SDHI-insensitive *P. teres* strains that were able to grow in the presence of 10 ppm of fluxapyroxad. In the UK, it has been found that the most SDHI-insensitive *P. teres* strain showed partial growth at 100 ppm fluxapyroxad. These isolates have SdhC-S135R mutations in combination with SdhD-G138V (Fraaije et al., 2020).

In 2020, nine samples were analysed by BASF for nine different SDHI mutations by pyrosequencing (Table 6). Only SdhC-S135R was detected in the populations. As SdhD-G138V mutations were not included in this investigation, it is not known if the combinations giving low sensitivity were present in the Danish and Swedish samples.

Table 6. QoI and SDHI mutations in populations of *Pyrenophora teres* from Denmark and Sweden based on analysis of leaf samples.

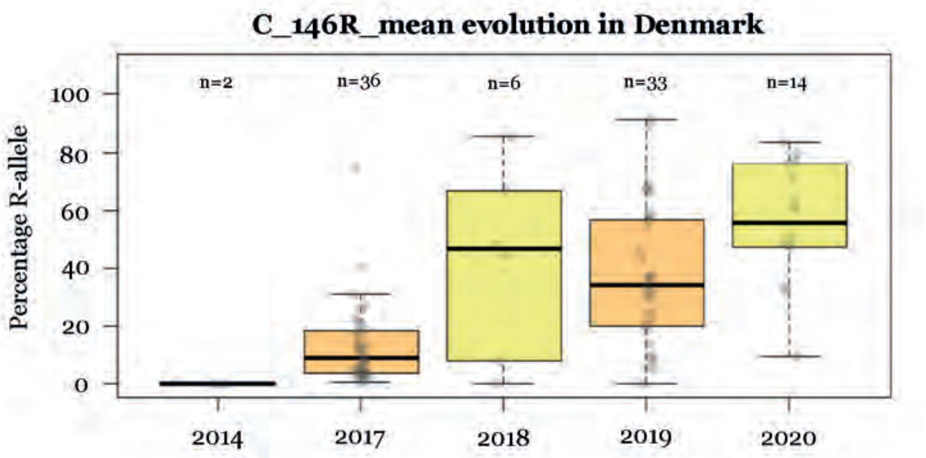
		QoI	SDHI								
Locality	Country	(F129L)	(B-H277Y)	(C-H134R)	(C-S135R)	(C-G79R)	(C-N75S)	(D-D124N/E)	(D-H134R)	(D-D145G)	(D-E178K)
Nykøbing Falster	DK	93%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Flakkebjerg	DK	19%	0%	0%	11%	0%	0%	0%	0%	0%	0%
Horsens	DK	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ringsted	DK	100%	0%	0%	63%	0%	0%	0%	0%	0%	0%
Lemvig	DK	50%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Hobro	DK	100%	0%	0%	32%	0%	0%	0%	0%	0%	0%
Vipperød	DK	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Flakkebjerg	DK	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vojens	DK	100%	0%	0%	55%	0%	0%	0%	0%	0%	0%
Ebbetorp, Kalmar	SW	75%	0%	0%	10%	0%	0%	0%	0%	0%	0%
Dalham, Romakloster	SW	43%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Åsmestad, Borensberg	SW	38%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Hov, Skänninge	SW	78%	0%	0%	11%	0%	0%	0%	0%	0%	0%
Sunnanbo, Tjerp	SW	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%
Gislöv, Trelleborg	SW	55%	0%	0%	13%	0%	0%	0%	0%	0%	0%
Hammarlöv, Trelleborg	SW	34%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Sensitivity to Ramularia leaf spot

In recent years, *Ramularia collo-cygni* has evolved resistance to QoIs. In addition, reduced efficacy of SDHI- and DMI-containing products has been observed. In Europe, several mutations in the target genes of SDHIs have been detected in the population of *R. collo-cygni* (B-H266Y/R, B-T267I, B-I268V, C-N87S, C-H146R, C-H153R and some others) with increasing frequencies since 2014 (Rehfus et al., 2019).

SDHI mutations in 89 Danish samples from 2017 to 2020 were investigated. AU Flakkebjerg organised the samples with help from advisors forwarding samples from across the country. At Flakkebjerg, we extracted DNA from leaf samples. The DNA was shared with Syngenta, who analysed for the SDHI mutations. A major increase in C146R was seen across the 4 seasons, while C154 R only was found at very low levels. The analysed samples were distributed across the country indicating that the shifting has taken place in all parts of Denmark (Figures 8 and 9).

From previous investigations, we know that the population has a high degree of strobilurin resistance. We also know that part of the populations has developed *CYP51* mutations, which can cause changes in sensitivity to azoles – mainly prothioconazole – which over the years has been the most effective azole for control of *R. collo-cygni*.



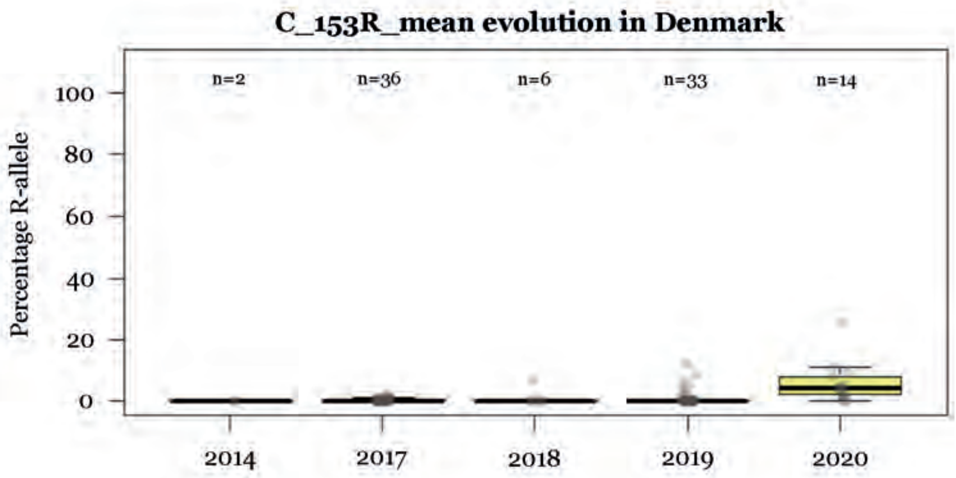


Figure 8. Evolution of *R.collo-cygni* sensitivity to SDHI in Denmark using quantitative molecular assays for specific mutation.

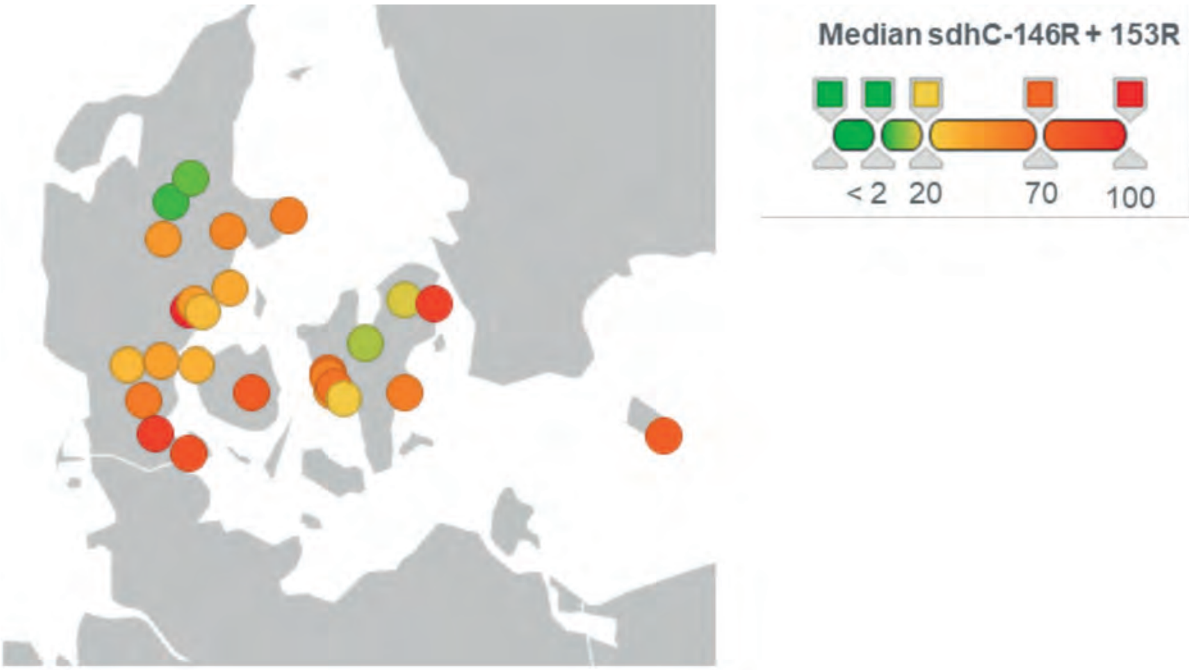


Figure 9. Frequencies of SDHI mutations in *R. collo-cygni* in Denmark using quantitative molecular assays for specific mutation assessed from 2017-2020.

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VII Fungicide testing against Sclerotinia stem rot (*Sclerotinia sclerotiorum*) in oilseed rape

Thies Marten Heick, Christian Appel Schjeldahl Nielsen & Hans-Peter Madsen

Summary
Oilseed rape trials were artificially inoculated with *Sclerotinia sclerotiorum* to test the efficacy of one-spray programmes against Sclerotinia stem rot. It was shown that inoculation with the pathogen is an excellent method to obtain reliable, significant results on control and yield.

Field trials
The efficacy of fungicides against Sclerotinia stem rot in winter oilseed rape was assessed in four randomised field trials at AU Flakkebjerg. The trials were sown at the beginning of September 2020. The cultivar DK Exclaim was used in all trials. The plots were artificially inoculated with *S. sclerotiorum* around growth stage 63-65 (full flowering: 50% flowers on main raceme open, older petals falling). Disease development was promoted by irrigation over ten days. One day after inoculation, the trials were treated once around growth stage 65 ('full flower' stage). Products tested were: 0.6 l/ha Proline EC 250, 1.0 l/ha Propulse SE 250, 0.5 kg/ha Cantus, 0.5 l/ha difenoconazole and 1.2 l/ha Revysol in one trial series (two trials) and 0.8 l/ha Amistar 250 SC, 0.6 l/ha Proline EC 250 and 2.0 l/ha Mirador Forte in another trial series (two trials). Disease incidence and severity were assessed at growth stage 85 (50% of pods ripe, with seeds dark and hard) on 100 plants per plot. The trials were harvested and yield (tonnes/ha) and oil content (%) determined.

Results
The inoculation with *S. sclerotiorum* resulted in large and uniform attacks of Sclerotinia stem rot in all four field trials. Disease incidence was around 50% on average, and disease severity between 30% and 35%. All fungicide treatments resulted in significant disease reductions. Treatments with 0.6 l/ha Proline EC 250, 1.0 l/ha Propulse SE 250, 0.5 kg/ha Cantus and 1.2 l/ha Revysol controlled the disease effectively. An application of 0.5 l/ha difenoconazole reduced Sclerotinia stem rot significantly compared to the untreated, but was significantly less effective than the previously mentioned products (Figure 1).

In another trial series, treatments with 0.8 l/ha Amistar 250 SC, 0.6 l/ha Proline EC 250 and 2.0 l/ha Mirador Forte lowered disease incidence and the severity significantly more than the untreated check. Proline EC 250 was significantly superior to Amistar 250 SC and Mirador Forte (Figure 2).

All fungicide treatments in both series, resulted in significantly higher yields (4.18–4.73 tonnes/ha) compared to an average of 3.6 tonnes/ha by the untreated control (Figures 3 and 4). Oil content (%) responded equally with an increase of a minimum 1% following fungicide treatment (Figure 5).

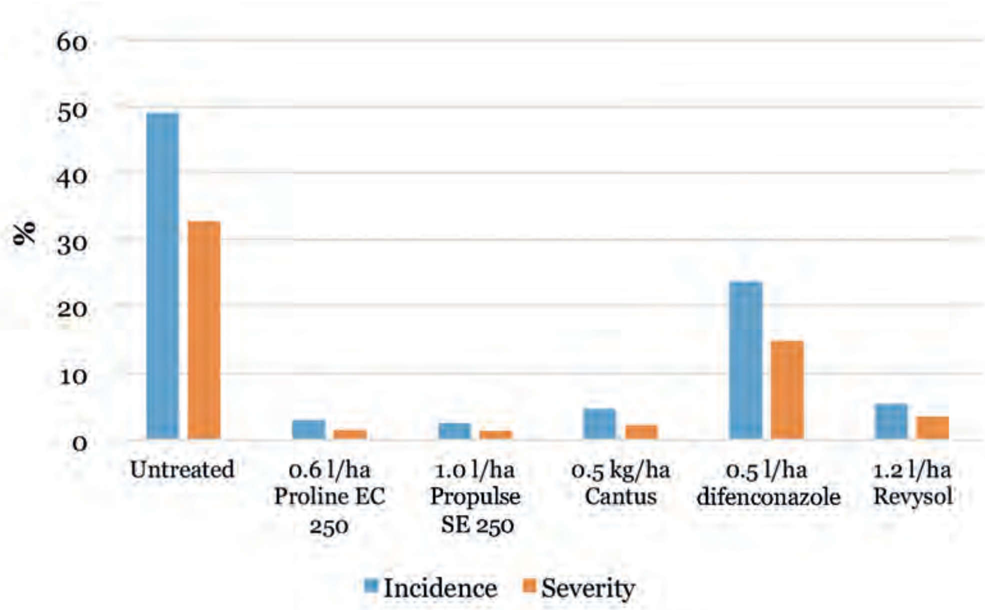


Figure 1. Disease incidence (%) and disease severity (%) of Sclerotinia stem rot in artificially inoculated field trials in 2020. Average of two trials (20601-1/2).

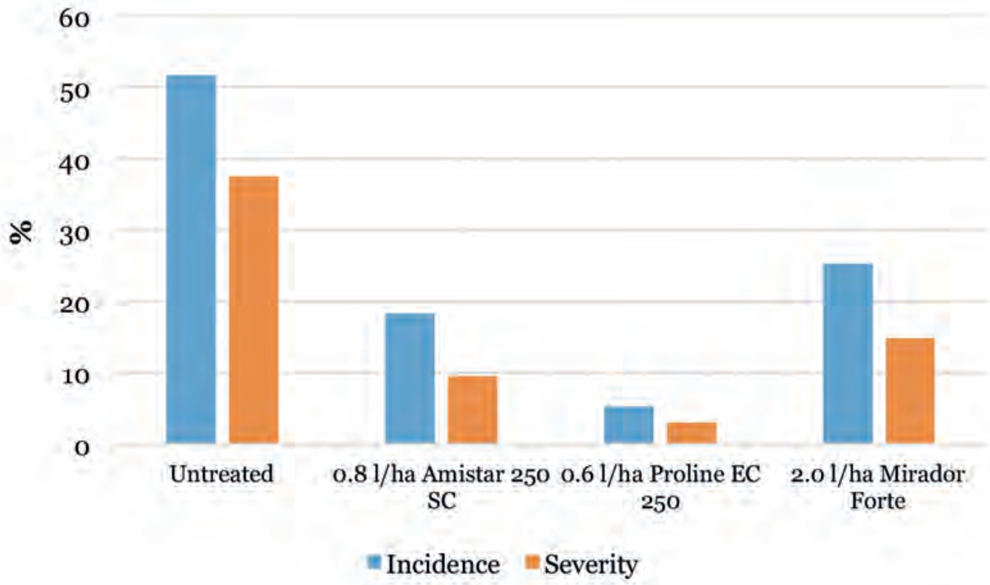


Figure 2. Disease incidence (%) and disease severity (%) of Sclerotinia stem rot in artificially inoculated field trials in 2020. Average of two trials (20602-1/2).

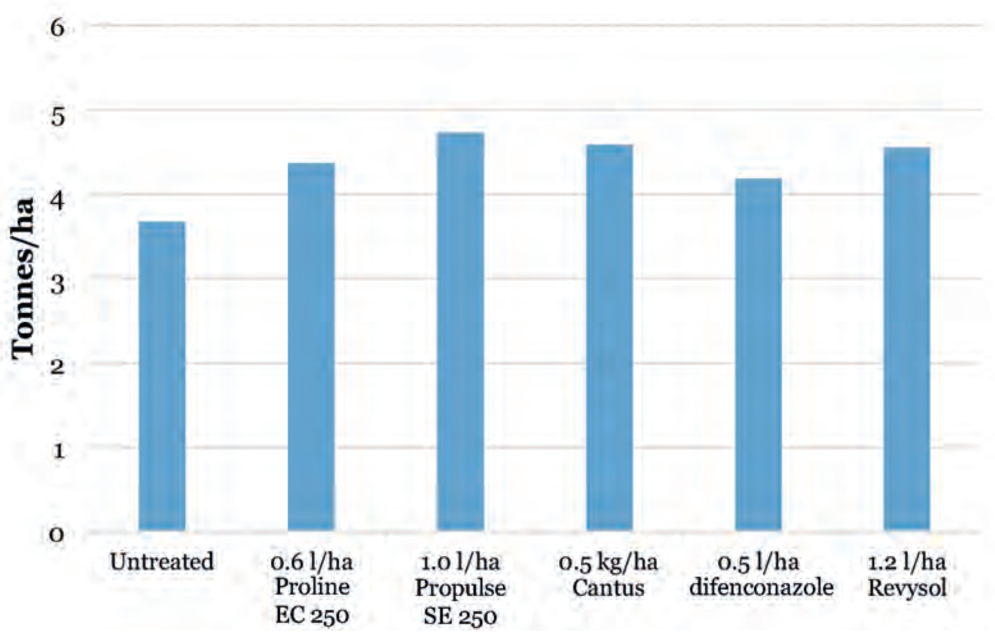


Figure 3. Yield (tonnes/ha) of winter oilseed rape following fungicide treatment in field trials artificially inoculated with *Sclerotinia sclerotiorum* in 2020. Average of two trials (20601-1/2).

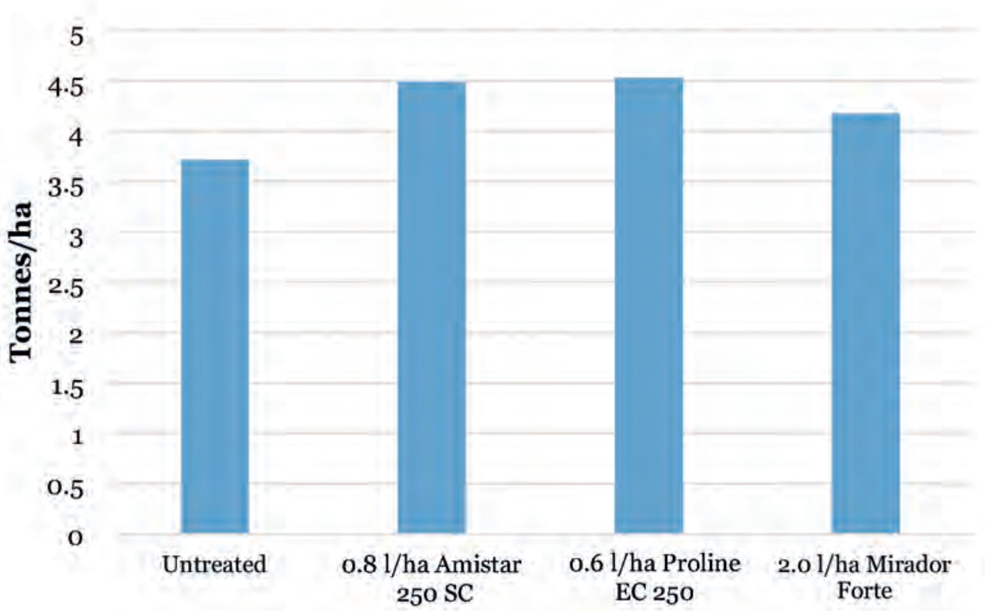


Figure 4. Yield (tonnes/ha) of winter oilseed rape following fungicide treatment in field trials artificially inoculated with *Sclerotinia sclerotiorum* in 2020. Average of two trials (20602-1/2).

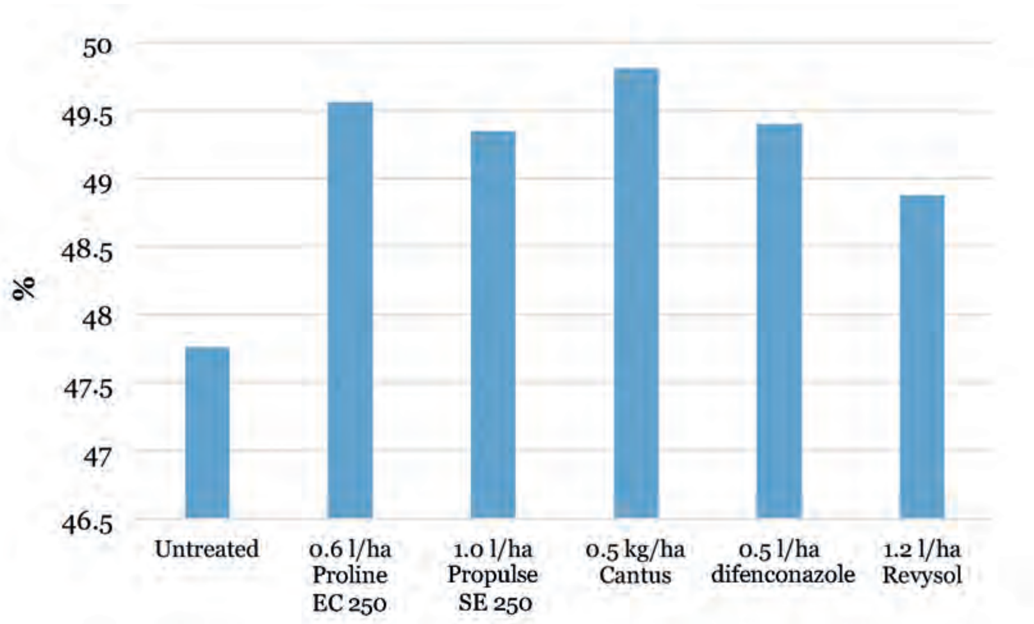


Figure 5. Oil content (%) of winter oilseed rape following fungicide treatment in field trials artificially inoculated with *Sclerotinia sclerotiorum* in 2020. Average of two trials (20601-1/2).

Typical symptoms of Sclerotinia stem rot in oilseed rape after artificial inoculation. (Photo: Christian Appel Schjeldahl Nielsen).

The trials were financed by Adama and Corteva.

VIII Fungicide strategies against powdery mildew resistance in sugar beet

Thies Marten Heick[1], Anne Lisbet Hansen[2] & Lise Nistrup Jørgensen[1]
[1] Aarhus University, [2] NBR Nordic Beet Research

Summary
Two field trials were carried out to test different fungicide control strategies on powdery mildew (*Erysiphe betae*) and to minimise the spread of strobilurin resistance. The treatments included registered products as well as not registered products including Propulse SE 250 and Balaya. As examples of alternative products, Serenade ASO (*Bacillus subtilis* QST 713) and Kumulus S (sulphur) were also included. All fungicide treatments controlled powdery mildew and rust effectively. Kumulus S reduced powdery mildew significantly and was comparable to the other fungicide solutions. Serenade ASO showed only a low effect on powdery mildew. Powdery mildew samples from Denmark and Sweden were tested for strobilurin resistance in 2020. Two samples from Denmark and two samples from Sweden were tested positive for strobilurin resistance in a trial under controlled conditions. All four samples harboured the point mutation G143A, which has previously been associated with strobilurin resistance. The results from this project show that strobilurin resistance in powdery mildew in sugar beet is a real risk. Furthermore, the results show that powdery mildew can still be effectively controlled and that spray strategies which may lower the risk of spreading strobilurin resistance are an option. The project was financed by ”Sukkerroeafgiftsfonden”.

Field trials
Investigations on the improvement on the control of powdery mildew in sugar beet were continued in a collaboration between Aarhus University and Nordic Beet Research (NBR). In the project ‘Fungicide resistance in powdery mildew in sugar beet (*Erysiphe betae*)’, the effect of different control strategies against fungal leaf diseases in sugar beet was tested (Table 1). Two randomised field trials were set up in Lolland and Zealand (Flakkebjerg). The trials were sown at the beginning of April. The cultivar Lombok was used in both trials; this cultivar is known to be susceptible to powdery mildew and moderately susceptible to rust (*Uromyces betae*). The trials were treated two to three times before disease onset in the week commencing 20 July (week 30) (T0 - A), at disease onset in the week commencing 27 July (week 31) (T1 - B) and in the week commencing 17 August (week 34) (T2 - C). Leaf diseases were scored at 10-day intervals on a scale of 0 to 100 (100 = 100% attacks).

Powdery mildew and rust were the predominant diseases. *Cercospora beticola* and *Ramularia beticola* appeared late and at a low level. Mildew attacks occurred earlier and developed more strongly in Zealand with attacks of 90% and 80% in the untreated check, respectively.

Table 1. Fungicide spray programmes tested against fungal leaf diseases in sugar beet.

Trt	T0 - A (week 30)	T1 – B (week 31)	T2 – C (week 34)
1		Untreated	
2		0.5 l/ha Opera	0.5 l /ha Opera
3		0.5 l/ha Revysol + 0.18 l/ha Comet Pro	0.5 l/ha Revysol + 0.18 l/ha Comet Pro
4		0.62 l/ha Comet Pro	0.62 l/ha Comet Pro
5		0.5 l/ha Amistar Gold	0.5 l/ha Amistar Gold
6		0.5 l/ha Propulse SE 250	0.5 l/ha Amistar Gold
7		0.5 l/ha Revysol + 0.18 l/ha Comet Pro	0.25 l/ha Amistar Gold
8		1 l/ha Revysol + 0.375 l/ha Comet Pro	0.5 l/ha Amistar Gold
9	4 l/ha Serenade ASO	4 l/ha Serenade ASO	4 l/ha Serenade ASO
10	4 l/ha Serenade ASO	0.62 l/ha Comet Pro	4 l/ha Serenade ASO
11	5 kg/ha Kumulus S	5 kg/ha Kumulus S	5 kg/ha Kumulus S
12	5 kg/ha Kumulus S	0.62 l/ha Comet Pro	5 kg/ha Kumulus S

Two treatments (trt) at T1 and T2 reduced attacks of mildew significantly compared to the untreated control (Figures 1 and 2). No differences were found among spray programmes (trt 2 to 8). Two treatments with 0.5 l/ha Revysol and 0.18 l/ha Comet Pro (trt 3) performed equally well as the standard recommendation of two times 0.5 l/ha Opera or two times 0.62 l/ha Comet Pro. The effect of spray programmes with different fungicides used at T1 and T2 (trt 6 to 8) was in line with the standard treatment. However, the effect of two applications of 0.5 l/ha Amistar Gold (trt 5) or spray programmes finishing off with 0.5 l/ha Amistar Gold (trt 6 to 8) was slightly inferior compared to the other fungicide solutions at later assessment dates. Still, those spray programmes can be regarded as an alternative to two times 0.5 l/ha Opera, which will not be available after 2021. Those alternative fungicide programmes might also help to reduce the spread of strobilurin resistance in powdery mildew as they are built up around mixing and alteration of different active ingredients. Three applications of 5 kg/ha Kumulus S (trt 11) showed a high effect against powdery mildew at the same level as treatments 2 to 8. The same strategy with 0.62 l/ha Comet Pro at T1 instead of Kumulus S showed a very high control of both moderate and high levels of attack. The application of three times 4 l/ha Serenade ASO (trt 9) had a low effect and only at the early assessment dates. The effect of Serenade ASO improved when alternated with 0.62 Comet Pro l/ha at T1 (trt 10). Results, however, varied between the two field trials (Figure 1).

The infection level of rust in the control plots was moderate to high: between 40% at Flakkebjerg and 70% at the site in Lolland (Figure 3). Spray programmes 2-8 showed moderate effect against rust.

Generally, fungicide treatments had a low effect in the field trial in Lolland. The treatments with Kumulus S and Serenade ASO were inferior to all fungicide solutions in controlling rust (Figure 3).

All spray programmes including fungicides resulted in higher root yield and higher sugar content (data not shown). Also treatments with Kumulus S and treatment 10 (Serenade ASO - Comet Pro - Serenade ASO) increased the root weight and sugar content. No significant differences were seen for yield parameters after a fungicide treatment. Only trt 9 with three applications of Serenade ASO resulted in significantly lower yields.

Table 2 shows a summary of the data from the four trials across the two seasons. It also summarises control of rust, which was present at a significant level along with minor attacks of Ramularia leaf spot and Cercospora leaf spot.

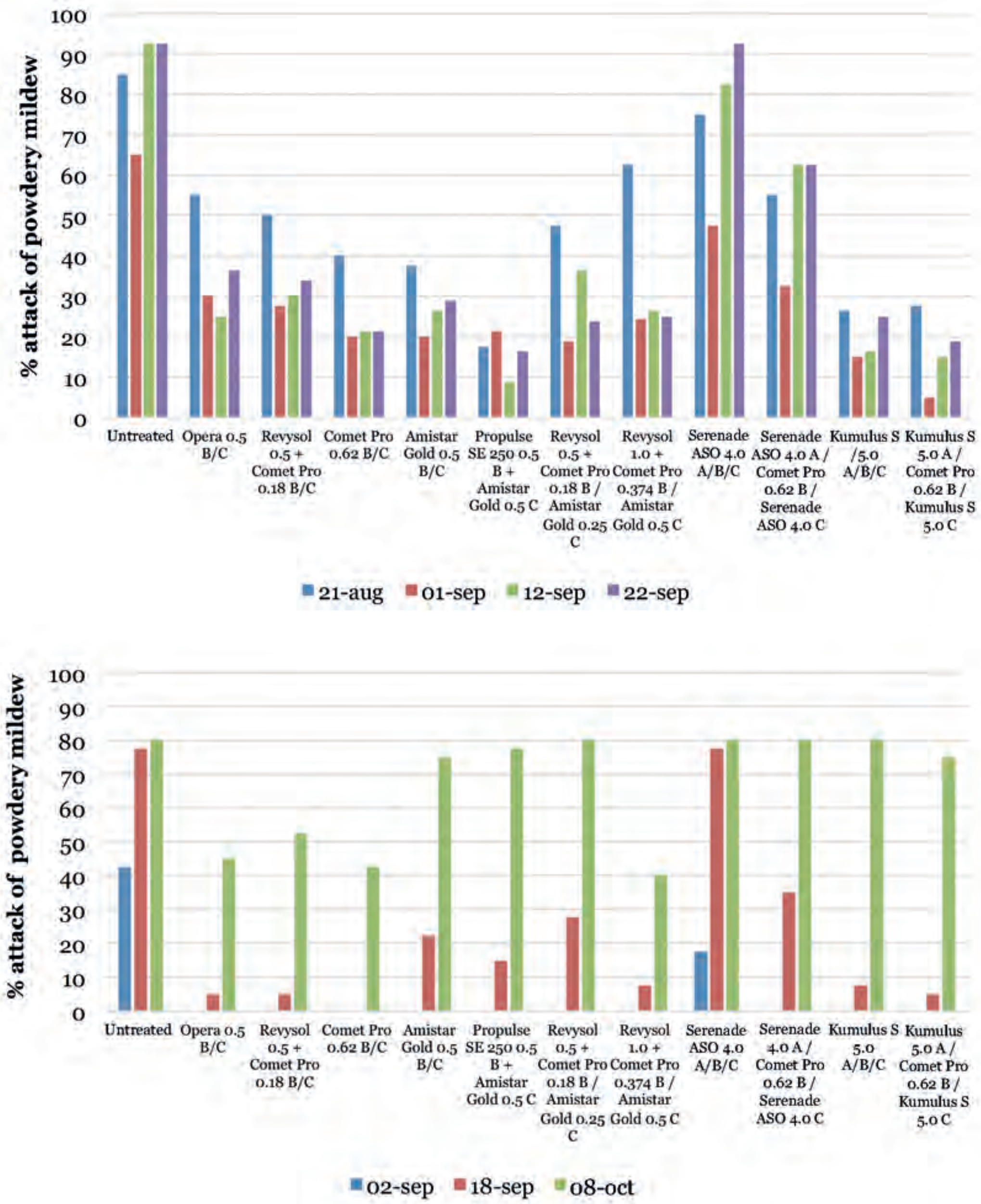
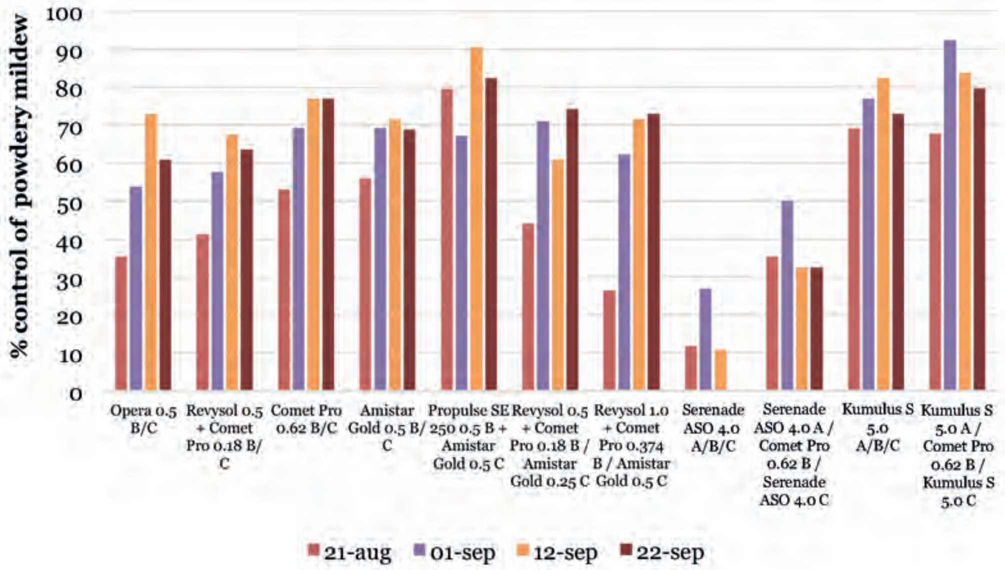


Figure 1. Per cent powdery mildew following different spray programmes assessed at four timings. Flakkebjerg at the top, Lolland below. A, B and C = spray timings T1, T2 and T3.



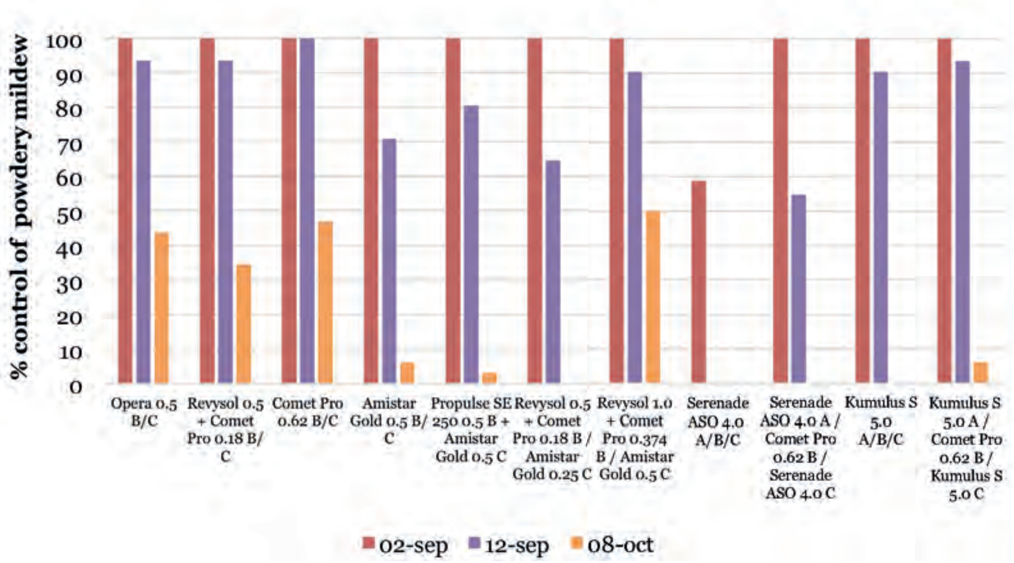


Figure 2. Per cent control of powdery mildew following different spray programmes assessed at four timings. Flakkebjerg at the top, Lolland below. A, B and C = spray timings T1, T2 and T3.

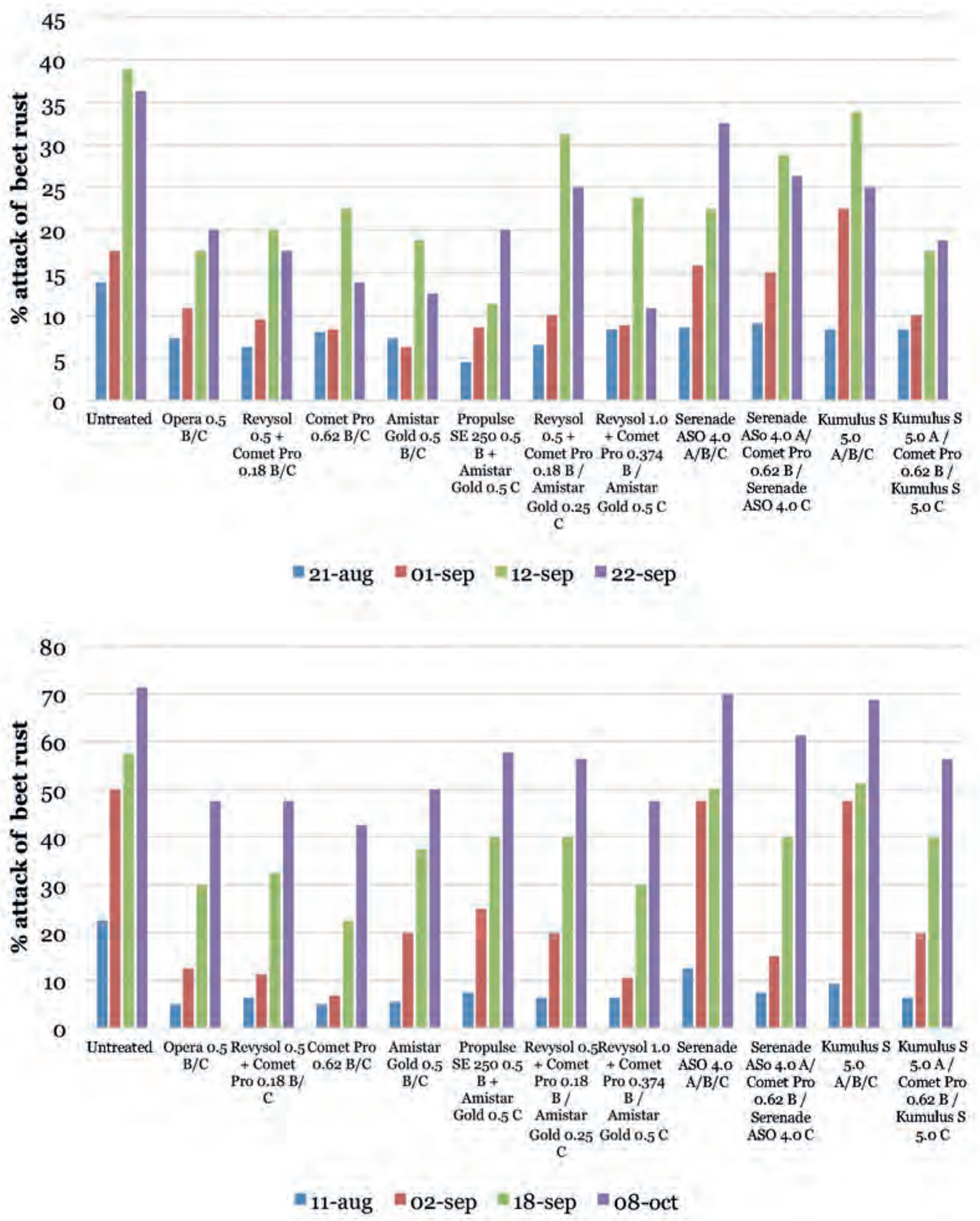


Figure 3. Per cent rust following different spray programmes assessed at four timings. Flakkebjerg at the top, Lolland below. A, B and C = spray timings T1, T2 and T3.

Table 2. Average attack of the four leaf diseases and yield responses from the four trials carried out in 2019 and 2020. The treatments were applied at A, B and C = spray timings T1, T2 and T3.

Treatments	Timing	Powdery mildew	Rust	*Ramularia*	*Cercospora*	Yield, t/ha	Sugar, t/ha
Untreated	BC	49.2	30.8	1.9	2.4	96.7	16.3
2 x 0.5 Opera	BC	7.5	11.3	0.4	0.6	104.6	18.1
2 x (0.5 Revysol + 0.18 Comet Pro)	BC	7.6	12.2	0.2	2.1	104.9	18.3
2 x 0.62 Comet Pro	BC	5.4	8.2	0.4	2.8	107.3	18.7
2 x 0.5 Amistar Gold	BC	5.3	12.9	0.3	0.6	106.0	18.2
0.5 Propulse SE 250 / 0.5 Amistar Gold	BC	5.9	14.8	0.7	0.8	106.7	18.4
0.5 Revysol + 0.18 Comet Pro / 0.25 Amistar Gold	BC	6.5	14.0	0.4	0.8	107.5	18.6
1.0 Revysol + 0.375 Comet Pro / 0.5 Amistar Gold	BC	6.1	10.4	0.1	0.4	106.2	18.3
3 x 4.0 Serenade ASO	ABC	35.8	28.1	0.4	1.3	96.4	16.3
4.0 Serenade ASO / 0.62 Comet Pro / 4.0 Serenade ASO	ABC	12.3	12.9	0.4	1.3	103.5	17.6
3 x 5.0 Kumulus S	ABC	4.3	31.5	0.4	3.9	103.6	17.5
5.0 Kumulus S / 0.62 Comet Pro / 5.0 Kumulus S	ABC	1.4	14.1	0.1	4.0	108.6	18.7
No. of trials		4	4	3	2	4	4
LSD_{95}		6.4	3.8	NS	NS	4.0	0.7

Resistance monitoring

In 2020, ten powdery mildew (*Erysiphe betae*) samples were tested for strobilurin resistance. Diseased leaves from five Danish and five Swedish sites were collected from commercial fields (Table 3). The leaves were used to infect disease-free plants (cv. Lombok - powdery mildew-susceptible) at growth stage 19. Powdery mildew was transferred by rubbing diseased leaves against uninfected leaves. Twelve plants per site were used; three plants were treated with either 0.5 l/ha Comet Pro (pyraclostrobin), 0.5 l/ha Opera (epoxiconazole + pyraclostrobin) or 0.5 Amistar Gold.

Table 3. Sites, from where powdery mildew samples were collected.

Swedish samples	Danish samples
1. Vadensjö	6. Byhave
2. Skegrie	7. Skelby
3. Österbo	8. Dannemare
4. Petersborg	9. Brandstrup
5. Lönnstrup	10. Døllefjelle

Table 4. Powdery mildew attacks 14 days after artificial inoculation. + = starting infection, ++ = moderately infected, +++ = highly infected.

	1	2	3	4	5	6	7	8	9	10
Untreated	+++	++	+	+++	++	+++	++	-	++	++
0.5 l/ha Comet Pro	+++	+	-	-	-	-	+	-	-	++
0.5 l/ha Opera	-	-	-	-	-	-	-	-	-	-
0.5 l/ha Amistar Gold	-	-	-	-	-	-	-	-	-	-

The plants were assessed for powdery mildew one, two and three weeks after inoculation (Table 4). A treatment with 0.5 l/ha Opera controlled all powdery mildew samples; however, powdery mildew developed symptoms on two Danish and two Swedish samples treated with 0.5 l/ha Comet Pro. Those samples were tested for the presence of *cytb* point mutation G143A, which is associated with powdery mildew strobilurin resistance (Bolton and Neher, 2014). All four samples tested positive for G143A, indicating that the strobilurin-resistant isolates occur in the Danish and Swedish *Erysiphe betae* population. The presence of resistance has not been seen at field level; however, choosing an alternative fungicide programme in order to minimise the spread of strobilurin resistance should be considered. This is especially the case when powdery mildew is the primary disease.

The project was financed by "Sukkerroeafgiftsfonden".

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IX Controlling late blight in susceptible and resistant potato cultivars with *BlightManager*

Isaac Kwesi Abuley, Jens Grønbech Hansen & Hans Henning Hansen

We carried out artificially inoculated field trials to evaluate two models for controlling late blight in susceptible (Folva) and resistant (Nofy) cultivars. The experimental plan and agronomic practices carried out were just as in Abuley and Hansen (2019).

Model description

The BlightManager model

The *BlightManager* (BM) decision support system (DSS) is an improvement of the previous *Skimmelstyring* DSS (Abuley and Hansen, 2019). In BM, we use infection risk and infection pressure sub-models, together with information on the proximity to current late blight-infested fields, as a basis for recommendations on fungicide application. *Skimmelstyring*, in comparison, lacked an infection sub-model (Figure 1). Another improvement of BM is the introduction of a minimum treatment threshold (set at an infection pressure = 10); *Skimmelstyring* had no treatment threshold related to the current infection pressure. Thus BM is more responsive to increasing infection pressure, which in effect makes it less conservative. Lastly, BM refines the decision support given by providing guidance on both the dosage and frequency of spraying.

Earlier, Abuley and Hansen (2019) described the infection pressure and proximity sub-models. The infection *risk* sub-model calculates the risk of infection when sporangia are present. The infection *pressure* sub-model calculates sporulation potential rather than infection itself. Although infection pressure can be a good indicator of infection as well (e.g. at very high infection pressures). However, the weather requirements for sporulation and infection are not the same. For example, an infection can occur at lower temperatures (<10°C) (Harrison, 1992) and leaf wetness duration (<6 hours) (Rotem et al., 1978) compared to sporulation, which requires a minium of 10°C (Harrison, 1992) and 7 hours' leaf wetness duration (Rotem et al., 1978).

In our new BM, we set a threshold for infection risk and infection pressure at 93% and 10, respectively, as the minimum requirement for spraying. However, these basic settings are further modulated according to the proximity to a late blight-infested field and to the resistance of the cultivar (Table 1). We used Models A+ and B+ for susceptible and resistant cultivars, respectively (Table 1).

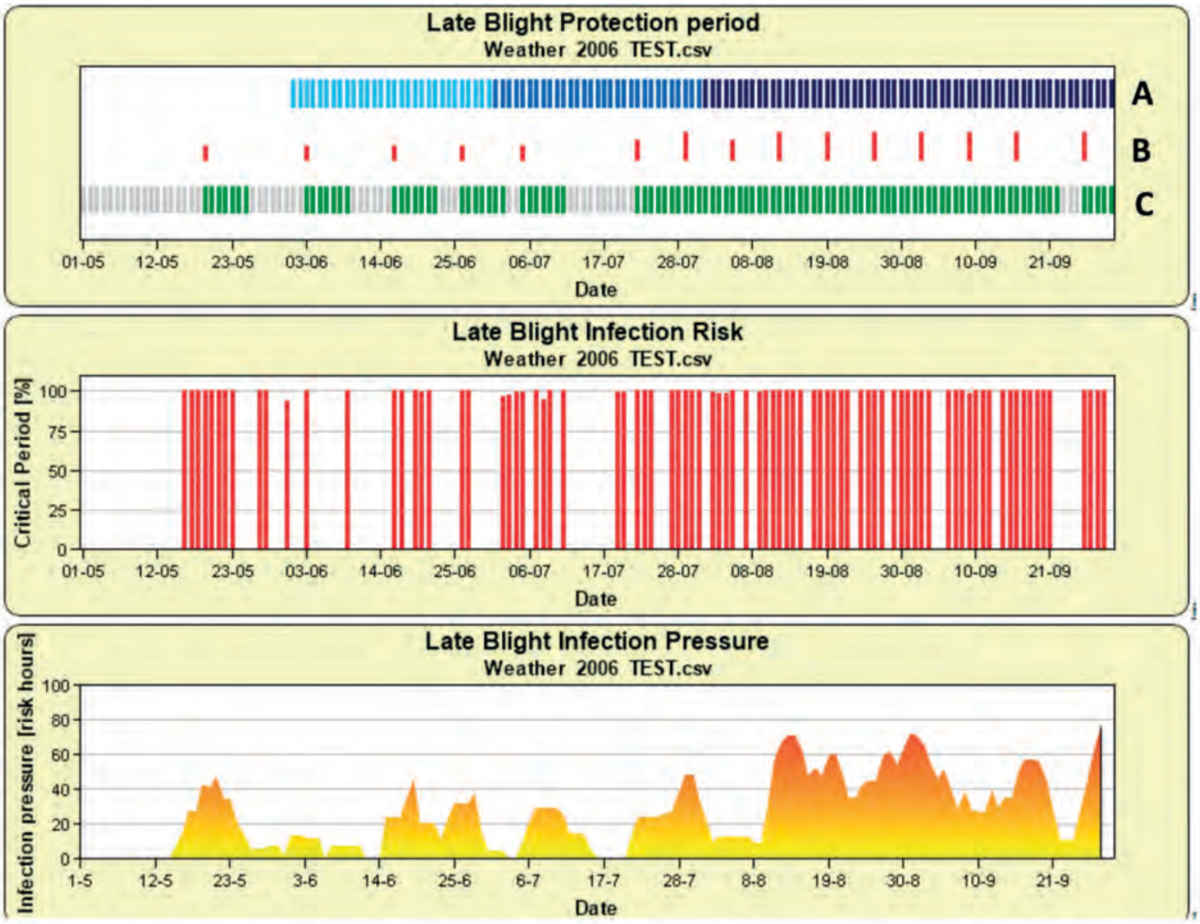

Figure 1. Sub-models in the *BlightManager* (BM) decision support system. **Upper panel**: (A) The proximity of late blight to the field (the darker the colour, the closer late blight is to the field; thus, an indication of a higher risk of infection when the conditions are favourable); (B) Amount/dosage (red bars) of fungicide sprayed (the higher the bar, the higher the dosage of fungicide sprayed/recommended); (C) Protection period (green bars) and unprotected periods (gray bars). **Middle panel**: Infection risk (red bars) (critical period (%)). The absence of a red bar means the infection is unlikely to occur on that day. **Lower panel**: Infection pressure (yellow area), which is a measure of the sporulation potential.

Table 1. Dose model for Models A+ and B+.

	Model A+				Model B+			
Infection pressure	Phase 1*	Phase 2*	Phase 3*	Phase 4*	Phase 1*	Phase 2*	Phase 3*	Phase 4*
>60	50	50	75	100	0	0	50	100
41-60	0	50	75	100	0	0	50	100
21-40	0	50	50	100	0	0	50	100
10-20	0	0	50	75	0	0	0	75
<10	0	0	0	0	0	0	0	0

*Phase 1: Late blight (LB) is not in the country; Phase 2: LB is in the country; Phase 3: LB in the region, within a radius of 50 km from the field; Phase 4: LB in the field on a cultivar with similar resistance as the cultivar of interest.

Treatments
We tested the following treatments:

1. Untreated (Folva and Nofy), in which no fungicide was sprayed to control late blight.
2. Routine (Folva and Nofy), in which fungicide (Ranman Top) was sprayed at weekly intervals starting from row closure.
3. Model A+ (only Folva), in which fungicide application (Ranman Top) was sprayed according to BM Model A+ (Table 1).
4. Model A+ (only Nofy), in which fungicide application (Ranman Top) was sprayed according to BM Model B+ (Table 1).

For treatments 2-4, Cymbal or Proxanil is sprayed when fungicide application is delayed for 1 or 2 days or actively sporulating lesions are seen on the potatoes in the plots.

Results
Fungicide application
The fungicide application during the season is shown in Figure 2.

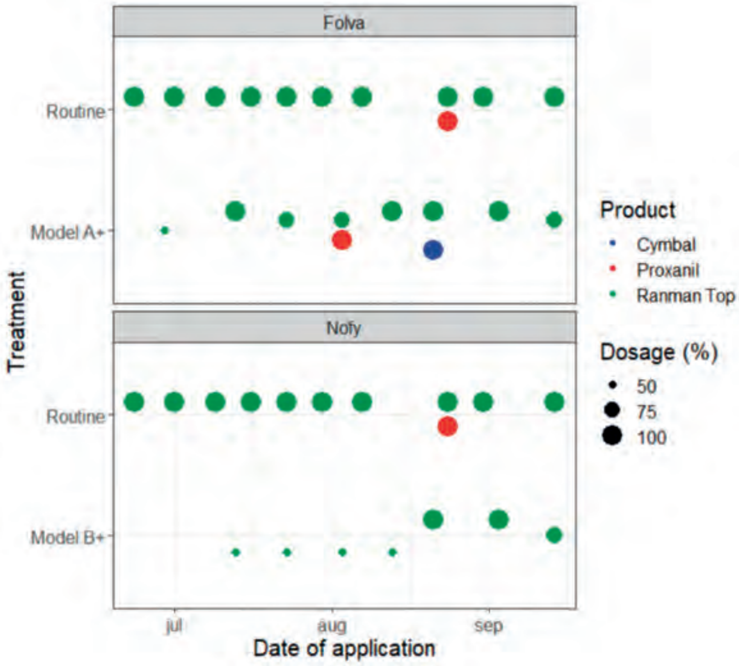

Figure 2. Details of fungicide application according to the models and the standard treatment.

Disease development
The disease progression on the untreated plots showed that late blight developed successfully and reached 100% severity on both the susceptible (Folva) and resistant (Nofy) cultivars (Figure 3a). However, the onset of the epidemic occurred about 50 days earlier in Folva compared to Nofy (Figure 3a). The fungicide treatments slowed the epidemic development in both Folva and Nofy. However, the severity of late blight in Nofy remained below 1% throughout the season in the fungicide-treated plots compared to Folva, which reached about 12% (Figure 3a).

Generally, there were no differences between the control efficacy in the model-based recommendation and the routine (Figure 3b). However, the models reduced fungicide by 70% in Nofy and 25% in Folva (Figure 3b).

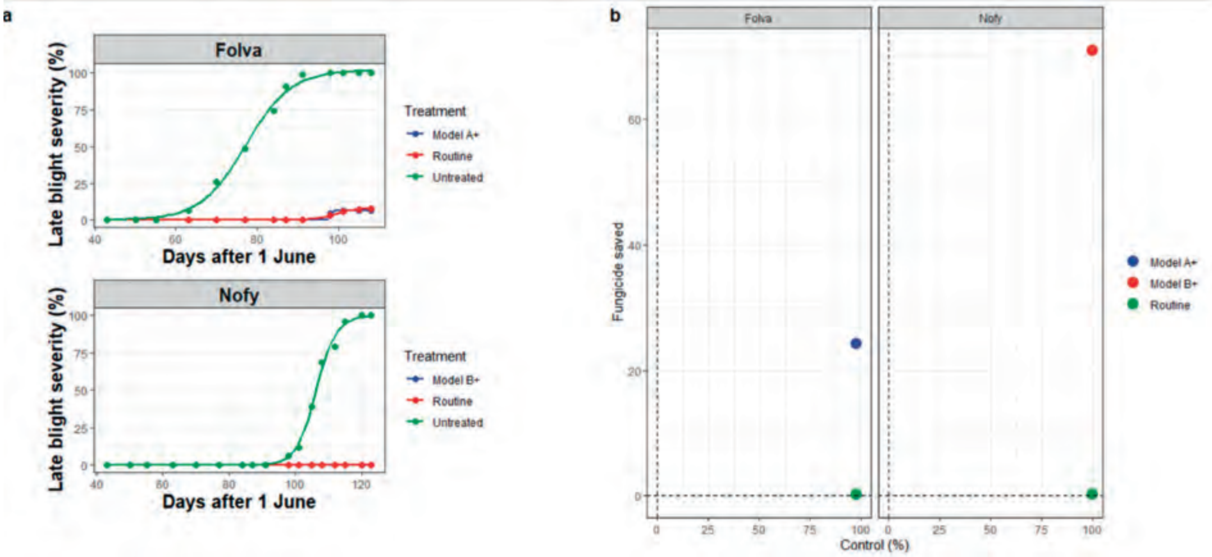

Figure 3. (a) Fitted disease progress curves (lines) and mean disease severity values (dots) of the Folva (susceptible cultivar) and Nofy (resistant cultivar) treated with a fungicide (as routine or model-based recommendation) or untreated. (b) Fungicide saved (%) and efficacy of control (Control (%)) for spraying with Models A+ and B+ compared to the standard/routine treatment. The fungicide saved was calculated relative to the routine application with a treatment frequency index of 11.2.

Starch yield

In Folva, the fungicide treatments resulted in a higher starch yield compared to the untreated (Figure 4). Starch yield did not differ between Model A+, Model B+ and routine application in either Folva or Nofy (Figure 4).

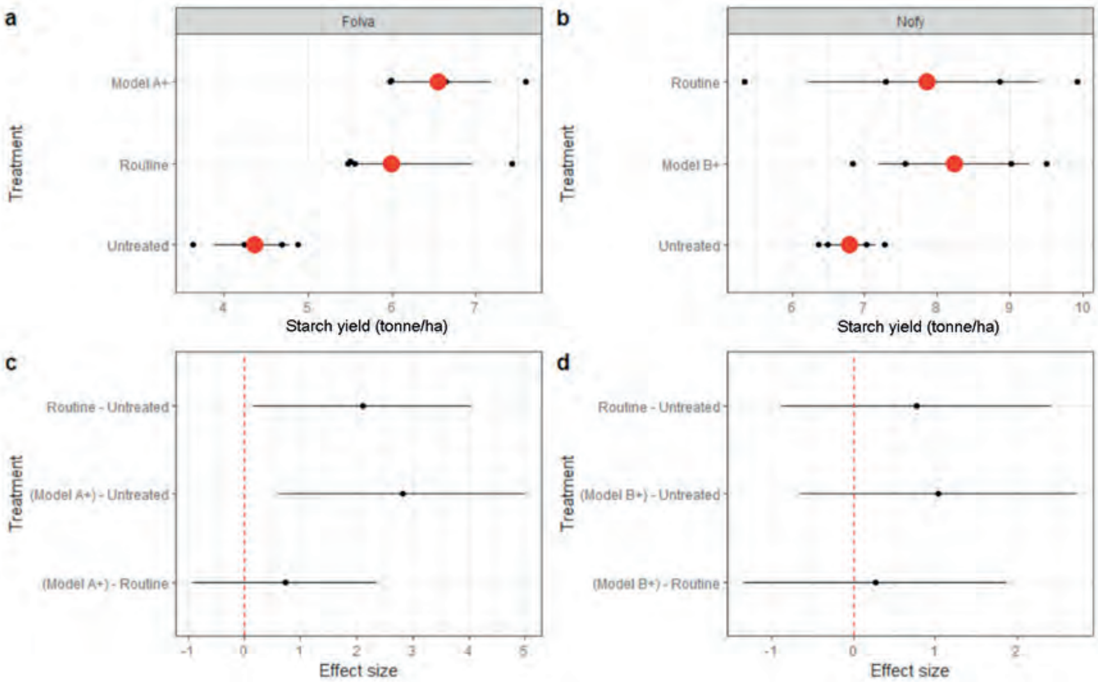

Figure 4. (a & b) The mean starch yield (tonnes/ha) (red dot) for Folva (a) and Nofy (b) spraying with fungicides (according to models or routine application) and untreated. The black dots and horizontal lines are the observed/measured starch yields per replicate and the 95% bootstrapped confidence interval. (c & d) The standardised effect size (Cohen's D) (black dot) between the treatments and their 95% confidence interval (black vertical line). Confidence intervals that include/overlap with zero are an indication of insignificant differences between the treatment pairs and vice versa.

Conclusion

The results in the present study have shown a huge potential to reduce fungicide use in late, resistant cultivars. The fungicide reduction of ~25% in the late blight susceptible cultivar (Folva) was also significant. However, as pressures from national (e.g. the Ministry of Environment of Denmark) and regional (e.g. EU Pesticide Directive (2009/128/EC)) policies and regulations to reduce fungicide increase, efforts must be made to use more resistant cultivars as the foundation of control strategies.

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IX Influence of boom height on spray drift from conventional sprayers

Peter Kryger Jensen

During field spraying, losses to the surroundings in the form of spray drift inevitably occur. Spray drift is defined as spray liquid transported away from the sprayed area without being deposited. A number of factors influence spray drift with application technique, meteorological conditions and hedges/ buffer zone canopy considered the most important. This study focused on the influence of boom height on spray drift. On conventional boom sprayers with a 50-cm nozzle spacing, the recommended boom height is approximately 50 cm above the crop/soil to achieve an even distribution with standard 110° hydraulic nozzles. A number of sprayer manufacturers now offer spray booms with a 25-cm spacing between the nozzles. By using this configuration an even spray distribution is achieved at a boom height of 25 cm. Previous studies have shown that the spray drift increases considerably when the boom height is increased above 50 cm height. However, no studies have reported the influence on spray drift of using lower than 50 cm boom height. In this study, spray drift using a boom height of 25, 50, 75 and 100 cm was measured.

Materials and methods

The investigation was carried out in a stubble field on Gavnø Estate near Næstved on 8 September 2020. A trailed Horsch sprayer with a 42-metre boom and 25 cm nozzle spacing was made available for the test by Gavnø Estate. During the test the sprayer was equipped with Lechler IDK-015 nozzles delivering 0.7 l/min and a spray volume of 340 l/ha at a sprayer speed of 7 km/h. At this pressure, the IDK-015 nozzle is classified as medium/coarse according to Lechler. The test was carried out according to the following plan:

Factor 1. Boom height

1. 25 cm
2. 50 cm
3. 75 cm
4. 100 cm

Factor 2. Sedimentation drift: Distance from sprayed area (edge of field is 0.25 metres from the outermost nozzle)

4 distances: 3 – 5 – 10 and 15 metres

A schematic overview is shown in Figure 1.

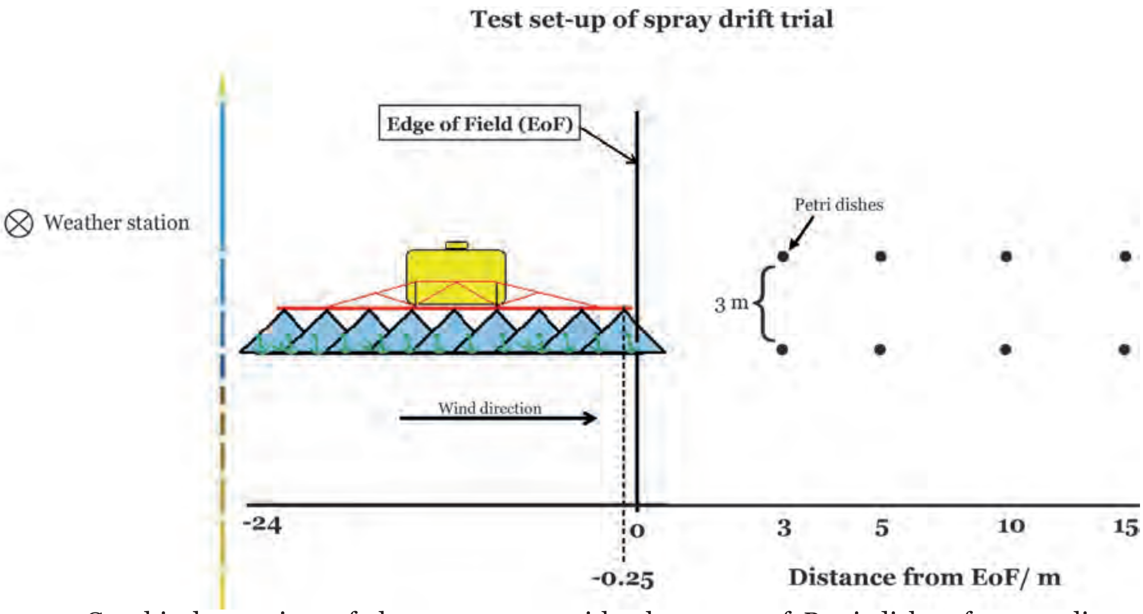


Figure 1. Graphical overview of the test set-up with placement of Petri dishes for sampling of sedimentation drift.

Sedimentation spray drift was collected in Petri dishes placed just above the soil/stubble level. The Petri dishes were placed in two rows with a mutual distance of three metres. During the field test, the wind direction should be perpendicular to the sprayed area although a deviation of +/- 30° is acceptable. In the test, spray application was carried out at a length of 100 metres, allowing application to be initiated at least 30 metres before the first row of drift collectors and until at least 30 metres after the last row of collectors. This - in combination with the requirement for wind direction - ensures that the drift created during application passes the Petri dishes and the masts with collectors. The sprayed area was in all treatments 24 metres wide.

Background contamination was tested by placing a Petri dish upwind. During each replicate, the wind speed was measured at two metres' height when the sprayer passed the rows of collectors. Temperature and humidity were measured during the entire test.

The spray liquid consisted of tap water and the fluorescent tracer acid brilliant flavine 7 g at a dose of 228 g/ha. Following each replicate, the Petri dishes were collected and new ones were mounted. Lids were put on the Petri dishes before collection. All samples were stored under cool and dark conditions until analysis. The test included 4 replicates.

The day of the test was rather windy with a mean wind speed of 7-8 m/s. Therefore, the test lane was placed 200 metres from a hedge where the wind speed was close to 5 m/s during the entire test but with some turbulence due to the location. The temperature varied from 15 to 16°C and the humidity was 85-90 RH during the test.

The tracer in the samples was solved with water and 0.1% non-ionic additive and the concentration of tracer was determined. The tracer content was determined using a Perkin Elmer model LS 50B luminescence spectrometer. The Petri dishes were shaken and a subsample of 6 µl was used in the fluorescence detector. The sample was excited at a wavelength of 410 nm and after excitation emission was measured at 518 nm. The content of the sample was quantified using a number of standard concentrations ranging from 2 to 192 µg/l. The total amount of tracer in the sample was calculated from the concentration of tracer in the subsample. The sedimentation spray drift values at increasing distance from the sprayed area are shown as a percentage of the applied dose. The drift values are also shown as relative figures, where the drift using a boom height of 50 cm is set to be equal to 100.

Application during the test.

Results and discussion

The sedimentation drift values shown as a percentage of the applied dose are shown in Figure 2. As expected, the spray drift values increased with increasing boom height. However, the increase in spray drift with increasing boom height was not as gradual as anticipated, which was probably due to the turbulent wind conditions. Especially at 75 and 100 cm a higher variability in the values was found. Statistically significantly higher drift values were found at 75 and 100 cm compared to the values at 25 and 50 cm at all four distances. However, there were no statistical differences between drift values using 25 and 50 cm boom height, and the differences in drift values at 75 and 100 cm boom height were also non-significant.

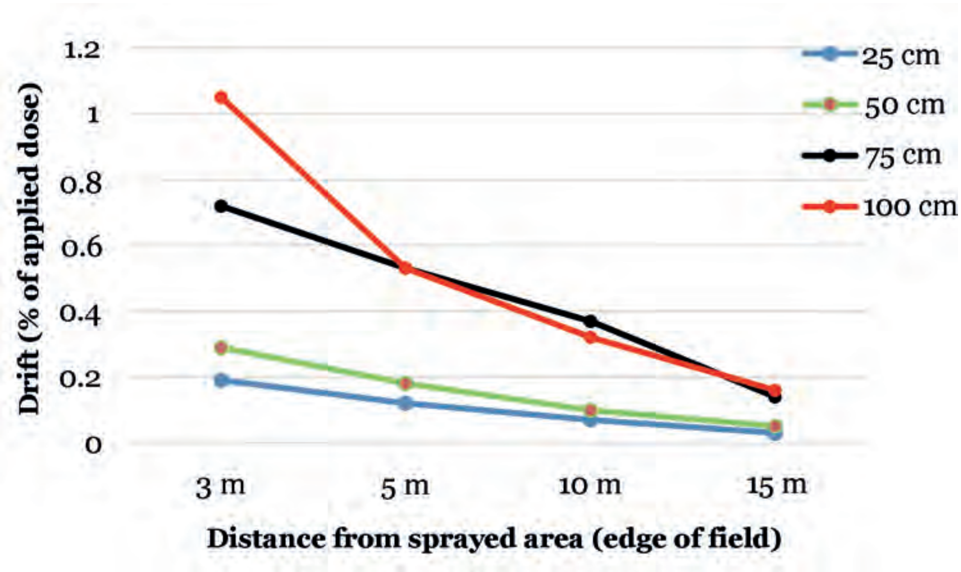


Figure 2. Influence of boom height on spray drift with a nozzle classified as medium/coarse. Spray drift values are shown as a percentage of the applied dose.

Table 1. Relative spray drift at increasing distance from sprayed area. The values at each distance are calculated as a percentage of the value at 50 cm boom height.

Distance from sprayed area (m)	Boom height (cm)			
	25	50	75	100
3	65	100	247	363
5	69	100	297	292
10	65	100	354	305
15	60	100	259	309

In Table 1 the drift values at each distance are calculated as a percentage of the values obtained at 50 cm boom height. The results show that there is a relatively constant difference between drift values at 25 and 50 cm boom height. The low boom height of 25 cm thus reduced drift by approximately 1/3 compared to 50 cm boom height. Spray drift was increased by a factor 2.5-3.5 depending on the distance to the sprayed area when the boom height was increased to 75 cm. Increasing the boom height further to 100 cm increased drift values by a factor 2.9-3.6.

Conclusion

When conventional field sprayers are used, boom height has a significant influence on the spray drift potential. In this test, the spray drift was measured using boom heights of 25 cm and 50 cm, which is optimal for sprayers with a 25- and 50-cm nozzle spacing, respectively. The results from the test showed that the spray drift was reduced by approximately 1/3 when the boom height was lowered from 50 cm to 25 cm. In the test, spray drift at 75 cm and 100 cm boom height was also measured. Higher than recommended boom height is often seen in practice, especially when sprayers without automatic boom height control are used. Using a boom height above the recommended 50 cm increased the spray drift significantly.

Acknowledgement

The study was financed by The Danish Environmental Protection Agency.

XI Results of crop protection trials in minor crops in 2020

Andrius Hansen Kemezys, Peter Hartvig, Louise Hjelmroth, Kaspar Ingvordsen, Mie Jensen, Per Elmegaard Andersen & Anja Lunn

In 2020, the minor crops group at AU Flakkebjerg carried out 54 field and greenhouse trials. There were 28 trials with weed control in minor crops (including 3 desiccation trials) and 26 trials with control of fungal diseases and insects. 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, GUDP, 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 which have 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 and enhancers or biostimulants. Within weed control there is an awareness that the times when chemistry could handle everything 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.

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

The project covers the geographical region around Øresund, Kattegat and Skagerrak, i.e. Denmark, Sweden and Norway. The primary purpose of the project is to create a binding collaboration on crop protection in minor crops, i.e. field vegetables, fruits and berries, greenhouse crops and nursery crops.

The project is in line with the programme's focus area of innovation. The cross-border regional cooperation in this project will contribute to a common platform for consultants and others who work nationally with or are responsible for applications and approval of crop protection products in minor crops. In the regional network, current crop protection challenges, knowledge and experimental results will be shared and used to optimise and coordinate crop protection product trials.

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

The purpose of the collaboration is, among other things, to define and ensure common experimental standards and to ensure that experiments can be used for applications for approval of crop protection products across regional borders. The collaboration also involves joint planning and execution of specific trials, based on a list of topics prioritised by the industry as well as on existing knowledge and experimental results in the participating countries.

Weed control in vegetables, nursery crops and strawberries in 2020

The weed control trials in vegetables were mostly a continuation of the trials from the previous year's trials with minor changes in the previous study plans. As in previous years, a substantial number of weed control trials in 2020 were again carried out as part of the Swedish minor use project under LRF.

Especially the Swedish onion and carrot growers have been severely affected by the changes in the availability of herbicides. The loss of Stomp (pendimethalin), Totril (ioxynil) and bromoxynil has been a theme in the trials for some years. Furthermore, the dose rate of Fenix (aclonifen) has in Sweden been reduced so that a maximum of 0.9 litres per hectare is permitted, which is considerably less than the dose rate in Denmark (2.5 l/ha) and Norway (1.75 l/ha). In 2020, the herbicide strategies in onion without pendimethalin and bromoxynil proved to be quite efficient, although phytotoxic effects on vegetables were observed.

Weed control trials within the Interreg project were carried out in **carrots**, **rose nurseries** and in a field with no crop in order to evaluate potential **alternatives to diquat in pre-emergence application** in seeded vegetables.

The Interreg trial in carrots was a comparison of different herbicide strategies with Fenix, Boxer (prosulfocarb), Centium CS (clomazone), DFF 500 SC (diflufenican), Sencor SC 600 (metribuzin), Starane 333 HL (fluroxypyr), Goltix WG (metamitron) and Lentagran 45 WP (pyridat). These products are either authorised in other Nordic countries or under development for use in carrots. All tested strategies were very efficient against dicot weeds but some herbicide strategies were found to cause very high crop phytotoxicity (Table 1). In particular Goltix WG, Starane 333 HL and Lentagran 45 WP seemed to cause very high crop injury early in the season, but the carrots were able to recover and the harvest results generally showed no significant yield differences. Moreover, it was observed that carrots from strategies including Starane 333 HL showed decreased quality in terms of presence of white spots, extra rooting and distorted/knobbly surface.

Table 1. Herbicide strategies studied in carrot in the Interreg project. Treatments 2, 3 and 4 are the 'reference' strategies in Sweden, Norway and Denmark, respectively. Treatments 5-7 are the test strategies including Lentagran 45 WP and Starane 333 HL.

	A		B	C		D		E		F		G	
	Post-seeding		3 days before emerging	BBCH 10-5-11		7-8 days after C		7-8 days after D		7-8 days after E		7-8 days after F	
Appl.	2 July 2020		2 July 2020	16 July 2020		23 July 2020		31 July 2020		8 August 2020		17 August 2020	
BBCH	07		07	11		13		13-14		42		42	
1	Untreated												
2	Goltix WG	1.0	Roundup Bio 1.5 l/ha	Fenix + Centium CS	0.3 + 0.05	Fenix + Centium CS	0.3 + 0.08	Fenix + Centium CS	0.3 + 0.08	Boxer + Sencor SC 600	1.0 + 0.06	Boxer + Sencor SC 600	1.0 + 0.075
3	Fenix + Centium CS + Sencor SC 600	0.75 + 0.08 + 0.04		Fenix + Sencor SC 600	0.15 + 0.02	Fenix + Sencor SC 600	0.2 + 0.03			Fenix + Sencor SC 600	0.25 + 0.05		
4.	DFF 500 SC	0.2	Roundup Bio 1.5 l/ha	Fenix	0.3	Fenix	0.5			Fenix	0.5		
5.	Goltix WG	1.0	Roundup Bio 1.5 l/ha	Fenix + Centium CS	0.3 + 0.05	Fenix + Starane 333 HL	0.3 + 0.1	Fenix + Starane 333 HL	0.3 + 0.1	Boxer	1.0	Boxer	1.0
6.	Goltix WG	1.0	Roundup Bio 1.5 l/ha	Fenix + Centium CS	0.3 + 0.05	Fenix + Centium CS	0.3 + 0.08	Fenix + Lentagran 45 WP	0.2 + 0.15	Fenix + Lentagran 45 WP	0.25 + 0.2	Boxer + Sencor SC 600	1.0 + 0.06
7.	DFF 500 SC	0.2		Fenix	0.3	Fenix + Lentagran 45 WP	0.2 + 0.15			Fenix + Lentagran 45 WP	0.25 + 0.2		
8.	Fenix + Centium CS + DFF 500 SC	0.75 + 0.08 + 0.065		Fenix + Centium CS	0.2 + 0.045	Fenix + Boxer	0.25 + 0.5			Fenix + Boxer	0.3 + 0.5		
9.	DFF 500 SC	0.2		Fenix	0.3	Fenix + Starane 333 HL	0.2 + 0.1			Fenix + Starane 333 HL	0.25 + 0.1		

All strategies provided excellent weed control against dicot weed species. However, some strategies caused more crop injury (phytotoxicity) than others (Table 2). Generally, the carrots were able to recover in most cases and no significant differences were observed between the untreated and the test strategies in terms of number of carrots and carrot yield at harvest. The table below shows the results of the assessment of phytotoxicity just before applications C, D, E, F and G and 8 days after application G (DA-G). The phytotoxicity was assessed using a 0-100% scale where phytotoxicity above 30% is considered to be serious damage that most likely will affect crop yield. The results marked in pink (20-30%), orange (30-40%) and red (>40%) highlight increasing levels of crop injury. The last two columns show the number of crop plants and yield at harvest.

Table 2. Assessment of phytotoxicity in carrots just before applications C, D, E, F and G and 8 days after application G (DA-G). The phytotoxicity was assessed using a 0-100% scale.

Assessed on:	16-07-2020		22-07-2020		31-07-2020		06-08-2020		17-08-2020		25-08-2020		06-10-2020		06-10-2020	
	0 DA-C		-1 DA-D		0 DA-E		-2 DA-F		0 DA-G		8 DA-G		No. of carrots/m^2		Yield, t/ha	
Trt 1 (untreated)	0	b	0	c	0	b	0	c	0	b	0	d	46.8	a	46.4	ab
Trt 2	3.8	b	33.8	a	51.3	a	40	ab	32.5	ab	31.3	b	51	a	44.5	b
Trt 3	0	b	13.8	b	31.3	a	18.8	bc	15	b	21.3	bc	45.8	a	47.8	ab
Trt 4	10	ab	11.3	b	35	a	13.8	bc	8.8	b	7.5	cd	51.7	a	53.2	ab
Trt 5	3.8	b	37.5	a	55	a	55	a	48.8	a	47.5	a	43.7	a	44.1	b
Trt 6	0	b	30	a	43.8	a	38.8	ab	30	ab	20	bc	46	a	50.7	ab
Trt 7	11.3	ab	12.5	b	36.3	a	23.8	bc	11.3	b	17.5	bc	50.4	a	52.6	ab
Trt 8	0	b	13.8	b	28.8	a	23.8	bc	12.5	b	10	cd	53.1	a	57.4	a
Trt 9	15	a	16.3	b	43.8	a	31.3	ab	31.3	ab	20	bc	51.4	a	48	ab
LSD (P=0.05):	7.62		6.38		16.9		18.35		23.59		12.76		10.35		7.46	

Weed strategies with fluroxypyr (Starane 333 HL) adversely affected the quality of the carrots in terms of the presence of white spots, extra rooting and distorted/knobbly surface. The photo to the left shows a sample from a plot treated with fluroxypyr, while unaffected carrots are shown in the photo to the right.

The Interreg trial in rose nurseries was aimed at screening for alternatives to glyphosate and diquat for pre-emergence applications in seeded rose beds. In this trial, 15 different herbicides which are authorised in other agricultural crops such as cereals, maize, oilseed rape and potatoes and which are known to control typical weeds in plant nurseries were tested. The test herbicides were tested at 1N and 2N dose rates in order to evaluate crop selectivity. The treatments were applied using a 'small plot' sprayer, where the plot size is just 1 square metre – this allows us to screen a large number of herbicides within a relatively small trial area, thus minimising crop losses in the trial area.

Treatments with Logo (foramsulfuron+iodosulfuron), Tocalis (mesotrione), Ronstar Expert (iodosulfuron and diflufenican), Stomp CS (pendimethalin), Mustang Forte (florasulam+2,4-D+aminopyralid), Cossack OD (mesosulfuron+iodosulfuron), Galera (clopyralid+picloram) and Rexade 440 (florasulam+pyroxsulam+halauxifen-methyl) were observed to cause very high levels of crop injury (phytotoxicity) to seeded roses (Table 3). Boxer and Korvetto (clopyralid+halauxifen-methyl) caused little crop injury at the 1N dose rate, but rather much injury at the 2N dose rate. Test products Spotlight (carfentrazone-ethyl), Gozai (pyraflufen-ethyl), Beloukha (pelargonic acid) and Goltix SC (metamitron) showed the lowest levels of crop injury similar to the reference products Reglone (diquat) and Glypper (glyphosate). The results with Proman (metobromuron) were very uncertain. The last two columns are control of dicot and monocot weeds, respectively. Unfortunately, treatments providing high levels of weed control caused very high levels of crop injury. The low efficacy of the reference treatments with Reglone and Glypper was due to the emergence of many new weeds shortly after the application. Phytotoxicity was assessed using a 0-100% scale, where phytotoxicity above 30% is considered to be serious damage that most likely will affect yield and quality of the rose. The results marked in pink (20-30%), orange (30-40%) and red (>40%) reflect increasing levels of crop injury.

Table 3. Weed control in seeded roses using 1N and 2N dose rates. Data on phytotoxicity and weed control are presented. Phytotoxicity was assessed using a 0-100% scale.

Treatments	Phytotoxicity (DA-T = Days After Treatment)						Weed control based on weed cover 36 DA-T			
applied 06-05-2020	20 DA-T		36 DA-T		78 DA-T		% control dicots		% control monocots	
Untreated Check	0	h	0	f	0	e	0	h	0	b
Reglone 2 l/ha	7.5	gh	5	f	7.5	e	21.7	fgh	0	b
Glypper 1.5 l/ha	11.3	fgh	2.5	f	21.3	de	7.5	gh	0	b
Logo 0.15 kg/ha	30	b-h	81.3	abc	95	a	65.8	a-f	100	a
Logo 0.3 kg/ha	28.8	b-h	90	ab	98.8	a	50.8	a-g	66.7	ab
Tocalis 0.3 kg/ha	77	a-d	98	a	100	a	75.8	a-d	0	b
Tocalis 0.6 kg/ha	68.8	a-e	99	a	100	a	91.7	ab	33.3	ab
Gozai 0.3 l/ha	5	gh	17.5	ef	10	e	31.7	d-h	0	b
Gozai 0.6l/ha	15	e-h	26.3	e	22.5	de	50.8	a-g	0	b
Spotlight Plus 0.25 l/ha	22.5	d-h	10	ef	22.5	de	10	gh	33.3	ab
Spotlight Plus 0.5 l/ha	26.3	c-h	10	ef	15	de	39.2	c-h	16.7	ab
Beloukha 16 l/ha	0	h	13.8	ef	7.5	e	12.5	gh	16.7	ab
Beloukha 32 l/ha	37.5	b-h	10	ef	15	de	10	gh	16.7	ab
Ronstar Expert 0.33 kg/ha	58.8	a-g	94.3	ab	90	a	71.7	a-e	66.7	ab
Ronstar Expert 0.66 kg/ha	84.5	ab	99.8	a	100	a	100	a	100	a
Stomp CS 1.6 l/ha	71.3	a-d	41.3	d	46.3	cd	45	b-h	16.7	ab
Stomp CS 3.2 l/ha	55	a-g	78.8	abc	77.5	ab	71.7	a-e	66.7	ab
Boxer 2 l/ha	51.3	a-h	18.8	ef	16.3	de	21.7	fgh	33.3	ab
Boxer 4 l/ha	73.8	a-d	88.3	ab	55	bc	43.3	b-h	66.7	ab
Goltix SC 700 1 l/ha	31.3	b-h	0	f	17.5	de	25.8	e-h	66.7	ab
Goltix SC 700 2 l/ha	33.8	b-h	13.8	ef	22.5	de	52.5	a-g	100	a
Mustang Forte 1 l/ha	77	a-d	97	a	97.5	a	84.2	abc	16.7	ab
Mustang Forte 2 l/ha	96.8	a	99.8	a	100	a	97.5	a	0	b
Cossack OD 0.93 l/ha	37.5	b-h	90.3	ab	98.8	a	74.2	a-e	83.3	ab
Cossack OD 1.86 l/ha	62.5	a-f	92.3	ab	100	a	84.2	abc	100	a
Galera 0.3 l/ha	71.3	a-d	94.3	ab	90	a	71.7	a-e	16.7	ab
Galera 0.6 l/ha	78	a-d	99	a	100	a	75	a-e	0	b
Rexade 440 50 g/ha	81.3	abc	96	ab	90	a	78.3	a-d	66.7	ab
Rexade 440 100 g/ha	81.3	abc	95.5	ab	96.3	a	95	a	66.7	ab
Korvetto 0.65 l/ha	41.3	b-h	25	e	27.5	de	35	c-h	0	b
Korvetto 1.3 l/ha	65	a-f	70.8	c	65	abc	50.8	a-g	0	b
Proman 2 l/ha	53.8	a-h	76.8	bc	67.5	abc	95.8	a	100	a
Proman 4 l/ha			17.5	ef	27.5	de	75	a-e	100	a
LSD (P=0.05):	30.21		11.97		19.56		27.65		48.01	

The Interreg trial in on pre-emergence application in seeded vegetables was aimed to screen for alternatives to the use of glyphosate and diquat just before emergence of seeded vegetables. The objective of this trial was not to find a substitute for glyphosate and diquat, but instead to try to combine the reduced dose rates of pre- and post-emergence herbicides as they are used in weed control strategies anyway. The pre-emergence herbicides Centium CS, Fenix, Stomp CS, Boxer and Goltix 70 WG were combined with the post-emergence herbicides Beloukha, Lentagran 45 WP and Spotlight Plus (not approved in Denmark) and were applied as tank mixes of two herbicides, respectively. Moreover, it was evaluated if inclusion of the liquid nitrogen fertiliser NS 30-2 increased efficacy.

As many different vegetable species are grown in the ØKS region, it was decided that the first step in finding alternatives to glyphosate and diquat was to rank possible combinations of soil and foliar herbicides according to efficacy. A trial with a total of 37 different combinations (including the untreated and the reference treatments with Reglone and Roundup Bio (glyphosate)) were tested in a field trial (Figures 1 and 2). Moreover, liquid nitrogen fertiliser NS 30-2 applied in a tank mix with the post-emergence herbicides Beloukha, Lentagran 45 WP and Spotlight Plus was found to increase efficacy. The results showed that the foliar herbicides and liquid nitrogen fertiliser NS 30-2 could contribute to higher efficacy of soil herbicides, especially Goltix 70 WG and Fenix.

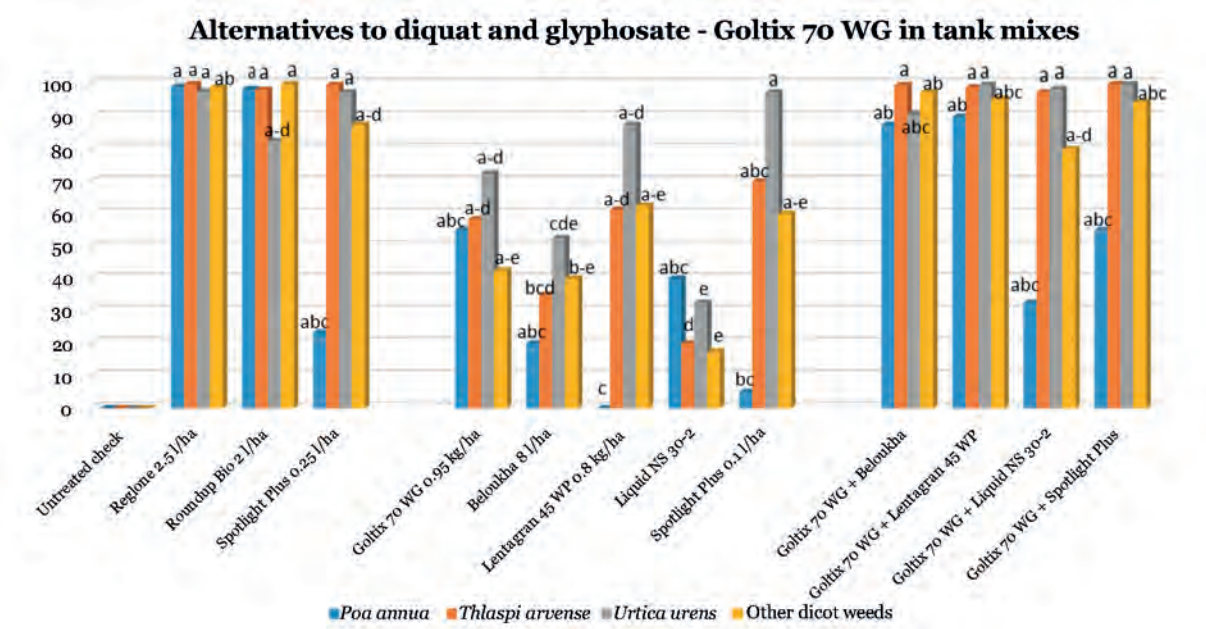


Figure 1. Efficacy of reduced dose rate of Goltix 70 WG and its combinations with liquid nitrogen fertiliser NS 30-2 and reduced dose rates of the post-emergence herbicides Beloukha, Lentagran 45 WP and Spotlight Plus. Assessed 10 days after treatment.

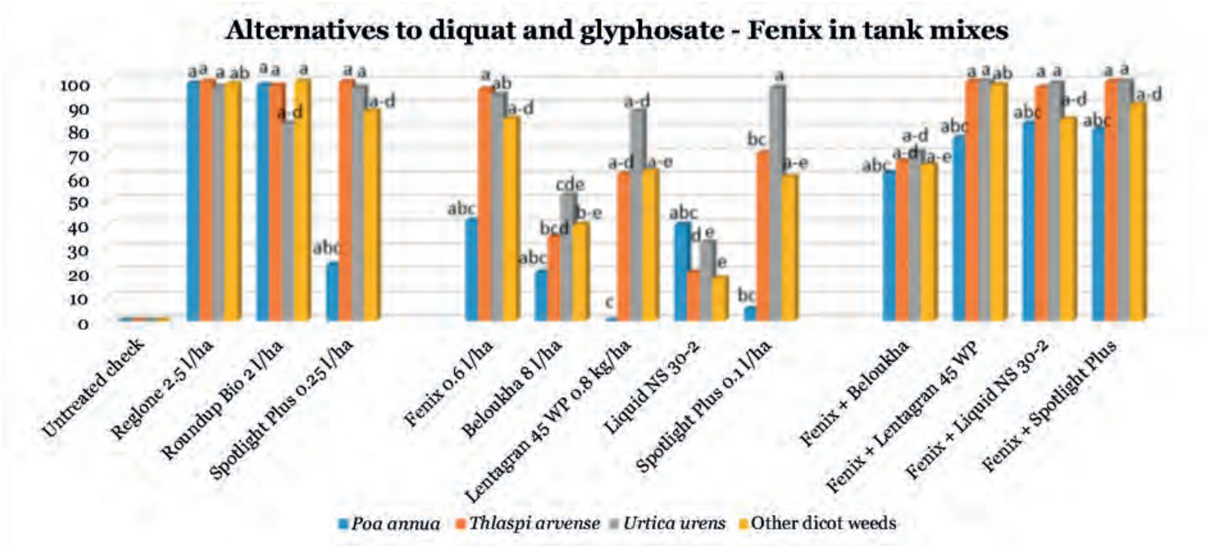


Figure 2. Efficacy of reduced dose rate of Fenix and its combinations with liquid nitrogen fertiliser NS 30-2 and reduced dose rates of the post-emergence herbicides Beloukha, Lentagran 45 WP and Spotlight Plus. Assessed 10 days after treatment.

Weed control in horticultural seed production in 2020

Denmark's status as the world's largest producer and exporter of spinach seeds is a major incentive for the industry to be continuously on the lookout for new herbicides or ways of controlling weeds. Another factor is that there is still an ongoing search for a replacement for Asulox (asulam), which is a key herbicide in spinach growing.

The future of phenmedipham – the active ingredient in Betanal – is also uncertain, and this has also contributed to the high number of herbicide trials in spinach.

In 2020, 6 trials were carried out in spinach for seed production. Different weed control strategies without Betanal were tested in two of the trials, where a number of strategies look very promising. Pixxaro EC (fluoxyoyr+halauxifen-methyl) is among the most promising new herbicides for weed control in spinach, but it can cause substantial phytotoxicity if applied at too high a rate and at certain growth stages. In trials in 2020, we investigated the dose-response of Pixxaro in terms of phytotoxic damage to spinach and confirmed that spinach in early developmental stages was more susceptible to Pixxaro than spinach that already had 4-6 leaves at the time of application.

Alternatives to diquat

Diquat was banned in the EU from 4 February 2020 due to concerns related to the exposure of bystanders, residents and birds. Diquat was widely used in minor crops for weed control and as a desiccant before harvest in horticultural seed crops. Diquat is used pre-emergence in a number of seeded vegetables and as a shielded spray (inter-row application) in plant nurseries, berries, pome trees and berry bushes. Diquat is also widely used as a desiccant in vegetable seed crop production.

Two trials were carried out with alternatives to diquat for desiccation in spinach for seed, and one trial was carried out in chives for seed production. Products containing pelargonic acid and pyraflufen-ethyl were identified as having a rather promising efficacy in spinach for seed, but it is uncertain if these products can be used in practice as the cost of products containing pelargonic acid is very high in Denmark and as pyraflufen-ethyl product has not yet been authorised. However, neither pelargonic acid nor pyraflufen-ethyl could provide satisfactory efficacy in chives for seeds. We expect to continue the work in 2021.

Christmas trees – glyphosate free weed control
Denmark is the leading exporter of Christmas trees in Europe. Germany and France are the two largest export markets accounting for more than 50% of the Danish Christmas tree export. Some importers in both countries have expressed a demand for 'glyphosate-free' Christmas trees, and as the future of glyphosate in the EU is uncertain, there is an increasing interest in Christmas tree production without glyphosate. Currently, glyphosate is a very important active substance in the production of Christmas trees and used in several ways including spring and autumn applications (over the trees before and after bud burst, respectively) and as shielded application after bud burst.

The Danish Christmas Tree Association's research fund has granted a one-year project for a third time for glyphosate- free production of Christmas trees. In autumn 2020, we established 3 trials with different weed control strategies evaluating combinations of different products in autumn and spring. A number of promising herbicides that efficiently control dicot weed species without causing any phytotoxicity damage to the Christmas trees were identified. The major issue in the 2020 trials was the control of monocot weeds. They were difficult to control without glyphosate and therefore we considered including some already authorised selective grass herbicides in the weed control strategies. The work on alternatives to glyphosate in shielded applications is also expected to be continued.

New GUDP project in quinoa (QUISACU)
In January 2020, there a new GUDP project was launched with the aim to improve cultivation of quinoa in Denmark. The minor crop group is involved in this GUDP project doing weed control in quinoa using reduced-tillage techniques with cover crops. As no herbicides are registered for quinoa production, and as there is a high demand for organically grown quinoa, there is a need for developing non-chemical practices in quinoa. In autumn 2020, three trials were established to evaluate how quinoa reacts to different cover crop systems and different soil tillage techniques, including strip tillage.

Control of fungal diseases in vegetables in 2020
Apart from the number of trials carried out for agrochemical companies, the trial portfolio 2020, in line with previous years, included a range of trials conducted for the growers' organisations dealing with current challenges and topics. One issue that has been on top of the agenda of both the Danish and Swedish growers for some years now is finding alternatives to Acrobat (dimethomorph+mancozeb) for control of downy mildew of onion. Two trials were carried out studying the control of downy mildew on onions in collaboration with LRF and ØKS Interreg. A number of different strategies were tested. Strategies with Zorvec Enicade (oxathiapiprolin) turned out to be very promising, and hopefully it can be authorised in the future.

Downy mildew in onions (*Peronospora destructor*). The disease can develop epidemically, cause great losses of yield and reduce yield quality.

Control of fungal diseases in spinach in 2020

Since 2016, work has been going on to develop strategies including other active substances than the few currently used for control of fungal diseases in spinach. Current practice is strategies with a relatively high input of pyraclostrobin and boscalid, with the risk that the fungi develop resistance to these substances. The work is carried out in collaboration with "Frøafgiftsfonden" and started in 2016. In 2020, the activities encompassed a total of 6 trials with 380 plots. As a new activity, a matrix trial was established with three different spinach cultivars that are known to be susceptible to different fungal infections. Zorvec Enicade and Balaya (pyraclostrobin+mefentrifluconazole) were identified as the products that can potentially control some of the diseases in spinach (especially *Peronospora*) and can possibly be included in disease control strategies in the future. However, there is a need for more data, and in 2021 we are planning to carry out trials in spinach with artificial inoculation of *Stemphyllium* and *Claudiosporum* in order to better control the level of fungal infection. Artificial inoculation is a method that is widely used at Flakkebjerg for trials in onions, potatoes and cereals and now the experiences from these crops will be transferred to spinach.

Screening of plant protection products against cabbage caterpillar – Interreg trial

The number of authorised insecticides has been decreasing over the years, but the problems with insects in farmer fields remain. Insects can cause substantial damage to certain crops or completely destroy the harvest. The cabbage caterpillar is an important pest in different species of cabbage, and it was decided to carry out a screening of insecticides and alternative products to test their efficacy when sprayed directly on the larvae. The idea behind this trial is that the efficacy of the tested products would help to rank the products for future field trials. Based on the results from the trials with the small and large larvae, the products Karate 2,5 WG (lambda-cyhalothrin), Steward 30 WG (indoxacarb), Mavrik Vita (tau-fluvalinate), Conserve (spinosad), Nemasys (nematodes), Mospilan SG (spinosad), Mainspring (cyantraniliprole), DiPel DF (*Bacillus thurigiensis*) and Movento SC 100 (spirotetramat) are ranked as the products that potentially can be a part of pest management in the cabbage fields in the future, but more trials are needed.

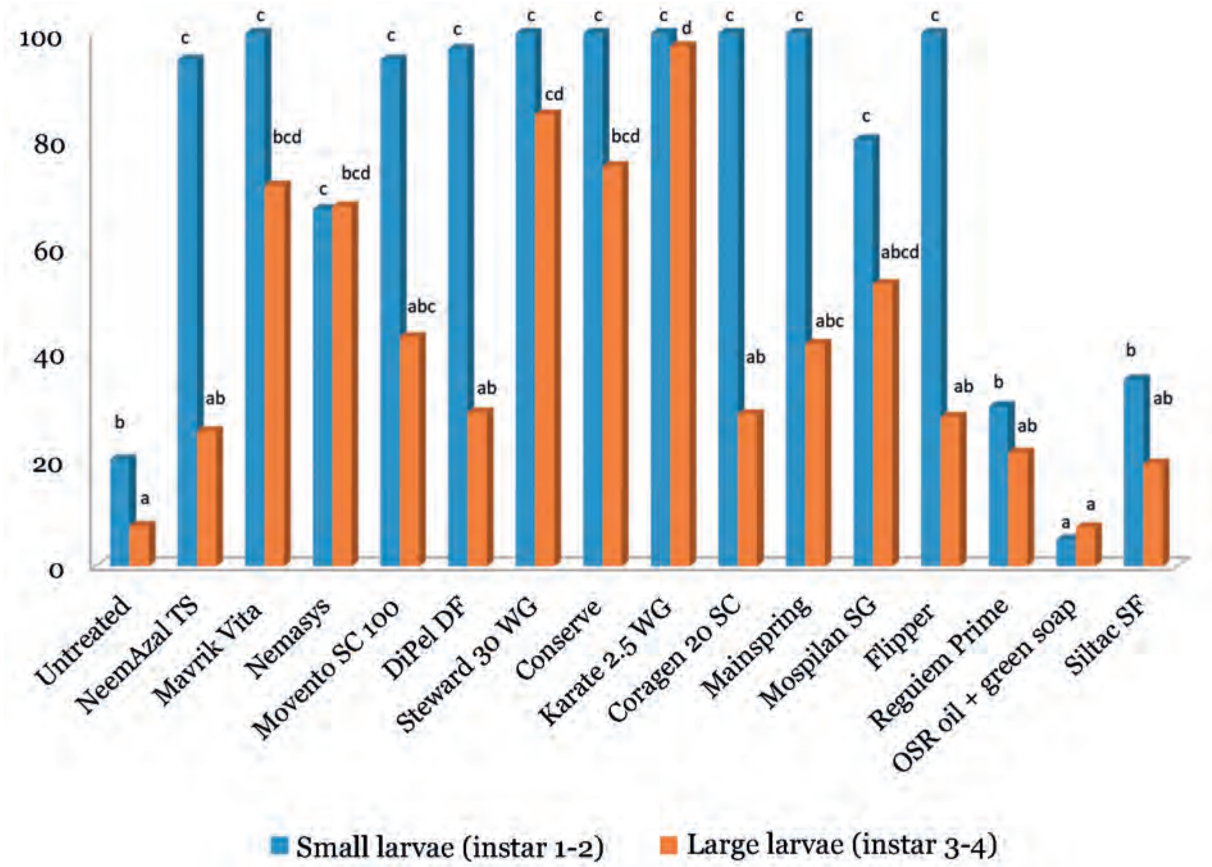
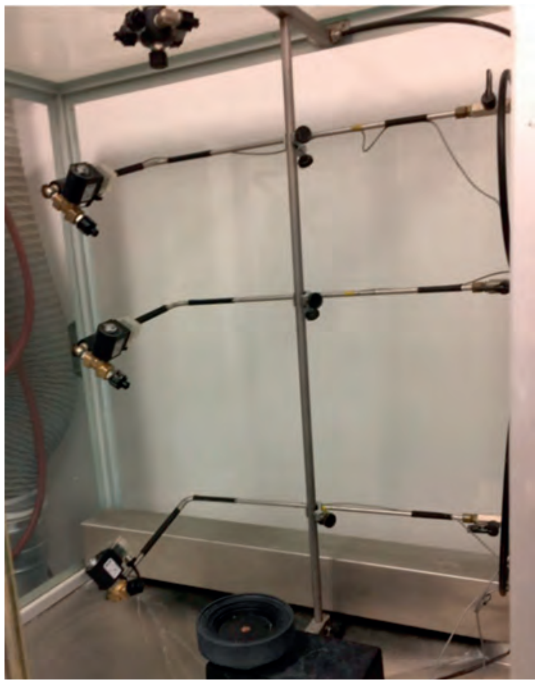


Figure 3. Screening of chemical and alternative plant protection products for efficacy against cabbage caterpillar (*Pieris brassicae*). Data from two trials sprayed on small (instar 1-2, trial no. 1) and large (instar 3-4, trial no. 2) larvae. Percentage of dead larvae 2-3 days after application is presented.

The results from the trials where the test products were sprayed on either small (instar 1-2, trial no. 1) or large (instar 3-4, trial no. 2) larvae are presented in Figure 3. The effect is presented as percentage of dead larvae 2-3 days after application. Many products, including some of the alternative products, showed a very high efficacy when applied directly on the small larvae. However, the results from the trial where the same products were applied on large larvae (instar 3-4) showed decreased efficacy.

Thrips in ornamental plants – Interreg trial

The decreasing number of available insecticides for control of thrips in ornamentals and in strawberries is also of great concern. The trials from previous years in a GUDP project showed a good effect of some alternative products, but it was also clear that spraying technique had a great influence, and in order to obtain high efficacy it is important that the spraying liquid comes in contact with the thrips. Thrips are often hiding under the leaves or they are in the flowers; therefore it can be difficult to achieve high efficacy.



In the Interreg trial, it was decided to use a cabin sprayer that can spray on a rotating pot plant with nozzles from all angles, ensuring an efficient coverage of the plants. This technique was used in the trial in order to obtain the best possible efficacy and to rank the teseed products for control of thrips, although it may be difficult to use the same technique in practice. Teppeki (flonicamid) and Mainspring were the two synthetic insecticides used in this trial along with a number of alternative insecticides (Figure 4).

A characteristic of the alternatives is lower effect and robustness. Furthermore, the environmental conditions and the method of application typically influenced efficacy more compared to synthetic pesticides as the alternatives all have a contact mode of action. However, when these parameters are taken into consideration, several of the alternatives are suitable for preventive use and as part of an Integrated Pest Management strategy.

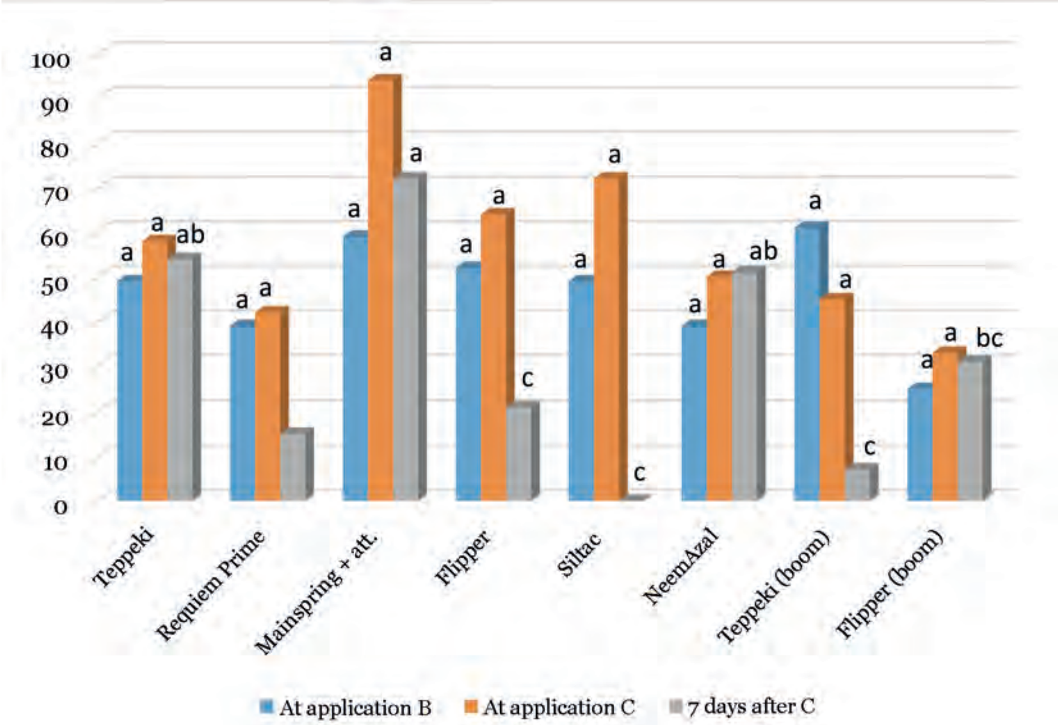


Figure 4. Screening of chemical insecticides and alternative products for efficacy against thrips (*Frankliniella occidentalis*) in greenhouses. The results in this figure are calculated as % efficacy based on the counts of nymphs in potted *Chrysanthemum*.

XII List of chemicals

Fungicides		
Name	**Active ingredients**	**Gram /L or kg**
Acrobat New	Dimethomorph + mancozeb	75 + 667
Amistar	Azoxystrobin	250
Amistar Gold	Azoxystrobin + difenoconazole	125 + 125
Ascra Xpro	Prothioconazole + bixafen + fluopyram	130 + 65 + 65
Balaya	Mefentrifluconazole + pyraclostrobin	100 + 100
BAS 175 AH F	Sulphur	600
BAS 750 01 F	Mefentrifluconazole	75
BAS 751 00 F = Balaya	Mefentrifluconazole + pyraclostrobin	100 + 100
BAS 752 03 F = Revytrex	Mefentrifluconazole + fluxapyroxad	66.7 + 66.7
BAS 830 01 F	Metyltetrapole	60
BAS 831 01 F	Fluxapyroxad + metyltetraprole	60 + 30
BAS 832 01 F	Metyltetraprole + mefentrifluconazole	100 + 80
BAS 950 60 F = Luna	Fluopyram	500
Bell	Boscalid + epoxiconazole	233 + 37
Bravo 500 SC	Chlorothalonil	500
Cantus	Boscalid	500
Comet Pro (Comet 200)	Pyraclostrobin	200
Curbatur	Prothioconazole	250
Delaro SC 325	Prothioconazole + trifloxystrobin	175 + 150
Elatus Era	Azoxystrobin + benzovindiflupyr	30 + 15
Elatus Plus	Benzovindiflupyr	100
Entargo	Boscalid	500
Folicur EW 250	Tebuconazole	250
Folicur Xpert	Tebuconazole + prothioconazole	160 + 800
Folpan 500 SC	Folpet	500
Imtrex	Fluxapyroxad	62.5
Juventus 90	Metconazole	90
Kumulus S	Sulphur	800
Luna	Fluopyram	500
MCW 406s	Difenoconazole	250
Miravis Pro	Adepidin + prothioconazole	622 + 75
Mirador Forte	Tebuconazole + azoxystrobin	100 + 60
Opera	Pyraclostrobin + epoxiconazole	133 + 50
Orius Max 200EW	Tebuconazole	200
Proline EC 250	Prothioconazole	250
Propulse SE 250	Fluopyram + prothioconazole	125 + 125
Prosaro EC 250	Prothioconazole + tebuconazole	125 + 125
Revysol (BAS 750 01F)	Mefentrifluconazole	100
Revytrex	Mefentrifluconazole + fluxapyroxad	66.7 + 66.7

Fungicides		
Name	**Active ingredients**	**Gram /L or kg**
Revystar XL (BAS 752 00F)	Mefentrifluconazole + fluxapyroxad	100 + 50
Rubric	Epoxiconazole	125
Serenade ASO	*Bacillus subtilis*	1000
Silvron Xpro	Bixafen + fluopyram	100 + 100
Thiopron 825	Sulphur	825
Thore	Bixafen	125
Vacciplant	Laminarin	45
Univoq	Prothioconazole + fenpicoxamid	100 + 50
Zorvec Enicade	Oxathiapiprolin	100

Herbicides		
Name	**Active ingredients**	**Gram /L or kg**
Beloukha	Pelargonic acid	680
Betanal	Phenmedipham	160
Boxer	Prosulfocarb	800
Centium CS	Clomazon	360
Cossack OD	Mefenpyr + iodosulfuron + mesosulfuron	2.5 + 7.5 + 7.5
DFF	Diflufenican	500
Fenix	Aclonifen	600
Galera	Clopyralid + picloram	267 + 67
Goltix WG	Metamitron	700
Goltix SC	Metamitron	700
Gozai	Pyraflufen-ethylen	26.5
Korvetto	Clopyralid + halauxifen	120 + 5
Lentagran 45 WP	Pyridat	450
Logo	Foramsulfuron + iodosulfuron-methyl-Na + isoxadifen-ethyl	300 + 10 + 300
Mustang Forte	Florasulam + 2,4 D + aminopyralid	5 + 180 + 10
Pixxaro	Fluroxypyr + halauxifen + cloquintocet	280 + 12.5 + 12.5
Rexade 440	Florasulam + pyroxsulam + halauxifen + cloquintocet	100 + 240 + 104.2 + 300.3
Ronstar Expert	Iodosulfuron + diflufencan	10 + 360
Proman	Metobromuron	500
Sencor WG	Metribuzin	700
Spotlight Plus	Carfentrazon-ethyl	60
Starane 333 HL	Fluroxypyr	333
Glypper	Glyphosate	360
Reglone	Diquat dibromide	374
Roundup Bio	Glyphosate	360
Stomp CS	Pendimethalin	455
Tocalis	Mesotrion	500

Insecticides		
Name	**Active ingredients**	**Gram /L or kg**
Conserve	Spinosad	120
DiPel DF	*Bacillus thuringiensis* subsp.	12000000000000 CFU/kg
Flipper	Carboxylic acid potassium	479.8
Karate 2.5 WG	Lambda-cyhalothrin	25
Mainspring	Cyantraniliprol	400
Mavrik Vita	Tau-fluvalinat	240
Mospilan SG	Acetamiprid	200
Movento SC 100	Spirotetramat	100
NeemAzal TS	Azadirachtin	10
Requiem Prime	Terpenoid QRD 460	152.3
Steward 30 WG	Indoxacarb	300
Teppeki	Flonicamid	500

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, including agroecology, animal science, food science, genetics and engineering.

The DCA centre unit supports and coordinates DCA activities in relation to research based policy support, industrial and sector collaboration, international collaboration, and communication.

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

DCA reports
DCA also publishes a report series, which primarily communicates policy support tasks from DCA to the Ministry of Food, Agriculture and Fisheries. The reports may be downloaded free of charge at the DCA website: www.dca.au.dk.

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

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